Proceedings of the First International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management

Marine Biology

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October 1-4, 1985
Galveston, Texas

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for
Carole Hoover Allen
and
HEART
for dedicated efforts toward
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Preface

These proceedings contain papers and abstracts based on presentations made at the First International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management, Galveston, Tex., October 1-4, 1985. We arranged this symposium to provide a forum for all who were interested in the subject.

Kemp's ridley sea turtle (*Lepidochelys kempi*), the most critically endangered sea turtle species, is on the brink of extinction. Past human overexploitation of the eggs and turtles and current mortality due to incidental capture by shrimp trawlers are probable major causes of the demise of this species. A number of lesser causes of Kemp's ridley mortality are related to other of man's activities in the marine and estuarine environments. It is fitting, therefore, that there should be considerable human effort made toward restoring its population. Conservation and management of Kemp's ridley, which ranges from the Gulf of Mexico to U.S. and European Atlantic waters, depend on international cooperation. This cooperation involves not only collection of scientific information, but also support and collaboration by national and state governments, conservation organizations, marine industries, coastal developers and the general public.

Kemp's ridley has only one known primary nesting beach, located near the Mexican village of Rancho Nuevo, in the State of Tamaulipas, bordering the western Gulf of Mexico. Therefore, the main focus of Kemp's ridley conservation and management, beginning in the mid-1960s, has been protection of this beach during the nesting and hatching seasons to reduce the harvest and natural mortality of eggs and turtles. Through the Endangered Species Act, passed in 1973 and reauthorized in 1988, Kemp's ridley and other sea turtles were listed to protect them from exploitation and commercial trade in the U.S. The U.S. joined with Mexico in 1978 in an international program of Kemp's ridley restoration and research. Despite combined efforts of Mexico's Instituto Nacional de la Pesca and U.S. agencies such as the Fish and Wildlife Service, National Park Service, National Marine Fisheries Service and Texas Parks and Wildlife Department, the number of female Kemp's ridleys nesting each year at Rancho Nuevo continues to decline. As a consequence, conservation organizations have become active in public education campaigns to encourage greater protection of Kemp's ridley on land and at sea, both in federal and state waters. Reauthorization of the Endangered Species Act has added additional protection for sea turtles in U.S. waters by requiring turtle excluder devices (TEDs) on shrimp trawls beginning in May 1989.

The symposium was composed of nine sessions, including eight with 37 presentations and a ninth as a panel discussion, each with a convener. However, the proceedings contain just 33 papers, with five presentations represented only by abstracts, because not all speakers submitted manuscripts. No manuscripts were rejected because of the wide range of popular and technical topics covered. Some authors updated their papers to make them more current upon publication in 1989. However, the questions and answers and the Panel Discussions represent transcripts from tapes made at the time of the Symposium, although they have been edited for clarity.

Of the 92 persons who registered for the Galveston symposium, most were from the U.S. However, there were registrants from Mexico, British West Indies and Australia as well.

We express our sincere appreciation to all who assisted in the symposium — speakers, panelists and conveners who participated in the symposium; colleagues, secretaries and students who assisted in many ways before, during and after the symposium; symposium sponsors; sponsors of social events and refreshments; and organizations that contributed toward preparation and publication of the proceedings.

Charles W. Caillouet, Jr.
André M. Landry, Jr.

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International Efforts in the Conservation and Management of Kemp's Ridley Sea Turtle (*Lepidochelys kempi*)

Jack B. Woody*

The international Kemp's ridley recovery effort is now in its twelfth year. This unique effort between government agencies of Mexico and the United States, as well as a number of private individuals and organizations, is attempting to reverse the decline of this species.

Until a much greater degree of cooperation is received from the Gulf of Mexico shrimp trawling industries of both Mexico and the United States, this species' status will not improve and, in fact, the species may continue to decline.

Prior to discussing the current international program related to Kemp's ridley sea turtle (*Lepidochelys kempi*), I want to point out that attempts, although unofficial, to establish a second nesting population of Kemp's ridley go back long before the current federal involvement and included unsung efforts of a number of private individuals such as Dearl Adams of Brownsville, Tex., and Ila Loetscher of South Padre Island, Tex. These people used their own time and money to salvage eggs from hueveros at Rancho Nuevo, transport them to Padre Island, hatch them and release the hatchlings into the Gulf of Mexico, hoping that someday the turtles would return to nest on Padre Island. This effort did not involve many eggs, but under the circumstances of that day, it is amazing that these conservationists were able to get back to Padre Island with any viable eggs. Travel from Texas to Rancho Nuevo took a minimum of 12 hours, and one was never sure of being able to get anywhere near the nesting beach unless on foot or horseback—and if one did, there was little guarantee of getting any eggs. These efforts had to be abandoned due to the costs of time and money, as well as increasing governmental restrictions by both Mexico and the U.S. regarding such international transfers of wildlife.

The National Park Service (NPS) contracted with the Fish and Wildlife Service (FWS) in 1976 to evaluate the suitability of the Padre Island National Seashore (PINS) as a turtle nesting beach. Results of this investigation indicated that the physical characteristics of the Seashore appeared suitable. The historical record indicated a past history of incidental nesting by both Kemp's ridley and loggerhead (*Caretta caretta*) along the south Texas coast. It appears that no more than a few turtles ever were documented as nesting in any one year, and in some years no nesting turtles were reported.

Three other species of sea turtles occur in Texas waters in addition to Kemp's ridley and loggerhead: Green (*Chelonia mydas*); leatherback (*Dermochelys coriacea*); and hawksbill (*Eretmochelys imbricata*). At one time a commercial green turtle fishery existed on the south Texas coast that primarily harvested sub-adults for local markets. Even with the common occurrence of Kemp's ridley, loggerhead and green sea turtles in Texas waters, there remain no corroborated records of other than incidental nestings on Texas beaches.

The NPS proposed discussions of a project whose goal would be to establish a nesting population of sea turtles at the Seashore. The possibilities of such a project were discussed in 1976 and 1977 between regional representatives of FWS and NPS, and it was decided to go forward on the project and seek support from our respective agencies. It was also agreed that contact would be made with our Mexican counterparts to explore with them the possibility of utilizing Kemp's ridley as the experimental species. Our second choice was the loggerhead, but Kemp's ridley was a better choice for a number of biological and administrative reasons. Logistics of time, distance and cost as well as the precarious status of Kemp's ridley dictated its selection as the species in need of greatest help.

Contact was made with Mexico's Departamento de Pesca, Texas Parks and Wildlife Department (TPWD) and National Marine Fisheries Service (NMFS), and a meeting was held in Austin, Tex., in January 1977. Attendees from Mexico, Texas, NMFS, NPS, and FWS established the present Kemp's ridley recovery program. The head start project to determine feasibility of establishing a Kemp's ridley nesting colony at the National Seashore is only part of the broader recovery program.

There exists no formal written agreement among all the parties involved, and the program has no grandiose plans or strategies, but it has functioned well, both nationally and internationally, for the past 11 years with very little disagreement or misunderstanding. In fact, cooperation among the participating agencies is often better than that

**U.S. Fish & Wildlife Service*

within any of the individual agencies. This program has gone so smoothly because we have kept it at the operational level, and we believe in what we are doing without regard to turf or other responsibilities. Often the more people involved in a program, the less is accomplished.

Cooperation among U.S. agencies would be of little value if Mexico were not cooperative, for the Mexican participants are key players, not only to the current program but also because they are responsible for the fate of Kemp's ridley. It is Mexico that permitted the U.S. to initiate the head start project, and it is Mexico that will or will not allow it to continue. I want to emphasize this point, because there is a tendency on the part of some "gringos" to overlook this fact. Fortunately, Mexico has been willing to cooperate, and has graciously accepted on-the-beach assistance from the FWS in exchange for permitting removal and export of 20 to 30 clutches of eggs (2,000 to 3,000 eggs) annually and specific joint research efforts.

The objectives of the Kemp's ridley recovery program for the past 11 years are few and simple. They are, in order of priority:

1. protect the Rancho Nuevo nesting beach and adult females, and maximize the hatch;
2. collect and transfer 2,000 to 3,000 viable eggs annually to the U.S. for hatching and imprinting at PINS;
3. head start as many hatchlings as possible; and
4. conduct appropriate research and management projects aimed at understanding the species and contributing to improved management leading to population recovery.

The goals are recovery of the species and establishment of a second nesting population at PINS. These objectives and goals are fairly clear and straightforward. However, to accomplish them in the real world is not that simple. It is difficult for outsiders to imagine the red tape, logistical problems, and human blunders encountered from year to year. Several examples will serve to enlighten. Our first year, 1978, was a political disaster. A U.S. Coast Guard, twin-engine Convair 440 and a large helicopter were seized, and 15 sailors, a NMFS special agent, and I were held for a few days in Tampico by Mexican military authorities. Evidently this occurred because the Coast Guard did not have clearance through the appropriate Mexican agencies to enter Mexico and land such military-like aircraft there. The Coast Guard was to fly out of Mexico with the eggs. This detention of U.S. aircraft and personnel created somewhat of an international incident that involved our State Department and a number of other Mexican and U.S. agencies, including top level administrators in the Department of the Interior. On another occasion, there occurred an oversight regarding U.S. endangered species permits, and a senior NMFS biologist at the Southeast Fisheries Center's (SEFC) Galveston Laboratory was under investigation by NMFS enforcement agents for having Kemp's ridley hatchlings in possession without having appropriate permits on his person. As a result, he faced disciplinary or legal actions for violation of the Endangered Species Act. The problem in this case was not some dastardly deed that adversely affected the ridley, but rather a question of not having followed the letter of federal permits. Technically there may have been a permit violation, but there obviously was no harmful intent. Certainly, whatever was being done by the biologist represented efforts to benefit Kemp's ridley.

A few years ago the NMFS SEFC's Galveston Laboratory faced termination of funding and closure, with the consequence of discontinuing head starting. Frantic efforts were taken to find other agencies or institutions to continue head starting because the hatchlings were already in the U.S. In government, this is the type of situation in which supporters look at their "hole cards" and call in favors. As a result, the news media, selected Congressional members and a number of other entities made their desires known, and the funding was restored. Now, funding appears more secure than ever.

Every year, we have major and minor problems, which are to be expected in a program of this nature. We have a bureaucracy and Mexico has a bureaucracy. Both are fraught with red tape and breakdowns in internal and external communications. Unfortunately, Mexico is struggling with serious economic problems affecting the whole nation. Needless to say, the Mexican fisheries people (Instituto Nacional de la Pesca, INP) involved in carrying out the field project at Rancho Nuevo have had to face and overcome many problems. René Márquez can provide examples of what he and other Mexican participants have had to overcome to keep this important recovery program going.

The nesting beach at Rancho Nuevo and the turtles coming ashore to nest are relatively secure under the present management program run by Mexico with assistance from FWS. I see this program continuing, and the FWS will continue to provide assistance so long as Mexico wishes. Not only does this help Mexico during a period of austerity, but it has provided an excellent opportunity for non-Mexicans to gain unique experiences in a truly integrated international program.

U.S. agencies involved in this program plan to continue present efforts with the concurrence of Mexico. Interest and support of private individuals and organizations have been of major significance in maintaining these efforts. Without this support, we could not have weathered some of the rough spots encountered over the years.

We have no indication that the species has made any real gains in survival, even with the nesting beach secured and

experimental efforts in place to establish a second nesting colony through head starting. Although factors that historically led to the major decline of the species have been overcome by Mexico, they have been replaced by others involving the U.S. to a much greater degree. Little progress has been made toward correcting those clearly identified conditions that continue to limit Kemp's ridley recovery. I could be less critical if we were dealing with a species that had a wider range or one for which we were still searching to identify factors limiting recovery or determining how to overcome such factors. That is not the case with Kemp's ridley. Under the cooperative program, FWS and NPS have each spent close to $600,000 and NMFS somewhere in excess of $2 million to identify the causes of the continued decline and to reverse it. The primary limiting factor keeping the species depressed in recent years is the incidental capture of turtles by U.S. and Mexican shrimp trawlers. There will be no progress toward recovery until the problem of incidental take by shrimpers is corrected. In fact, we may see further decreases in the number of turtles nesting annually.

The shrimping industry and government agencies are aware of the problem, and corrective mechanisms are available. How fast the industry will move to overcome this problem remains to be demonstrated. The FWS and others were led by shrimp industry representatives to believe that this problem would be solved on a voluntary and timely basis, with the support of government agencies, rather than requiring an adversarial climate. Regardless, significant progress must occur within the very near future if Kemp's ridley is to avoid extinction.

There have been a number of research efforts undertaken in and out of Mexico by the combined Mexican and U.S. participants, apart from the primary management project at the nesting beach, the transfer of eggs, and head starting in the U.S. Some of this work has been somewhat esoteric, such as determining hatchling scute counts and variations. More practical work has been aimed at ensuring survival and production, such as determining optimum sand moisture levels for maximum hatch and determining incubation temperatures required for obtaining desired sex ratios in clutches to be transplanted. The NMFS SEFC Galveston Laboratory has carried out research on identification and treatment of diseases and to solve other problems associated with maintaining ridleys in captivity. Initial experiments with satellite tracking have been completed, and we are now in the process of further refinements in transmitter package design in anticipation of expanding a joint U.S.-Mexico field project during the nesting season. Mexican turtle biologists have developed a technique that apparently greatly simplifies determination of the sex of hatchlings, making unnecessary the costly and laborious histological methods previously required. Cooperative verification and comparison of these techniques are underway in Mexico, Canada, and the U.S.

Mexico and FWS have encouraged research having direct management benefits to the species, and FWS will continue to help these efforts, making its resources available to the greatest extent possible. Research of less direct or obvious benefit is not discouraged, but we may not always be able to provide all the support desired, including appropriate permits, if some of the work must be done in Mexico by a foreigner.

Mexico has requested that FWS serve as the clearinghouse for all requests by non-Mexicans who wish to visit or work on the Rancho Nuevo nesting beach. This includes researchers, news media, and any other entity. Our recommendations on each request are transmitted to Mexico for a final decision. This is done for a couple of reasons. The primary one is that the turtle camp is finite, and its resources as well as the site itself are not capable of sustaining extra personnel without prior notification and arrangements by both the FWS and Mexico. Food, water and shelter are often very limited as are transportation and sanitary facilities.

From the inception of the U.S.-Mexico cooperative Kemp's ridley recovery program in 1978 through 1987, there have been approximately 776,000 eggs protected, 486,000 hatchlings released at Rancho Nuevo, 12,000 eggs transferred to PINS, and 12,400 head started turtles released. A number of ridleys of various year-classes also are being maintained at marine aquaria in the U.S. In addition, Cayman Turtle Farm (CTF) is maintaining about 30 Kemp's ridleys of the 1979 and 1980 year-classes. Two of these animals nested at CTF in 1984, but the hatch was poor and no hatchlings survived. This was the first time the species had nested in captivity. In 1986 and 1987, nestings among the captive Kemp's ridleys at CTF produced hundreds of viable hatchlings, and about 160 of the latter year-class were exported to the NMFS SEFC's Galveston Laboratory for head starting. These events demonstrate successful reproduction among these animals under captive conditions. However, it should not be expected that captive propagation will ever become a significant supplement to the wild population. Various other research projects are underway or have been completed. More will be initiated.

The past 11-year cooperative effort (nationally and internationally) is unique in government. Although we cannot point to a population increase in the species of concern, I think the efforts of Mexico and the U.S. have been instrumental in reducing the rate of further decline in the population. We can now focus attention on recognized limiting factors and on increasing our efforts to overcome these. If this can be done, there is still hope that the Kemp's ridley will begin the recovery for which we all have hoped and worked.

Mexico's Contribution to Kemp's Ridley Sea Turtle Recovery

René Márquez Millan, Daniel Ríos Olmeda, Jose Manuel Sánchez P. and Juan Díaz*

The Kemp's ridley nesting beach near Rancho Nuevo, Mexico was discovered by the scientific world a long time after traffickers overexploited the eggs. Donkey trains were loaded with thousands of eggs during the nesting season between March and August. There were both directed and incidental catches of turtles off the nesting beach, on the Campeche Bank, in Florida Bay and in coastal waters of Texas, Louisiana, Mississippi and Alabama.

Location of the nesting beach was published by Hildebrand (1963) and Carr (1963) after they viewed a movie of nesting turtles taken by Mr. Andres Herrera, an engineer and sportsfisherman from Tampico, Mexico. Herrera's film showed an arribada *(Spanish for arrival) of thousands of females nesting on the beach of Barra Coma on June 18, 1947. Based on this film, it has been estimated that more than 40,000 females made up the* arribada. *The nesting population had declined to only about 10 percent of the original* arribada *when the first turtle camp was established in 1966 by fisheries investigators of the Mexican Secretariate of Commerce. By the 1980s, it had fallen further to about two percent of the original* arribada.

The Mexicans translocated nests to beach corrals, protected and tagged adult females, and released an average of 21,000 hatchlings annually from 1966 through 1977. A total prohibition on commercial trade of the eggs was declared in 1963, and the same was applied to turtles. In 1973, the prohibition was extended to any use of Kemp's ridley. Rancho Nuevo was declared a Natural Reserve in 1977, and by 1978 a definitive Turtle Station was under construction. Also in 1978, the U.S. Fish and Wildlife Service joined in efforts of the Departamento de Pesca, and a program entitled "Restoration and Enhancement of the Kemp's Ridley in the Gulf of Mexico" was implemented. From then on, more than 50,000 hatchlings were released annually on the beach, and hatchlings obtained each year from 2,000 eggs donated by the Mexican government were "imprinted" and head started.

The decline in the population seems to have been slowed, but any catastrophic problem that affects the habitat or part of the population will increase the danger of extinction of this species.

The Kemp's ridley (*Lepidochelys kempi*) is the most vulnerable of the sea turtle species for several reasons:

1. it is unique in that its population is nearly completely confined to the Gulf of Mexico;
2. it nests almost exclusively along a 60 km strip of sand beach on the northern gulf coast of Mexico;
3. its feeding behavior of seasonal wandering for food on the shrimp grounds brings it in contact with shrimp trawlers; and
4. a part of the population, specifically the juveniles, migrates out of the Gulf of Mexico through the Florida Strait with the possibility of no return.

The combination of these factors, amplified by man's impact, led to the rapid decline in nesters from tens of thousands of females in the 1940s to the remaining few hundred forming *arribadas* of the nesting seasons of the 1980s. This dangerous decline in population has been discussed very often, especially during the MEXUS-GULF meetings. Obviously there must have been some major causes of attrition affecting all stages of the life cycle, especially eggs, preadults and adults. Factors beyond the control of our cooperative efforts in enhancement and recovery of the population, such as shrimp trawling by-catch of sea turtles, oil pollution, beach deterioration, plastics in the ocean, etc., have had counteractive effects.

Several actions have been developed to reduce the decline in the Kemp's ridley population, such as manning the turtle camp at Rancho Nuevo during the nesting season (from 1966 to date), closed seasons on directed catch, prohibitions on harvesting and selling of eggs, declaration of Rancho Nuevo as a Natural Reserve in 1977, and prohibition on trawling in waters adjacent to the reserve. A U.S.-Mexico joint working arrangement was initiated in 1978 to increase the effort during the nesting season in protecting eggs, hatchlings and females, and to allow donation of 2,000 eggs to the U.S. for imprinting and head starting of hatchlings in hopes of establishing a new nesting colony at the Padre Island National Seashore near Corpus Christi, Tex. Important actions by the U.S. included attempts to diminish incidental catch of turtles by developing a Turtle Excluder Device (TED) for use in shrimp trawls. Formal actions to solve the problem of marine pollution are not yet organized in any international agreement. Support for development

* *Instituto Nacional de la Pesca, Mexico*

of a captive brood stock of Kemp's ridley, such as that at the Cayman Turtle Farm, Grand Cayman, BWI, has recently been forthcoming.

Fisheries Administration

The following will review briefly the more important actions taken by the Mexican government after discovery of the Rancho Nuevo nesting beach by Mr. Andres Herrera, an engineer and sportfisherman from Tampico, Mexico (Carr, 1963; Hildebrand, 1963):

1. The Tabla General de Vedas, published in 1956, decreed general closed seasons for commercial fisheries but made no special mention of Kemp's ridley. It included a prohibition on harvesting sea turtle eggs.
2. Circular 63, published on October 2, 1963, by the Direccion General de Pesca, included an experimental regulation prohibiting harvest of sea turtle eggs between October and March and a closed season on harvesting them between April and September (Direccion General de Pesca, 1963).
3. Circular 104, published on November 21, 1964, by the same office, added two months to the prohibition on harvest of sea turtle eggs from beaches (i.e., during March through October), but allowed open commerce from November through February for eggs removed from females caught during the fishing season from September 1 to April 30 (Direccion General de Pesca, 1964). There was no reference to Kemp's ridley.
4. Circular 9, dated April 27, 1965, included a decree of total prohibition on commercialization of eggs from nests or from sacrificed females, and established for the first time a closed season on catch of Kemp's ridley between May 1 and August 31 (Direccion General de Pesca, 1965). No size regulation was included.
5. Communicacion 15, "Disposiciones vigentes sobre Vedas y Tamaños Minimos de Captura - 1967," dealt with the closed season for sea turtle catch and minimum size limits for the year 1967 (Direccion General de Pesca, 1967). It confirmed the former dispositions, and they were in force until 1971.
6. A total closed season for all sea turtles and their parts was declared from June 1, 1971, to December 31, 1972.
7. Sea turtle catch was reinitiated on September 1, 1973, but only for fishing cooperatives, after the "Diario Oficial" dated July 13, 1973 (Departamento de Pesca, 1973). A total prohibition on catch of Kemp's ridley and leatherback sea turtles (*Dermochelys coriacea*) was established, which is in force to this day. A total prohibition on commerce of any kind involving sea turtle eggs also was established.
8. The Decree of the "Zona de Refugio y de Veda para la Proteccion de la Tortuga Lora Marina *Lepidochelys kempi*" was published on July 4, 1977 (Departamento de Pesca, 1977). It explained regulations protecting Kemp's ridley sea turtle on its unique nesting beach named Rancho Nuevo, municipality of Aldama, in the State of Tamaulipas, Mexico.
9. A last complementary disposition was prohibition of trawling offshore of the nesting beach between Barra del Tordo and Barra de Ostionales during the nesting season from April to August.

Historical Review of the Kemp's Ridley Turtle Program

After discovery of the Rancho Nuevo nesting beach was announced by Hildebrand (1963) and Carr (1963), attention was drawn to this species and its conservation. One of the pioneers in Kemp's ridley conservation efforts was Mr. Dearl Adams of Brownsville, Tex. He made several visits to Barra Coma, the most accessible beach near Barra del Tordo's sport fishing camp, and translocated several thousand eggs to Padre Island, Tex. (see Table 1 in Márquez, Villanueva and Burchfield, 1989), but with poor incubation success. These represented the first trials to protect and enhance the population. The first Mexican turtle camp was occupied in 1966 by technicians of the Direccion General de Pesca. From that time on, the program has remained in operation despite logistical and economic problems during 1969 to 1971. In the first period, 1966 to 1977, more than 250,000 hatchlings were released, or more than 22,000 per year. Since 1978, with the increased effort associated with the U.S.-Mexico joint working arrangement, more than 600,000 hatchlings have been released at Rancho Nuevo, or around 50,000 per year. At the same time, several studies were undertaken such as tagging of female adults, which provided biological information including fecundity, breeding cycle, total mortality, recruitment, etc. (Márquez, Villanueva and Sánchez, 1982). A diagnosis of the population was approximated from these studies.

The Kemp's ridley program at Rancho Nuevo is considered in Mexico as a classic sea turtle research and conservation work, and it is used as a training camp for national and foreign students. At the time the first Rancho Nuevo turtle camp was established, the condition of the Kemp's ridley population was worse than that of any other sea turtle species. Recruitment to the adult population had decreased to near zero between 1950 (at least) and 1965 (P. C. H. Pritchard, Florida Audubon Society, personal communication; Márquez, 1984), and the mean age of the nesting females appeared to be more than 15 years. The situation improved after 1966 with beach protection, but the

adult population continued to decrease until new recruits to the nesting beach appeared after reaching the age of maturity. In the meantime, natural mortality, contamination, debris and incidental catch of sea turtles by shrimp trawlers and other fishing gear took their tolls. From 1966 to 1977, additions to the adult population through recruitment were offset by mortality from all causes because the annual nesting population size had stabilized at a low level. Were there no continued negative factors reducing survival of the population, we would expect that the number of nesters should increase, because the high hatch rate at Rancho Nuevo has been repeated from 1978 to the present, and has been reinforced by additions to the population at large by head starting and release of thousands of yearlings during that time.

Proposals for Future Action

The following actions are proposed for the future:

1. continue the joint U.S.-Mexico efforts for five more years after the first 10-year period ending in 1988;
2. reduce incidental catch of Kemp's ridley, especially that associated with shrimp trawling;
3. develop information at a popular level about efforts to reduce mortality and increase population size of Kemp's ridley and disseminate it widely;
4. continue biological research on sex ratios, the relationship between incubation temperature and survival rates, and the monitoring of temperature of nests and the beach during the entire season;
5. continue support of imprinting and head starting work at Padre Island and Galveston, Tex., respectively;
6. continue the education program for students, especially those of the Universidad del Noreste;
7. conduct bathymetric work in front of the Rancho Nuevo beach; and
8. if possible, increase the effort to study migration behavior of juveniles and adults through the use of remote sensors.

Acknowledgements

The authors wish to express their thanks to the Mexican and U.S. fisheries authorities for their assistance and support in the continuation of the work. Heartily we acknowledge the friendship of the people of Rancho Nuevo and its value in helping solve day-to-day problems in the turtle camp. We also wish to express our deep gratitude to Ing. Ernesto Corripio C., Director of the Centro Regional de Investigaciones Pesquera de Tampico, for his assistance in the logistical work, to the Director and students of the Escuela de Biologia of the Universidad del Noreste, and to the U.S. student volunteers for their enthusiastic work on the beach and at the camp. And last but not least, we thank the Delegado Federal de Pesca and his staff, and the Mexican Navy personnel for their vigilance during each season.

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The National Park Service's Role in the Introduction of Kemp's Ridley Sea Turtle

Milford R. Fletcher*

The National Park Service has been involved since 1978 in a multi-agency effort to establish a nesting population of Kemp's ridley sea turtle at Padre Island National Seashore near Corpus Christi, Tex. The procedures call for turtle eggs to be transported from Rancho Nuevo in Mexico to Padre Island, where the eggs are hatched in polystyrene foam boxes. The hatchlings are then released on the beach to make their way to the surf. Exposure to the beach and surf is assumed to imprint hatchlings to Padre Island as their natal beach. Upon entering the surf, hatchlings are captured and transferred to the National Marine Fisheries Service, Southeast Fisheries Center's Laboratory in Galveston, Tex.

Imprinting is a phenomenon that has been documented in birds and fish, but the process is hypothesized to be among the mechanisms responsible for sea turtles returning to nest at natal beaches. This is the 11th year of the recovery program, and slightly more than 17,000 hatchling turtles have been imprinted at Padre Island to date. There have been no documented returns of head started turtles to Padre Island National Seashore.

The National Park Service has been involved since 1978 in a multi-agency effort to establish a nesting population of Kemp's ridley sea turtle (*Lepidochelys kempi*) at Padre Island National Seashore (PINS) near Corpus Christi, Tex. The project, involving the Fish and Wildlife Service (FWS), the National Marine Fisheries Service (NMFS), the Texas Parks and Wildlife Department (TPWD), the Instituto Nacional de la Pesca (INP) of Mexico, and the National Park Service (NPS), has as its primary objective the establishment of a new nesting colony of Kemp's ridley sea turtles on a protected beach in the United States. The history and decline of the Kemp's ridley is documented and discussed elsewhere in these proceedings, so my remarks will be confined to the role of the National Park Service at Padre Island.

Kemp's ridley is the smallest of the sea turtles and probably the most endangered. So far as is known, the only extant nesting concentration occurs on an approximately 20-km stretch of beach near Rancho Nuevo in Mexico, although Kemp's ridleys have been sporadic nesters on Padre Island and elsewhere for many years.

Under the terms of the original agreement, the NPS was to become involved in four major activities:

1. receiving eggs from Mexico under permits from TPWD and FWS;
2. providing personnel and facilities to incubate the eggs until they hatched;
3. imprinting hatchling turtles to the Padre Island beach; and
4. transferring imprinted hatchlings to the NMFS Southeast Fisheries Center's (SEFC) Galveston Laboratory for head starting.

The process is fairly straightforward. First, polystyrene foam boxes are filled with moist sand from Padre Island and transported to the Rancho Nuevo beach. Eggs are collected from laying females at Rancho Nuevo by catching them in plastic bags as they are laid. Eggs gathered in this way are promptly carried to polystyrene foam boxes and packed into Padre Island sand. Eggs, sand, and boxes are then transferred from Mexico to Padre Island where the eggs are held in a hatchery until they hatch.

The first part, receiving the eggs and moving them to Padre Island, has gone smoothly over the years with only a few logistical problems. The NPS, TPWD and FWS all have been involved in one way or another in transporting eggs to Padre Island. Sometimes eggs have been flown to the Corpus Christi Naval Air Station; at other times, to the Corpus Christi Airport; and several times, directly to the Padre Island National Seashore near the hatchery facility.

The second part, hatching the eggs, is very labor intensive. Upon arrival at Padre Island, boxes containing the eggs are transferred to a specially constructed hatchery facility. Multi-channel, temperature probes record temperatures hourly at three elevations in the incubation boxes, and large quantities of data are generated and synthesized. Sand moisture and presence-absence of molds or fungi are monitored daily. The NPS staff at Padre Island computerizes the data records to facilitate their evaluation. Evidence is now mounting that sex of Kemp's ridley hatchlings is determined by the temperature at which eggs are held during a certain phase of their development (Shaver *et al.*, 1988). By artificially elevating incubation temperatures, we are now producing a great preponderance of females. Implications of this concept are profound.

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The third part that NPS plays is imprinting hatchlings. Sea turtles, like salmon, are thought to imprint on their natal surroundings. Something in their physical environment acts to imprint the animals. Imprinting is a phenomenon that is better known in birds and certain fishes than in sea turtles, but the process is assumed to be similar. There are three classical components of imprinting that are thought to be important in this project. First, it occurs at an early age. Precocial birds, like ducks and chickens, imprint on the largest moving object they see after hatching. This is usually their mother, but if the mother is absent and the young are exposed to a moving balloon or a toy train during this critical period, they instead will form a strong attachment to such objects and retain that attachment as an adult. Interestingly enough, the more difficult the moving object is to follow, the stronger is imprinting. This may have a parallel in the difficulty with which hatchling sea turtles dig their way out of the nest and traverse down the beach to the sea.

The second factor of imprinting is that it occurs in a relatively short time. Mallard ducks, for example, imprint best somewhere between 13 and 16 hours after hatching. Chicks do not follow a moving object when they are a few hours old or when they are several days old, but only during a fairly short period of time. Gosslings, for example, when hatched in an incubator, readily imprint on the first large object they see, often a human.

The third factor is that the attachment is permanent and is retained from the time of imprinting to adulthood. Pacific salmon eggs and fry imprint on the chemical smell and taste of the water in which they hatch. After a sea journey of several years they mature, and the adult salmon unerringly return to the same stream they hatched in years earlier. One compelling demonstration of this is afforded by tagged salmon that return to a fish hatchery as adults.

Any of these factors could contribute to turtles returning to their natal beaches to nest. The reasoning is as follows. First, adult female turtles have the ability to find the nesting beach with great accuracy after several years at sea. In the case of the Rancho Nuevo beach, turtles nest along a stretch approximately 20 km long. Why only this particular stretch of beach, when there are thousands of kilometers of beach available? Somehow, after more than seven years at sea, females, and evidently males, are able to locate this unique stretch of beach and reproduce. Second, the experience with the natal beach is limited. Embryos develop within approximately 60 days after eggs are laid. After this time, hatchlings dig their way out of the nest, scurry down the beach, and enter the surf, thus disappearing into the sea for the next few years. The time from hatching to entering the sea may range from minutes to a few hours. Something happens to the embryonic or hatchling turtles during these 60 days or so to permanently imprint them on the geographic location or other characteristics of the beach. We feel that the embryonic turtles imprint to either the sand in which they are incubated and hatched or to physical or chemical characteristics of the beach itself. A chemical imprinting system is postulated under which embyonic turtles sense, imprint on, and retain at least some natal impressions they receive during the incubation period. If this is so, then those turtles expected to return to Padre Island should be exposed to nothing but Padre Island sand. This, then, is our reason for moving Padre Island sand from the U.S. to Mexico and back.

It is impossible to exactly recreate the natural conditions under which Rancho Nuevo turtles are incubated and hatched, but insofar as is possible an attempt is made. After the eggs hatch, the hatchling turtles are transported a short distance to that portion of the Padre Island beach that is closed to vehicular traffic, and there they are released to make their way down to the surf. Activity increases and a mass exodus to the surf begins as the hatchlings are warmed by the morning sun. They orient themselves toward the surf and morning sun and scurry across the beach. Some observers speculate that these few minutes of exposure to the sun, sand, beach and surf are what imprint a turtle to return to that beach. Perhaps, like salmon, hatchling turtles chemically imprint on the particular chemical makeup of the sea water at that particular beach. Although neither of these possibilities has been quantified beyond doubt, there is evidence that turtles hatched and imprinted at Padre Island later show a preference for Padre Island sea water when offered a choice between that and sea water from other sources.

Even though the eggs are placed directly in sand from Padre Island, and hatchling turtles are exposed to the smell or taste of that beach, this does not guarantee that imprinting to that beach has thus occurred. There has been speculation that the geographical location of the developing eggs may be significant. Tiny bipole magnets have been discovered in organisms as varied as bacteria and pigeons. Biomagnetic orientation is believed to facilitate homing movements in pigeons and may act in concert with other environmental factors to provide the homing mechanism in turtles. If this is so, and the magnetic bipoles are oriented during embryonic development, it follows that developing eggs should be moved to Padre Island as soon as possible after collection in Mexico. Because of several factors, this has not always been done.

After imprinting on the beach, the young turtles are quickly gathered from the surf and moved to the NMFS SEFC's Galveston Laboratory. This initiates the final phase of the head start project in which the turtles are reared in captivity for a number of months to allow them to reach a size that significantly reduces their vulnerability to predation after their release. Hatchlings have been either driven by vehicle or flown by aircraft from Padre Island to Galveston. Through the years, the NPS has provided personnel or funds for nearly every facet of the head start project, in addition to contracting several scientific studies related to the project. Excellent press coverage has been a part of the entire U.S.

Table 1. Summary of the incubating-hatching-imprinting phase of the Kemp's ridley sea turtle head start project at Padre Island National Seashore [a].

Year-class	Number of eggs received from Mexico	Hatching percent at Padre Island	Number of hatchlings imprinted	Number of imprinted hatchlings transferred to NMFS
1978	2,191	88.1	1,867	1,848
1979	2,053	85.7	1,754	1,661
1980	2,976	84.1	2,487[b]	1,611
1981	2,279	83.3	1,887	1,868
1982	2,017	77.6	1,559	1,524
1983	2,006	12.1	235	230
1984	1,976	90.7	1,783	1,544
1985	1,978	84.1	1,720[c]	1,692[b]
1986	2,011	88.3	1,775	1,759
1987	2,001	64.3	1,283	1,282
1988	1,019	91.6	929	925
Total	22,507	77.1	17,279	15,944

[a]Data from Shaver *et al.* (1987) and Donna Shaver (NPS Padre Island National Seashore,personal communcation, December 1988).
[b]Includes 811 from Rancho Nuevo eggs that were released as hatchlings at Padre Island.
[c]Includes 69 hatchlings from a natural nesting at Padre Island.

operation. Table 1 indicates that 17,279 hatchlings have been imprinted to Padre Island National Seashore since the inception of the project. A great deal of knowledge about Kemp's ridley biology has been gained in the intervening years, and we are slowly probing the secrets of one of the oldest existing groups of reptiles. The NPS is proud to be associated with this singular attempt to establish a new nesting colony of Kemp's ridley sea turtles at Padre Island, and look forward to the day when the Kemp's ridley is again a common sight on the Texas coast.

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The National Marine Fisheries Service's Kemp's Ridley Sea Turtle Research and Management Plan: Progress and Needs

Charles A. Oravetz*

The National Marine Fisheries Service's (NMFS) Kemp's Ridley Sea Turtle Research and Management Plan was prepared largely because of a recommendation made by a constituent review panel at a NMFS sea turtle program review in Miami, Florida on May 3-4, 1984. Five plan components relating to Kemp's ridley (Lepidochelys kempi) *are performed by the NMFS Southeast Regional Office:*

Information and Education*—A broad range of independent and cooperative activities inform and educate the general public and fishermen of the need to conserve Kemp's ridley. These activities include development and distribution of posters, video tapes, brochures and other means of communication.*

TED Technology Transfer *—TED is an acronym for Trawling Efficiency Device or Turtle Excluder Device. The TED was developed principally to allow escapement of sea turtles from shrimp trawls, thereby enhancing conservation of all sea turtles including Kemp's ridley. Use of the TED provides benefits to shrimpers such as reductions of trash and finfish by-catch. The NMFS has encouraged the voluntary use of the TED, is continuing to transfer TED technology to shrimpers, and is implementing TED regulations.*

Incidental Catch *—Incidental catch information can be used for management purposes and to increase conservation through awareness. Amendments to the Endangered Species Act (ESA) allow reporting of the incidental take of the endangered Kemp's ridley. An incidental catch reporting scheme has been explored with various components of the shrimping industry.*

Sea Turtle Recovery Plan *—A plan for the recovery of six species of marine turtles was completed in September 1984. This plan defines recovery actions for Kemp's ridley. Recovery actions such as head starting, captive propagation, and at-sea monitoring have been implemented.*

Section 7 Consultations*—Section 7 of the ESA requires that all federal agencies conserve endangered species and consult with the Fish and Wildlife Service and/or the NMFS to make sure that they do not jeopardize the existence of any listed species. Section 7 consultations are used to mitigate adverse impacts to Kemp's ridley.*

The National Marine Fisheries Service's (NMFS) Kemp's Ridley Sea Turtle Research and Management Plan was developed in August 1984, largely in response to recommendations made by a constituent review panel at a NMFS Sea Turtle Program review. This panel of environmentalists, scientists, commercial fishing representatives and administrators assembled in Miami on May 3-4, 1984, to learn of NMFS' activities regarding sea turtles. The panel was asked to critically review NMFS' programs and recommend changes. Many recommendations were made and many applied specifically to the Kemp's ridley (*Lepidochelys kempi*). There appeared to be a general consensus of the panel that more emphasis on this critically endangered species was needed. As follow up, the Southeast Regional Office (SERO) and Southeast Fisheries Center (SEFC) of NMFS developed a planning document to specify which of our activities related to the Kemp's ridley. The management part of the plan basically consists of five program elements that are performed by two people in the Protected Species Branch of the SERO in St. Petersburg, Fla.

Information and Education

In my view, information and education activities are highly valuable in enhancing the conservation of endangered species. The public cannot be expected to conserve if they are not informed, and sometimes the information has to be pretty basic. In a conversation with a shrimper about the TED, I was told that he had caught only one dead sea turtle in his lifetime. The turtle apparently was partially decapitated, so he removed its head, and the skull now adorns his retail seafood market. He also told me that he resuscitates comatose sea turtles that he catches, then paints the name of his seafood company on their backs before releasing them. At sometime in the past, that shrimper learned that sea turtles could be resuscitated and knew that recapture data were important. However, information and education efforts had failed to convince him that it was illegal to take and display a sea turtle skull [Editors' note: except for scientific or educational purposes under appropriate federal and state permits, or if it can be proven that the artifact was obtained prior to listing of the sea turtle as threatened or endangered].

* *National Marine Fisheries Service*

Information and education activities are important, but it is difficult to determine what approaches to use and how to evaluate their effectiveness – so we continue with a shotgun approach aimed at informing the public of the need to conserve sea turtles and of ways to do this. This approach has produced a variety of individual and cooperative informational and educational materials. The Kemp's ridley video tape, *Heartbreak Turtle*, sponsored by KUHT television station, Channel 8, Houston, Tex., and the book *The Great Ridley Rescue* (Phillips, 1989) are fine examples of specific, in-depth documentaries of a special conservation effort. I have had the opportunity of extending KUHT's effort by providing copies of the video tape to several marine science centers where it is shown to visitors.

An example of a more general education effort is a Sea Turtle Identification Poster. This poster was developed cooperatively by NMFS and the Center for Marine Conservation (CMC). At least 15,000 of these posters have been distributed worldwide. A Spanish version has been produced by CMC and is part of an educational packet for teachers in Spanish-speaking countries. The packet has been distributed widely in Puerto Rico and the Dominican Republic. NMFS purchased about 300 packets to supplement private distribution efforts in Mexico.

Three other educational projects specific to Kemp's ridley have been completed or are planned. A Kemp's ridley identification poster was printed in July 1985 and distributed. Another species identification sheet depicting the five sea turtle species in our region was distributed. One of its main purposes was to gather information from fishermen who catch ridleys incidentally. A third effort that has not progressed beyond the planning stage is the joint production of a brochure about Kemp's ridley similar to one developed on the Hawaiian Monk Seal. This is proposed by the NMFS central office in Washington, D.C.

TED Technology Transfer

TED is an acronym for Trawling Efficiency Device or Turtle Excluder Device as the case may be. This piece of gear was developed principally to exclude sea turtles from shrimp trawls. Because of its other benefits such as trash exclusion, reduction of finfish by-catch, and improved shrimp catch, NMFS encouraged its voluntary use. NMFS' TED technology transfer activities have involved publicity, demonstrations, and distribution of sample TEDs. The TED is the subject of another paper being presented at this symposium, so it is not being discussed in detail here. However, NMFS currently is implementing TED regulations (Department of Commerce, 1987).

Incidental Catch

Incidental catch information has several uses. It can be used to identify locations of occurrence of sea turtles, their sizes, time periods of abundance, and who in the fishing industry most often encounters sea turtles. It can also be used to stimulate conservation. In the case of the Kemp's ridley, we know that shrimpers take them as do recreational fishermen using hook and line gear, both from boats and from shore. I also read somewhere that the Kemp's ridley is taken in gill nets. This is all good information that can be used to concentrate efforts to reduce the catch, especially if there is associated mortality. Incidental catch information provides data for researchers and for other management applications such as Section 7 consultations under the Endangered Species Act (ESA) of 1973. Perhaps more important, it can be used for conservation exercises.

Let me provide an example of what I mean. Several years ago, I was meeting with some Georgia shrimpers concerning a very high frequency of strandings of sea turtles on Georgia beaches. The shrimpers did not deny that they caught and accidentally killed some sea turtles, but they let me know in no uncertain terms that they would not be held responsible for all the dead sea turtles that washed up on beaches. They hinted that if someone were to try imposing burdensome regulations on them, we might see twice as many dead turtles on the beaches.

Some of those same shrimpers that were so adamantly opposed to imposed turtle conservation at that time cooperated in a sea turtle tagging project with the University of Georgia. The results of their first year of effort were summarized in *Marine Turtle Newsletter* (No. 34, p. 1-2, 1985). Briefly, cooperating shrimpers caught, tagged, measured and photographed 40 sea turtles. Of these, 31 were loggerheads (*Caretta caretta*) and nine were Kemp's ridley. In addition to the valuable scientific information this project provided, it enhanced sea turtle conservation. I believe that only two of these turtles were brought up dead, and I am sure that this was unintentional. Moreover, the 45 other users of this shrimping cooperative's facilities, and their fellow shrimpers in Georgia, were no doubt influenced to conserve sea turtles by this effort.

It would be nice if we could involve every shrimper in the southeast in a similar project. We cannot, but we have tried to expand this effort to Texas, in cooperation with shrimper groups. Amendments to the ESA made it easier to issue permits allowing the inadvertent taking of an endangered species. A condition is the establishment of a conservation plan. We have explored the possibility of establishing a sea turtle by-catch reporting scheme with shrimpers and some data collection has begun. A conservation plan that would be developed as a permit condition might include measures such as proper resuscitation, relocation and release of sea turtles, limits on the length of tow time, and even the testing-adoption of TEDs. Major advantages could be realized by the shrimpers, who would be

protected from an otherwise prohibited act, and for the sea turtles, because a person who has a definite role in controlling its life or death would be involved in its conservation.

A Recovery Plan for Marine Turtles

A Recovery Plan for Marine Turtles (Hopkins and Richardson, 1984) that covers six species of marine turtles was prepared by a recovery team and approved by the NMFS Director in September 1984. The plan sets forth those activities that should be taken by agencies so that sea turtles can be restored to levels where they no longer need protection under the ESA. That is the textbook description of what a recovery plan should be. In reality, for the Kemp's ridley, the plan sets forth those actions that should be taken to try to stop the drastic decline of this species. The actions are prioritized and lead agencies defined. In some cases, one agency is identified and in other cases several. For NMFS there are 10 lead actions for the Kemp's ridley:

1. Regulate the petrochemical industry. NMFS probably does not have authority to regulate the petrochemical industry directly, but can best achieve this objective through Section 7 consultations with the Department of the Interior's Minerals Management Service.
2. Use hatcheries and head starting. This project is ongoing at our NMFS SEFC's Galveston Laboratory.
3. Maintain a total ban on commercial, recreational and subsistence take. I can assure you we have every intention of continuing to do this.
4. Establish captive breeding colonies. This is another activity accomplished through our Galveston Laboratory. Kemp's ridleys captive-reared at the Galveston Laboratory have been distributed to a number of cooperating organizations, in part to provide a reservoir of animals for captive propagation experiments (Caillouet, 1984).
5. Regulate spoil dumping, sea floor mining and trawl tows. NMFS shares this lead with the Environmental Protection Agency with regard to the first two items. Our answer to regulating trawl tows, as least thus far, is TED.
6. Maintain and enforce the ban on take throughout the range. This is similar to item 3, which we are doing in cooperation with many other agencies.
7. Regulate shrimping methods, gear, areas, and seasons in U.S. waters. Steps in this direction are being taken through the TED technology transfer program, through the incidental catch reporting system and through TED regulations.
8. Recommend regulations for shrimping methods, area, year, and season in Mexican waters. Our approach to this action is cooperation with Mexico in TED technology transfer.
9. Determine unknown mortality factors, if any, and take appropriate action. The Kemp's ridley pathology project that was carried out at our Galveston Laboratory has been discontinued. One reason is that mortality during head starting Kemp's ridley was reduced to less than 15 percent through improvements in rearing methods.
10. Determine feasibility of aerial and other means of at-sea monitoring. NMFS has several projects in progress or planned.

Section 7 Consultations

Section 7 of the ESA requires several things of federal agencies. First of all, it requires that all federal agencies "...in consultation with and with the assistance of the Secretary [of Commerce or Interior], utilize their authorities in furtherance of the purposes of this act by carrying out programs for the conservation of endangered species and threatened species..." It also requires federal agencies to "...ensure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered species or threatened species..." Section 7 is truly a powerful tool that can be used for the conservation and management of endangered species, and it is used to the extent practicable in the NMFS Southeast Region. We complete about 110 such consultations each year. Our jurisdiction covers five endangered whales, one fish – the shortnose sturgeon (*Acipenser brevirostrum*) – and the five sea turtles that occur in the southeast and U.S. territorial waters in the Caribbean. Most of our Section 7 consultations are with the U.S. Army Corps of Engineers, often over channel dredging or dredge-and-fill operations, and generally our main concerns are the possible impacts on sea turtles. We try to complete most consultations on an informal basis; that is, we try to get the federal agency to incorporate appropriate mitigating measures into its assessment of impacts, to assure that the net result of that agency's action will not be adverse to sea turtles. In some cases, like dredging of the Port Canaveral, Florida Ship Channel, or dredging and filling in Corpus Christi Bay, Tex., we get involved in a formal consultation. The main differences involve time requirements and procedures for issuance of permits. Specifics of how the Section 7 process is being used to protect the Kemp's ridley are discussed in another part of this symposium's proceedings.

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Questions and Answers

Blanche Lynn: *Do the Mexican people still have the privilege of taking a certain number of ridleys for one purpose or another for their own use? People who come to our shows tell of one experience after another in which a ridley has been taken for personal use.*

Márquez: You are aware that the Mexican people have many necessities including food. They also need money to survive. This is so in all our States. Not only does this create a problem for the Kemp's ridley nesting beach at Rancho Nuevo, but for all our other sea turtle nesting beaches in Mexico. We do not watch the Rancho Nuevo beach at the beginning of the nesting season, and people go to the beach prior to our arrival and take eggs, and sometimes the turtles. If we are not on the beach at the beginning of the season we cannot stop these activities, because the people around that area know when our work is going on there. I do not know for how long a time they have been doing this, but for many years there has been consumption of eggs taken from that beach. The local people remember that their grandmother or someone like this made bread with the turtle eggs, and then they wish to eat that kind of food again. The commercial harvesting there has been stopped since 1966. Some people go to the beach anyway when we are not patrolling it. We make patrols two times each day, and then they go to the beach in the afternoon. Sometimes one or two ridleys appear nesting in the afternoon, when we are not there. From such causes we lose about 10 percent of the eggs during a season. Sometimes we cannot tell whether the eggs are lost to people or to predators. In some cases, we are not able to collect eggs from the nests when the wind is very strong. But after 50 days or so, sometimes hatchlings appear on the beach in natural condition. Therefore, some of the eggs that we miss remain on the beach and hatch out, but some others are still stolen by people, dogs or coyotes. Usually they do not take the adults, just the eggs.

Klima: *Would you comment on the educational program you have started with the people at the village of Rancho Nuevo?*

Márquez: The turtle camp was begun in 1966, and at that time we had some conflicts with the people in the village, because they thought that we were foreigners. Also, they wanted to continue taking eggs as usual. As time passed, the people began to understand the problem and help us. In 1985 we used a new approach to reach the people through the primary school in the village near the turtle camp. When the hatch occured and there were many hatchlings on the beach, we invited the children in the school to help in releasing all those hatchlings from the beach. The children and the teacher of this school participated, and it was a very enjoyable time for everybody. We hope to do this with other schools in 1986. It also would be good if we were able to invite some people from Brownsville, Tex., to participate in a hatchling release – students and teachers – to make the same joint effort at Rancho Nuevo.

David Forcucci: *You said that the commercial harvest of eggs was stopped in 1966. From that point on, how much poaching was there? Was it prevented? Were the beaches watched from then on?*

Márquez: The problem was not stopped until the joint Mexico-U.S. program was initiated in 1978. After the joint program began we had motorcycles and it was easier to remove the poachers. But before that time, we were confined to walking the 32 km beach or sometimes covered it by horseback, and occasionally we had a good look by jeep. The poachers on the beach during 1966 to 1977 were using horses. It was very difficult to pursue the poachers across the marsh, when they were on horses and we were in a jeep. We estimate that after 1977, the loss of eggs averages 10 percent per season, not only from poaching but from other natural causes as well.

Ross Witham: *I have some concern about the release of head started turtles. There is a possiblitity that the imprinting may occur during the offshore swim, when the turtles are swimming away from Padre Island. That could be either magnetic, or it might be a sonic conditioning. Do you have any comment on that?*

Fletcher: You are absolutely correct. It could well be that the imprinting phase of the turtles takes place in the surf or as they move offshore. That could well be the case. However, the reason that we have not tried to do anything with that is because once they would get offshore it would be too late to retrieve them for head starting. As it is difficult to catch them in 1 foot (30 cm) of water in the surf. Once they hit the surf, they are extremely difficult to catch. So if we actually did let them swim out farther than that, we would lose them. So we do not really have any choice about that.

Witham: *I do not disagree with you on that, but what I am suggesting is that the head started turtles should be released from Padre Island, so they can swim offshore from there. They may benefit from that experience. I think there is some evidence that shows a very precise post-hatch learning in some sea turtles.*

Fletcher: I can say that we certainly will take that into account in our deliberations.

Marydele Donnelly: *What sort of changes have been made in the nesting temperature? Are you trying to have more females in your population, and if so, what sort of sex ratios do you have for ridleys? What I am concerned about is that there is some indication with green sea turtles that there are three or four males per female.*

Fletcher: That question is long and involved. I am sure someone else is going to present data on this. Basically, we have been producing a preponderance of male Kemp's ridleys – up to 70 percent male. We feel now that the sex of turtles is pretty well determined by the temperature during the middle third of the incubation period, and yesterday in our intergovernmental deliberations we agreed that we will change our hatchery facilities and hatching regimen to raise the temperature from an average of around 28°C or 29°C to somewhere between 30°C and 32°C, with the hope of bringing the male-female ratio nearer to 50:50.

Donnelly: But do you know that 50:50 is correct?

Fletcher: No, we do not. The evidence that we have so far is that, in box turtles for example, the sex ratio is around 60 females to 40 males. We do not know what the sea turtle sex ratios are in the wild.

Klima: You are probably aware of the extreme difficulty there is in identifying the sex of hatchlings, and we have acquired the technology to do this just recently. The National Park Service and Instituto Nacional de la Pesca have been working on this problem, and we have just recently obtained information on the sex ratios of some of the hatchlings. This information says basically that we have produced a preponderance of males, and just before this symposium we took action to see that in the future we will have more of a natural situation, or one similar to that which occurs at Rancho Nuevo. So in that regard, we assume that we will produce a sex ratio similar to that which occurs at Rancho Nuevo. Whether that is good or bad, we do not know, because sex ratio could be cyclic. There are many questions related to this problem, not only for Kemp's ridley but for other sea turtles as well.

David Bowman: Would you agree that we should point out that the only way the sex of a sea turtle can be determined is if it is dead, and we are not prepared at this time to sacrifice a lot of turtles to determine sex ratios?

Klima: Yes, this is a problem. The turtle has to be dead, so our samples are from dead turtles. They may not be representative of the sex ratio of live ones.

Burchfield: Another point that we have been looking at is what we now have at the Rancho Nuevo natal beach are isolated nests by individual turtles. If we look back at the historical nesting effort at Rancho Nuevo, it is a predator swamping type of reproductive strategy, in which on one day in 1947 there were an estimated 40,000 turtles on the beach within a 2- to 3-hour period. We have some preliminary evidence that the thermal dynamics of closely packed nests under such an *arribazon* situation may be dramatically different from those of isolated individuals nests. So even if we understand what is presently taking place at Rancho Nuevo, in terms of the nesting or breeding population, it still may not be indicative of what made up the natural population historically.

Paul Raymond: Have you considered eliminating the polystyrene foam box hatcheries and going to a natural, on-the-beach hatchery on Padre Island?

Fletcher: Yes, we have. We have considered that option several times. The problem, and I am sure that one of the speakers will present some data on this, is that the beach temperatures at Padre Island are not the same as at Rancho Nuevo.

Raymond:Would they not reflect more natural temperature conditions than the foam boxes?

Bill Lukens: We have considered moving the eggs to the Padre Island Beach. The problem is linked to when we get the eggs out of Mexico. It is usually past the point in incubation at which we feel the eggs can be safely moved to a beach. So we have been putting them in the boxes, to hold and to transport them. That has been the easiest way. In 1986, we are going to maintain temperature during the incubation period with considerably less fluctuation. Bob King and I have discussed eliminating the foam boxes and using some different kind of material.

Terry Cody: You mentioned the incidental take in Georgia and the study that involved cooperating shrimpers. When you talk of permitting Texas shrimpers, are you suggesting that the fishermen will be able to keep the turtles in their possession?

Oravetz: No. What we are trying to do is to get the shrimpers permitted for what is now technically an illegal activity under the Endangered Species Act, with the hopes that instead of being fearful of the law and throwing the turtle overboard, the fishermen will take some steps to resuscitate the turtle, tag it, and perhaps release it in an area where it is not subject to being captured again.

André Landry: What utilization does National Marine Fisheries Service make of county marine extension agents, particularly in working with shrimpers? I know the extension agents have very close contact with shrimpers and have some rapport with shrimpers that National Marine Fisheries Service may or may not have.

Oravetz: I should have mentioned this. In our case, there are four of us. We can spread ourselves only so far. We have had a tremendous amount of support and help from the cooperative marine extension service - mainly the Sea Grant Marine Advisory Agents. Specifically, they assist in passing the word to the shrimpers about the use and availability of the TED. Sea Grant has a network of Marine Advisory Agents in all Gulf of Mexico and South Atlantic coastal states. The program is very good, particularly in Texas. We utilize the agents extensively to help get information about turtles and shrimp to the fishermen.

Nesting Population and Production of Hatchlings of Kemp's Ridley Sea Turtle at Rancho Nuevo, Tamaulipas, Mexico

René Márquez Millan, Aristoteles Villanueva O. and Patrick M. Burchfield*

Nearly all mature females in the population of Kemp's ridley sea turtle (Lepidochelys kempi) nest at Rancho Nuevo, located between Barra del Tordo (23°3.5'N, 97°45.3'W) and Ostionales (23°24.6'N and 97°45.7'W), in Tamaulipas State, Mexico. Small groups also nest in several locations such as Playa Washington and south of Barra del Tordo in Tamaulipas and Tecolutla in Veracruz. There are solitary nestings at Padre Island, Texas, Cabo Rojo, Veracruz, and Isla Aguada, Campeche, Mexico. Nevertheless, the annual number of nests outside of Rancho Nuevo usually is less than 50.

The annual nesting population at Rancho Nuevo has shown a great decline since the discovery in 1947 of an arribada *of more than 40,000. Nowadays, there are fewer than 800 females nesting annually at Rancho Nuevo. The total nesting population can be assessed through life cycle characteristics and fecundity. However, sex ratio at sea is unknown.*

The quantity of hatchlings produced has varied annually, and is related not only to number of females that nest every year and natural meteorological disturbances such as storms or floods but also to the intensity of our biological work at the Rancho Nuevo Turtle Camp. About 664,000 hatchlings were released from the Rancho Nuevo beach between 1966 and 1985. From 1978 to 1985 about 13,000 hatchlings emerged from eggs collected at Rancho Nuevo and incubated at Padre Island. These hatchlings were imprinted at Padre Island then head started for 10 to 11 months in Galveston, Texas. Head started survivors were released into the Gulf of Mexico as yearlings or younger from sites off Mexico, Texas and Florida.

The Kemp's ridley sea turtle (*Lepidochelys kempi*) is unique among sea turtles in many characteristics and behavior, especially in its panspecific adaptation to only one primary nesting beach in the Gulf of Mexico (Carr, 1963; Hildebrand, 1963; Pritchard, 1969; Casas-Andreu, 1971; Pritchard and Márquez, 1973; Chavez and Kaufmann, 1974; Márquez, 1976, 1978; Márquez *et al.*, 1989), and there are no documented data to the contrary in historical times. This natural adaptative feature of one major nesting site has been a determinant of Kemp's ridley population abundance. Maybe it works favorably against natural predation, but for man it has provided an attractive opportunity for easy and profitable exploitation. The result has been that over exploitation by man, coupled with predation and other natural mortality, has reduced the nesting population to 2 percent of the largest documented *arribada* recorded on film in 1947 (Hildebrand, 1963). Because of this decline, the largest arribal of each season is no more than 200 to 300 nesting females, and the total number of nesters per season is no more than 800. Such low numbers emphasize the high vulnerability of this endangered species to any change in ambient physical environment or to increases in fishing effort of any kind that might result in the taking of Kemp's ridley.

Nesting of nearly all adult females in the Kemp's ridley population takes place principally between the sandbar outlets of Ostionales (23°24.6'N, 97°45.7'W) to the north and Barra del Tordo (23°3.5'N, 97°45.3'W) to the south on the beach called Rancho Nuevo, in Tamaulipas State, which has been designated by decree as a natural reserve for Kemp's ridley (Departamento de Pesca, 1977).

As a characteristic behavior of the genus *Lepidochelys*, the nesting is massive and known as *arribazon* or *arribal*. Nevertheless, it is difficult to consider a nesting group of 200 females dispersed over several km of beach as an arribazon. The last small *arribal* comprising about 2,000 females occurred in May 1968. In general, Kemp's ridley's *arribales* are dissimilar to those of the Pacific or olive ridley (*L. olivacea*) because they occur during the day, usually in the morning.

Protection of the nesting beach to achieve recovery of Kemp's ridley was initiated in 1966 by the Direccion General de Pesca (now Secretaria de Pesca), through its Fisheries Research Institute. The turtle camps, occupied each nesting and hatching season, have continued without interruption to this day. The efforts of Mexico were integrated with those of a U.S. assistance team of university students during 1978, and this joint effort was continued for 10 years.

The more important daily work at the turtle camp includes:

1. detection and translocation of nests and incubation of eggs in protected areas;

**Márquez and Villanueva - Instituto Nacional de la Pesca, Mexico; Burchfield - Gladys Porter Zoo*

2. near the end of the nesting season, polystyrene foam boxes containing Padre Island sand are used to hold about three to five percent of the total egg production from Rancho Nuevo, to provide hatchlings for head starting and release;
3. tagging female adults, and recording each nesting female and its nest; and
4. taking temperature of incubation of eggs in foam boxes and temperature profile of the beach at several depths.

The general methodology of work originated at Tortuguero, Costa Rica (Márquez, 1966), and it was modified during the years following (Márquez, Villanueva and Contreras, 1973). It has been used as a model by several beach workers in Mexican turtle camps.

Nesting Distribution

Nesting of Kemp's ridley is concentrated in space and time. This evolutive behavior works as a mechanism regulating population size, and it is induced and affected by internal and external factors that are not clearly understood. It is not easy to reach a diagnosis concerning population size, but despite of that, we can say that such nesting behavior has been successful thus far, as the population still survives. Distributed among the *arribales* are solitary nestings of Kemp's ridley, and it is supposed by Robinson (in press) for olive ridley that such nests have higher survival rates than those from massive arribazones.

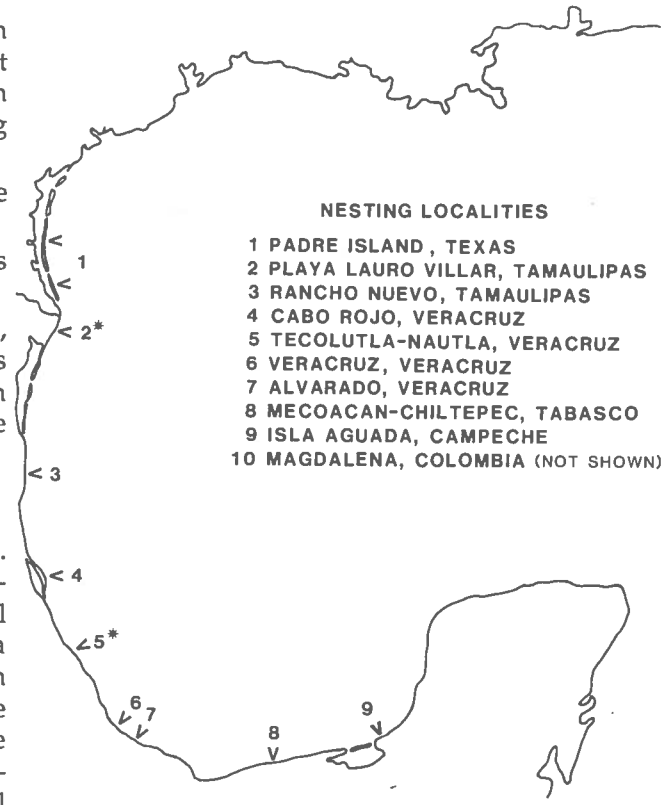

*Figure 1. Nesting localities of Kemp's ridley sea turtle (*indicates small group nestings).*

Geographical Dispersion

Most Kemp's ridley nesting is restricted to approximately 32 km of sandy beach from Barra del Tordo northward (Figure 1). Outside of this area, there are sporadic and dispersed *arribales* of very few nesters; e.g., at Padre Island, Texas (Werler, 1951; Carr, 1961; Adams, 1966, 1974; Pritchard and Márquez, 1973; Francis, 1978; Hildebrand, 1982), at Playa Lauro Villar, Washington Beach, Tamaulipas (Márquez, Villanueva and Sánchez, 1982; Mager, 1985), in Tecolutla and Alvarado, Veracruz (Márquez, 1983, 1984; Márquez and Fritts, 1987), in Mecoacan, Tabasco (Márquez, 1970), and in Isla Aguada, Campeche (R. González, Oficina de Pesca, Secretaria de Pesca, Subancuy, Campeche, Mexico, personal communication; Márquez, manuscript). We are aware of only one record out of range, that being for the Caribbean coast of Magdalena, Colombia (Chávez and Kaufmann, 1974; Meylan, 1982). As far as we have been able to determine, there exists no historical documentation of other Kemp's ridley nesting places as important as Rancho Nuevo anywhere else in the world. It is possible that nesting in the past, at least in Tecolutla, was more intense than it is now and that nesting at Rancho Nuevo covered a wider area to the north and south as compared to the current nesting zone.

Rancho Nuevo Beach

Spatial distribution of nesting at Rancho Nuevo changes with the weather. When the wind blows strongly, nesting usually is concentrated in a more narrow area than on calm days. In general, all *arribazones* strike between Barra del Tordo and El Carrizo, but from time to time dispersion is wider, and a few animals lay north or south of this area. More than 80 percent of the *arribazones* strike between Brasil and San Vicente.

The mechanism of fixity of the nesting site has not yet been clarified. As in other sea turtle species, around 50 percent of the individual Kemp's ridley renest beyond 1.6 kilometers from their former nest during the same season, and less than 40 percent of the individuals renest beyond 1.6 kilometers of their former nest from season to season (Márquez, manuscript). The apparently greater fixity in nest site selection by the same individual from season to season, as contrasted with that within the same season, has no clear explanation.

Population Assessment

Evaluation of population status for Kemp's ridley is more reliable than that for other species because nearly all Kemp's ridley nesting is at Rancho Nuevo, and because nearly all the turtle crawl tracks that occur there on a given day are observed and recorded. The estimated number of nesters and number of nests recorded during 1978 through

Table 1. Estimated number of Kemp's ridley sea turtle females nesting at Rancho Nuevo as determined through fecundity rate[a].

	Years								
	1978	1979	1980	1981	1982	1983	1984	1985	1986
No. of nests	959	1,013	927	946	821	823	892	738	964
No. of females [b]	723	763	699	713	619	620	672	556	727

[a]From Márquez *et al.* (1982) and René Márquez Millan (Instituto Nacional de la Pesca, personal communication).

[b]The average number of nests per female per season was assumed constant at 1.326, but it is known to change from year to year (see Márquez, manuscript).

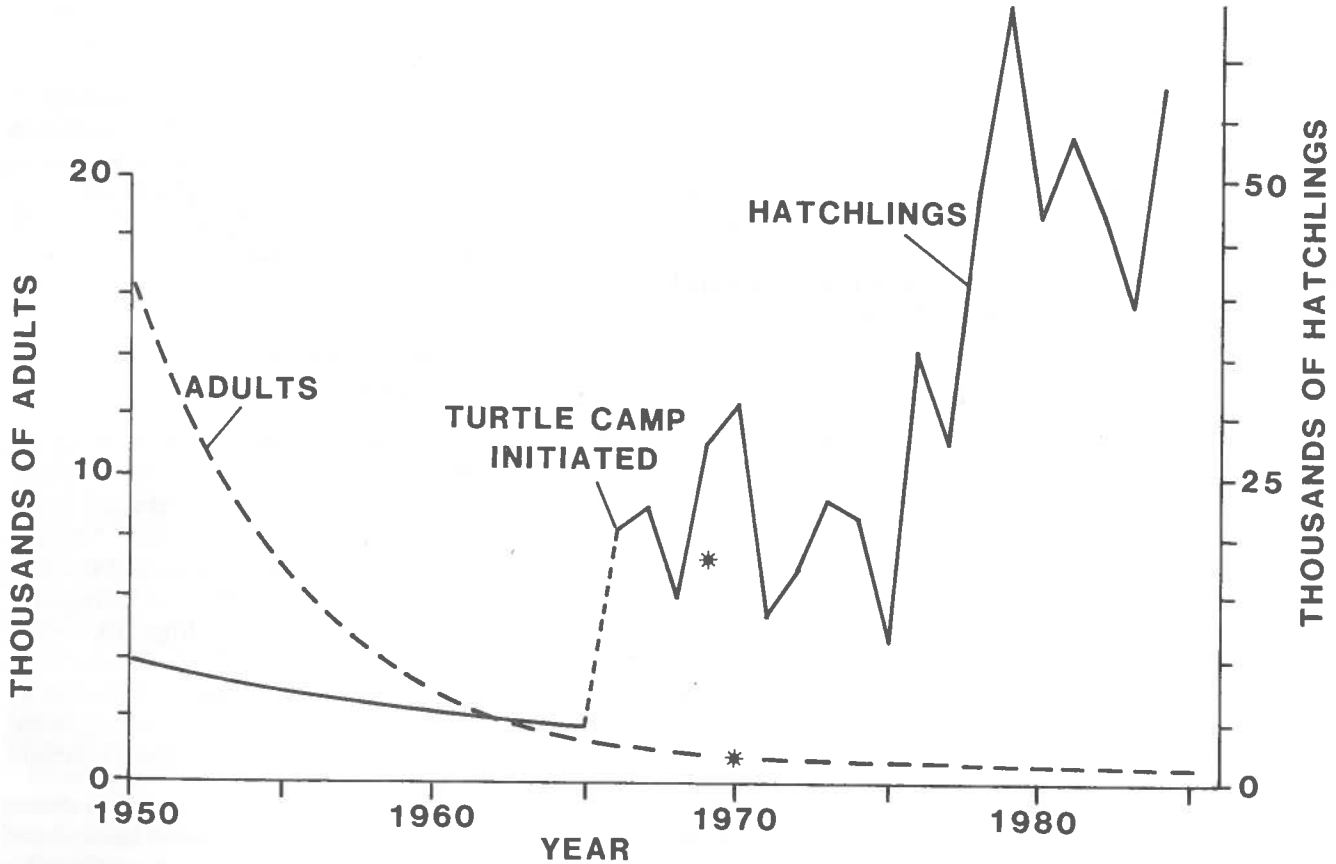

*Figure 2. Empirical decline in numbers of nesting Kemp's ridley sea turtles (long dashes) and increase in numbers of hatchlings produced and released at the Rancho Nuevo beach (*represents numbers of nesters estimated by Casas-Andreu, 1971).*

1986 are shown in Table 1. Because the average number of nests laid per female per season is 1.326 (Márquez *et al.*, 1982), annual number of nesting females is easily obtained. The historical trend in numbers of nesters and hatchlings produced for the same period is presented in Figure 2.

Acknowledgements

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Questions and Answers

Edward Klima: *What do you think are the prospects for that population of nesters?*

Márquez: That is very difficult to say. We have doubled the equipment as compared to what we had when we began protection of the beach. The turtles take about 10 years to reach maturity, and we spent 10 years asking for equipment. The nesting population decreased in the last 10 years, but if we obtain the necessary equipment, we hope to increase the population. In the 1985 season we had about 100 females less than in former years. If that is a cyclic change in the population it could mean the reduction is not due to our situation. It might also mean some other worse situation for the population, we do not know exactly. But if next year the diminution in number of nesters continues, that would mean that the pressure on the beach and surrounding area and on the population is worse than at the beginning of our work. I really do not know.

David Forcucci: *Regarding the decrease in number of adult females nesting on the Rancho Nuevo beach, from 1,000 to 2,000 in 1970 down to what it is now, is it the result of mortality of the adult females or the hatchlings from previous years? To what do you attribute that decrease?*

Márquez: I think it is a combination of many things. The turtles take more than 10 years to reach maturity. We had no recruitment from 1966 to 1976. Beginning in 1976, we have observed recruitment of new adult females to the beach. Despite this, the total number of nesters per season continued to decline. Natural mortality and pressure from fishing continued. Since 1978, we have doubled the production of hatchlings per year compared to the period from 1966 to 1977. From 1976 until now, perhaps the recruitment balanced the total mortality and the nesting population did not increase. Maybe after 10 years of this kind of work, we will have some improvement in the size of nesting population. The fishing pressure and various kinds of pollution remain. During the period when only the Mexicans protected the beach, we stopped that part of the decline of the population due to removal of eggs. After joint Mexican-U.S. work began, we greatly increased the production of hatchlings. We anticipate an increase in the number of nesters in the future.

Forcucci: *Do you expect to have a big or gradual increase in the number of nesters?*

Márquez: Not a big increase, but maybe a slight increase each year until an equilibrium is reached.

Richard Byles: *What is happening with enforcement of the trawling ban off the nesting beach? I noticed that trawlers are still out there during the season. Are there any plans for further enforcement of that trawling ban?*

Márquez: The prohibition is written on paper, but enforcement is not so easy. In 1986, we hope to stop the trawling in front of the beach. The Head of the Fisheries Station in Tampico is in contact with the Commandant of the Navy in the Port of Tampico, and we hope to have some assistance in enforcement from the Navy, by making patrols of the area off the beach. We will ask them to prevent the Mexican shrimp boats from trawling in the area, at least between April and August when the nesting season occurs.

Roderic Mast: *How many nests get left* in situ *on the beach, and have you noticed any significant differences in hatch rate or other differences among the* in situ *nests, the corral nests and the nests that are sent to Padre Island?*

Márquez: In 1985, we left 20 nests *in situ*. Had we taken care of all 20 *in situ* nests we would have had a lower hatch rate than in corrals, but we made two mistakes. We did not avoid the coyotes at the beginning and the middle incubation times. Also, if we had put some stones around the small enclosures placed around the *in situ* nests, we would have saved a few more hatchlings and perhaps would have shown a little better hatch rate than in the corrals. We can expect to lose more than 80 percent of the *in situ* nests, if left in a natural condition without protection by enclosures. There are many coyotes and skunks as well as other small predators on the beach, and there are cows walking on the beach. Cows may squash the nests if they put their feet on them. Then people are able to find the nests more easily the next day. But after one day, they will not be able to find the nests. Coyotes will take the nests during the first days of incubation, and near the end, because the nests have a strong odor when the eggs are freshly laid and when the hatchlings break out of the eggs and release the odor. At those times, coyotes are able to find and attack the nest more easily.

Bob Whistler: *Are the clutches in the corrals monitored? In other words, do you have records for each clutch concerning where it was found and also the temperature of that spot? Do you keep such records?*

Márquez: Yes, we have, but someone else might provide an answer about incubation temperature.

Burchfield: Each nest in a corral has its own specific data sheet which stays with it constantly from the point at which it is collected. Within the last 3 to 4 years we have been looking very closely at nest temperatures within the corrals. All the *in situ* nests were checked with thermal probes, as were some of the corral nests, to try and compare what the

two types of nests were doing. This is what I alluded to a little while ago — comparing the potential thermal dynamics of close packed nests resulting from an *arribada* with thermal dynamics of isolated nests. As best we can at the Rancho Nuevo field station we are looking at temperatures on natural nests, *in situ* nests and corral nests, as well as those that are artificially incubated in hatchery buildings. We are looking at all of those different aspects of the temperature effect.

Promoting Conservation of Kemp's Ridley Sea Turtle Through Public Education

Carole H. Allen and Albert L. Barr *

HEART (Help Endangered Animals-Ridley Turtles), a non-profit organization, is a special committee of the Piney Woods Wildlife Society, North Harris County College, Houston, Tex. A brief history of HEART is given, beginning in 1982 with discussions between the senior author and Dr. Edward Klima, Director of the National Marine Fisheries Service (NMFS), Southeast Fisheries Center's (SEFC) Galveston Laboratory in Galveston, Tex. Some of the accomplishments and contributions of HEART are outlined as well as the activities of HEART committee members, including presentations to student groups, scout troops, nature clubs and other organizations.

Goals of HEART are discussed, including (1) financial support to head starting operations at the NMFS SEFC Galveston Laboratory and to the beach operations at Rancho Nuevo, Mexico; (2) education of the general public, emphasizing the need to continue the Kemp's ridley recovery program; and (3) encouraging contacts with state and federal legislators to provide funding for all segments of the recovery program.

HEART (Help Endangered Animals-Ridley Turtles) is a special committee of the Piney Woods Wildlife Society, the nature club of North Harris County College, located north of Houston, Tex. The primary goals of HEART are education, communication, and support of the entire Kemp's ridley recovery program.

When we organized in 1982, we found that more people needed to know about the head starting of Kemp's ridley sea turtle (*Lepidochelys kempi*) by the National Marine Fisheries Service (NMFS) Southeast Fisheries Center's (SEFC) Galveston Laboratory, the work done by Mexico's Instituto Nacional de la Pesca (INP), U. S. Fish and Wildlife Service (FWS) and Gladys Porter Zoo on the nesting beach near Rancho Nuevo, Mexico, and the incubation, hatching and imprinting efforts of the National Park Service (NPS) at the Padre Island National Seashore near Corpus Christi, Tex. As a result of a sea turtle workshop at Texas A&M University at College Station in January 1983, priorities for Kemp's ridley research and conservation were later published (Owens *et al.*, 1983), and they stressed the need to inform and educate the public. We took those recommendations very seriously.

First of all, we want to commend Dr. Charles W. Caillouet, Jr., and all the head start research staff at the NMFS SEFC Galveston Laboratory for the fine work they do. We at HEART also want to thank them for the continued assistance, cooperation, and courtesy they always have extended to all of us with HEART.

We first began working with students at Oak Creek Elementary School in Spring Independent School District, Harris County, Texas. They formed a HEART Council and planned a field trip to Galveston to see the Kemp's ridley hatchlings. More than 200 enthusiastic students and their parents went on the field trip. We have been busy ever since.

We see head starting as an absolutely necessary and potentially effective way to increase the number of ridleys. In addition to head starting work at Galveston, we support all phases of the Kemp's ridley recovery program, including:

1. the work at Rancho Nuevo conducted by René Márquez Millan and others of INP with assistance from the FWS, Dr. Patrick Burchfield of Gladys Porter Zoo, Brownsville, Tex., and volunteers;
2. the NPS' incubation, hatching and imprinting processes at the Padre Island National Seashore; and
3. the NMFS' Turtle Excluder Device program.

In other words, we promote this recovery program to everyone who will listen, including the folks in Washington, D.C., and we have a lot to promote. We feel that the Kemp's ridley recovery program represents the best of everything - cooperation between Mexico and the United States, cooperation among our own agencies both at state and federal levels, contributions from the private sector, and involvement of the public.

HEART's program allowing people to sponsor food for head starting Kemp's ridleys has been very successful. Anyone making a contribution of $4.00 sponsors one turtle for a year, and we place his or her name on a small, red, plastic heart on a wall in one of the quonset huts in which turtles are reared in Galveston. Kemp's ridleys may also be sponsored through purchases of T-shirts, sea turtle-shaped pillows or the "Raisin' Ridley Cookie Cutter Kit" (Figure 1) from HEART. Those who sponsor a Kemp's ridley feel a personal involvement in the head start project. A class, club or scout group may choose to sponsor five turtles and comply with other educational requirements in order

* *HEART (Help Endangered Animals - Ridley Turtles)*

to form a HEART Council, receive a certificate from HEART and have a larger heart on the wall. Currently there are almost 100 HEART Councils.

The financial support received from individuals, industries, and foundations reflects the tremendous interest in sea turtles and the concern for their survival. We have had great support from EXXON Company U.S.A., Mr. Earl Burke of Pel-Tex Oil Company, The Harris and Eliza Kempner Fund of Galveston, the SER-Jobs for Progress office in Galveston, DeMets Turtle Candy Save the Turtle Fund and Dr. Joe Flanagan and his staff of the Houston Zoo.

One of us (Al Barr) spent time at Rancho Nuevo during four summers. He has also been in charge of the HEART exhibit at the Marine Education Symposium at Texas A&M University. His environmental science classes from Westfield High School, Spring Independent School District, Harris County, Tex., have assisted with HEART's Annual Open House held on or about St. Valentine's Day at the head start facilities in Galveston.

Figure 1. Daphne Hernandez, 9-year-old student of Spring Independent School District, Harris County, Tex., and Junior member of HEART, preparing "Raisin' Ridley" cookies (note the HEART T-shirt).

One of the most important jobs we do is publicizing the Kemp's ridley head start project and the recovery program. Publicity increases public awareness and gives us the opportunity to communicate and educate. Our annual Open House brings hundreds of visitors from the Gulf coast area to see the turtles and rearing facilities. It was one of HEART's Open Houses that inspired Pamela Phillips to write her entertaining and informative book, *The Great Ridley Rescue* (1989). Copies of the book may be ordered directly from HEART. We constantly seek media coverage of major events such as the annual release of tagged turtles into the Gulf of Mexico. Within the last few years, the head start project has received publicity on television Channels 2, 8, 11, 13 and 26 in Houston, and also on ABC, CNN and CBS nationally. An article in the children's publication of the National Wildlife Federation in November 1984 brought hundreds of inquiries from students, librarians, teachers and others in 40 states, Canada, Venezuela, India and Singapore. Galveston's Mayor, Janice Coggeshall, proclaimed the City's first "Turtle Week" in April 1985, providing more newspaper coverage. HEART committee members give presentations in the Houston area using a slide show, and we mail copies of "The Heartbreak Turtle," a one-hour video feature story produced by Houston's public television station, on loan out of state. We also work with students in the preparation of reports about turtles. We encourage people to write their congressmen in Washington, D.C., about the need for continued protection and conservation of sea turtles. For example, the Chicago Herpetological Society asked its 600 members to write their legislators to gain support for the Kemp's ridley recovery program. HEART worked closely with other conservation organizations to lobby for recent reauthorization of the Endangered Species Act and against weakening amendments to the act.

As we look ahead, we see many opportunities for HEART work and hard work. Continuation of the entire Kemp's ridley recovery program and expansion of the head starting phase are needed. Since completion of the new rearing facility at Galveston, about 2,100 ridleys can now be raised and released each year. We will continue to stress that the Kemp's ridley recovery program is an excellent example of cooperation between the United States and its close neighbor Mexico. It is our belief that your income tax dollars are well spent wherever work is going on for the benefit of ridleys. We support captive breeding of Kemp's ridley, and will work with zoos, marine aquaria, universities, and other organizations and agencies where Kemp's ridleys are being kept for that purpose. We urge that strict controls be maintained to ensure the welfare of sea turtles being held by such facilities around the country and in foreign countries. We recommend frequent contacts and inspections as often as possible.

As more hatchlings are released and as the turtles reach maturity in the wild, it is imperative that visitors to possible nesting sites along the Gulf coast be well informed about ridleys. More clean, quiet, restricted beach areas are needed to support sea turtle nesting. Turtle Excluder Devices must be used in the shrimping industry so that accidental catches and kills are reduced to a minimum as quickly as possible.

There is much to be done for Kemp's ridley sea turtles, and HEART pledges continued efforts. We may be very close to more exciting accomplishments toward the recovery of ridleys, or we may need to continue indefinitely to assure

their survival. With patience, determination, and increased public support, both here and in Mexico, we can have success. Let's go for it!

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The Role of Sea Turtle Incorporated in Kemp's Ridley Sea Turtle Conservation and Public Awareness

Ila M. Loetscher*

*After the project to establish a new nesting population for Kemp's ridley sea turtle (*Lepidochelys kempi*) was relocated to the Padre Island National Seashore in the mid-1970s, Sea Turtle Incorporated (STI) was able to put greater emphasis on its public awareness programs while continuing to assist in conservation measures to protect and propagate the critically endangered Kemp's ridley. Beginning in 1980, this non-profit corporation initiated a breeding program for captive ridleys using its female,* Little Fox.

Twice-monthly shows plus shows by reservation are given to acquaint the private sector with the problems and needs of Kemp's ridley and other sea turtles of the Gulf of Mexico. Brochures are published by STI, and slide presentations have been produced for school grades 1-12 and for adult audiences. A demonstration of the typical turtle show was given at the symposium.

Attendance records at the shows and expressed public attitudes have demonstrated an overwhelmingly supportive response. This, in turn, has allowed STI to channel funds, when needed, toward the support of on-going studies by Dr. David Owens, Department of Biology, Texas A&M University, and by Dr. Henry Hildebrand, Corpus Christi, Tex. and to support experimental breeding programs.

Our work has received vast international and national coverage in newspapers, regularly published magazines and professional publications.

The work of Sea Turtle Incorporated (STI) actually began in 1965 when I went with Dearl Adams to Rancho Nuevo, Mexico, and brought Kemp's ridley sea turtle (*Lepidochelys kempi*) eggs back to South Padre Island, Texas. We did not know if sea turtles eggs could be moved and successfully hatched, but we were determined to find out. We brought the eggs, including the mucous and sand from where they had been laid, to South Padre Island and buried them on our beach, duplicating the natural nest as exactly as we could.

The first step worked...the eggs hatched! From 2,000 eggs we got 1,102 babies off to sea. We were so excited that we invited the entire community to see the turtles hatching and crawling off. It was so early in the morning and the lights of the cameramen were so bright that they seemed to confuse the little ones, so some hatchlings were getting badly disoriented. From this we got the feeling that it was the strong light of the sun that sets the course for newly hatched ridleys.

In the excitement, two of the 14-gram precious babies were stepped on. Another was too weak to crawl to sea. These three were given to me to care for and to begin compiling information as to their growth patterns, diet, and habits. We named the turtles *Wynken, Blynken* and *Nod*. This trio so won our hearts that we were caught – hook, line, and sinker! We have never regretted that first step. The benefits and learning experiences have proven boundless. So very little was known about sea turtles at that time. Dr. Archie Carr's first books on the subject were just being published. The libraries, scientists and teachers had very few facts to share with us, but with three loving turtles to coax us on our way, it was not hard to dedicate our hearts and time to better the situation for the declining populations of sea turtles.

Dr. Henry Hildebrand was a frequent visitor, as were folks who came for fun and sun. Noticing the growing interest as more and more people stopped by our turtle kraals to see the turtles fed and to watch their interaction with humans, Dr. Hildebrand suggested we organize a program to acquaint the general public with these marine animals. Most of the inland tourists had never seen a turtle that did not have clawed feet and could not pull its head into its shell. And so our program, "Meet the Turtles," began and has grown and grown and grown.

We quickly learned that "Meet the Turtles" gave the schools a great field trip. We realized that teachers wanted to get over being afraid of the turtles, so we put Atlantic greens (*Chelonia mydas*), ridleys, and hawksbills (*Eretmochelys imbricata*) into roles of little boys and girls, gave them names, and dressed them in original costumes for our shows. Not even the most timid child could be afraid of *Geraldine* in flowing chiffon with her wig tipped over her beak. None of them forgot *Jonathan Livingston Sea Turtle*, our Texas A&M "Aggie," wearing his school's maroon and white colors and applauding his team. To children, the turtles became real people. *Geraldine, Jonathan*, and many others created

* *Sea Turtle Incorporated*

characters the children loved and held dear. Nowadays, we never see a child who hangs back, afraid to get close to our flippered crew. To them a sea turtle is a loving friend. "Meet the Turtles" is now scheduled twice each week. More than 4,400 people attended our shows during the summer of 1985. Winter attendance is even higher.

From the first days when we served punch and cookies and made costumes for the turtles, our involvement has expanded. During the years, we found that some income was needed to support our program, so Sea Turtle Incorporated was established as a non-profit corporation in the State of Texas. Once we started accepting donations, we found it was possible not only to enlarge and improve the turtle housing facilities, but also to respond to needs for monies for scientific equipment and research. In addition to other projects, we were involved with artificial insemination probes and an electro-ejaculator designed and made by Carol Platts. This equipment is now on loan to the Gladys Porter Zoo, Brownsville, Tex. We were able, also, to give Honda ATVs (All Terrain Vehicles) to the ridley recovery team for its use on the beach at Rancho Nuevo. We have been able to award small grants to various scientific programs. It is with deep satisfaction that we are able to assist in many ways, making possible studies that are daily ensuring the survival of sea turtles.

From our small beginnings with the local press, we have seen that the story of the ridleys and our work has appeared in 56 different magazines, including *National Geographic, World, Southern Living, People, Texas Parks & Wildlife, Texas Highways,* practically all of the major newspapers nationwide, and even the *National Enquirer*. Television has given us fantastic coverage – ABC, CBS, and NBC – on "Today," "Tonight," "Real People," "PM Magazine," "Eyes of Texas," "Believe It Or Not," and innumerable other programs. The story has been aired in Japan, France, and Great Britain by their TV companies. A large quantity of mail is received constantly, all tremendously supportive.

Fishermen and beachgoers alike are aware of our sea turtle rehabilitation program. When they find a turtle in distress, they make every effort to get the word to us so that we, with the help of the veterinarian at the Gladys Porter Zoo, can give the turtle every chance to recover. One of our disabled turtles has spent his days happily with us for more than nine years. He is a tremendous help in making children aware of the awful consequences suffered by turtles and other marine animals when people thoughtlessly use the ocean as a garbage dump. Our visitors see turtles that are bobbing along with only three flippers, turtles whose growth has been stunted after having been mixed up in "blobs" of tar, and those that are severely handicapped by genetic defects leaving them in need of lifelong care in captivity. Through this exposure, youngsters and adults are given a lasting impression, a desire to protect creatures in the wild, and a deep respect for these animals that have been members of earth's life chain for so long.

In 1980, we initiated an experimental breeding program for captive ridleys. With the advice of Dr. David Owens, Department of Biology, Texas A&M University, and the cooperation and encouragement of John Kerivan, Sea-Arama Marineworld, Galveston, Tex., we took our then 9-year-old female, Little Fox, to Sea-Arama. The following year, we returned her to South Padre and brought males from Sea-Arama to be with her in South Padre, and in 1983 sent her to Miami Seaquarium. She was returned to us in 1986. We have a male (nine years old in 1985), Dr. *Porter*, who we are hoping will be a useful addition to our brood stock. Using captive-reared animals, we think it may be possible to "milk" the males and artificially inseminate the females. Our plans are on-going as we pursue the best ways to continue this experimental breeding program, perfecting artificial insemination and developing methods to store and ship sea turtle semen. Dr. David Owens, Steve Rabalais of Louisiana Universities Research Consortium, Chauvin, La., and Tim Bentley of the University of Miami, Rosenstiel School of Marine and Atmospheric Science, have been very supportive in this program. To date we have not achieved any of our goals, but we are not about to give up!

We will continue to support the breeding program, continue our intensive public awareness campaign, continue to give assistance to the many scientific studies, and always provide a safe haven for disabled or ill sea turtles in need of our help.

Fishing Industry Perspective on Conservation and Management of Sea Turtles

Ralph Rayburn*

Shrimp vessels on the horizon and stranded sea turtles on the beach have provided the ingredients for a conflict equal to the major historical disputes between commercial and environmental interests. Fortunately, through rational discussion and mutual cooperation between both interest groups, a program has been undertaken that will provide greater protection for threatened and endangered sea turtles.

The key elements in this successful effort were education of crewmen, incorporation of the Trawling Efficiency Device (TED) into many fishing areas, and incorporation of turtle protection into the Fishery Management Plan for the Shrimp Fishery of the Gulf of Mexico.

Since its origin in the bay systems of the Gulf of Mexico, the shrimp harvesting industry has faced countless challenges. Initially, harvest areas were limited to shallow water where drag seines or cast nets could be used. With the incorporation of the internal combustion engine into the fishery, vessels became larger, harvesting equipment was improved, and the area available for harvest was enlarged. However, shrimp consumption remained confined to coastal areas due to lack of adequate refrigeration and basic consumer ignorance.

Offshore shrimp stocks were discovered in the mid-1930s. In the late 1940s, following World War II, the popularity of shrimp as well as its availability in the market began to soar. The period from 1950 through 1979 was marked by significant growth in the industry. Vessels, shoreside facilities and processing plants increased in number as shrimp was established as a highly demanded seafood item. Also during this time, the shrimp industry developed a reputation for being a good investment. Individuals who had here-to-fore owned and operated their own single vessel acquired a fleet of vessels and became fleet managers. This action removed a substantial amount of experience from the cadre of shrimp vessel captains. The latter quarter of this period was marked by economic upheavel in the industry, brought about primarily by the relatively rapid rise in energy costs. Influenced by increases in costs of fuel and ice, the industry's economic equation, which had been its key preservation medium, was thrown out of balance.

International law also was in a state of flux as coastal nations expanded their jurisdictions in the oceans of the world. Much of the shrimp fleet operated under U.S. flag, at least seasonally, in waters off the coasts of foreign countries, especially Mexico. International custom was moving toward some form of coastal states' jurisdiction extending to 200 nautical miles offshore. During 1975-1976, Mexico and the U.S. formally extended their jurisdictions to 200 nautical miles as did most other coastal nations. While, in some cases, a phase-out period was allowed so that traditional fisheries could adjust, the fishing grounds available to our domestic fleets ultimately were drastically reduced in these zones of extended jurisdiction. Past experience could no longer form the basis for future decisions. Members of the "new generation," following in their parents' footsteps, watched in disbelief as opportunity in the family business turned into an economic anchor. Times were changing and the future was stormy. Into this gloomy economic picture came the need for protection of sea turtles.

The seriousness of the shrimper-sea turtle relationship was clearly recognized as a result of a proposal in the May 20, 1975, Federal Register to list green (*Chelonia mydas*), loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) sea turtles as threatened. Some interest groups were proposing that Section 4(e) (similarity of appearance cases) of the U. S. Endangered Species Act of 1973 be imposed on these three species. This would have been a de-facto evaluation to the endangered category, especially as pertains to incidental catch by the shrimping industry.

Testimony in the public hearing of February 25, 1976, yielded comments running the full gamut from those that acknowledged the problem of incidental take of sea turtles by shrimp fishermen, while questioning its dominance as an effect on sea turtle populations as a whole, to those that denounced shrimp trawlers as the real threat to sea turtles in this hemisphere and proposed that the entire outer continental shelf of the Gulf of Mexico be designated as a critical habitat. Specifically, the incidental catch of loggerhead sea turtles in the sounds of Georgia and South Carolina was identified as a problem of concern to environmentalists. In addition, some environmentalists expressed their opinion

* *The Texas Shrimp Association*

that the endangered Kemp's ridley sea turtle (*Lepidochelys kempi*) was being brought to extinction in the Gulf of Mexico by shrimpers.

Environmentalists' expressions of concern did not go unheeded by the shrimp industry. Shortly after the public hearing, key representatives of the shrimp industry met in Houston, Tex., to seek a solution to the problem. Based on these discussions, immediate action was taken to survey the shrimp harvesting industry to learn the extent of the problem and to prepare educational materials for distribution to captains. A survey by Dr. Bruce Cox, then a Texas Sea Grant County Marine Extension Agent in the Brownsville-Port Isabel area and Mr. Bob Mauermann, then Executive Director of the Texas Shrimp Association (TSA), was used as a model by other states (Cox and Mauermann, 1976). It was agreed that neutral parties such as Sea Grant Marine Extension Agents be used to conduct the survey. As for educational materials, it was recommended that a small poster, using as a guide a memorandum prepared by Euclid Lewis of Georgia and entitled "When It's Turtle Time," be prepared and distributed to all shrimp vessel captains. The bottom line objective of the shrimp industry at that time was to make a good faith effort to ensure that sea turtles and shrimp harvesting activities could co-exist. It appeared that the environmental community was not trying to put the shrimpers out of business, but was expressing deep concern. One such concern was expressed by Dr. Archie Carr, professor of zoology, University of Florida, Gainesville, who estimated that the nesting arrivals of Kemp's ridley at Rancho Nuevo had dropped from at least 40,000 in 1947 to 1,200 in 1974.

Shrimp industry representatives remained quite active in moving the brewing crisis into a problem-solving mode. Two issues needed to be resolved. The first was solving the jurisdictional problem between the National Marine Fisheries Service (NMFS) and the Fish and Wildlife Service (FWS). In the spring of 1977, officials of the FWS initiated and later formalized actions that gave NMFS, through the Department of Commerce, responsibility for all activities, regulations and controls over sea turtles while they are in the water. FWS, through the Department of the Interior, retained control of sea turtles while they are on land. The second issue was one of information. During this same period, NMFS, with encouragement by the shrimp industry was setting aside monies for research. The shrimp industry strongly supported NMFS' efforts toward advancement of technology while continuing to ensure that those causative agents more difficult to assess — such as habitat destruction, losses to predators, illegal trade, and interference by other human activities — would not be ignored. Some members of the shrimp industry continued to make light of the crisis, but this attitude was changing.

The seriousness of the situation was realized in the summer of 1979 when a number of mutilated sea turtle carcasses washed ashore on the Padre Island National Seashore near Corpus Christi, Tex. Immediately, the finger was pointed at the shrimp industry based primarily on circumstantial evidence. The Director of NMFS' Southeast Region met with shrimpers from Aransas Pass, Tex., and warned them that a continued high rate of turtle mortality might mean closing Gulf waters to shrimping. There were a few cases in which crewmen on board shrimp vessels were arrested and jailed for illegally taking sea turtles. Word of these actions spread across the waterfront, highlighted by the large bail bonds set in some cases.

Using information supplied by enforcement agents, TSA distributed notices to vessel owners whose vessels had been identified as working in the south Texas area. These notices advised shrimp boat operators of the state-of-the-art precautions to be taken in areas through which sea turtles migrate. The response to these notices was excellent.

Through numerous meetings and other means of communication, various courses of action were developed via joint efforts by the industry, the environmental community and government agencies. The shrimp industry was as active as possible in those areas for which it was responsible. Assistance was given to the development, organization and conduct of the World Conference on Sea Turtles held in Washington, D.C., in November 1979. During this same period, the industry actively assisted NMFS in development of a Turtle Excluder Device (TED), later to be called Trawling Efficiency Device. Regional trade associations formed a conduit for financial reimbursement to industry operatives who suffered losses in shrimp catch due to utilization of the TED. We encouraged development of a NMFS sea turtle poster that would allow better identification of the different species of sea turtles by anyone coming in contact with them. The shrimp industry also joined in the fight in Washington, D.C., to maintain monies for TED development and for the NMFS Southeast Fisheries Center's Galveston Laboratory where Kemp's ridley head starting is carried out. Additional money from industry trade associations, the Gulf and South Atlantic Fisheries Development Foundation (a private corporation established by commercial fishing interests in the southeast region) and NMFS was funneled toward the various other objectives of protecting sea turtles.

As co-chairman of the committee to incorporate TEDs into the trawl fishery, I can report that the process is working. NMFS scientists and technicians have advanced the technology for excluding turtles from trawls to a point at which, with various area-specific modifications, it is adaptable to the fishery. The voluntary program of incorporating this technology has proven to be the best course of action, in that human nature and especially fishermen's nature respond more favorably to a want to than to a have to mode. Also, crews are better educated to the need for protection and proper resuscitation of sea turtles they happen to catch incidentally while trawling for shrimp.

The shrimp industry has come a long way in the past fourteen years toward meeting the challenge of sea turtle protection. No longer will laughs be generated among fishermen by mention of sea turtle protection in the context of its relation to the livelihood of the shrimp industry. It is incumbent upon us all not only to maintain the momentum we currently have, but also to focus on other user groups such as recreational interests and the offshore petroleum industry, to ensure that they too are aware of the plight of sea turtles, so that they may refrain from harming these important sea creatures.

In final analysis, something else equal in importance to the rehabilitation of sea turtle stocks has been achieved through our experiences with this conservation effort. Two groups, initially on opposite sides, have found a way to meet an emotionally charged issue head on and to develop a strategy toward achieving the goals of both groups. This is not to say that the problem is solved, but that we have made a significant step in that direction together.

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TED—Trawling Efficiency Device (Turtle Excluder Device): Promoting Its Use

Wilber R. Seidel and Charles A. Oravetz*

A Trawling Efficiency Device (TED), or Turtle Excluder Device, has been developed to release captured sea turtles from shrimp trawls. The incidental take of sea turtles in shrimp trawls is reduced by more than 97 percent, so sea turtle mortality otherwise associated with trawling is essentially eliminated.

*Besides conserving endangered and threatened sea turtles, the TED provides benefits to shrimp fishermen. Unwanted by-catch is decreased considerably, thus reducing the amount of labor in sorting the catch and improving quality of the shrimp harvested. Cannonball jellyfish (*Stomolophus meleagris*), which sometimes occur in such large numbers that they clog shrimp trawls and decrease towing time, are eliminated so that tows of longer duration can be made. Finfish in the by-catch from shrimping are released at rates exceeding 50 percent at night and 60 percent during daytime. Overall, the reduction of by-catch usually results in a slight increase in shrimp catch. Because of its ability to improve the quality and efficiency of shrimp catch in addition to conserving sea turtles, the TED is now more appropriately described as the Trawling Efficiency Device.*

*The National Marine Fisheries Service is conducting a technology transfer program aimed at educating shrimp fishermen and demonstrating to them the benefits that can be realized by using the TED. This promotional activity has introduced TEDs to shrimp fishermen in all shrimping states on the Atlantic and Gulf of Mexico coasts of the U.S. in an effort to achieve voluntary use of the TED. The TED also has been demonstrated in several foreign countries. Development work is being conducted on a smaller TED for shrimp nets normally used in inshore waters. If it is effective, the small TED could play a significant role in protecting juvenile Kemp's ridleys (*Lepidochelys kempi*) and other sea turtle species in inshore waters.*

The TED (Turtle Excluder Device) was developed by the National Marine Fisheries Service (NMFS) to decrease mortality of sea turtles caught in shrimp trawls. Extensive testing in trawls has demonstrated that the TED releases more than 97 percent of the sea turtles captured incidentally and essentially eliminates trawl-related sea turtle mortality. At the same time, the TED does not cause shrimp loss and may in fact produce a small increase in the catch of shrimp (Watson, Mitchell and Shah, 1986).

In addition to protecting endangered and threatened sea turtles successfully, the TED can provide positive benefits to shrimp fishermen who use the device, by making shrimp trawling more efficient. TEDs can effectively reduce the by-catch of cannonball jellyfish (*Stomolophus meleagris*), sponges, horseshoe crabs (*Limulus polyphemus*), sea turtles, sharks, rays and bony finfish. Finfish reduction rates for trawls with TEDs exceed 50 percent at night and 60 percent during the daytime (Watson *et al.*, 1986). The large reduction in by-catch allows longer towing times, reduces labor required to sort shrimp from the by-catch, and improves quality of the shrimp catch by reducing amounts of broken or damaged shrimp normally associated with long tows and by-catch.

Shrimp fishermen have been urged to use TEDs voluntarily through a technology transfer effort aimed at educating them and demonstrating to them the operational and economic benefits that can be realized from TEDs. TED is now commonly known as the Trawling Efficiency Device because it has broad benefits beyond the conservation of sea turtles.

Description of the TED

The original TED design has been improved significantly. The latest design is light, easy to handle and collapsible. TED originally was constructed of steel pipe and measured 0.8 m high by 0.9 m long by 1.3 m wide. It weighed 44 kg. The original TED had good performance characteristics, but its weight and handling requirements were less than desirable to fishermen who tried the device. Data collected since 1978 on the capture of sea turtles in shrimp trawls were analyzed to see if size of the TED could be reduced. The 0.9 m width of the escape door is sufficient to provide a turtle release rate approaching 100 percent. However, the analysis showed further that if the width were reduced 15 cm, more than 95 percent of the captured sea turtles still would be allowed to escape because less than 5 percent of turtles captured had a carapace width greater than 0.8 m. Even some of the turtles with a carapace width greater than 0.8 m would escape if they could move and turn inside the TED. With the escape door reduced to a 0.8 m width,

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**National Marine Fisheries Service*

the overall width of the TED could be reduced to 1.1 m. The length of the TED was retained at 0.9 m because it is necessary to maintain the angle of the deflector bars at less than 45 degrees (from the horizontal) to ensure proper operation.

The second major change in TED design to encourage its acceptance by fishermen was that of making it collapsible. The collapsible TED has been thoroughly tested on commercial shrimp boats including those towing four nets or quad-rigs. It takes up much less space when on deck, is considerably easier to handle and is very stable during fishing. Making the TED collapsible removed much of the steel structural material from its frame. These changes resulted in a steel, collapsible model of the TED that weighed only 15 kg .

Fiberglass and other plastic materials also were investigated to determine their effectiveness. Fiberglass was found to be the best of these light and strong materials, and the collapsible TED made of fiberglass weighed only 11 kg. Fiberglass, however, seems to be a little less durable than steel and its use required more labor in construction of the TED. Problems also were encountered in obtaining a consistent, inexpensive supply of fiberglass rod material for TED construction. For these reasons, the steel collapsible model of the TED is recommended.

Technology Transfer Approach

TED technology currently is being transferred to the shrimp industry. Through our earlier efforts we attempted to achieve, on a voluntary basis, a significant level of TED usage by the shrimp industry. It was hoped this could be achieved by making shrimp fishermen aware of direct benefits the use of TEDs can provide them. Technology transfer work is directed at demonstrating the ability of TEDs to remove unwanted parts of the by-catch and to improve efficiency.

Particularly troublesome to shrimp fishermen in various areas of the southeast are cannonball jellyfish, small finfish and large objects such as skates, rays, loggerhead sponges, etc. The spacing between deflector bars in the TED normally is 15 cm. When heavy concentrations of jellyfish, large fish and bulky objects like sponges are encountered, they can be ejected by reducing the distance between deflector bars. This is usually accomplished by adding an insert that reduces this distance to about 8 cm. Such objects are then very effectively removed from the by-catch by the TED. Finfish escapement is achieved by adding a finfish deflector grid behind the main deflector bars together with openings in the webbing around the TED. Webbing panels help guide fish out of the trawl.

Education programs, workshops and at-sea demonstrations are being conducted to describe and promote the benefits of TED, especially that of reduction in by-catch. Jellyfish and finfish frequently are so abundant on some shrimping grounds that shrimping operations either must be severely curtailed or occasionally stopped altogether. Reducing by-catch of such items in shrimp trawls with TEDs, particularly during periods when they are in heavy concentrations, represents a significant economic incentive to fishermen who can make longer tows under otherwise adverse conditions. There also is a significant reduction in labor required to separate shrimp from the by-catch.

Another advantage of TED use usually is a 5 to 7 percent increase in shrimp catch as compared to that in a standard trawl. Although we have not been able to come up with a complete explanation for this result, it probably occurs because reduction in by-catch lessens the weight of total catch in the trawl, thus allowing a greater spread in the mouth of the trawl. This benefit, however, is not highlighted during technology transfer activities. Many variables occur during shrimping that could affect or reduce this benefit, so the increase in shrimp catch is left for shrimpers to determine for themselves. However, it is stressed that if TEDs are used they will not cause any shrimp loss.

Results of TED Technology Approach

Key elements in the NMFS TED technology transfer program have been support of the shrimp industry and participation of the Sea Grant programs in selective placement of TEDs on shrimp vessels in various shrimping areas. Some shrimp industry leaders have fully supported the use of TED and have strongly urged shrimpers to use TED. Sea Grant, participating through its marine advisory program, has publicized and encouraged TED use in many ways.

During 1985, 50 steel collapsible TEDs were given to selected fishermen in all the southeast coastal states of the U.S. In each case, one or two TEDs were placed on a boat, and a demonstration fishing trip was conducted to ensure that the vessel captain understood how to install TEDs in shrimp trawls and to use them properly. Construction demonstrations also were conducted at several net shops to stimulate commercial manufacture of TEDs so fishermen would have access to places where they could purchase TEDs.

At the present time, it is difficult to state precisely how many TEDs are in use because of the diverse, independent and mobile nature of shrimping operations. The following are brief descriptions of known TED use:

Domestic Use

1. "Old design" TEDs (196 in number) were constructed and distributed under contract to Desco Marine of St. Augustine, Fla. Their level of use varied, but they were used primarily during periods of heavy by-catch

concentrations. The majority of these TEDs were distributed on the Atlantic coast of the southeastern U.S.

2. Under a joint Alabama Sea Grant and Saltonstall-Kennedy project, a dozen or so TEDs were built by two different net makers in Alabama and were distributed to northern Gulf shrimpers.
3. Due to workshops and direct construction assistance to individual shrimpers, about 45 TEDs have been built.
4. New collapsible TEDs (50 in number) were constructed and installed on shrimp boats in coastal states from North Carolina to Texas during the summer of 1985.
5. A significant number of TED-like devices have been built in some shrimping areas, principally to solve by-catch problems. Several hundred are used periodically in Louisiana for finfish by-catch reduction. Most of these are designed as jellyfish eliminators and will probably eject sea turtles if the eliminators are of sufficient size.

Foreign Use

1. A TED workshop was held in June 1984 in Tampico, Mexico. Results were not very good. The vessel could not go to sea for a checkout during the workshop, and an old design TED constructed from aluminum was used. The TEDs became bent during subsequent use. Aluminum is no longer used as a construction material.
2. In Indonesia, more than 1,000 TEDs are in use in the western part of the country on joint-venture Japanese vessels. Indonesian gear trainees have been sent to the NMFS Harvesting Technology Division, Mississippi Laboratories on three occasions to help them stay current in TED developments. The latest trainee was in Pascagoula, Miss. between July 1 and September 30, 1985, to learn how to build the collapsible TED.

Future Direction

Continued work on TED will focus on three areas:

1. continuation of technology transfer to individual shrimpers;
2. testing of a small model TED for use in inshore waters; and
3. potential TED manufacturers.

The continuation of vessel-based demonstrations, workshops and publicity activities is necessary over the long term. A major purpose of work on the small TED is protection of juvenile Kemp's ridleys (*Lepidochelys kempi*) and other sea turtles in inshore waters. The size of the small TED was chosen to accommodate juvenile ridleys and to be compatible with smaller shrimp trawls used in inshore fisheries. The effectiveness of a smaller TED in reducing jellyfish, finfish and other by-catch has yet to be determined. If results are comparable to those obtained with the large TED, a major push will be made to introduce small TEDs. Emphasis on stimulating commercial production of TEDs is necessary to ensure that TEDs are readily available at a reasonable price. We in the NMFS feel that TED technology transfer is the number one priority item for sea turtle conservation in the southeast region.

Literature Cited

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Trawling Efficiency Device Acceptance and Use by Louisiana Commercial Shrimpers

Paul D. Coreil*

*Commercial shrimpers have always attempted to develop techniques and devices that allow exclusion of non-target species from trawl catches. By-catch species most often encountered include finfish, jellyfish, blue crabs (*Callinectes *spp.) and, to a lesser extent, sea turtles.*

Prior to 1978, many Louisiana fishermen utilized an excluder device, constructed of polyvinyl chloride (PVC) pipe, that deflected unwanted by-catch out of the trawl through a top opening cut in the trawl "throat."

From 1978 to 1983, the National Marine Fisheries Service (NMFS) developed a turtle excluder device (TED) with a steel, top-escape, hinged door. Fishermen found this TED to be cumbersome and heavy, but exclusion performance was good. During this period, Louisiana shrimpers also modified the PVC excluder considerably, and developed an aluminium excluder device that allowed by-catch elimination through a cut in the throat of the trawl along the top attachment point of the webbing (no hinged door was used). The weight of the Cameron Aluminum Excluder (CAE) was considerably less than that of the NMFS TED. The CAE was determined by NMFS to provide good turtle exclusion and was well accepted as a jellyfish excluder in Louisiana.

Use of the CAE was widespread in southwest Louisiana in 1985 and 1986, with one port showing as much as 75 to 80 percent usage during periods of maximum jellyfish occurrence.

Exclusion of by-catch from trawl catch always has been a challenge to commercial shrimpers. In many cases, conventional shrimp trawls cannot be pulled in some areas because of the tremendous amounts of non-target species such as finfish, cannonball or jellyball jellyfish (*Stomolophus meleagris*), other jellyfishes and blue crabs (*Callinectes* spp.) present in the catch. In an effort to eliminate as much by-catch as possible, various homemade devices have been built by fishermen in Louisiana that, when placed in the throat of a conventional shrimp trawl, aid in reducing the amount of by-catch entering the cod end of the trawl. It should be noted that most, if not all, of these homemade excluder devices, even though not designed specifically for the exclusion of sea turtles, will, in fact, allow turtles to escape unharmed without their entering the cod end of the trawl.

In this report, the development of homemade excluder devices in Louisiana will be discussed, and the most recent design, currently being used by many fishermen, will be illustrated. Comparison of this device to the National Marine Fisheries Service's (NMFS) Trawling Efficiency Device (TED) also will be made.

Excluder Device Development

PVC Excluder Device

Most Louisiana commercial shrimpers who used excluder devices prior to 1978 utilized a polyvinyl chloride (PVC) pipe excluder device sewed into the throat of the trawl. It allowed cannonball or jellyball jellyfish, large finfish and large crabs to escape. This square device was placed in the trawl throat at a 45° angle, allowing unwanted by-catch to slide along the plastic bars and out of the trawl through a cut in webbing along the excluder device's top attachment point. Spacing between the bars varied from 6 to 8 cm. The device, therefore, could only deflect or exclude by-catch species larger than this spacing. Problems encountered with the PVC excluder included poor durability and distortion of net configuration. Even though this device served well as a turtle excluder by default, it provided a prototype from which more sophisticated excluder devices were developed.

Aluminum Excluder Device

From 1978 to 1983, many changes took place in excluder design, from the points of view of excluding by-catch (including sea turtles). TED research and development by the NMFS intensified, and in 1983 a steel TED designed with a top-escape, flap door was released to Gulf of Mexico shrimpers. This TED was designed primarily to exclude sea turtles. However, NMFS tests indicated good exclusion of jellyfish and large finfish. This particular TED weighed more than 34 kg and was extremely cumbersome for shrimpers to handle.

The homemade, PVC excluder device also became less popular during this period. Shrimpers working out of the

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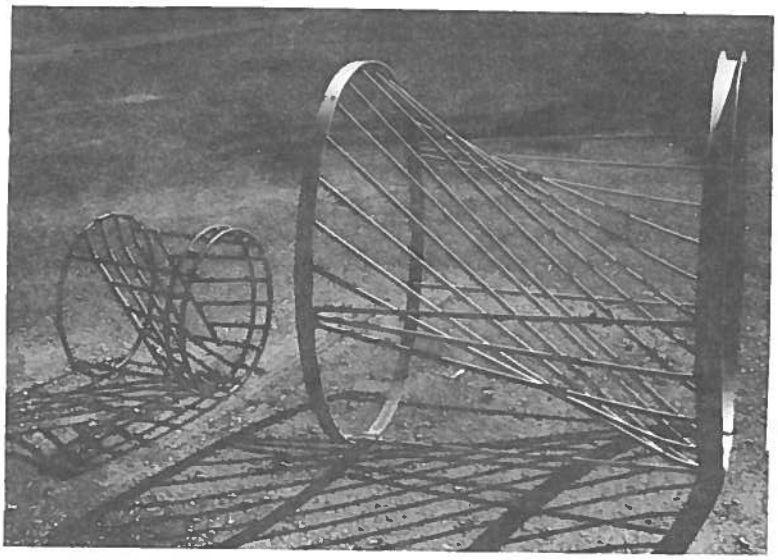


Figure 1. Cameron Aluminum Excluders (CAE) used by commercial shrimpers in Louisiana to eliminate unwanted by-catch in large shrimp trawls (larger CAE), test trawls (try nets) and butterfly nets (smaller CAE).

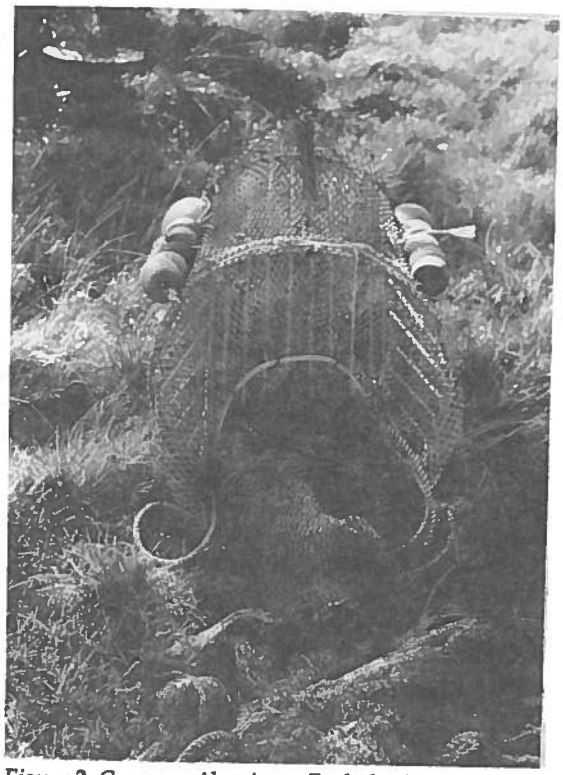


Figure 2. Cameron Aluminum Excluder (CAE) placed in the throat of a conventional shrimp trawl.

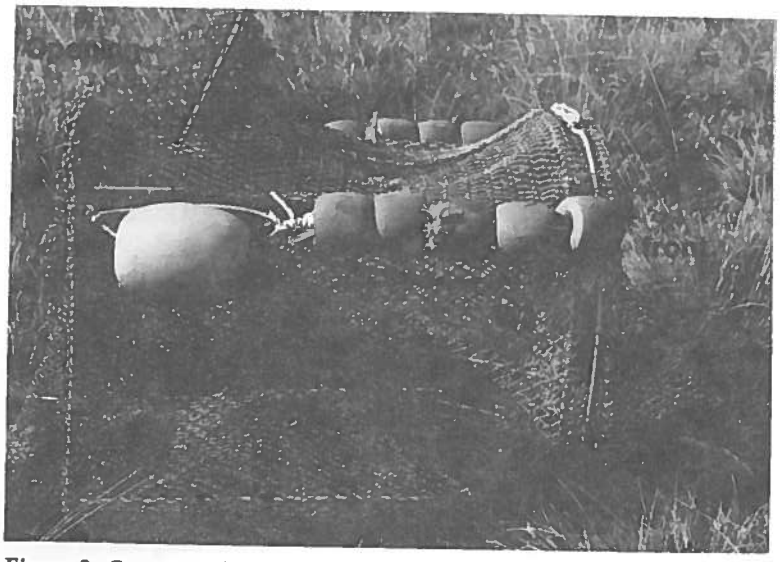


Figure 3. Cameron Aluminum Excluder (CAE) positioned in the throat of a conventional shrimp trawl illustrating the opening (cut in the top webbing) that allows deflected by-catch to escape.

Port of Cameron in southwestern Louisiana developed a device similar in design to the NMFS TED (Figures 1-3). However, aluminum was used for the framework, and a slit in the webbing of the trawl throat was utilized to allow escapement of by-catch (in lieu of using a hinged door as in the NMFS TED). The weight of the Cameron excluder ranged from 8 to 11 kg, which was considerably lighter than the original NMFS TED. This device, placed into the throat of the trawl, was developed primarily to exclude jellyfish, which are numerous throughout southwestern Louisiana in late summer, fall and winter (Figure 2). Turtle exclusion is a secondary benefit of the Cameron Aluminum Excluder (CAE). In no case did fishermen report that turtles were caught while fishing with this device. Most fishermen do not want the hassle of handling large sea turtles on their boats nor the risk of exposure to large fines or prison terms associated with the willful harming of an endangered species. A smaller CAE design (Figure 1) also was developed for use in 5 m test trawls (try nets) and butterfly nets that are used extensively in the Louisiana shrimp fishery.

Performance Comparisons

To compare the NMFS TED and CAE, field tests were conducted in June 1983 on the double-rigged, shrimp vessel GAMBLER off the coast of Cameron. Onboard handling and fishing performance of the NMFS TED and CAE were compared by fishing one of each type of excluder device on opposite sides of the vessel. Both excluders performed well in excluding jellyfish. However, weight of the NMFS TED seemed to cause some additional handling problems when compared to that of the CAE. Through these field tests it was determined by onboard NMFS personnel that the CAE would work well as a turtle excluder in addition to its primary use as a jellyfish excluder.

NMFS Collapsible TED

In 1984, NMFS introduced a much lighter collapsible version of the TED that weighs less than 9 kg, which is a lot less cumbersome than the old steel TED first released for testing in 1983. The additional feature of fish exclusion developed by NMFS was provided to give the shrimp industry an incentive to use this TED. To date Louisiana shrimpers have not voluntarily used the collapsible TED to any great extent.

Conclusion

Marine advisory agents throughout Louisiana have conducted workshops in several coastal communities to highlight advantages of the NMFS collapsible TED and CAE. Information on construction of both excluder devices has been distributed to thousands of fishermen. Use of the CAE throughout Louisiana has varied depending on cannonball jellyfish densities; however, one port had as much as 75 to 80 percent usage during peaks of jellyfish occurrence in 1985 and 1986.

As a Marine Advisory agent working with commercial shrimpers out of the Port of Cameron, La., I have had the opportunity to conduct shrimp retention demonstration on at least seven shrimp vessels. These vessels range in size from 14 m to greater than 60 m. TEDs tested included the NMFS TED, the Georgia Jumper, the CAE and the "Morrison" Soft TED.

In all cases, shrimp loss was experienced, and it increased with increase in by-catch volume. It is my opinion that areas with greater by-catch, such as jellyfish, jellyballs, small finfish, blue crabs, etc., will experience greater shrimp loss due to an increased volume of by-catch being excluded from the trawl. This increased volume being excluded apparently carries additional shrimp out of the net and, therefore, increases shrimp loss. Shrimp loss seems to increase with decrease in by-catch, and I assume it is because the excluder hole or door is left in closed position, reducing the opportunity for shrimp to be lost.

Louisiana experiences times during the year when by-catch is a tremendous problem. The greatest problem seems to be with jellyfish and/or jellyballs. During the summer and fall of 1987, a large population of jellyfish was noted. One vessel testing the shrimp retention of a "Morrison" Soft TED experienced 19.7 percent shrimp loss in heavy jellyfish concentrations. This compares to a 4.6 percent shrimp loss on another vessel pulling in areas of low jellyfish concentrations.

TED testing in areas of high by-catch, especially jellyfish, are needed to assure that commercial fishermen choose a device that will cause the least amount of economic hardship. The shrimp fishery in Louisiana is a by-catch area and will experience shrimp loss with high by-catch using TEDs currently certified.

It is my hope that cooperation between the Cooperative Extension Service, Sea Grant, NMFS and the commercial shrimping industry in the southeastern U.S. can continue, not only in the improvement of trawling efficiency but also in continuing the search for a long term, mutually agreeable solution to the sea turtle decline in the Gulf of Mexico and Atlantic states of the U.S.

Sea-Arama Marineworld and Kemp's Ridley Sea Turtle: A Look Into the Future

John M. Kerivan*

A brief history is given of Sea-Arama Marineworld's involvement in the Kemp's Ridley Sea Turtle Head Start Research Project. Sea-Arama Marineworld maintained a captive stock of Kemp's ridley sea turtles (Lepidochelys kempi) from 1979 to 1988. Some of the methods of husbandry and health care used at Sea-Arama are discussed.

Sea-Arama Marineworld celebrated its 20th anniversary in 1985. Opening in 1965, this aquatic entertainment center has had more than 5 million people pass through its gates. Sea-Arama was the idea of a group of Texas businessmen who understood the need for a marine life park in Texas. The main building and primary seawater systems are designed after those of Marineland of St. Augustine, Fla., the oldest marine life park in this country. Sea-Arama's main theme is entertainment, although many of the shows and exhibits lean heavily toward education. There is another side to Sea-Arama of which few people are aware. In recent years, Sea-Arama has become involved in captive propagation and rehabilitation programs involving threatened and endangered species of wildlife, including the Kemp's Ridley Sea Turtle Head Start Research Project.

Breeding Experiments

Sea-Arama always had Kemp's ridley sea turtles (*Lepidochelys kempi*) in its animal collection. These turtles have been on display at times, along with the collection of green (*Chelonia mydas*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricata*) and olive ridley (*L. olivacea*) sea turtles.

Sea Arama's involvement with the Kemp's Ridley Sea Turtle Head Start Research Project began in 1979, with an inquiry from Dr. James McVey, formerly with the National Marine Fisheries Service (NMFS), Southeast Fisheries Center's Galveston Laboratory, who asked if Sea-Arama would be interested in holding a captive brood stock of 10 Kemp's ridleys. Within a two-month period, preparations were completed to accept the turtles, and Sea-Arama became one of a select few marine aquaria to house these rare turtles for future breeding. We had the opportunity to learn first hand, gaining much useful information regarding the health and husbandry techniques for raising these turtles from yearlings to sexually mature adults.

Research has been conducted on these Kemp's ridleys by Dr. David Owens, Department of Biology, Texas A&M University, who is investigating hormone levels of these animals and trying to pinpoint the age at sexual maturity. Laparoscopy also was performed on a number of our turtles, enabling researchers to have a first-hand view of reproductive organ development. Findings from Owens' research indicate that the Kemp's ridley reaches maturity far sooner than originally was thought. Prior estimates of age to sexual maturity ranged from 9 to 12 years, but Owens' test results indicated that they reach maturity at five to six years of age in captivity.

Further evidence to substantiate Owens' findings was obtained at the Cayman Turtle Farm, Ltd., Grand Cayman Island, British West Indies. Two five-year-old captive-reared Kemp's ridleys nested there in 1984, and three hatchlings were produced. Although none of the hatchlings survived, this event indicated that captive propagation of these turtles would soon be a reality. In 1986, 1987 and 1988, hatchlings survived from nestings of this adult stock.

Not only has research been done on Sea-Arama's captive brood stock, but we attempted to breed the resident adult turtles. Steven Rabalais, The University of Texas Marine Science Institute, Port Aransas, acquired two of our adult males for breeding research. The males were placed with females in hopes of achieving active couplings. Although some attempts were made by the males, the females proved unreceptive.

Other attempts at captive breeding using these animals also produced some interesting results. Ila Loetscher, of Sea Turtle Incorporated, South Padre Island set up a program with Michael Hughes, D.V.M., and Caroll Platts, a research biologist at the Gladys Porter Zoo, Brownsville, Tex. The plan was to introduce Ila Loetscher's female Kemp's ridley to two of Sea-Arama's males. We decided to place a two-week time limit on the turtles' responses. Interestingly enough, the female seemed receptive, but the males showed no interest. It was decided beforehand that if there were no breeding responses within the specified time frame, the males would be electro-ejaculated to collect sperm, and

* *Sea World of Texas; formerly with Sea-Arama Marineworld*

the female would be inseminated artificially. Sadly, this program produced no results.

Attempts at captive breeding at Sea-Arama ended with the transfer of the adult ridleys to Sea World of Texas in December 1988.

Husbandry and Health Care

We learned much about husbandry and health care of these turtles over the years. Knowledge of requirements for seawater quality, foods, feeding techniques, and medical treatment has been greatly expanded.

Seawater System and Tanks

Sea-Arama's seawater system can be described as either semi-closed or semi-opened. Raw seawater is pumped from the Gulf of Mexico into a large settling basin under the main aquarium building where the Kemp's ridleys are housed. After a specified time allowed for settling of beach sediment particulates, the seawater is pumped through two large anthracite filters to remove remaining particles of sediment before entering the main system. Filtered seawater is used mainly for refilling this system after being used to backwash a 74-meter sand and gravel filter. This biological filter is backwashed twice a week, resulting in the dumping and replacement of 303,000 liters of water, or 40 percent of this 757,000-liter system.

The turtles used only a fraction of this system, requiring about 45,400 liters of seawater. The Kemp's ridleys were housed in eight 1,760-liter concrete holding tanks, one turtle per tank. Initially, two turtles were housed per tank. Due to the aggressive nature of juvenile Kemp's ridleys, it was necessary to separate each pair. This was accomplished by installing marine plywood partitions between them. Holes were drilled randomly in each partition to allow seawater flow throughout the tank.

Seawater quality parameters were monitored daily. Once a day is adequate, but due to use of chemicals in the marine mammal systems, seawater tests were conducted three times daily. These tests included the portion of the system housing sea turtles. No chemicals were used in these systems except soda ash (anhydrous sodium carbonate) added daily for slight adjustment of pH. Seawater pH was maintained at 7.5 to 7.8 in this way. Seawater temperature was maintained at 29°C during summer months and not less than 13°C during winter.

Each sea turtle tank was cleaned daily. Each tank was scrubbed with a stiff brush, debris was allowed to settle and then siphoned out. After each feeding, any leftover food was removed, and the tank was cleaned again. The need for good maintenance of seawater cannot be stressed enough. The health and well-being of animals can be related directly to proper seawater quality.

Spatial requirements for Kemp's ridleys during the rearing process are minimal. These turtles can be housed in relatively confined areas over long periods of time. Initially, yearling turtles were confined two to a tank, allowing 871 liters of seawater within each compartment of dimensions 107 cm x 117 cm x 69 cm for each turtle. Turtles were raised to an average weight of 30 kg in such compartments. We then removed the tank dividers, placing one turtle in each tank, allowing each turtle 1,760 liters of seawater within tank dimensions of 213 cm x 117 cm x 69 cm.

One very important aspect of the housing requirements for juvenile Kemp's ridleys is that these turtles must be separated from one another from the time of hatching until they are several years old. If they are kept in close confinement, this period may extend to sexual maturity and possibly beyond. These animals are tremendously aggressive and, without hesitation, will attack and inflict serious injury upon one another. Adult ridleys do not display as aggressive a behavior and can be housed together if needed and if given enough room. The aggressive nature of these turtles is interesting in itself and worthy of further investigation.

Foods and Feeding

Over the years, we developed fairly efficient methods of feeding, selected the proper foods, and found a useful feeding technique. Working with Kemp's ridleys that are sometimes finicky feeders, we fed them herring (Clupeidae), mackerel (Scombridae), white-bait and silversides (Atherinidae), capelin (*Mallotus villosus*), squid (Cephalopoda), shrimp (Penaeidae), and live crabs (*Callinectes* spp.) during the course of the project. The basic diet consisted of capelin (18.8 percent protein, 79.0 percent moisture, 2.1 percent fat, 1.1 percent ash) and vegetable matter. We also fed them fresh, leafy spinach. Of course, the favored foods of these turtles are crustaceans. During the crabbing season, we supplemented their diet with a weekly feeding of live blue crabs (*Callinectes sapidus*). In 1985 we were feeding them three times each week with each turtle receiving approximately 0.5 kg of fish at each feeding. Such feeding level and frequency might seem adequate only for subsistence, but monthly weighings and carapace measurements showed that steady weight gain and growth in length were achieved.

One problem we faced in the beginning of the project was an accelerated weight gain due to overfeeding. This can lead to death in these animals within a short period of time. Feeding frequency and portion size were reduced until we achieved a properly controlled weight gain, as monitored with a daily feeding chart or record for each turtle. Feeding routines for individual turtles can often inform you of problems that can be corrected before they become

serious. If an animal is off its regular feeding routine, this often means trouble and usually needs to be investigated. However, feeding patterns do change somewhat due to seasonal fluctuations in seawater temperature.

Another feeding problem we noticed in Kemp's ridleys was swallowing air during surface feeding. This was only an occasional problem, but its correction can sometimes be rather time-consuming. When feeding larger turtles, make sure that the foods you use sink to the bottom of the enclosure so they can be eaten without the possibility of the turtles gulping air. This problem is sometimes referred to as a floater or gas-in-the-gut problem. Such animals may swallow so much air that they have a relatively hard time swimming to the bottom, and usually float back to the surface. This can sometimes be very stressful to the animals, and after a while they tire and float in an odd plane at the surface. For some reason, certain turtles have difficulty passing the air out of their systems. If this problem does not correct itself in a few days, one may be in for a long period of hand feeding below the water surface until the air is dissipated.

Although all foods fed to the turtles were of the highest possible quality and nutritional value, it was necessary to supplement their diet with a good vitamin program. Vitamins supplied during each feeding included A and D tablets for proper shell growth, vitamin E for prevention of steatitis, and Sea Tabs (distributed by Pacific Research Laboratories, Inc., P.O. Box 1877, El Cajon, Calif. 92022), a multi-vitamin and mineral supplement formulated especially for marine animals.

Weighing, Measuring and Record Keeping

The Kemp's ridleys were weighed and their carapace measured monthly when Sea-Arama first received them, and less frequently after their first year at Sea-Arama. Weighing was accomplished by suspending the turtle in a specially made cargo net. The rectangular net was constructed of soft, knotless, nylon webbing with large stainless steel rings on each corner. The net was spread on the floor, and the turtle placed in its center. The net was pulled up around the turtle to restrain it, then the rings were placed together and hung on the hook of an overhead scale. This method worked well, with no injuries reported during weighing sessions. When using this method, make sure that the flippers are folded against the body in a natural position. Care should be taken to prevent webbing from contacting the eyes. Straight line carapace length and width were measured with a yardstick caliper.

We keep three individual record systems for these animals. The records contain daily and monthly accounts of weights and measurements, weight gains and losses, seawater quality, general conditions, foods, feedings, general observations and comments. Needless to say, accurate, up-to-date record systems are essential to maintaining good health and husbandry.

Identification Tags

Identification tags have posed a problem. The metal flipper tags we originally used were soon outgrown, causing some tissue pinching. There also were problems with electrolysis of these tags. The tags corroded and disintegrated to the point of falling off. Some older, smaller tags were replaced with new ones, but within a year, we experienced the same problems. Many identification options were discussed with NMFS. Plastic, livestock ear tags have replaced the old metal clip tags. The Allflex Tag System (Allflex Tag Company, Ltd., P.O. Box 3132, Santa Monica, Calif. 90403) is described as a two-part plastic tag, applied with a hand held applicator. This tag punctures the flipper and is secured on the top and bottom, allowing free movement. There are two benefits from this type of tag. It allows unrestricted growth with no flipper pinching and, after two years, there is no loss due to electrolytic deterioration.

Health Care

Health related problems were few, although shell lesions caused by bacteria and fungi are a recurring problem. Although we never had serious problems combating these infections, treatments tended to be time consuming. Of the three treatments we have used, bactericidal ointments, fungicidal scrubs (Selemium Sulfide Shampoo, for nonspecific dermatoses, Rugby Laboratories), and exposure to direct sunlight, it seemed that exposure to direct sunlight yielded the best results. A lighting system over the turtle tanks could come very close to duplicating natural sunlight.

Among the important aspects of rearing are stress-related problems due to handling. These turtles frighten easily when handled and sometimes will injure themselves by swimming head-on into tank walls. Capture leads to their loss of bowel control on almost every occasion. We also had turtles refuse to feed after being handled. It is my personal opinion that the less these turtles are handled, the fewer will be the problems related to stress.

Unfortunately, there were mortalities within the group of head started turtles, and three of ten had died as of December 1988. One turtle died following laparoscopy in July 1988. This death was preceded by two that died within a 48-hour period. A third turtle became ill at that same time but it recovered. By far, the most unusual problem with these deaths was that there were no indications of illness or other symptoms associated with the turtles before their deaths. The animals appeared normal the day before they were found dead. The third turtle was reported dead, but it was only moribund. Though presumed dead, the turtle was removed from the water, placed on a 15.2-cm-thick foam mat, and kept damp with wet towels. After a lengthy discussion with Dr. Jack Brundrett, Sea-Arama's

consulting D.V.M., the following drugs were administered: Flo-Cillin (sterile Penicillin G, Benzathine and Penicillin G Procaine in aqueous suspension), injectable vitamins Super B and B_{12}, Solu-Delta Cortef (prednisolone sodium succinate, Upjohn), and Depo-Medrol (methylprednisolone acetate, Upjohn). Treatment continued over a 22-day period, with full recovery within six weeks. The final laboratory conclusion as to cause of illness was clostridial septicemia.

Plans for the Future

More than seven years ago, preliminary plans were drawn up for what the staff at Sea-Arama hoped would be the largest, possibly one-of-a-kind, sea turtle exhibit and breeding facility to come into existence. Due to lack of funding, the new Sea Turtle Research Institute, as we proposed to name it did not materialize. However, my ideas of such a facility are shared with you in the context of what might be the ideal for such a facility.

Upon entering the institute grounds, guests would have the opportunity to view first hand a mixed-species exhibit of sea turtles housed in a 227,000-liter outdoor tank. Graphics would describe and identify each species. Guests would enter the main exhibit hall where a number of wall graphics and free standing exhibits would explain evolution, biology, life history and importance of the sea turtles. In the main hall would be various exhibits, including:

1. explanations of biological aspects of predation;
2. displays of egg laying and nest chambers;
3. a static exhibit of the leatherback turtle; and
4. sea turtle products and uses prior to the passage of the Endangered Species Act.

Adjacent to the exhibit hall, the guests would be able to view a mixed-species, sea turtle and fish exhibit representing a coral reef habitat.

A mini-movie theater, adjacent to the main exhibit hall, would have a seating capacity of 150. Films such as Heartbreak Turtle and multi-screen slide presentations would be offered. The guests also would get a first-hand view of the research laboratory and its activities through glass viewing panels. Of major importance would be the breeding lagoon and nesting beach. The lagoon would be an average of 1.5 m deep, with a sloping ramp rising to the nesting beach. Actual dimensions would be at least 30.5 m x 9.1 m x 1.5 m with a total capacity estimated at 378,000 liters. The nesting beach would run the entire length of the lagoon on one side. The opposite side would be used for public viewing, giving the guests a first-hand view of breeding activities and actual nestings.

Of all Sea-Arama's programs, that involving Kemp's ridley has proven to be the most costly and labor-intensive. But the expenses and time contributed to this project may, in the long term, prove to be worth more than any monetary investment or physical effort we made. The seven surviving adults are now housed at Sea World of Texas in San Antonio, where they will be available for research by Dr. Owens and others.

Questions and Answers

Jack Woody: Mr. Rayburn, do you have a time frame or schedule, as far as Texas is concerned, to get marjoity use of TEDs by shrimp vessels and boats?

Rayburn: That item has been brought up in our discussions over the past number of years. We have been asked to give a time frame or date for the shrimpers to have a majority, at least 50 percent or more, TED adoption. We have never come up with one. Perhaps if one needs something to include in a report, that is important. We in the shrimping industry take the position that a forcing or a mandating of regulations of this sort are not in the best interest of what we are trying to do, because of a number of reasons that we could go into. No, we have not set a deadline. We have not set a time-frame. Our objective is to proceed as quickly as possible to achieve what we feel is in the best interest to both groups, and that is the tact we have taken in agreement within the TED committee that I serve on as co-chairman. Basically, that is the mode that we continue to be in.

Marydele Donnelly: Are you getting any type of resistance from the fishermen?

Rayburn: The technology is still being introduced into the fishery on this side of the world. There was early resistance to TEDs primarily during the development process. This involved the various prototypes that were developed as turtle excluders. First, the use of large mesh over the mouth of the trawl, then the problem of bulkiness of the original TED apparatus that was used in the Atlantic states years ago. Concerning the first device, there was a negative visual impact of a net hanging from the webbing, i.e.; an apron over the mouth of the trawl. There was very much concern over the possible loss of shrimp from this large mesh barrier. The bulky structure of the TED that was developed a few years ago caused a great deal of concern for the lives of the crewman because of its weight and bulk. The collapsible, light-weight TED that is now being incorporated is promising. We had at our past convention a sample for display. The initial response was that the apparatus looked very complicated. All fishermen have not had the opportunity to see it on board a vessel. They have not tested it on the style vessel that they use or with the type of trawls they have. That is now (1985) being done in our particular area. Fishermen are now getting to see how it operates. So as far as having fishermen resist the TED, I would say at this time that there probably is some, primarily because of ignorance about just exactly how the new TED looks and what it does. With fishermen, there is a resistance to any type of change. To say there is no resistance on anything is just impossible. So, if the kinds of resistance we have seen so far is typical — and I am hoping that it does not increase — we can deal with it through education. If an attempt is made to overcome resistance through a regulatory process or to force implementation, I think that would really be self-defeating in this particular case. I really did not come here to try to place some kind of barrier between regulation and education and those kind of things. I really feel that, in this case, and from my experience working with the fishermen, the people I work with on a day-to-day basis and talk to on a day-to-day basis, education is a key to solving the problem. I am sure that if you have spoken with Ila Loetscher here, she perhaps has commented to you about the response she gets down in the Brownsville-Port Isabel area from the shrimpers. The fishermen there are interested. They are people that live off the sea, and they are not interested in going around killing sea turtles at all. The answer is to give them a method of protecting sea turtles that works, and I think they will adopt it. I really do. I think the approach we are taking is the correct one. If not, we are in the position where we can change it.

Sally Murphy: If the other type fishing gear you mentioned – the "quad-rigged" trawls – were adopted within, say, a six month period, or at least over one season, why do you think it is taking so long to get acceptance of TEDs by the shrimping industry?

Rayburn: The quadruple-rigged trawls represented a technology that had been around for quite a while. Not many fishermen were involved at first. Adoption of quadruple-rigged trawl technology took place in a short time once some fishermen tested the gear and proved it to be successful. Then it caught on like wildfire, but it was not something all the fishermen jumped into right away. So, the clock for TED adoption, in my opinion, has not necessarily started yet. We are still showing the fishermen, through the work of the Marine Advisory agents, the National Marine Fisheries Service and others, that these devices can work and be effective in solving some of the problems (e.g., by-catch) that they deal with on a daily basis.

André Landry: Could Charles Orvatez, or Ralph Rayburn, address the role that economics plays or will play in the acceptance and implementation of the TED? Also, do you envision the need for financial incentives in lieu of regulation to get 100 percent usage of TEDs?

Oravetz: Well, I certainly think that if we could prove conclusively to the shrimp fishermen that use of TEDs was by far of great economic benefit it would enhance the rate of TED adoption. We had a preliminary economic analysis of the very first model TED about four years ago. It essentially was favorable. I am not sure whether or not we have had any additional economic analyses of the TED since then. Perhaps Ralph Rayburn has something to add.

Rayburn: The shrimpers do not now have, or in the last three to four years, have they had any excess monies that could be used for experimentation with TEDs. That represents the negative economic side to the industry adopting any new technology. The positive side is what Charles Oravetz referred to. It has been shown to some extent already that there is a positive effect of reduced work from the use of the TED. But, one has to pay for a TED first, then hope that one

gets economic returns on that investment. So we are at a point in the shrimping business at which one has to deal with the realities of economics.

Frank Judd: How much does a TED cost and how long does it last?

Oravetz: A metal TED without webbing costs less than $200. A TED with the webbing around it — one ready to be inserted into and attached to the shrimp trawl — costs about $400 to $450. The latter will last at least two years, depending on how badly it gets banged up during use (e.g., what kinds of hangs the fishermen may run across while trawling with a TED-equipped trawl).

David Bowman: Could you repeat exactly how long the TED technology has been available and how many TEDs are being used in the Gulf of Mexico at this time?

Oravetz: We think that there are around 200 to 300 TED devices being used throughout the shrimp industry in the Atlantic coast states, probably on a parttime basis. The technology transfer program essentially has been in effect there for about two years. But TEDs have gone through a metamorphosis during that time, so even though we were involved in a TED technology transfer program a couple of years ago, it was not the right TED we were testing then. We think we now have overcome the major objections with the TED we now have, based on what we have been told is an acceptable TED. So the technology transfer program involving the new TED essentially started with the distribution of 50 of these TEDs in the summer of 1985.

Bowman: In other words, is the present level zero?

Oravetz: I did not say that. I said the present level is 200 to 300.

Bowman: Are most of these in the Atlantic, or entirely in the Atlantic?

Oravetz: Yes, because that is where we first focused the TED effort. We have only begun to move the new TED technology transfer program to the Gulf during the 1985 shrimping season, with the introduction of 50 collapsible TEDs into the fishery.

Larry Ogren: Is use of the TED from Cameron Parish, La., spreading eastward to any other parishes? Why is that TED so unique to the Cameron area, and why has it not been adopted sooner, or its adoption expanded to the east side of the Mississippi river or even to Terrebonne Parish?

Coreil: Fishermen are more or less port-oriented, and the word on technology developments generally is held among those within a port, and they do not share very much information about it outside that port. In our job as Marine Advisory agents we try to spread information to other ports. It is difficult for any one of us to go from port to port, so we give our information to other agents in other ports. The other agents are now distributing the Cameron Excluder Device technology to other ports. When you tell a fisherman in another port that "this is a Cameron Excluder Device," he automatically says, "Well, I don't want to do something that Cameron does." We must try to overcome that type of resistance, and we are at that stage now. In 1985, we are working to distribute TED sketches and blueprints to the fishermen in other parishes. We are attempting to get fishermen in each port to put Cameron TEDs in their trawls and spread the news about their experiences. If one fishermen, who is well accepted, uses the TED then more will accept it as time goes on.

Edward Klima: What about the other Sea Grant Marine Advisory agents in Texas, Louisiana or Mississippi? Are you trying to spread the news about the NMFS TED or the Cameraon Excluder Device to them, and, if so, why?

Coreil: We are trying to spread information about both the Cameron Excluder and the NMFS TED, because the NMFS TED is working well too. We always bring a NMFS TED to our workshops, but we also bring the Cameron Excluder to show the fishermen that they can build an excluder device themselves, without having to use exact specifications to achieve what the government says will work. If a fisherman builds the device himself - for example Cameron fishermen built the Cameron Excluders themselves — he will feel a lot better about using it than if told to use one designed by the National Marine Fisheries Service. It gives the fishermen a greater sense of control if they build excluders themselves. The Cameron Excluder works in the same way as the NMFS TED. Fishermen may use the NMFS TED, but they feel better knowing that they can design and build something that will also work.

Jack Woody: Am I correct, from what you said, to assume that one of the variations in this equipment is in standard use in Cameron Parish now, and on both vessels and boats?

Coreil: Yes, throughout the industry, on shrimping vessels and boats alike.

Woody: We have heard NMFS' estimates of $200 to $400 for the NMFS TED. What do these homemade excluders cost in Louisiana?

Coreil: About $150 each, but that is without the netting around them. They would probably cost about $200 apiece with netting.

Woody: So, they are in the same ballpark cost-wise as the NMFS TED.

Trash, Debris and Human Activities: Potential Hazards at Sea and Obstacles to Kemp's Ridley Sea Turtle Nesting

Anthony F. Amos*

Considerable quantities of trash and debris impact Gulf of Mexico waters and beaches of south Texas. Many of these materials come from offshore oil and gas operations, merchant marine operations and commercial and sport-fishing activities. Seagoing observations have been made on cruises-of-opportunity, and a beach survey, in its eighth year in 1985, has provided 1,200 separate observations of a 12-km long transect on Mustang Island, Texas.

Assemblages of natural and man-made debris and tarballs often concentrate at sea in wind rows along with planktonic food organisms that attract birds, fish and probably juvenile sea turtles. Beached Kemp's ridley sea turtle (Lepidochelys kempi) juveniles frequently have tar and occasionally small plastic and fiber particles in their mouths and throats. Sea turtle entanglement with plastic debris has been observed.

Trash and debris accumulations on the beach have been recorded both in notes and photographically, and for the past two years (as of 1985) an attempt has been made to quantify this material within various frequently seen categories. Offshore debris includes drums of chemicals and oils, often unmarked and leaking, and sometimes containing toxic materials. In addition, Mustang Island's beachgoers leave large quantities of litter on the beach. Peak times for offshore debris are spring and fall. Litter originating from beachgoers peaks in summer, as does the number of beachgoers.

People, dogs and cars are increasing disturbances to wildlife on once-remote beaches. This survey documents the rapid increase in beachfront condominiums and the numbers of people using the beach.

The Kemp's ridley sea turtle may find obstacles on or near Mustang and Padre Islands, Tex., at several stages of its life-cycle:

1. *when females come ashore to nest,*
2. *during the already hazardous dash to the sea by the hatchlings, and*
3. *at sea during the so-called lost year(s).*

* *The University of Texas Marine Science Institute*

Kemp's Ridley Sea Turtle Strandings Along the Texas Coast, 1983-1985

Robert G. Whistler*

The Sea Turtle Stranding and Salvage Network was established at an international sea turtle conference held at the U.S. State Department in Washington, D.C., in 1978. At that time, the author was asked to coordinate a volunteer group to document sea turtle strandings along the Texas coast. This effort has continued as a viable program since that time. Prior to 1981, the National Park Service (NPS) staff at the Padre Island National Seashore and others collected stranding data and reported the data on various forms. Starting in 1978, the NPS staff at the National Seashore documented all strandings along Texas beaches and recorded the data as far back as 1976 on NPS stranding forms. In 1982, the National Marine Fisheries Service developed standardized forms and procedures to be used by all network participants. Copies of stranding forms completed since 1975 are retained in NPS files.

This paper deals with strandings of Kemp's ridley sea turtle (Lepidochelys kempi) *and other sea turtles on the Texas coast since 1983, and includes the following: species, month and location of strandings, number stranded and environmental factors. Results are interpreted, trends are presented and conclusions are drawn.*

Strandings and reports of strandings have increased dramatically during the last few years. The publicity provided by the Kemp's Ridley Sea Turtle Restoration and Enhancement Program, posters distributed along the south Texas area by the NPS and the interest of citizens and the various media have helped promote this stranding and salvage network. As a result, additional types of data are being acquired that were not obtained earlier in the program. This new information is an important factor in determining the causes of strandings.

The Kemp's Ridley Sea Turtle Recovery Program was initiated in 1977 through a meeting of the following agencies: National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (FWS), Texas Parks and Wildlife Department (TPWD), Instituto National de la Pesca (INP) of Mexico, and National Park Service (NPS). Its goal is to save Kemp's ridley sea turtle (*Lepidochelys kempi*) from becoming extinct (Anonymous, 1982). Various sea turtle authorities assisted in developing the program by providing technical guidance. There existed an awareness that Kemp's ridley at one time nested along the shores of Padre Island (Hildebrand, 1963), and that persistent nesting occurred only on one natal beach at Rancho Nuevo, Mexico. Therefore, the recovery program includes an attempt to establish a new nesting colony of Kemp's ridley on Padre Island by translocating eggs from Rancho Nuevo to Padre Island and imprinting the hatchlings there before they are head started and released into the Gulf of Mexico.

Of concern to the agencies were many things that impact Kemp's ridley and other sea turtle species by affecting their natural life processes, population status and behavior in the Gulf of Mexico. The impacts of man on Kemp's ridley, particularly during its early development and travels along the Gulf coast, were of major concern. Among the questions that arose were (1) what would be the effect of man on the Kemp's ridley nesting colony if it finally became established on Padre Island, and (2) what effects would man have on Kemp's ridley movements and life history. The Sea Turtle Stranding and Salvage Network (STSSN) can provide input to answering such questions. It can increase awareness and concern of the public and resource managers. It can provide information to researchers and scientists and lead to further study and understanding of the turtles and their ecology.

The purposes of this paper are to describe Texas' participation in the STSSN and to summarize stranding data obtained from various sources along the entire Texas coast from 1983 to 1985. This summary extends the studies of Rabalais and Rabalais (1980) and Rabalais (1983) which describe Texas' sea turtle strandings for the periods 1976 through 1979 and 1980 through 1982, respectively.

Methods

Varying numbers of volunteers in the STSSN over the life of the network, frequency of monitoring the beaches, area covered, and degree of response to reports of strandings have influenced the effectiveness of the stranding network and quality of the data obtained. Public interest in strandings has grown, and there is greater public response to sea turtle sightings as a result. This greater public awareness has been generated through various publicity efforts including:

* *National Park Service*

1. turtle posters prepared and distributed in Texas to alert the public about who should be contacted about stranded turtles;
2. newscasts on radio and television;
3. television interviews of network participants;
4. television documentaries; and
5. newspaper coverage.

Such publicity has been increasing and improving. Publicity has generated greater understanding of the purpose and importance of the STSSN. This has improved the quality and quantity of data obtained, but also has created greater demands for interpretation of the information with regard to its significance to sea turtle conservation.

The NPS staff at the Padre Island National Seashore responded to reports of stranded sea turtles along Padre and Mustang Island beaches from 1976 to 1978 and documented the strandings on NPS forms. These forms were revised and improved from time to time until 1982 when the NMFS Southeast Fisheries Center (SEFC) Miami Laboratory established a standardized form (Figure 1) to be used throughout the southeast coastal states to document strandings. These new forms were used to report the data summarized by this paper for the years 1983 to 1985. All stranding reports from Texas volunteers were sent to my office where they were examined, validated and corrected as necessary before being copied and forwarded to STSSN headquarters at the NMFS SEFC Miami Laboratory.

Volunteers represent the foundation of the STSSN. STSSN volunteers in Texas were screened by the NMFS SEFC and were given proper permits. They enabled us to get not only the type of data requested, but also additional information recorded in the comments section of the data form, when they thought that such additional observations about the stranded turtle and its surroundings were pertinent. Such comments added a new dimension to our data collecting. Stranded sea turtles were measured in centimeters down the length of their carapace. Included in these data are some measurements that were estimated rather than being accurately measured directly.

Network volunteers and other individuals also were encouraged to record observations about live specimens sighted within Gulf and coastal estuarine waters. I have received information from a number of fishermen and others concerning sightings of turtles within their natural habitats. These observations include specific areas where turtles were sighted, their observed activities at the time and their feeding activities. Such observations represent the least complete segments of our data because they do not contain measurements or correct species identification. Nevertheless, they do provide important information on number, time of year and location of sea turtle sightings. Such information can be used to detect changes in abundance of sea turtles. Its accuracy will improve as more interest is generated. However, improved methods for species identification of sighted sea turtles must be devised and used to improve this source of data. Our data on sightings may be very helpful, and they will be compiled and summarized in time.

Interested parties have saved the carcasses of a few stranded sea turtles for necropsy. Many of the turtles found exhibit no external clues to the cause of death, and this represents an opportunity for additional investigation. Only through necropsy can one hope to make a determination of the cause of death. We at the National Seashore have neither the capability nor resources to handle this function, but I understand that others at The University of Texas Marine Science Institute at Port Aransas, and at Texas A&M University in College Station and Galveston are conducting necropsies of stranded carcasses.

Data accumulated from 1983 through 1985 are the source for my results and discussion.

Results and Discussion

Figure 2 shows the number of each species stranded along the Texas coast during 1983 to 1985. Loggerhead (Caretta caretta) dominated the stranding records, with Kemp's ridley second in number of reported strandings. Figure 3 shows the number of strandings reported by species and month of the year. This gives a picture of the seasonal occurrence of each species in the strandings. Total reported strandings were highest in April and May. Kemp's ridley strandings occurred in highest number in April and June through October (Figure 3). This is similar to the findings of Rabalais (1983). October appeared to be the secondary peak month for strandings. Rabalais (1983) shows November and July as secondary peaks in strandings. What factors could be at work to provide peak strandings in spring and fall?

Frequency of carapace lengths of stranded Kemp's ridley sea turtles, grouped in 10-cm size classes, is depicted in Figure 4. These sizes include not only the turtles that were measured directly but also those for which sizes were estimated. Figure 5 shows the strandings of sea turtles by species and county. Nueces County had the highest number of sea turtle strandings followed by Jefferson County. Fritts *et al.* (1983) noted that the majority of Kemp's ridleys were observed off the eastern and western coasts of Florida. They made no mention of Texas. Sabine Pass and Sea Rim State Park in Jefferson County have provided the greatest number of stranding reports for Kemp's ridleys in Texas. Port

SEA TURTLE STRANDING AND SALVAGE NETWORK - STRANDING REPORT

PLEASE PRINT CLEARLY AND FILL IN ALL APPLICABLE BLANKS. Use codes below. Measurements may be straight line (caliper) and or over the curve (tape measure). Measure length from the center of the nuchal notch to the tip of the most posterior marginal. Measure width at the widest point of carapace. **CIRCLE THE UNITS USED.** See diagram below. Please give a specific location description. **INCLUDE LATITUDE AND LONGITUDE**

Observer's Full Name _____ Stranding Date ____ - ____ - ____ (year, month, day)

Address Affiliation _____

Area Code Phone Number _____

Species _____ Turtle Number By Day _____

Reliability of I.D. (CIRCLE) Unsure Probable Positive Species Verified by State Coordinator? Yes☐ No☐

Sex: (CIRCLE) Female Male Undetermined How was sex determined? _____

State _____ County _____

Location (be specific and include closest town) _____

Latitude _____ Longitude _____

Condition of Turtle (use codes) _____ Final Disposition of Turtle (use codes) _____

Tag Number(s) (include tag return address and disposition of tag) _____

Remarks (note if turtle was involved with tar or oil, gear or debris entanglement, wounds or mutilations, propellor damage, papillomas, epizoa, etc.) continue on back if necessary

MEASUREMENTS: CIRCLE UNITS

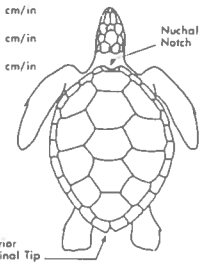
Straight Length _____ cm/in

Straight Width _____ cm/in

Curved Length _____ cm/in

Curved Width _____ cm/in

Mark wounds, abnormalities, and tag locations



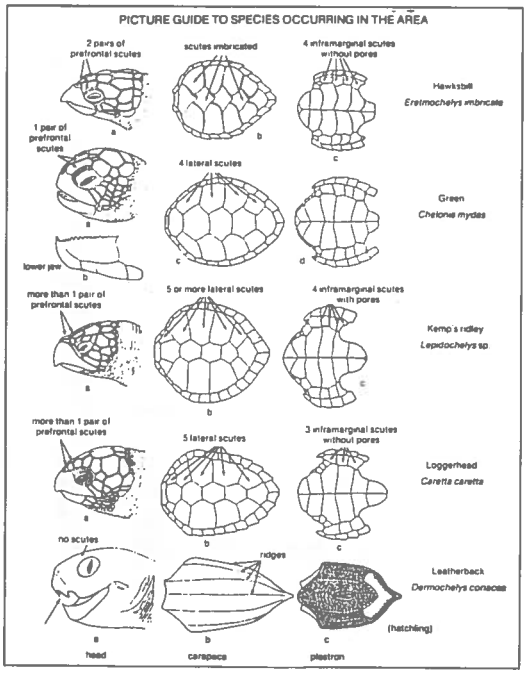
CODES:

SPECIES
- CC = Loggerhead
- CM = Green
- DC = Leatherback
- EI = Hawksbill
- LK = Kemp's ridley
- UN = Unidentified

CONDITION OF TURTLE
- 0 = Alive
- 1 = Fresh dead
- 2 = Moderately decomposed
- 3 = Severely decomposed
- 4 = Dried carcass
- 5 = Skeleton, bones only

FINAL DISPOSITION OF TURTLE
- 1 = Painted, left on beach
- 2 = Buried on beach / off beach
- 3 = Salvaged specimen, all / part
- 4 = Pulled up on beach or dune
- 5 = Unpainted, left on beach
- 6 = Alive, released
- 7 = Alive, taken to a holding facility

Figure 1. Sea turtle stranding and salvage network stranding report (reduced).



The back of the stranding report form includes a species identification guide.

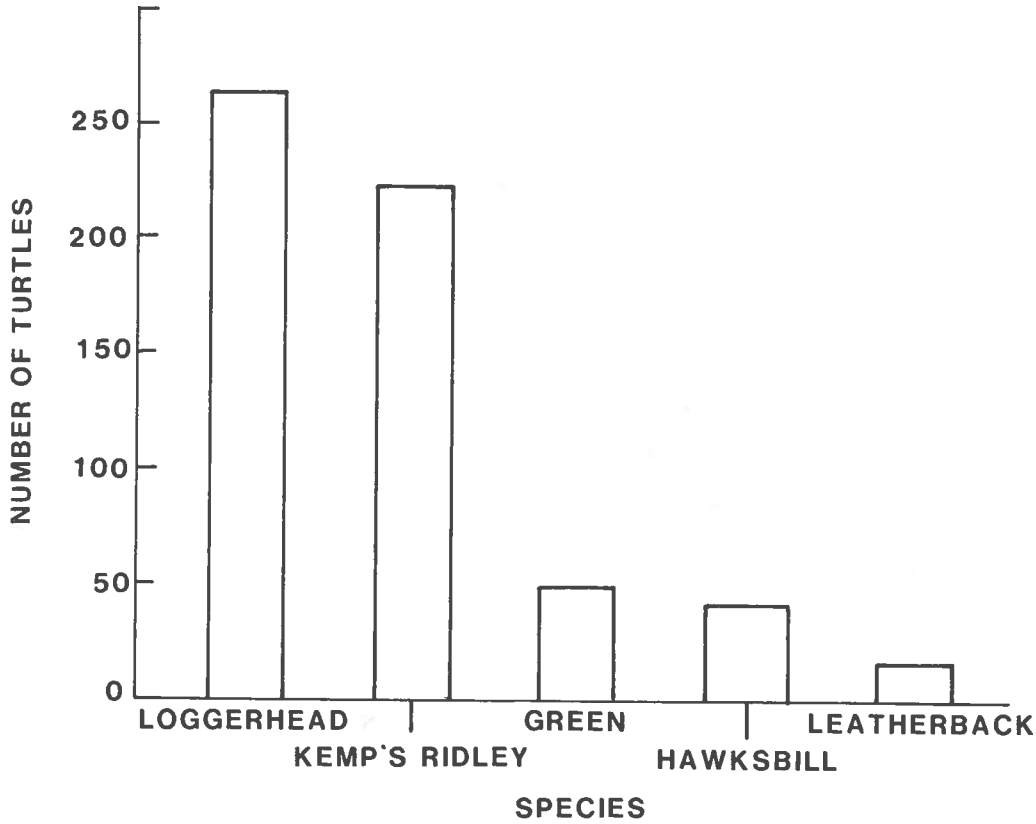


Figure 2. Sea turtle strandings in Texas by species, 1983 to 1985 combined.

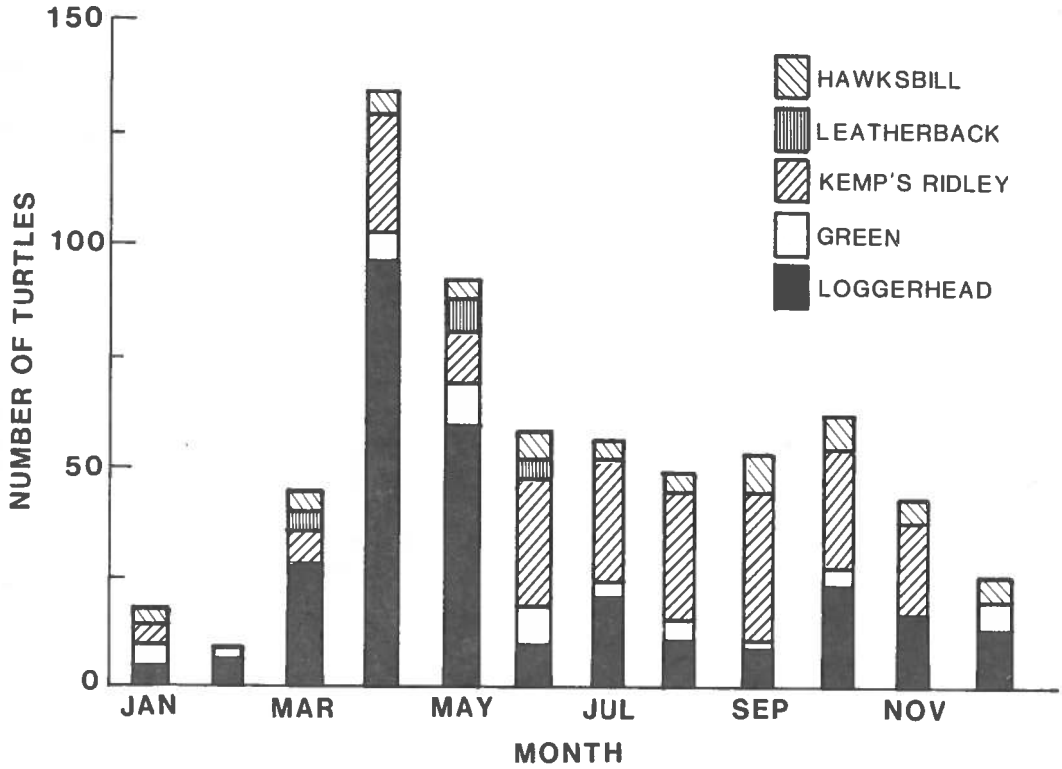


Figure 3. Sea turtle strandings in Texas by species and month, 1983 to 1985 combined.

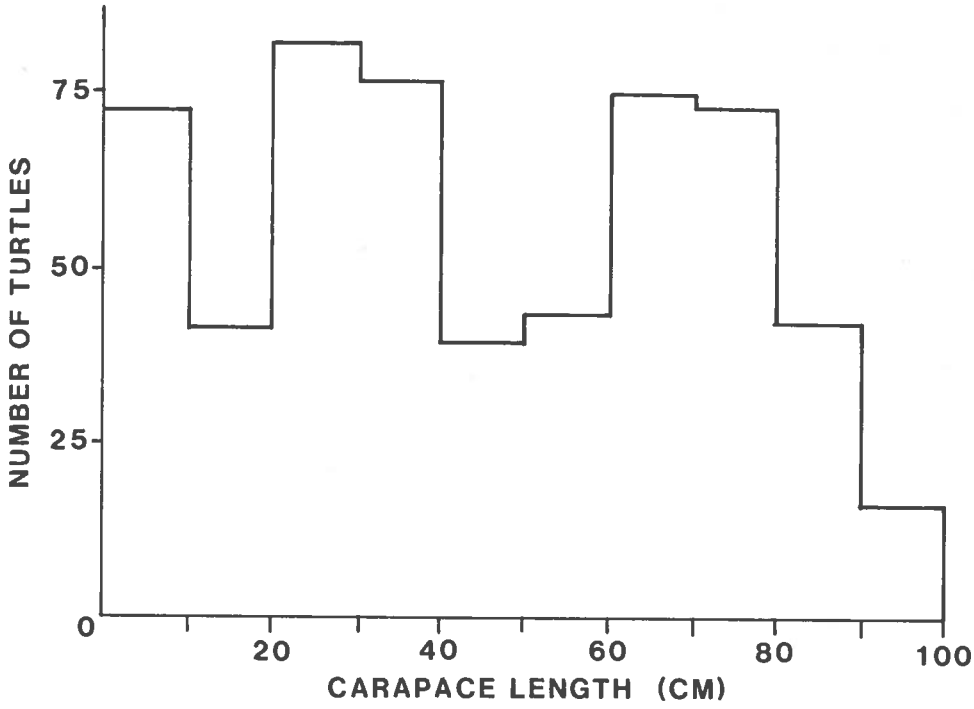


Figure 4. Carapace length-frequency for Kemp's ridley sea turtles stranded in Texas, 1983 to 1985 combined.

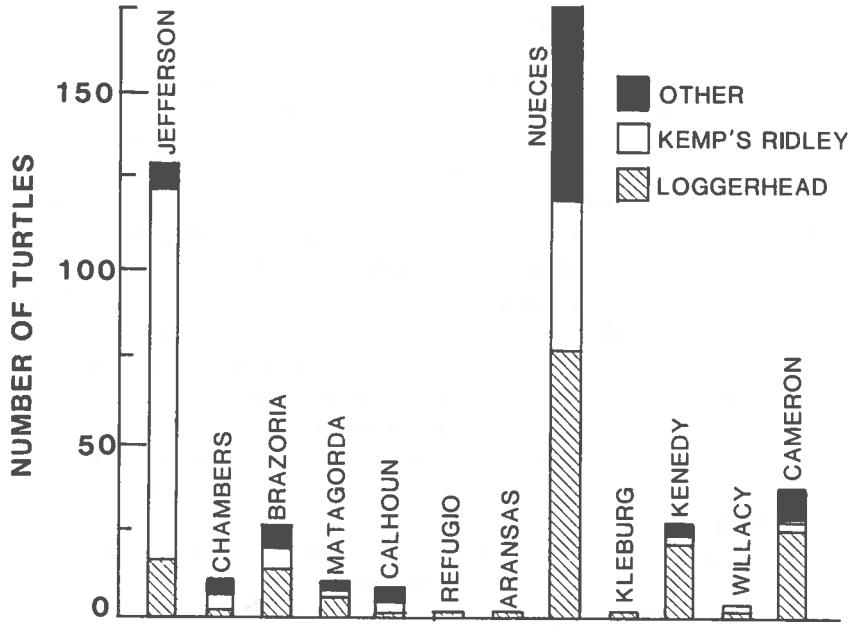


Figure 5. Sea turtle strandings in Texas by species and county (left to right represents north to south along the Texas coast), 1983 to 1985 combined.

Table 1. Frequency of observations concerning condition of stranded Kemp's ridley sea turtles, probable causes of death in those found dead, disposition of the turtles and notes on their surroundings by month, 1983 to 1985 combined[a].

Category[a]	Jan	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Head damaged		2	2	2			3	2	2		1	14
Head missing			2	4	2	1	2	1	3			15
Carapace damaged		1	1		1	3						6
Carapace missing			1	3								4
Flippers damaged		2	1	1	2	1	2		1		1	11
One flipper missing		1	2	1	1		3	2	2	1		13
All flippers missing				1		1		2	1			5
Shark bitten				1			1					2
Wounded in rear			1					1				2
Deliberately killed			2	3		1		1	2			9
Drowned[b]						3		5	1		1	10
Oiled or tarred					6		2					8
Skeletal remains					1	1						2
Necropsy performed		1	1			2			1			5
Rehabilitated[c]	2		3		6	1	1	2	1	1		17
Released alive[d]	2		2		11	5	5	6	1	1		33
Free swimming			1		2	2	1	1	1	1		9
Seemed to be unharmed	2	2	15	5	4	5	2	3	2	4		44
Shrimp boats working at time				2		9	12	4	1			28
No comment			4	5	7	8	4	13	12	8		61

[a] The categories in this table are not mutually exclusive. There were no strandings in February.
[b] Ascertained in an indirect way.
[c] To some degree at some facility.
[d] Usually after rehabilitation.

Aransas and Mustang Island in Nueces County have been second in frequency of Kemp's ridley stranding reports. Other areas along the Texas coast account for the rest of the Kemp's ridley strandings. Sightings and strandings of Kemp's ridley have been reported from inshore waters, including Sabine Lake, between the jetties of Sabine Pass, in Aransas Pass, and in other bays of the upper coast of Texas, as well as in Intracoastal Canal and Laguna Madre. Therefore, Kemp's ridley obviously occurs in bays and inlets of the Texas coast.

Shown in Table 1 are frequency, by month, of 20 categories representing the condition of stranded sea turtles and the circumstances under which they were found, as well as their final disposition. These categories are not mutually exclusive, as a given turtle stranding can be assigned to more than one of the categories. Such data can be used to link strandings to man's various at-sea activities or events. Included are data for dead turtles found fresh and without external wounds or damage of any sort. Clearly, these deaths were not caused by natural predation or mutilation. Still other turtles were found with various wounds on the carapace and other parts of the body. Additional observations not shown in my data summaries include unusual wounds on the flippers and other parts of the body as a result of entanglement in plastic rope or netting. Many reports have been received of young ridleys caught by hook-and-line sportsfishermen using cut mullet (*Mugil cephalus*) as bait while fishing in the surf adjacent to Gulf beaches. Turtles reported as caught in this way ranged from 19- to 43-cm carapace length.

The STSSN provides an incomplete picture of total strandings, and it reflects in part the varying degree of coverage of Texas' coastal beaches by volunteers. To date, it has not shown the true total number of sea turtle strandings. Also, not enough necropsies have been performed to determine the true causes of death. Yet, it is probable that human activities and perhaps pollutants caused the death of stranded sea turtles, either directly or indirectly.

As we look at the history of development of the STSSN compared to its present status, it is obvious that it is now providing a much better overall picture of strandings in Texas than here-to-fore has been available. I refer not only to the documented numbers of sea turtles washing ashore, but also the growing number of sightings of live turtles

in open waters, observations on the condition of sea turtles found stranded and attempts to determine indirect or direct causes of strandings.

Stranded sea turtles are found on the Texas coast during every month of the year (Figure 3). Large numbers of stranded Kemp's ridleys are neonates (<10 cm carapace length; Figure 4). There seems to have been an increase in number of stranded Kemp's ridleys reported during 1983 to 1985, but reported strandings of other species of sea turtles have not increased during the same period [See Rabalais (1983) and Rabalais and Rabalais (1980)]. This is true even if confined to Nueces and other lower-coast counties.

NPS is pleased that park visitors began reporting their sightings of live sea turtles to us in 1985. This is attributed to previous NPS efforts aimed at publicity for the STSSN. Reports of Kemp's ridley nestings at the National Seashore in 1985 are not unusual when taken in the context of sporadic natural nestings reported for Padre Island in the past. However, increased sightings of turtles coming up on the beach in 1985 show that nesting is continuing, and that there may be more nesting activity by Kemp's ridley on Padre Island than we have been aware of before.

There are definite indications derived from stranding reports that man is causing serious impacts on the turtles and their habitats. The observation of shrimping activity within view of the beach is one that frequently appears on sea turtle stranding reports during the late summer months. Also reported by STSSN participants is the occurrence of many other kinds of marine animals stranded on the beaches at the same time, but such observations are not summarized by this paper. Simultaneous strandings of sea turtles and other marine animals suggest linkage to a common cause, so such additional observations are very important.

Tar and oil have been found on stranded Kemp's ridleys at various places along the coast, and this is a serious matter. Reports of tarred or oiled ridleys, ranging in carapace length from 6 to 17 cm, were confined almost entirely to summer months. Most of them were head started Kemp's ridleys, including many with tar in their mouths, found on Mustang Island. Only two of the tarred or oiled ridleys were not head started animals. Several were still alive and were rehabilitated. Others were found at Galveston and Sabine Pass. Witham (1978) reported that most young turtles dying at sea from this cause would not be expected to be found washing onto shore. He also stated that undetermined numbers of young sea turtles die at sea due to ingestion of petroleum residues.

Stranding data show that motorboats cause traumatic and serious injuries to sea turtles. There likely are more cases in which motorboats have caused sea turtle deaths than are documented. In one reported case, a motorboat propeller blade almost cut off the head of a sea turtle. This animal was taken to a veterinarian who performed surgery in an attempt to save the animal's life, but it finally died. I have observed various types of sea turtle wounds that could have resulted from motorboat impact. Additional information from volunteer workers who encounter motorboat injured turtles would be helpful, so that wounds of this nature could be treated. A large number of stranded turtles have been found with their heads missing or with other signs of deliberate and severe damage to the head that caused their death. However, inference of deliberate harm to sea turtles by man is difficult to confirm without first-hand, eyewitness accounts. Other impacts noted include a few stranded sea turtles reported to have been bitten by sharks.

Stranded sea turtles with one or more flippers missing occur in fairly large frequencies. Such trauma would be expected to cause eventual death, as it would be difficult for the turtle to manuever, even if it survived the trauma and shock of losing an appendage and blood. Often, the observation of missing flippers is found in turtles with missing heads and other body damage.

Live-stranded sea turtles have been rehabilitated and released, according to a number of reports we have received. Saving such turtles requires that a network participant or concerned citizen find them and bring them to the attention of the proper authorities so that the turtles can be collected and transferred to rehabilitation facilities for treatment and care. Publicity about the network is essential to saving such turtles. The costs of rehabilitation have not been documented, but rehabilitations have involved much time, effort and expense.

Our observations over the years suggest that there has been a continued rise in strandings and reports of strandings. Part of this increase must be the result of increased voluntary efforts and publicity. Also, the reporting of sightings of live sea turtles has increased due to publicity generated by the STSSN.

Rabalais (1983) showed that loggerheads were the most commonly stranded turtle in Texas and Kemp's ridley was the second most common on Mustang and Padre Islands. Kemp's ridley strandings also were less frequent than loggerheads during the period of study from 1976 through 1979 (Rabalais and Rabalais, 1980). Our data represent a wider area of Texas beaches, but substantiate their observations. Nueces County ranks as the highest in number of reported strandings of the combined five species of sea turtles, and second only to Jefferson County in Kemp's ridley strandings. The combined sea turtle strandings noted by Rabalais and Rabalais (1980) and Rabalais (1983) for the periods 1976 to 1979 and 1980 to 1982, respectively, totaled 259. The total encountered in our data for 1983 to 1985 was 583.

Kemp's ridley strandings almost doubled between the studies by Rabalais and Rabalais (1980) and Rabalais (1983).

Yet the proportion of neonate Kemp's ridleys in the strandings decreased. For example, only six neonate ridleys were reported in Nueces County in 1982 by Rabalais (1983). In this study, Jefferson County led in total number of sea turtle strandings, but neonates have continued to decrease in their ratio to total numbers of sea turtles found stranded. There also have been decreases in the number of areas in which neonates are found, and in the times of the year in which neonate strandings occur.

Conclusion

It is very important that STSSN activities continue to assess sea turtle strandings, and to bring them to the attention of the public. Greater public awareness will stimulate concern about the problems faced by sea turtles. The wealth of available data and the many problems associated with sea turtle conservation provide opportunities for research by graduate students and others interested in lending their talents toward solutions to the problems and to the critical situation facing these valuable natural resources.

In closing, I will share with you some of the questions that have been asked me while in pursuit of this work, and which provide opportunities for research:

1. Are there certain routes traveled by sea turtles and time frames in which certain age groups of sea turtles are found in certain places?
2. Are there certain areas (bays, inlets, nearshore areas, sargassum weed beds, etc.) that sea turtles seek out for the purpose of finding food or for various other reasons?
3. When a sea turtle is killed at sea, what happens to its carcass? Does it continue to float? Presumably it will sink until it becomes bloated. What happens if sharks attack it, and parts are eaten or removed? Does it sink again? If so, will such a carcass ever reach shore? How long does a sea turtle carcass float? In other words, do strandings provide an accurate picture of all the turtles that are killed in one way or another at sea?
4. What can we say about the total sea turtle population based on data from strandings? What effect does such loss of animals have on sea turtle populations? What percentage of the sea turtle population is represented by the reported strandings, by species? Are certain age-groups particularly susceptible to various impacts leading to strandings, and what are the reasons?
5. Are there additional regulations that can be developed to help prevent strandings of sea turtles? It has been proposed that shrimping operations be regulated by requiring use of a Turtle Excluder Device (TED) in shrimp trawls. If such regulations are implemented, how likely are they to be accepted by the shrimp industry?
6. If these questions suggest additional needs for information, what are they, and how should the studies be designed to answer the questions?

Perhaps the STSSN will help answer some of these questions in the future.

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Recent Strandings of Sea Turtles, Cetaceans and Birds in the Vicinity of Mustang Island, Texas

Anthony F. Amos *

Strandings of sea turtles, small cetaceans and birds are common events along south Texas beaches bordering the Gulf of Mexico. In recent years, the incidence of such strandings has been recorded formally as part of a long-term study of bird populations utilizing Mustang Island beach near Corpus Christi, Tex. Data have been submitted to the Marine Mammal Stranding Network and Sea Turtle Stranding and Salvage Network and to the Atlantic and Gulf Coast Beached Bird Survey.

*One-hundred twenty sea turtles of five species have been reported stranded from 1983 to 1985. In order of abundance they are loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempi*), hawksbill (*Eretmochelys imbricata*), green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*). Kemp's ridleys were found most frequently following the offshore releases of head started yearlings; several found alive were later re-released. The occurrence of 12 juvenile hawksbills, most of them alive, is notable as this species has been virtually unreported for Texas waters. Peak abundance for loggerheads, almost always found dead, is in March and April and appears to coincide with shrimping activities offshore.*

*Thirty-five small cetaceans have been reported stranded in the same period. Nine of these have been live strandings of uncommon to rare pelagic species, including pygmy killer whale (*Feresa attenuata*) and dwarf sperm whales (*Kogia simus*), spinner dolphin (*Stenella longirostris*), short-snouted spinner dolphin (*S. clymeme*), and striped dolphin (*S. coeruleoalba*). Live strandings have occurred in October, December, April and May.*

*Fifteen-hundred birds have washed ashore dead from 1980 to 1985. Mortality of laughing gull (*Lagus atricilla*), the most commonly found dead bird, peaked dramatically following the opening of the Gulf to shrimping in July. More than 4,000 oiled birds have been observed and a periodicity in the frequency of oiling (spring and fall) discovered.*

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The Effects of Petroleum on Sea Turtles: Applicability to Kemp's Ridley

Peter L. Lutz and Molly Lutcavage*

*Contact with petroleum is likely to be harmful to all sea turtles. Yet, because of reduced population size and restricted nesting distribution, the Kemp's ridley (*Lepidochelys kempi*) may be especially vulnerable to damage from accidental spills. In behavioral studies with green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) sea turtles there was no evidence that sea turtles detect and avoid oil slicks or distinguish tar balls from food items. Physiological studies showed that loggerhead sea turtles chronically exposed to crude oil in our laboratory showed cell abnormalities of the skin, alteration of respiratory patterns and blood cell dysfunctions. During exposure, sea turtles ingested oil incidentally, and oil sometimes appeared in the feces. Salt secretion and minor ion regulation by the salt gland were reduced or delayed. At sea, failure of osmoregulatory systems could prove fatal. It appears that sea turtles are highly sensitive to oil, which must be considered another factor threatening the Kemp's ridley. Management options for mitigating the damage of accidental oil spills are urgently required.*

The biological effects of petroleum on marine fishes, mammals and birds have received substantial attention in recent years (Moore and Dwyer, 1974; Light and Lanier, 1978). However, despite the endangered or threatened status of sea turtles, virtually nothing is known about potential biohazards of oil on these animals (Witham, 1983). This is surprising considering that the mode of life of sea turtles may put them in a particularly high risk category. In an oil slick the turtles' habit of surfacing to breath ensures a continued contact with the oil. If the turtles passively drift with the oil slick, then contact is prolonged. Some species may pursue and swallow tar balls. Finally, nesting beaches can be inundated by oil spills.

Out of seven species of sea turtles living today, five are found in the Gulf of Mexico: Kemp's ridley (*Lepidochelys kempi*), loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and leatherback (*Dermochelys coriacea*). Oil pollution poses a threat to these animals and may even challenge the survival of the species most at risk, the Kemp's ridley. In fact, the IXTOC I oil well blowout released crude oil near the Kemp's ridley's only known primary nesting beach near Rancho Nuevo, Mexico (Delicat, 1980).

Evidence of harmful effects of oil on sea turtles has been established in several published accounts. Oil-covered hatchlings and juveniles have been found stranded on beaches: loggerheads in Panama (Rutzler and Sterrer, 1970), and greens in Puerto Rico (Diaz-Piferrer, 1962) and Florida (Chan, 1977; Witham, 1978). Witham (1978) rehabilitated several juvenile green turtles whose oral cavities were occluded by tar, while other oiled turtles apparently died as a result of oil ingestion. In 1983, about 90 heavily oiled yearling Kemp's ridleys were found stranded on the beaches of Texas (Fontaine *et al.*, 1989). They were part of that year's release of head started ridleys of the 1982 year-class that apparently had run into an oil slick shortly after being released. Presumably the actual number of yearlings affected was very much greater than that found stranded.

There are very few studies of hydrocarbon effects on sea turtles. Frazier (1980) outlined potential impacts of pollutants on sea turtles in the coastal zone. Baseline levels of heavy metals and pesticides in feral sea turtles and their eggs were provided by Hillestad et *al.* (1974), Schwartz and Flamenbaum (1976), Thompson, Rankin and Johnson (1974), Stoneburner, Nicrora and Blood (1980) and Clark and Krynitsky (1980).

Bennett and Kleerekooper (1978) determined changes in locomotion caused by oiling. In a study by Fritts and McGehee (1981), effects of oiled sands on incubating loggerhead and Kemp's ridley eggs were examined. Interestingly, they found that while loggerhead eggs incubated in artificially oiled sands had reduced survival rates and altered morphology, Kemp's ridley eggs incubated in oiled sand on the native beach showed no significant differences in embryo survival. These field study results indicated that oil effects on sea turtle eggs may be complex and determined by the interaction of several factors. These may include type of oil, its concentration and degree of weathering as well as the nest environment itself.

It is very likely then that oil pollution can be very harmful to sea turtles, and for some like Kemp's ridley, which is barely holding onto survival, a serious encounter with oil could threaten survival of the species. Published accounts of oil effects on turtles do not critically assess how oil exposure disrupts behavior and physiological functions in these animals. However, it is only by understanding the cause-effect relationship that the full impact of oil exposure on sea turtle populations can be appreciated and realistic mitigating measures formulated.

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Methods

In a study funded by Minerals Management Service, U.S. Department of the Interior, green and loggerhead sea turtles were exposed for various periods to weathered, South Louisiana Crude Oil. Minimal exposures were used, consistent with levels that might occur in a natural spill. In all cases in which harmful effects were seen, the experiments were terminated, and there was full recovery of all experimental animals.

Results

A preliminary analysis of the behavior data by Dr. D. Odell showed no evidence that either green or loggerhead sea turtles actively avoided weathered oil. Therefore, the possibility exists that sea turtles can be in extended and prolonged contact with oil in a spill, without making an effort to leave the area.

The potential effects of oil on sea turtles, as indicated by our studies, are shown in Figure 1. To our surprise all primary contact routes appear to be affected:

ROUTE	RESULT
SKIN	accelerated cell division sloughing neoplastic response
LUNG	reduced diffusion capacity decreased oxygen consumption
GUT	decreased digestion efficiency internal effects (hematopoesis salt gland immune response)
SENSE ORGANS	tissue damage to nares and eyelids

Figure 1. Potential effects of oil on sea turtles.

1. Skin — Dr. G. Bossart has found evidence of dermatological damage and abnormal cell differentiation in the skin. Presumably, these effects would eventually be lethal, but they certainly would open routes of attack for parasites and infection.
2. Lungs — We recently found that sea turtles are among those reptiles having the most efficient and highly developed lungs (Lutcavage, Lutz and Bauer 1987). Any interference with operation of the lungs would probably reduce a sea turtle's capacity for sustained activity (aerobic scope) and its dive time, both effects decreasing the turtle's chance of survival. Marked changes in respiratory patterns were in fact evident in oil-exposed turtles, with an increase in both tidal volume and frequency following exposure and a decrease in oxygen consumption. It appears that oxygen extraction is compromised in oiled turtles.
3. Gut — Studies on the effect of oil on digestive efficiency are still underway at the time (1985) of this writing, but we have found that oil is swallowed by experimental turtles, probably when they surface to breath, and oil has been found in their feces. One of the most striking differences between chronically oiled and control (non-oiled) turtles was the hematological response, presumably due to the passage of oil products across the gut lining. Even so, mean red blood cell counts, hematocrits and hemoglobin concentrations were lower in oiled turtles compared to controls. These results indicated dysfunction of red blood cell-forming tissues. We recently found that the salt gland in sea turtles is a very important organ. In the leatherback it is continually active (Hudson and Lutz, 1986a) and in the loggerhead it is involved actively at least in regulating minor ions such as Mg^{++} and Br^{-} as well as Na^{+} and Cl^{-} (Hudson and Lutz, 1986b). We have indications that the operation of this organ is disrupted with exposure to oil, but the disturbance does not appear until several days after exposure.
4. Hormones and Sense Organs — We have not yet looked at hormone balance, but we observed that the eyes and nares were coated with oil that required cleaning. Disruption of either sensing system would have highly deleterious consequences.

Discussion

Experimental results indicate that sea turtles would indeed be at great risk if they were engulfed by an oil spill. This was a surprising finding considering the high tolerance of sea turtles to severe physical damage. Contact with oil would be particularly harmful if it occurred when adults congregated during the nesting season to copulate and lay their eggs or when hatchlings emerged and crawled over the beach in large numbers.

For the precarious Kemp's ridley these observations have serious implications. Effective strategies must be quickly formulated to mitigate the damage of oil pollution since, without doubt, we will be faced at some time in the future

with a crisis; e.g., a large oil slick approaching a beach where ridleys are hatching. It is essential that we have plans to deal with such emergencies. One of the most attractive possibilities, for example, is the use of chemical dispersants to break up the oil slick, but we do not know if the use of dispersants is an acceptable management option. Because sea turtles have been shown to be extraordinarily sensitive to oil, they also might be highly affected by dispersants. These and similar questions must be answered before we will be able to protect Kemp's ridley from the potentially devastating effects of a major oil spill.

Acknowledgements

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The Corpus Christi Bay Landmass Project: An Example of NMFS' Role in Protecting Marine Turtles Via Section 7 of the Endangered Species Act

Paul W. Raymond*

Section 7 of the Endangered Species Act (ESA) requires that Federal agencies ensure that their actions (whether performed, funded or permitted by the agencies) are not likely to jeopardize the continued existence of threatened or endangered species. The National Marine Fisheries Service conducts Section 7 consultations with various Federal agencies for ESA-listed marine mammals, fishes and sea turtles that occur in the marine environment. The often-misunderstood types, components and procedures for Section 7 consultations are discussed.

Biological assessments and opinions on proposed construction activities and their potential effects on threatened and endangered species should be based on the best scientific and technical data available. Often these data are scarce and additional research is warranted. This paper demonstrates the consultation process by reviewing the dredge-and-fill project known as the Landmass Project in Corpus Christi Bay, Tex. The Corpus Christi-Nueces Bay system historically has supported a large population of the green sea turtle (Chelonia mydas)*, and recent findings indicate the presence of the Kemp's ridley sea turtle* (Lepidochelys kempi)*. Most ridleys reported from this system have been released by the Kemp's Ridley Head Start Research Project. Potential direct impacts of the Corpus Christi Bay Landmass Project on sea turtles include dredge-related mortalities and loss of foraging habitat. Indirect effects are often more difficult to identify and assess.*

The Endangered Species Act (ESA) of 1973 provides for protection, conservation and propagation of species of plants and animals in danger, or potential danger, of becoming extinct. To meet this objective, the ESA mandates various responsibilities of federal agencies, one of which is interagency cooperation required by Section 7 of the act. Section 7 of the ESA applies to all threatened and endangered species and imposes three burdens upon Federal agencies, as stated in the U. S. Code of Federal Regulations CFR-50, Part 402:

> "First it directs them to utilize their authorities to carry out conservation programs for listed species. Second, it requires every federal agency to ensure that its activities or programs in the United States, upon the high seas, and in foreign countries will not jeopardize the continued existence of a listed species. And third, Section 7 directs all federal agencies to ensure that their activities or programs do not result in the destruction or adverse modification of critical habitat."

The U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS) share responsibilities for conducting Section 7 consultations. Generally, marine species are under the jurisdiction of the NMFS and all other species are under the jurisdiction of the FWS. Listed sea turtles occurring in the U.S. are shared between the two services, with the NMFS having jurisdiction in the marine environment and the FWS having jurisdiction on land (e.g., nesting beaches). Other federal agencies proposing projects must consult with the FWS and NMFS to determine how these projects (whether performed, permitted or funded) may affect threatened and endangered sea turtles (and marine mammals). The NMFS' Southeast Regional Office (SERO) conducts approximately 100 to 150 Section 7 consultations each year. Many of these consultations are with the various U.S. Army Corps of Engineers (COE) Districts and involve dredge-and-fill projects and their potential impacts on listed sea turtles and marine mammals.

This paper discusses an interagency consultation on a proposed landfill project located in Corpus Christi Bay, Tex. Emphasis is given to information on abundance, natural history and distribution of sea turtles in the estuarine and coastal areas of the Corpus Christi Bay-Nueces Bay system. The purpose of this paper is not to discuss details of the rules and regulations of the Section 7 process, as this would be an arduous task and one not appropriate for a symposium on sea turtle biology, conservation and management. Instead, I will attempt to explain the Section 7 process by using the Corpus Christi Bay Landmass Project as an example.

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* *National Marine Fisheries Service*

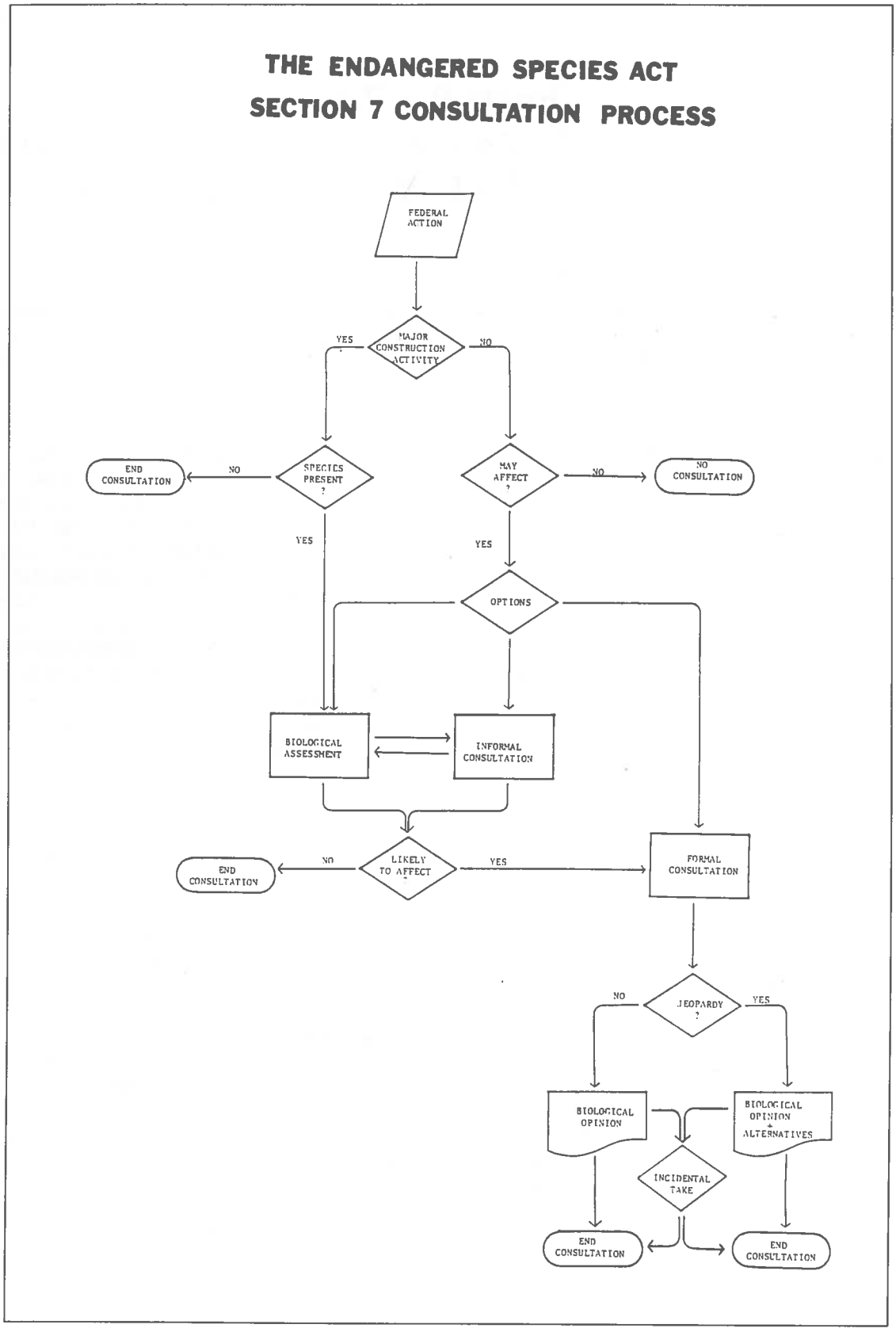

Figure 1. Generalized flow chart of the Section 7 consultation process (Note: the process has been modified to incorporate the 1985 proposed regulations).

Section 7 Consultation Procedure

Figure 1 is a flow chart depicting procedures and options of the Section 7 process. Amendments to the ESA have modified the process in the past, and proposed regulations undoubtedly will change the interpretation of specific segments in the future. Details of regulations governing interagency consultations involving threatened and endangered species can be found in the Code of Federal Regulations CFR-50, Part 402, or by contacting the Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Habitat and Protected Species Division, Washington, D.C. 20235.

Background on the Corpus Christi Bay Landmass Project

On July 24, 1985, the Corps of Engineers Galveston District provided the NMFS SERO a Biological Assessment (BA) for a permit activity to construct a 3.2-hectare landfill structure in Corpus Christi Bay. This activity, known as the Corpus Christi Bay Landmass Project, was proposed by the City of Corpus Christi, and is hereinafter referred to as the Landmass Project. It was proposed to be located within the city's marina for the purpose of supporting a waterfront recreational center and tourism complex, an aquarium complex, boat slips, and a breakwater-fishing pier.

Based on data regarding the presence of threatened and endangered sea turtles in the Corpus Christi Bay system, the Corps determined that the proposed Landmass Project might affect the endangered Kemp's ridley sea turtle (*Lepidochelys kempi*). Therefore, pursuant to Section 7 of the ESA, they requested initiation of a formal consultation. Consequently, the NMFS was required to review the available data and prepare a document known as a Biological Opinion, which would determine if the proposed development was likely to jeopardize the continued existence of the Kemp's ridley. The NMFS was also concerned with the potential effects of the proposed activity on three additional sea turtle species: the endangered hawksbill (*Eretmochelys imbricata*), and the threatened green (*Chelonia mydas*) and loggerhead (*Caretta caretta*).

Proposed initial construction was to use an hydraulic dredge to dig a trench around the perimeter of the landfill site removing approximately 35,170 cubic meters of bay bottom sediment and placing it in the center of the landfill site (Corps of Engineers Galveston District, 1985). Approximately 3.2 to 3.6 hectare of bay bottom at the landfill site would have been eliminated by these construction activities. In addition, the proposed activity was to construct 425 boat slips and a breakwater-fishing pier.

Species Accounts

Those ESA-listed species under the jurisdiction of the NMFS and identified as potentially occurring in the Landmass Project area were Kemp's ridley, green, hawksbill and loggerhead sea turtle. All four species had been documented as occurring in the Corpus Christi-Nueces Bay system. A brief species account for each of these sea turtles is provided, with emphasis on their occurrence in Texas bays. These species accounts were used by NMFS in preparing the Biological Opinion.

Kemp's Ridley Sea Turtle

The primary range of the Kemp's ridley sea turtle is the Gulf of Mexico, but juveniles occur along the Atlantic coast of the U.S. from Florida to New England (Lazell, 1980; Lutcavage and Musick, 1985). The Kemp's ridley is a turtle of coastal areas. Hildebrand (1982) hypothesized that the two areas of greatest concentration of Kemp's ridley were the shallow water areas of Louisiana, from Marsh Island to the Mississippi Delta, and the Tabasco-Campeche area of Mexico. Both areas are thought to be feeding grounds for subadult and adult Kemp's ridley turtles (Chavez, 1969; Hildebrand, 1982). These waters are extremely productive and are abundant with decapod crustaceans, particularly two genera of crabs (*Ovalipes* and *Callinectes*), which are favored foods of Kemp's ridley. Other regions of known relative abundance of Kemp's ridley are the coastline of Texas, the Cedar Key-Crystal River region of West Florida, and the Chesapeake Bay region of Virginia (Larry Ogren, NMFS SEFC Panama City Laboratory, Panama City, Fla., personal communication, July 1985; Carr and Caldwell, 1956; Anonymous, 1984; Lutcavage and Musick, 1985). The number of Kemp's ridley strandings on the Texas coast has increased in the past five years. This is probably due to a variety of factors such as the better identification of species and more efficient Sea Turtle Stranding and Salvage Network (STSSN) activities. Rabalais and Rabalais (1980) documented only 15 Kemp's ridley strandings (2 adults, 7 subadults and 6 hatchlings) between September 1976 and October 1979, in the area from Port Mansfield to Port Aransas, Tex. In contrast, the 1984 total for the coast of Texas was 68 stranded Kemp's ridley (Anonymous, 1984), but already there have been 34 reported strandings of this species in the first seven months of 1985.

It is becoming increasingly evident that Kemp's ridleys utilize shallow water bays throughout their known distribution. Lutcavage and Musick (1985) reported at least 43 subadult Kemp's ridleys found in a three year period in Chesapeake Bay. They concluded that the Kemp's ridley distribution is closely related to the abundance of seagrass

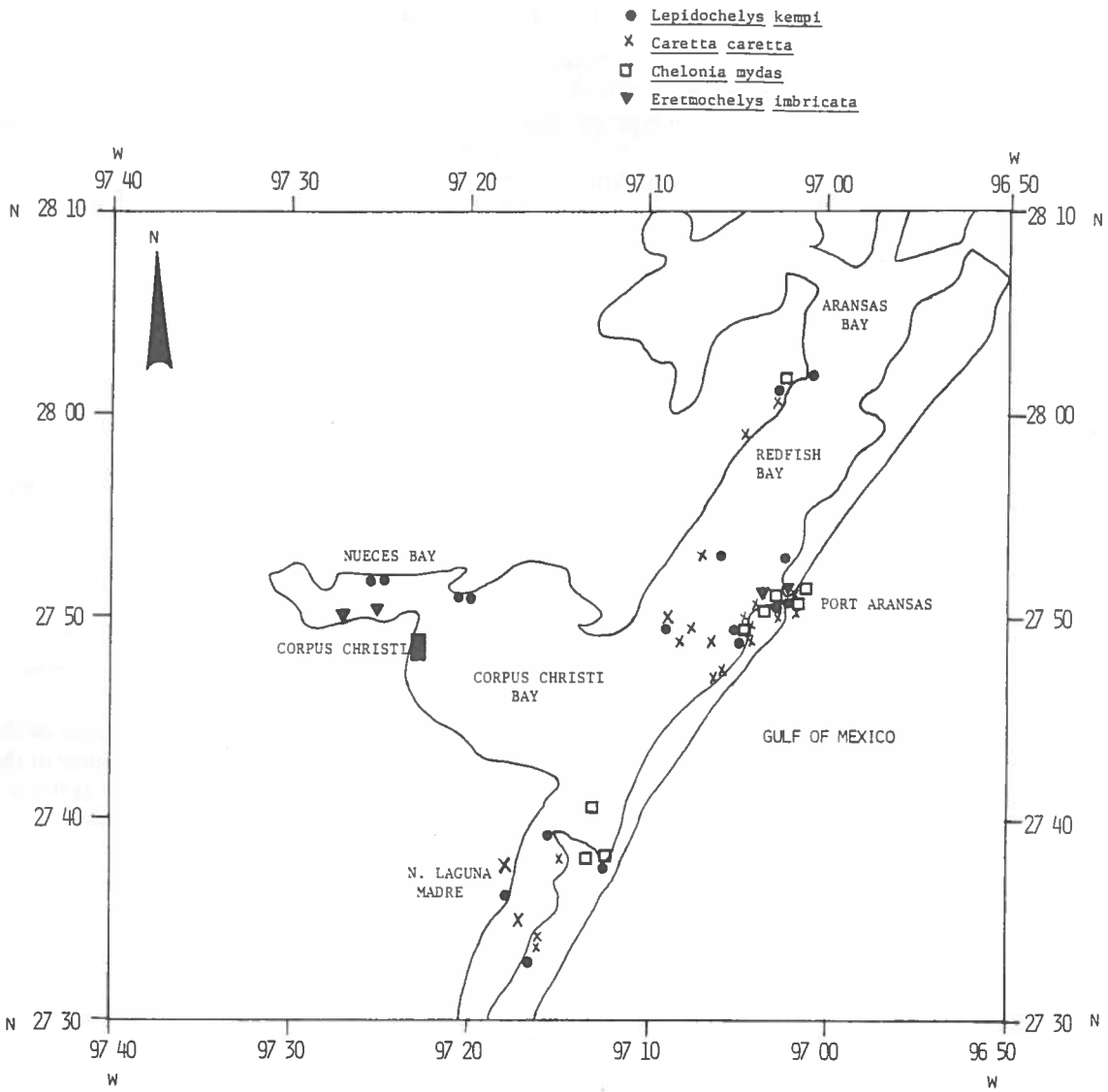

Figure 2. Distribution of documented sea turtle strandings in the Corpus Christi Bay region (Does not include records for strandings on beaches bordering the Gulf of Mexico or strandings of head started Kemp's ridleys; Data supplied by the Sea Turtle Stranding and Salvage Network, National Marine Fisheries Service, Southeast Fisheries Center, Miami Laboratory).

beds and blue crabs (*Callinectes sapidus*) in the bay. Subadult ridleys also have been found in Cape Cod Bay in New England (Lazell, 1980). East coast bays appear to provide developmental habitat for juvenile ridley turtles in the summer. In the Gulf of Mexico, the west coast of Florida once was described as an area of maximum abundance for Kemp's ridley (Carr, 1957). Kemp's ridley has been documented by Larry Ogren (*ibid.*) in Lake Pontchartrain (Louisiana), Biloxi Bay (Mississippi) and Choctawahatchee and Apalachicola Bays (Florida). Historically, reports of Kemp's ridley in bays of the western Gulf of Mexico have been scarce. However, there are scattered reports of ridleys in Aransas Bay, Corpus Christi Bay, Galveston Bay and Laguna Madre, Tex. (Hildebrand, 1980).

The STSSN data provide evidence that Kemp's ridleys may be more common near inlets along the Texas coast than earlier believed (Anonymous, 1984). Figure 2 illustrates ridley stranding locations from Aransas Bay to the north end of Laguna Madre. This map includes only untagged wild ridley strandings compiled over the past several years. Figure 2 also illustrates that such ridleys occur occasionally in the Corpus Christi Bay region. Hildebrand (1980) suggested that, historically, Kemp's ridleys may have been relatively rare in Texas bays, but cautioned that this impression may have resulted from inadequate reporting. Undoubtedly, most of the turtles caught incidentally by the inshore shrimp fishery are not reported. In addition, ridleys often have been misidentified as loggerhead turtles, thereby making earlier assessments of apparently low ridley abundance in Texas bay systems highly suspect.

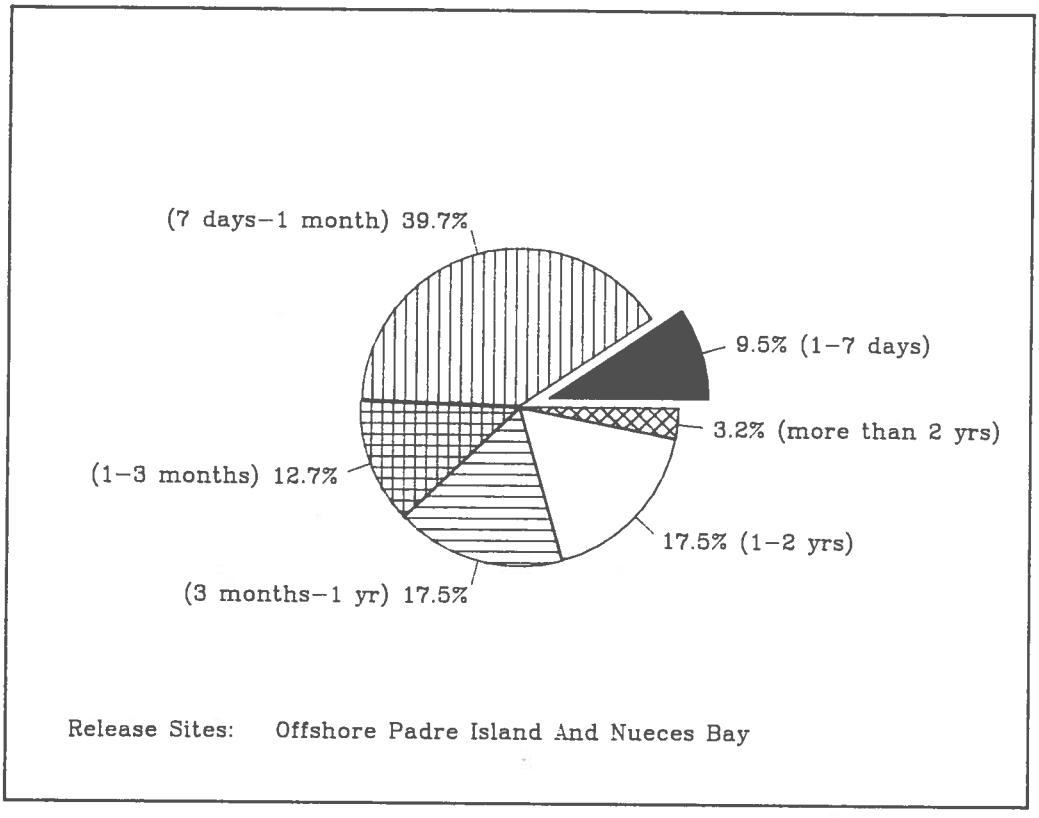

Figure 3. Distribution (in percent) of time from release to recapture of head started Kemp's ridley sea turtles recaptured in the Corpus Christi Bay area (Data supplied by National Marine Fisheries Service, Southeast Fisheries Center, Galveston Laboratory, Galveston, Tex.).

Since 1978, the NMFS has been participating in an international recovery program to save the Kemp's ridley from extinction (Caillouet, 1984; Fontaine and Caillouet, 1985). As part of this program, seven year-classes of ridleys have been head started (i.e., reared in captivity) during their first year of life at the NMFS SEFC Galveston Laboratory, then tagged and released into the Gulf of Mexico. As of February 1, 1985, 8,241 ridleys had been head started and released at a variety of locations where immature ridleys historically have been known to occur (Fontaine and Caillouet, 1985). Some of these tagged individuals have been recaptured, thus providing valuable information on movements, growth and survival (Fontaine *et al.*, 1989). They may also be reasonably good surrogates for estimating growth and movements of immature, naturally occurring ridleys (McVey and Wibbels, 1984). McVey and Wibbels (1984) reported that a number of head started-tagged-recaptured Kemp's ridley were found in or near estuaries and suggested a preference for such habitat. They also pointed out that such preference unfortunately could lead to an increase in the likelihood of capture by the fishermen, because these areas are heavily fished and shrimped by man.

Head started Kemp's ridleys were released primarily in the coastal areas of west Florida in 1979 and 1980 (Fontaine *et al.*, 1989). Beginning in 1981, the majority of releases were made offshore Padre and Mustang Islands, Tex. In addition, some head started ridleys were released in Nueces Bay, Tex., on June 7, 1983. Head started ridleys released in Texas have been recaptured sporadically throughout the Corpus Christi Bay system. Data from NMFS' SEFC Galveston Laboratory indicate that there have been 63 recaptures of head started Kemp's ridleys reported for the Aransas Bay-Corpus Christi Bay system, and that time spent in the wild ranged from one day to two years (Figure 3). Apparently, the head started turtles released in Nueces Bay were able to adapt to inshore waters. Recapture sites were relatively close to release sites, even for those turtles that spent more than one month in the wild before recapture. Ridleys released offshore of Padre Island frequently were found within the adjacent inlets and bays and appeared to adapt to the bay system (21 turtles released off Padre Island were found in the Aransas Bay-Corpus Christi Bay system after spending at least one month in the wild). Figure 4 shows recapture locations of head started Kemp's ridley within the Corpus Christi Bay system. Such findings weighed heavily in the Corps' decision to request a formal Section 7 consultation with NMFS for the proposed Landmass Project (Corps of Engineers Galveston District, 1985).

Green Sea Turtles

The green turtle is listed as threatened under the ESA. However, the Florida nesting population has been given endangered species status because current estimates of females nesting per year are less than 200 (Bacon *et al.*, 1984;

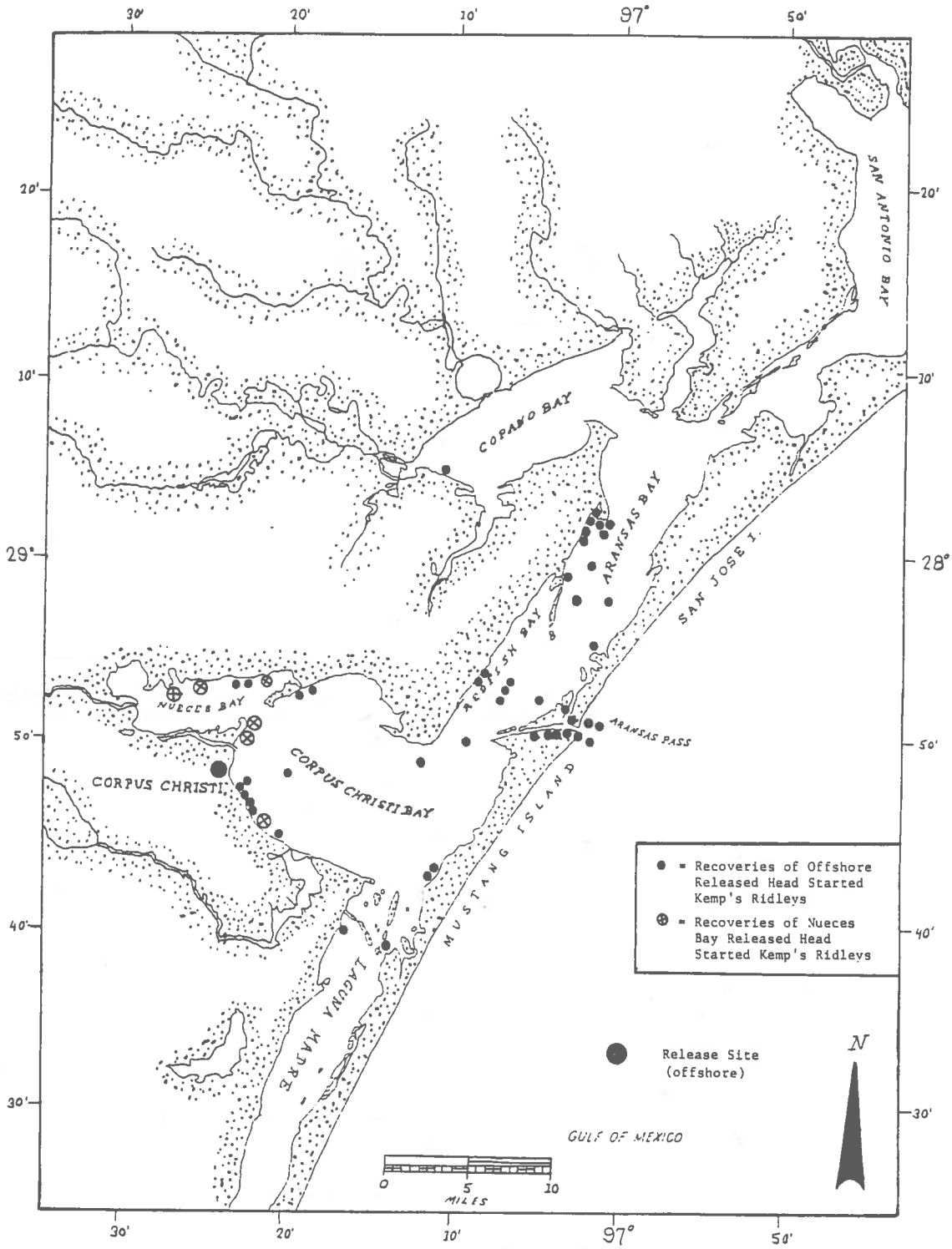

Figure 4. Distribution of recovery sites for head started Kemp's ridley sea turtles in Corpus Christi Bay and surrounding inland waters (Data supplied by the National Marine Fisheries Service, Southeast Fisheries Center, Galveston Laboratory, Galveston, Tex.).

Harris, Conley and Huff, 1984). Juvenile or subadult green turtles (carapace length < 81 cm) are known to inhabit lagoonal waters and bays along the coasts of Florida and Texas. In Florida, Sebastian Inlet, Mosquito Lagoon, the Florida Keys and Cedar Key are areas of known aggregation. Green turtles once flourished in Texas bays and were exploited by the turtle fishery in the late 1800s (Hildebrand, 1980 and 1982; Doughty, 1984). Texas bays contain extensive beds of turtle grass (*Thalassia testudinum*) and shoal grass (*Halodule wrightii*), which provide important food sources for the green turtle. Hildebrand's (1982) excellent account of the historical status of green turtles in Texas states that "the most important species in Texas was and is the green turtle, which fed in the seagrass meadows from Matagorda Bay to the lower Laguna Madre." Corpus Christi fishermen captured green turtles primarily in Aransas Bay and Laguna Madre. Apparently those two bays supported adult as well as juvenile greens as average weights were reported by Doughty (1984) as 121.5 kg. Texas' green turtle catch reached a record high in 1890 with 265 metric tons reported for the entire coast of Texas (Stevenson, 1893). By the last half of the 1890s, the turtle population could no longer sustain such high levels of take. By 1900 the turtle industry had dropped off significantly.

Green turtles still inhabit the same Texas bays today, but in reduced numbers (Hildebrand, 1980 and 1982). Stranding and capture records are scarce, due partially to incomplete reporting. Figure 2 illustrates green turtle strandings in the Aransas Bay-Corpus Christi Bay regions. All current records indicate that the inshore greens are of subadult size (< 81 cm). The distribution of green turtle observations resembles the distribution of grass beds in Aransas Bay, Nueces Bay, Corpus Christi Bay and Laguna Madre.

Loggerhead Sea Turtle

The loggerhead is listed as threatened. Like most other sea turtle species, it inhabits coastal areas. It frequents temperate waters of the U.S. continental shelf along the Atlantic Ocean and Gulf of Mexico, foraging around rocky places, coral reefs and shellfish beds. Subadult loggerheads commonly enter bays, lagoons and estuaries (Ernst and Barbour, 1972; Mendonca and Ehrhart, 1982). The greatest concentration of loggerheads in the U.S. is found in Atlantic coastal waters. Lesser concentrations are found along the west Florida and Texas coasts. The loggerhead is the most abundant species in Texas waters, and its preferred habitat is the inner continental shelf rather than the bays (Hildebrand, 1980). The subadult population of loggerheads has been under extreme stress during the last 10 years due to an increase in incidental mortality in shrimp trawls. In 1984, 105 loggerheads were reported stranded along the Texas coast, and many of these occurred on Mustang and Padre Islands (Anonymous, 1984).

There are records of sporadic occurrence of loggerheads, all of them subadults, in Texas bays. Recent strandings within the Corpus Christi Bay system are illustrated in Figure 2. As with the other species discussed herein, the depicted strandings of loggerheads do not represent total strandings on beaches along the Texas coast, but only those reported for inshore or bay waters (i.e., there are addititional records of strandings on the gulfside beaches of the Texas coast that are not illustrated in Figure 2). Hildebrand (1980) reported two records of loggerheads in Corpus Christi Bay in the 1970s and one in Rockport in 1980. There also have been numerous reports of subadult loggerheads occurring within the Laguna Madre system.

Hawksbill Sea Turtle

The hawksbill is rare within the continental waters of the U.S. Its distribution is more tropical than that of other species as it prefers coastal reef habitats like those found in the Caribbean and Central America. However, there are accounts of hawksbills in south Florida and a surprising number in Texas. Most of the Texas records are for very small individuals, perhaps one to two years of age. Many of the stranding records indicate that these hawksbills were unhealthy or injured when found (Hildebrand, 1980 and 1982). The absence of sponge-covered reefs and the cold Texas winters probably contribute to the lack of hawksbills abundance in Texas. In 1984, 10 hawksbill strandings were reported on the Texas coast (Anonymous, 1984). Few hawksbills have been observed within Texas bays. However, there are two records of hawksbills captured in Nueces Bay (Figure 2). Hildebrand (1980) speculated that hawksbills that enter the shallow water bays of Texas probably do not survive the cold winters if they are unable to exit in time to avoid them.

Potential Impacts of the Landmass Project on Endangered or Threatened Sea Turtles

The most obvious impact of the Landmass Project on listed sea turtle species is the destruction of 3.2 hectare of open

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[1] As stated in the following letters:

(a) 16 August 1984, from Southeast Regional Director, National Marine Fisheries Service, to Col. A. L. Laubscher, U.S. Army Corps of Engineers, Galveston District, regarding Landmass Permit Application 17069, Corpus Christi Bay.

(b) 18 August 1984, from Regional Director, U.S. Fish and Wildlife Service, to Col. L. Laubscher, U.S. Army Corps of Engineers, Galveston District, regarding Public Notice No. 17069, City of Corpus Christi.

(c) 14 February 1985, from Executive Director, Texas Parks and Wildlife Department, to Col. L. Laubscher, U.S. Army Corps of Engineers, Galveston District, regarding Permit Application No. 17069, City of Corpus Christi.

bay habitat. The proposed disposal site provides nursery and foraging habitat for a variety of recreationally and commercially important estuary-dependent organisms[1]. These organisms include blue crab, white shrimp *(Penaeus setiferus)*, southern flounder (*Paralichthyes lethostigma*) and a variety of other finfishes. Data are lacking on the foraging behavior of juvenile Kemp's ridleys in the Corpus Christi Bay system. However, it is well documented that a favored prey of ridleys is blue crab (Pritchard and Marquez, 1973; Hildebrand, 1980; Lutcavage and Musick, 1985). Productive crab habitat occurs throughout much of the Corpus Christi Bay system, especially in nearby Nueces Bay and in the shallow waters of Redfish Bay and the East Flats of Corpus Christi Bay (K. Meador, Texas Parks and Wildlife Department, Rockport, Tex., personal communication, July 1985). Kemp's ridley habitat also occurs within this bay system.

Historically, green turtles were much more abundant within the Corpus Christi Bay system than Kemp's ridley. Before the demise of the green turtle in the late 1890s, this species was common and an active feeder on sea grasses in the bay. Hildebrand (1980) concluded that, while juvenile green turtles still occur in grassy bays and grass flats of this system, its numbers are being reduced by deposition of dredge-spoil and by channeling. The bay bottom of the proposed 3.2-hectare fill site currently consists of soft bottom sediments, apparently without seagrass beds. In this regard, no data were supplied by the Corps of Engineers' Biological Assessment, but lush seagrass beds exist in portions of Corpus Christi Bay, Nueces Bay and the adjoining waters of Redfish Bay and Laguna Madre (K. Meador, ibid.). The NMFS assessment concluded that Kemp's ridley, loggerhead, and green sea turtles would suffer some loss of habitat and disturbance if the proposed project was permitted.

While it is unlikely that direct injury or mortality of sea turtles would result from the construction activities of the proposed Landmass Project, several potential conflicts were possible. Dredging projects have caused mortalities in bottom dwelling loggerhead sea turtles in Florida's Port Canaveral Navigation Channel (Raymond, 1980; NMFS, 1984). Mortality occurred because the density of loggerheads inhabiting the bottom of Canaveral Channel was high and mobile hopper dredges have powerful suctions. The Landmass Project plan proposed the use of a cutterhead dredge to dig a perimeter trench. No data are available and no studies have been conducted on the impacts of cutterhead dredges on sea turtles. No dredge-related sea turtle mortalities have been documented for dredgings of Texas bays in the past, but these activities have never been monitored adequately.

The proposed Landmass Project would construct 425 boat slips and two small fishing piers. Indirect effects of additional boat traffic and increased fishing activities on sea turtles are difficult to predict. Data obtained from the STSSN indicated an increase in the number of documented cases of boat-turtle collisions in the southeastern U.S. (B.A. Schroeder, NMFS SEFC Miami Laboratory, Miami, Fla., personal communication, July 1985). In Virginia, 5 percent of the documented sea turtle strandings were attributed to propeller impacts (Lutcavage and Musik, 1985). In Florida, sea turtles were found wounded by propellers more frequently in inlet areas than elsewhere (L. Ehrhart, University of Central Florida, Orlando, Fla., personal communication, July 1985). The impact of boat traffic on turtles along the Texas coast is unknown. No correlation between increased incidence of propeller wounds and increase in marina developments has been reported, but no such correlation analysis of stranding records has been done. Reports of entanglement and hook-and-line capture of juvenile sea turtles also have been increasing. Recapture records show that 16 headstarted Kemp's ridleys were caught on hook-and-line after release. Some of these recaptures occurred in the Corpus Christi Bay area. Hook-and-line fishermen often catch sea turtles from piers and jetties (Hildebrand, 1980). The turtles either swallow the hook or became foul-hooked. In most cases, such turtles are released alive. Entanglement of sea turtles in discarded monofilament line and other fishing gear is of greater concern. The line entangles the flippers and head and often causes loss of a limb or death.

Recommendations

NMFS made the following recommendations to the Corps to eliminate or reduce potential adverse impacts to threatened or endangered sea turtles resulting from the proposed Landmass Project activity:

1. The proposed non-water-dependent facilities should be constructed landward of Corpus Christi Bay shoreline, as also recommended by NMFS' Environmental Assessment Branch, FWS and Texas Parks and Wildlife Department[1]. In other words, NMFS strongly recommended that the majority of the dredge and fill activities be terminated.
2. The Corps should initiate a thorough assessment of abundance, distribution and frequency of occurrence of subadult Kemp's ridley and green sea turtles inhabiting the bay system, based on (a) interviews with the inshore commercial fishermen, (b) radio and sonic tagging and tracking of several individuals of both species to determine their movement patterns and/or (c) seasonal and systematic trawling surveys combined with tagging and recapturing sea turtles.
3. A survey of the remaining turtle grass beds should be made to determine their current use by juvenile green turtles. Specific mapping of sea grasses such as turtle grass, shoalgrass and wigeongrass *(Ruppia maritima)* should be performed.

4. The food supply of Kemp's ridley within the Corpus Christi/Nueces Bay system should be identified to assess impacts of future landfill projects on the feeding grounds in that system.

Biological Opinion

It was the opinion of the NMFS, based on the best available information, that construction of the 3.2-hectare Landmass Project was not likely to jeopardize the continued existence of Kemp's ridley, green, loggerhead and hawksbill sea turtles. Although a no jeopardy opinion was issued to the Corps of Engineers Galveston District, several potential adverse impacts were identified as described above. Consequently the NMFS recommended that the permit to construct the Landmass Project be denied. Thus, the final decision to issue or deny the permit was left to the Corps. Conversely, had a jeopardy opinion been derived and issued, and had the Corps proceeded to permit the Landmass Project, then the Corps would have run the risk of violation of Section 7(a)(2) of the ESA. However, NMFS' opinion was that the potential adverse effects of the Landmass Project would not reach a level of "jeopardizing the continued existence" of listed sea turtles. In other words, the strict language of Section 7(a)(2) did not allow the potential adverse effects to be used as a basis for issuing a jeopardy opinion.

Although a no jeopardy ruling was made, the NMFS study did anticipate that there would be some low level of incidental take of turtles as a result of the proposed Landmass Project, were a permit issued. Take, in this case, would be in the forms of harassment and loss of habitat. Therefore, the following mandatory terms and conditions were established to minimize potential take if a permit were issued by the Corps of Engineers:

1. A trawler must survey the waters in and around the proposed Landmass Project site prior to any construction.
2. Construction activities must be halted if any sea turtles are observed in the vicinity.
3. Sea turtle identification posters must be displayed by the city at appropriate piers and marinas.

As with all Section 7 consultations, if new information revealed potential impacts not considered in the NMFS' Biological Opinion, or if the project were modified in a manner not previously considered, then the Corps would have to reinitiate the Section 7 consultation.

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Questions and Answers

Sally Murphy: I noticed that your highest frequency of strandings is in April. Do you have any clue as to what is causing these April strandings? Do they coincide perhaps with offshore oil coming in, or do you know what else might be causing the April strandings?

Whistler: We can only make inferences. We need someone to help us evaluate such results. There tend to be, for example, the effects of the currents at that time. As Tony Amos has found and as we have found, the most numerous deposits of material and debris on the beach occur at that time. I think there is shrimping at that time. We need to evaluate this further. I have summarized the data up to 1985, hoping that we now can begin to look at these data in greater detail to evaluate factors that may be causing the strandings.

Amos: We can say that strandings may coincide with currents, and they may coincide with oil coming ashore. But our greatest challenge is not to say what may be happening, but to be able to say with certainty what are definitely the causes of the strandings. That is a very difficult thing to do. There obviously are periods during which we know that shrimpers are out there. But is anybody confident that shrimpers will tell them how many turtles they catch out there? For example, I can show that the number of dead birds, especially gulls, increases as soon as the shrimp boats get out there. Now is that because I am prejudiced against the shrimp boats, or is that a genuine linkage between shrimping and occurrence of dead birds, or is something else happening the same time that we do not understand? Until we do some more research and get some of the shrimpers themselves to help us, we will not have the answer. We must convince the shrimpers that we are not trying to blame them for the strandings, but that instead we are really trying to get to the bottom of the problem.

Thomas Rennie: Was the insult that you subjected the turtles to a fresh oil?

Lutz: No, it was South Louisiana crude oil and it was weathered.

Rennie: How long had it weathered?

Lutz: Twenty-four hours and it was concentrated quite a lot.

Rennie: Are you planning to look at oil that has been weathered for a longer period of time to try to show what might actually be happening in the field during an oil spill event in which it might take three to five days for the oil to approach the shoreline? Would there be a loss of volatiles, aromatics and things like that in such a case?

Lutz: Our results are 24-hour related and that is why the oil was weathered. Actually we found that within 12 hours there was only a slight change in the mass of the oil.

Rennie: Then a large percentage of the aromatics had already been lost — is that correct?

Lutz: Yes, within 24 hours.

David Forcucci: Concerning the effects on the lung, you said that the turtles increase their inspiration, and that the ability of the lung to pick up oxygen was lowered.

Lutz: That is correct.

Forcucci: Could that be due not only to the effect on the lung tissue, but also due to the effect that you found on the hemoglobin?

Lutz: That certainly could be a confounding effect, but the difference here was that the oxygen profile, the partial pressure of oxygen, was the same. It did not change. So there had been no change in the gradient.

Forcucci: Do you mean the partial pressure of oxygen in the blood?

Lutz: Yes. There was no change in the oxygen partial pressure in the blood, but there was a decrease in hemoglobin. The compensation could be due to an increase in blood flow through an increase in heartbeat rate, which is a reasonably simple one. All the conclusions are tentative, and all the results could have other interpretations, but the basic interpretation is as I stated it; i.e. that the increase in inspiration is necessary to overcome a decrease in efficiency of the lung in handling oxygen. That explanation is a tentative one. There are no data to support the idea that the oil has that precise effect on the turtle.

Milford Fletcher: Concerning the control of habitat loss through Section 7 consultations under the Endangered Species Act, if we lose eight acres of prime habitat in one place now, and later another 20 acres of prime habitat, at what point does one become concerned about the cumulative long-term environmental impacts of such losses? When the last eight acres of the bay get filled in, then all we have is a golf course!

Raymond: Prior to the consultation related to the Corpus Christi Bay Landmass Project, our office had been doing Section 7 consultations for several years on projects such as maintenance dredging of the Corpus Christi Channel and

other landfill projects like the Land Mass Project. There are many such projects in bays up and down the Texas coast. The Land Mass Project consultation was the first time that evidence had come forward, primarily from the NMFS SEFC Galveston Laboratory, indicating that the bays are habitat for Kemp's ridley (e.g., at least for head started Kemp's ridley). I agree that cumulative effects should be addressed. We did not decide to address cumulative effects on this particular project, because we wanted to consult on this as a separate project to look at the data supplied by the Corp of Engineers on turtle abundance and habitat use in the bays, before we consulted with them on the next project.

Amos: Yes, that is a very good point. Corpus Christi seems to be particularly vulnerable to this sort of thing. Just last week one of the largest projects in Texas was announced — to dredge open a channel between Mustang and Padre Islands. That is why I say we should look at the overall effect, and not just each little bit of habitat that is disappearing.

Standard Operating Procedures for Collecting Kemp's Ridley Sea Turtle Eggs for the Head Start Project

Patrick M. Burchfield and F. James Foley*

*A summary of Kemp's ridley sea turtle (*Lepidochelys kempi*) conservation efforts at Rancho Nuevo, Tamaulipas, Mexico, during 1978 through 1985 was presented. Artificial hatchery techniques using polystyrene foam boxes and facsimile nests on the beach were described.*

Egg collection techniques and the initial incubation of eggs earmarked for further incubation and imprinting at the National Park Service's Padre Island National Seashore near Corpus Christi, Tex., were described. Experiments for the 1984 and 1985 nesting seasons were presented. These activities supplied hatchlings to the National Marine Fisheries Service, Southeast Fisheries Center's Galveston Laboratory for head starting.

Beach sand temperatures were monitored at Rancho Nuevo at a 30 cm depth along a beach transect perpendicular to the water's edge. Temperatures were read three times daily. Every two weeks a 24-hour study measured beach temperature at 2-hour intervals. This was done to re-adjust the times of day at which transect temperatures were read to assure that daily high and low temperatures were recorded throughout the season.

The temperature in the concrete hatchery building was mechanically regulated to correspond as closely as possible to the temperature regime of the natal beach. Moisture content of the incubation medium, Padre Island sand, ranged from 1 to 29 percent saturation with a mean of 14 percent within the polystyrene foam incubation boxes, each containing one clutch of eggs. Moisture content of natural nest cavities ranged from 7 to 21 percent saturation, with a mean of 14 percent. Incubation temperatures at the Rancho Nuevo hatchery ranged from a low of 26.4°C to a maximum of 37.5°C (once metabolic heating commenced). Of the 2,274 eggs incubated at Rancho Nuevo in polystyrene foam boxes in 1984, 2,032 (88 percent) hatched. Those in boxes sent to the Padre Island National Seashore produced a 90.7 percent hatch.

The major thrust of our work at the Rancho Nuevo sanctuary in Tamaulipas, Mexico, involves assisting biologists of the Instituto Nacional de la Pesca (INP) in tagging as many nesting Kemp's ridley sea turtle (*Lepidochelys kempi*) females as possible and transplanting as many nests as possible to protected corrals. Continuity is the key to success in such long-term programs. With continuity in mind, we established a standard operating procedure for collection, early incubation and transport of Kemp's ridley eggs for the joint Mexico-U.S. head starting experiment. Practical field problems are addressed in our paper as well as logistical considerations. The procedures include what should be done, but give explanations of what actually has been done when prevailing conditions prevented optimum procedures.

Collection of Eggs

It is best to collect eggs for the Padre Island phase of head starting on days of minimal ridley nesting activity. All members of the field party at Rancho Nuevo are trained to collect eggs for Padre Island in advance of their arrival at the beach site. Prior to doing beach surveys called *recorridos*, each member of the U.S. team is equipped with data recording instruments, data forms, etc. Two or more transparent, U.S. Department of Agriculture-approved, 100 percent virgin polyethylene bags with a silica slip are carried in each member's field backpack at all times for collection of eggs for Padre Island. The term "slip" refers to the chemical substance used on the bags so that they do not stick together. Some slips could pose contamination problems as could colored bags because some pigments may contain toxic chemicals. These bags are designed for use in organ transplant work, and their use minimizes the potential for transfer of unwanted chemicals or microbes to the freshly laid eggs.

To collect eggs for Padre Island, a team member must locate a turtle in the initial stages of nesting. Turtles in the initial nest-site-search process are frightened easily and return to the water, so they are approached with caution. Once the turtle has commenced excavating her nest cavity in earnest, one person approaches cautiously from behind while maintaining a low profile. Once established on the sand in a prone position behind the turtle, the beach worker commences digging an access hole directly behind the turtle and into the cavity being dug by the female. The access hole need not be much bigger than 11 x 11 cm in cross section. Extreme care is taken to avoid touching the turtle's hind feet or carapace, as the slightest disturbance may frighten her off the nest cavity. Therefore, the worker makes

Gladys Porter Zoo and Potentials, Inc.

intermittent excavations when the turtle pauses in its alternating excavations with left and right hind flippers. Once the access hole is completed, the worker grasps one of the polyethylene bags by hand roughly 8 cm down on the neck and folds the top portion over the hand in the same fashion as one would do to prepare to blow up a paper bag by mouth.

When the turtle reaches the point where she can no longer excavate sand with her hind flippers fully extended into the nest cavity, she centers herself over the cavity to lay her eggs. At this time the worker's bagged hand is positioned directly beneath and encircling the cloacal opening of the turtle. On occasion the first two or three eggs may drop before the bag is in position. These eggs are not retained for Padre Island, but are added to a corral nest maintained under supervision of INP biologists. Once oviposition commences it typically lasts roughly 15 minutes. When the female finishes laying she immediately begins to cover the eggs with sand, so the top of the bag is closed quickly to avoid exposure of the eggs to Rancho Nuevo sand. The most expeditious way to accomplish this is to lift the back end of the turtle with a free hand and pivot her off the nest cavity. The female seems oblivious to what happens at this point and often continues to cover, shell-tamp and obliterate the "nest," even though removed more than 1 meter from the actual nest site.

Handling of Eggs

After the eggs are collected, the bag containing the eggs is placed on the sand while vital data are recorded and the nester is measured and tagged. However, the hot sand at the surface is brushed aside by hand or foot prior to putting the bag of eggs on the sand. The same is done when Kemp's ridley eggs are collected for the Rancho Nuevo corrals because the extremely high temperatures of the surface sand may kill eggs in direct contact with it.

Eggs for Padre Island are protected from heat of the sun and taken immediately to camp. This is best accomplished by placing them in a polystyrene foam box on a cushion of Padre Island sand. On occasion, it is not possible to return immediately to camp when there are large numbers of turtles on the beach and the workload is heavy. In this case the bag of eggs is sealed tightly with data card inside, then placed inside the nest cavity and covered with cool sand. The location is marked for easy retrieval at the earliest convenience. The entire nesting process requires approximately 45 minutes, and during that time the attending worker is not available for other duties of the camp's work force.

Padre Island Sand

Eggs from each clutch destined for Padre Island are placed in a separate incubation box containing incubation medium, Padre Island sand, as soon as possible. Dimensions of the polystyrene foam boxes are 19.5 x 27.9 cm and 35.6 cm deep. Each year since 1978, Padre Island sand has been collected and transported in such boxes from the Padre Island National Seashore to the Rancho Nuevo sanctuary and back.

Moisture Content

Using the technique described by McGehee (1978), we determined that 22 ml of distilled water added to 100 g of oven-dried Rancho Nuevo sand produced 100 percent saturation. Sand samples collected from Padre Island in 1983, 1984 and 1985 were oven-dried and also required 22 ml of distilled water per 100 g sand to achieve 100 percent saturation. The amounts of added water required were determined from 12 trials each with samples of Rancho Nuevo and Padre Island sand.

Our studies in 1983, 1984 and 1985 at Rancho Nuevo of 21 natural nests at mid-nest depth of 30 cm indicated that female Kemp's ridleys selected nest sites with moisture contents ranging from 7 to 21 percent saturation (1.5-4.6 ml of water per 100 g of sand) with a mean of 14 percent. Sand used for incubation of eggs translocated to Padre Island should be of the same moisture level as that selected by Kemp's ridleys nesting at Rancho Nuevo. Therefore, we consider 14 to 16 percent saturation (3.1-3.5 ml of water per 100 g of sand) as optimum moisture content for Padre Island sand used for early incubation and embryonic development of Kemp's ridley eggs. Distilled water is added, if necessary, to raise the moisture content to the proper level.

Placing Eggs in Boxes

Once the eggs have been transferred from the beach to the Rancho Nuevo research station they are placed in the incubation boxes as soon as possible. Sterile surgical gloves are used in handling the eggs. First, a layer of Padre Island sand about 2.5 cm deep is placed in the bottom of the box prior to adding the first layer of eggs. The eggs are placed in rows for ease of counting. A margin 2.5 cm wide is left between the eggs and sidewalls of the box, then this space is filled with Padre Island sand. Next, the remaining eggs are placed in rows on top of the first layer and cloacal fluids from the polyethylene bag are poured over the eggs. A layer of Padre Island sand at least 2.5 cm thick is poured over the top of the eggs and leveled off. Weight is an important factor in airlifting the boxed eggs to the U.S., so excess sand is avoided.

As eggs are placed into the box, the worker judges how many layers of eggs the clutch will form, so a temperature

probe can be placed in the center of the clutch. The probe is used to monitor incubation temperatures at the Padre Island hatchery.

Rancho Nuevo Hatchery

The Rancho Nuevo hatchery is a concrete structure containing shelves to hold boxed eggs during the early stage of incubation. At each shelf level within the hatchery, ambient air temperature and temperature of a box containing only sand (as a control) are monitored. Shelf levels 1, 2 and 3 are 168 cm, 124 cm and 70 cm from the floor, respectively. The hatchery building is mechanically thermo-regulated to approximate natural incubation temperatures as closely as possible. There is no constant source of electricity at the camp, so temperature control by electrical cooling and heating is not possible. A thermal transect established on the nesting beach provides information to guide hatchery thermo-regulation. Bailey BAT-23 digital read-out thermometers are used. Temperatures at 30 cm depth are read three times daily. In addition, a 24-hour (at 2-hour intervals) study is done every two weeks to provide data for adjusting times of day when transect temperatures are read, so that daily high and low temperatures of the beach sand can be monitered throughout the season.

Transport

Ideally, eggs should be exported to Padre Island within the first 24 hours following their collection. This has not been possible for several reasons. First and foremost, export permits are required from Mexico's Instituto Nacional de la Pesca and Mexico's Secretaria de Relaciones Exteriores, and authorization is required from the Secretaria de Aeronautical Civil authorizing an U.S. aircraft to export the eggs. A Mexican INP inspector must issue a document called a Guia de Pesca in effect for 72 hours, whereby Officials of Mexico's INP donate the eggs, on site, to the U.S. government, in compliance with Mexican law. These legal requirements coupled with the unpredictable arrivals of nesting turtles and vagaries of weather affecting both vehicular and aircraft transportation to and from the site make long-term planning difficult, if not impossible. Therefore, it seems best to allow eggs to develop for 2.5 weeks or more before transporting them to Padre Island to avoid killing embryos by moving them too soon. After this initial interval of incubation, eggs can be moved safely and with good success, barring some catastrophic occurrence. A typical box loaded with a clutch of eggs and filled with sand to not more than 2.5 cm above the uppermost layer of eggs weighs about 14 kg. Twenty boxes containing a total of 2,000 eggs would weigh about 0.28 metric tons, and 30 boxes containing 3,000 eggs would weigh as much as 0.42 metric tons. Actual weights could vary above or below these averages.

According to King, Shaver and Phillips (1984), the incubation boxes had walls 22 ml thick and an internal volume of 23,250 cubic cm. The shape of boxes originally used was not suitable for loading and shipping, so different boxes were selected that contained 16,390 cubic cm of interior space and were more nearly square. Holes, 6 ml in diameter, were drilled in each box; 30 each in the top and bottom, eight through each side and six through each end. We recommend continued use of boxes of this size and shape, both for convenience and for continuity in technique.

Each box containing eggs must be marked with genus, species and number of eggs contained within to comply with U.S. import regulations. Persons accompanying the shipment must possess a U.S. Fish and Wildlife Service threatened and endangered species permit and a CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) export permit in addition to the requisite Mexican permits previously mentioned. The shipment must depart from the Republic of Mexico for the U.S. via the Matamoros Airport. To avoid dilemmas that might occur at the border, the Mexican Consul must be provided copies of all appropriate documents and his assistance requested in dealing with authorities at the Port of Matamoros.

The earthen airstrip at Rancho Nuevo is approximately 0.3 km long. When the strip is dry and in good condition, a Cessna 206 with balloon tires can transport the pilot, one passenger and up to 20 boxes of eggs and sand. A Cessna 207 with balloon tires is necessary for 30 boxes. From mid-June through July, the rainy season begins, and the airstrip is usable only intermittently. In both 1984 and 1985, landings and takeoffs were made on the beach because the landing strip was inundated by water. When landings and takeoffs on the beach are necessary, flight times for transport of the boxed eggs must coincide with low tides. This can present additional problems in that the Matamoros Airport has no landing lights and closes at night. Thus, egg export flights must occur only during daytime.

Once the flight leaves Matamoros Airport, it can continue on to Padre Island National Seashore where boxes are offloaded and transferred to the hatchery. At that time, the National Park Service takes over and completes the incubation and imprinting phases of head starting Kemp's ridleys.

It is hoped that the preceeding information will serve as a helpful guide to those who in the future are involved in the long-term effort to establish a new nesting colony of Kemp's ridley on Padre Island through head starting.

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Beach Temperature Versus Polystyrene Foam Box Temperature in Incubation of Kemp's Ridley Sea Turtle Eggs

Robert E. King*

*Center-clutch temperatures were recorded hourly in 20 polystyrene foam boxes containing sand in which Kemp's ridley sea turtle (*Lepidochelys kempi*) eggs were incubating from June 23, 1982, through the onset of hatching. During this same period, weekly 24-hour beach temperature profiles at sand surface and depths of 15, 30 and 45 cm were recorded on the Kemp's ridley imprinting beach at Padre Island National Seashore near Corpus Christi, Tex. Throughout the entire incubation period, temperatures were generally lower in the polystyrene boxes than at any of the three depths on the imprinting beach. There were also differences between boxes and beach in daily temperature range and in times of occurrence and duration of maximum and minimum temperatures.*

A direct 24-hour comparison between center-clutch incubation temperatures in a single polystyrene box and temperatures at the imprinting beach at 30 cm depth (the Kemp's ridley "mid-nest" depth on the natural nesting beach at Rancho Nuevo, Mexico) was also made weekly throughout the incubation period. During the first two trimesters of incubation, polystyrene box center-clutch incubation temperatures were 1° to 3° C cooler than the temperatures at 30-cm depth on the imprinting beach for each 24-hour period. Clutch metabolic heating during the last trimester raised the center-clutch incubation temperatures dramatically above those recorded on the imprinting beach at the 30-cm depth. Temperature differences such as those seen during the first two trimesters can be expected to alter sex ratios in clutches incubated in boxes as compared to those incubated in situ. *Only polystyrene box incubation which mimics the mid-nest temperature profile of a natural nesting beach, should be considered as a viable option for sea turtle conservation programs.*

Incubation of sea turtle eggs in polystyrene foam boxes has played, and will continue to play, an important role in many sea turtle conservation efforts. However, this method places the eggs in an artificial environment in which incubation temperature may bear little resemblance to that of the natural nesting beach.

The discovery that sex of sea turtles is determined by incubation temperature emphasizes the need for understanding how natural and artificial incubation of eggs differ in their effects on sex ratios of clutches. If box incubation is to remain a viable part of sea turtle conservation efforts, these effects must be clearly understood.

The use of polystyrene foam boxes containing beach sand for the incubation of sea turtle eggs is among the most widespread and simplest tools of sea turtle conservation (Mrosovsky, 1983). It has also become controversial because it is known that incubation temperature determines sex in sea turtles, the cooler temperatures having a masculinizing effect. Polystyrene foam boxes are used for incubating Kemp's ridley sea turtle (*Lepidochelys kempi*) eggs translocated from Rancho Nuevo, Mexico to the Padre Island National Seashore near Corpus Christi, Tex. Therefore, it is imperative to know how temperatures in the boxes and on the beach compare.

The purposes of this study were two-fold: (1) to determine the typical pattern of temperatures from surface to 45 cm depth for the Kemp's ridley imprinting beach at Padre Island National Seashore; and (2) to determine differences, if any, between this imprinting beach's temperatures at 15, 30 and 45 cm depths and simultaneously recorded temperatures in polystyrene foam boxes containing incubating Kemp's ridley eggs. This study was conducted under the incubation and imprinting phase of the U.S.-Mexico Cooperative Project designed to establish a breeding colony of Kemp's ridley sea turtles on Padre Island, Tex.

Methods

Six rows of three thermocouple probes (total of 18 probes) were established on the Kemp's ridley imprinting beach at the Padre Island National Seashore, from the high tide zone to half-way up the foredunes. Each probe had temperature sensors at 15, 30 and 45 cm depths. Rows and columns in the array of probes were 15 m apart, so the array spanned a segment of beach 30 m wide and 75 m long, from the high tide zone to halfway up the foredunes. One day each week, beginning at the end of May and continuing through mid-August 1982, temperatures at the sand-surface and at 15, 30 and 45 cm depths were recorded every two hours over a 24-hour period.

Department of the Interior, National Park Service

On June 23, 20 polystyrene foam boxes containing Padre Island sand and incubating Kemp's ridley eggs were received from Rancho Nuevo. Each box contained a thermocouple implanted within the center of the clutch when the eggs were placed in boxes. The boxes were transferred to a screened shed (hatchery) and incubation continued under ambient (air) temperature conditions. Incubation temperatures were recorded hourly for each clutch (one per box) from their arrival until the commencement of hatching.

Results

Figure 1 depicts a typical 24-hour cycle in beach temperature profile. Twenty-four hour trends of temperatures for all six rows of thermocouple probes were similar in form throughout the monitoring period although differences between rows, within rows and among dates were noted. Surface temperature maxima were much higher for probes located in the upper portions of the beach than for those in the tidal zone, but the beach location of probes (from tidal zone to dune) had a diminishing effect on temperatures as depth of the sensors increased. Heat transfer through the sand, from the surface into deeper layers, occurs at a constant rate. Rain of brief duration altered the form of Figure 1 by causing a sharp decline in sand surface temperature, but it affected temperatures at various depths only slightly. However, prolonged periods of heavy rain probably would have a pronounced effect on subsurface temperatures, but this was not encountered during the study.

The temperatures at 15, 30 and 45 cm depths show a diel cycle related to surface temperature, but heat transfer from the beach surface through the sand is delayed (Figure 1). Each weekly, 24-hour beach temperature series for row 3 (rows were numbered 1-6 from tide zone to dunes) at 15, 30 and 45 cm depths was compared to temperatures in box 645 (Figures 2-7). These comparisons were restricted to a single row of temperatures and a single clutch of eggs for simplicity. Row 3 was chosen because it was located at approximately mid-beach. Eighty to ninety percent of Kemp's ridley nests are laid from the mid-beach to the top of the first foredune at Rancho Nuevo (Burchfield *et al.*, 1984), corresponding to rows 3-6 of this study. Clutch 645 was chosen because it represented a typical and successful clutch (124 eggs, 92 percent hatch and incubation period 52 days) and its incubation period closely matched the beach temperature monitoring period.

According to Burchfield, Foley and Noyes (1983), Burchfield *et al.* (1984) and Burchfield and Foley (1985), mid-nest depth for Kemp's ridley is 30 cm. In the early stages of incubation (Figures 2-4), before metabolic heat production occurred, temperatures at 30 cm were generally 1° to 3°C warmer than incubation temperatures in box 645. In the later stages of incubation (Figures 5-7), metabolic heat from embryos first raised incubation temperatures to those at 30 cm (Figure 6) depth and then significantly higher. This temperature relationship continued until hatching occurred. Sex determination probably occurred during the middle trimester of incubation (Mrosovsky, 1983) in box 645 (Figures 4 and 5).

Peak temperatures occurred at different times of the day in the incubation box than at the 15, 30 and 45 cm depths on the beach throughout the study. The daily peak usually occurred between hours 1800 and 2000 in the boxes and between hours 1600 and 1800 at 15 cm, hours 2000-2200 at 30 cm, and hours 0000 and 0600 at 45 cm on the beach. In addition, the duration of these daily peak temperatures was different. The peak temperature at 45 cm depth on the beach often lasted four to six hours as contrasted with peak temperatures within the box and at 15 and 30 cm depths, which seldom lasted longer than two hours. Disparities of a similar magnitude were found for the time of occurrence and duration of minimum temperatures. The amplitude of daily temperature excursions was greatest at 15 cm depth (4.4° to 6.2°C) but much less within the box (1.1° to 1.7°C), at 30 cm depth (1.6° to 2.5°C) on the beach, and at 45 cm depth (0.9° to 1.2°C) on the beach. Thus, at mid-nest depth (30 cm) for the Kemp's ridley, the time of occurrence and duration of maximum and minumum temperatures and daily range of temperatures were not markedly different from those of the incubation box.

Discussion

The most dramatic and probably significant difference between incubation box and beach mid-nest depth temperature patterns in this project is the 1° to 3°C lowering of incubation box temperatures during the first two trimesters of development. Differences in temperature pattern between incubation boxes and beach at nest depth are not confined to the Kemp's ridley project, and may vary with species and hatchery conditions. Processes responsible for such differences are common to all conservation efforts employing polystyrene foam box incubation of sea turtle eggs under ambient conditions. Specifically, incubation temperature in the boxes follows a cycle similar to that of the surrounding ambient (air) temperatures. Temperature ranges and times of occurrence and duration of peak temperatures vary with nest depth. Thus, sand at greater depths gains heat more slowly and retains heat longer. Amplitude of the temperature excursion diminishes or dampens with increase in depth from the surface on the beach.

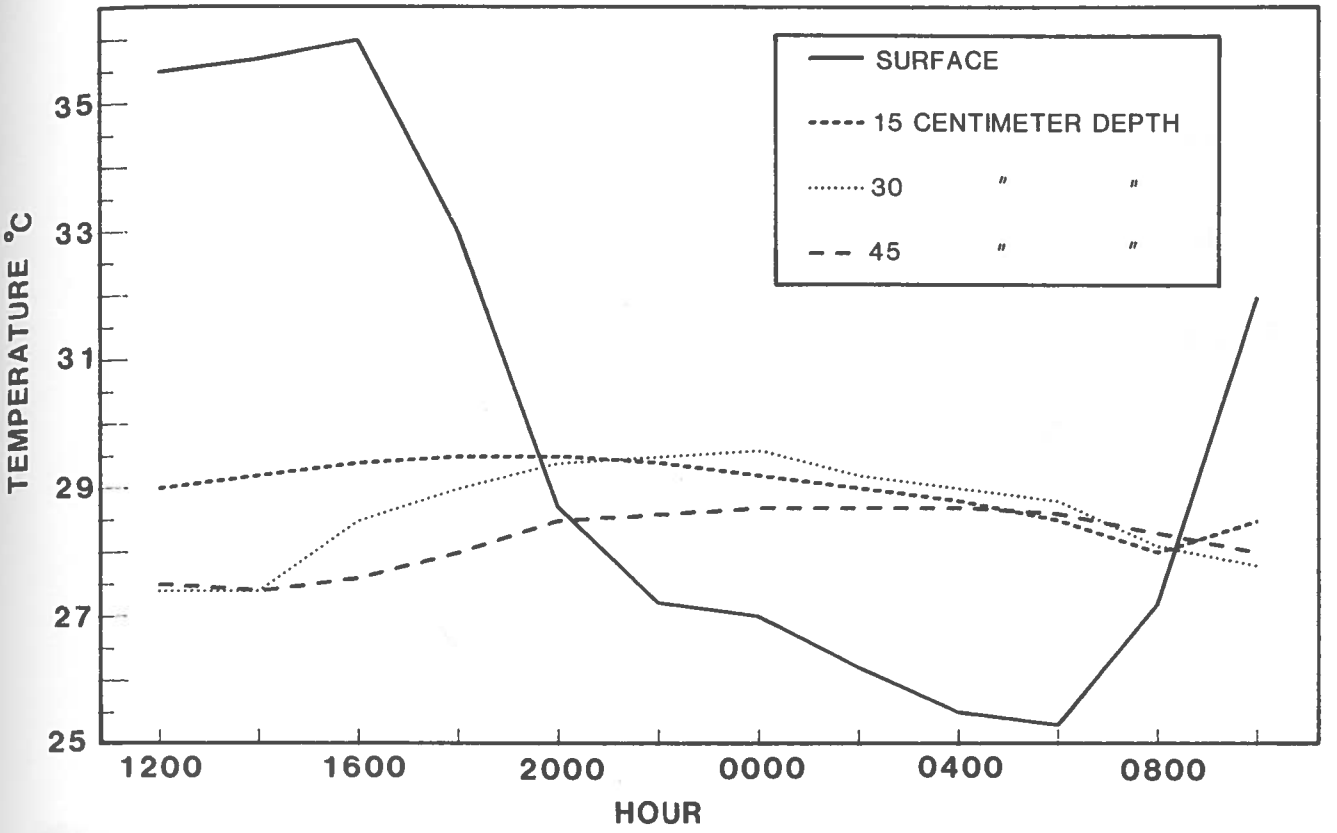

Figure 1. Typical Padre Island beach sand temperature profile at surface and at 15, 30 and 45 cm depths over a 24-hour period.

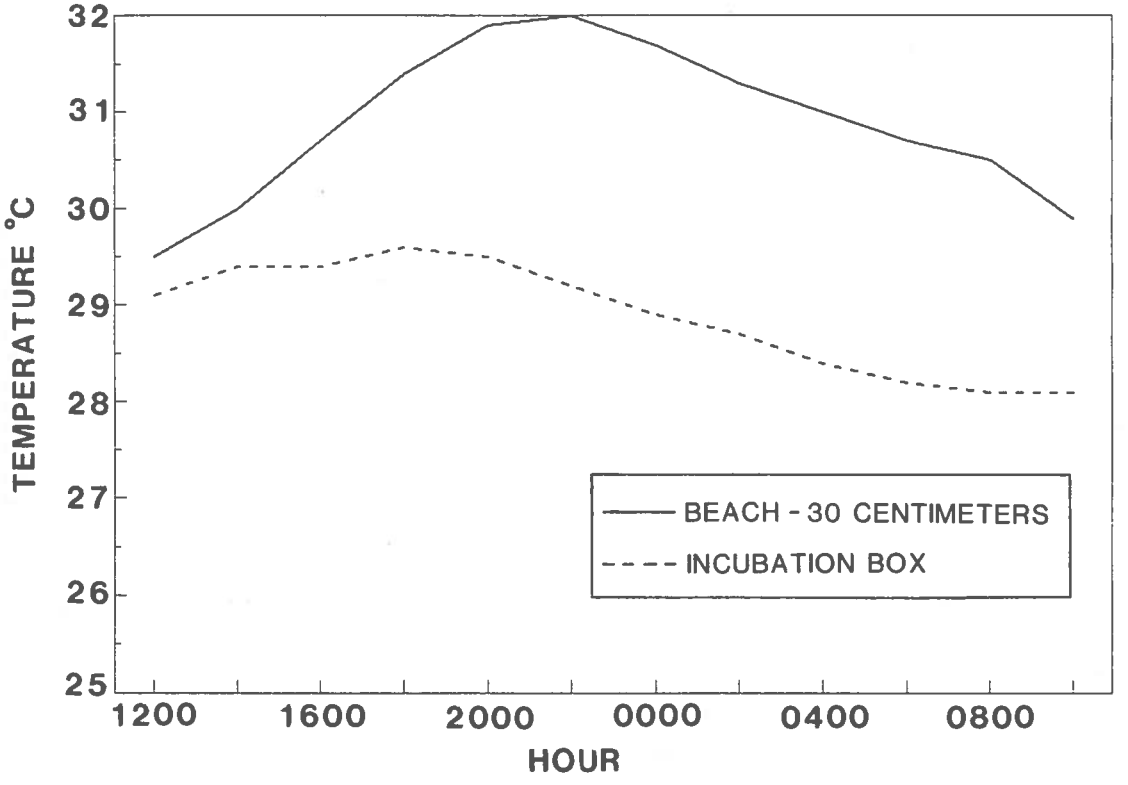

Figure 2. Padre Island beach sand temperature at 30 cm depth and incubation temperature for clutch 645 in a polystyrene foam box over a 24-hour period (incubation days 10 and 11, June 24-25, 1982).

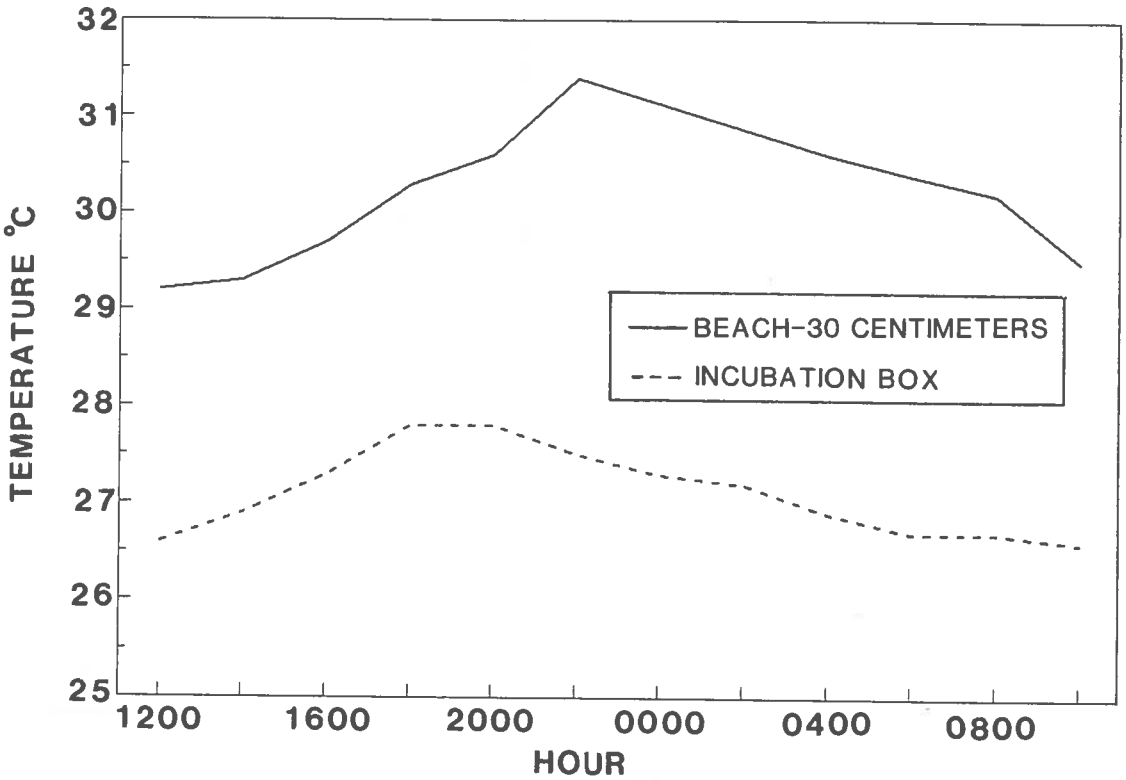

Figure 3. Padre Island beach sand temperature at 30 cm depth and incubation temperature for clutch 645 in a polystyrene foam box over a 24-hour period (incubation days 17 and 18, July 1-2, 1982).

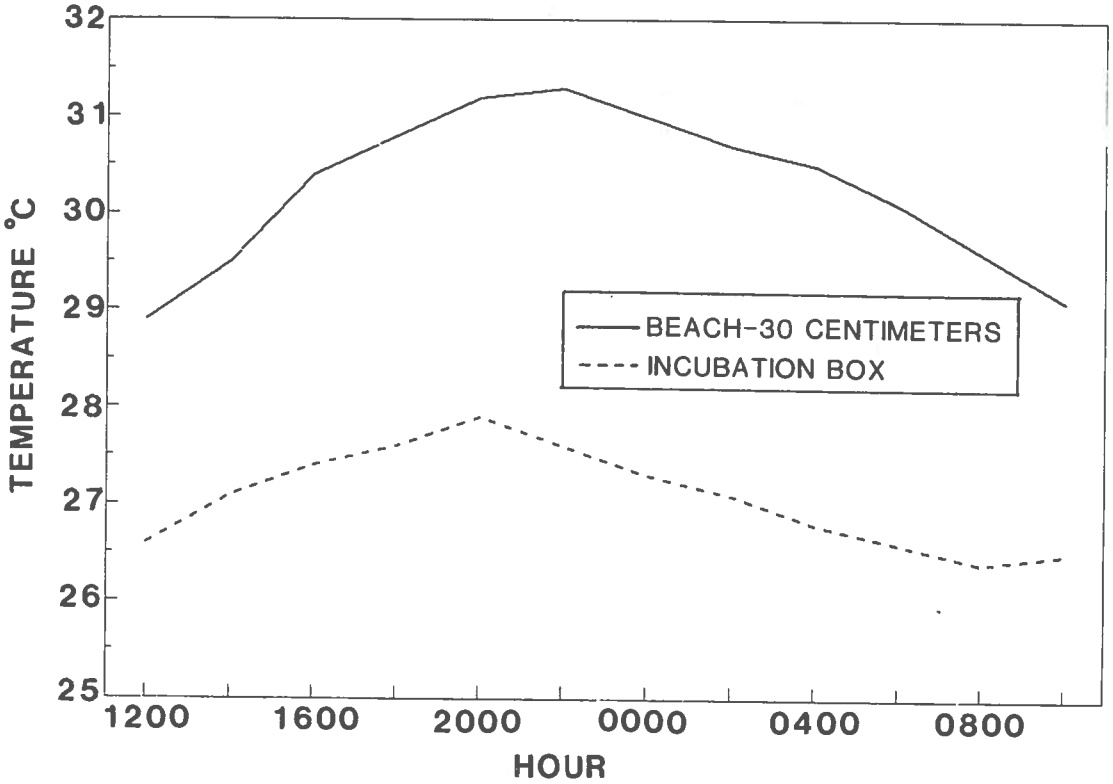

Figure 4. Padre Island beach sand temperature at 30 cm depth and incubation temperature for clutch 645 in a polystyrene foam box over a 24-hour period (incubation days 24 and 25, July 8-9, 1982).

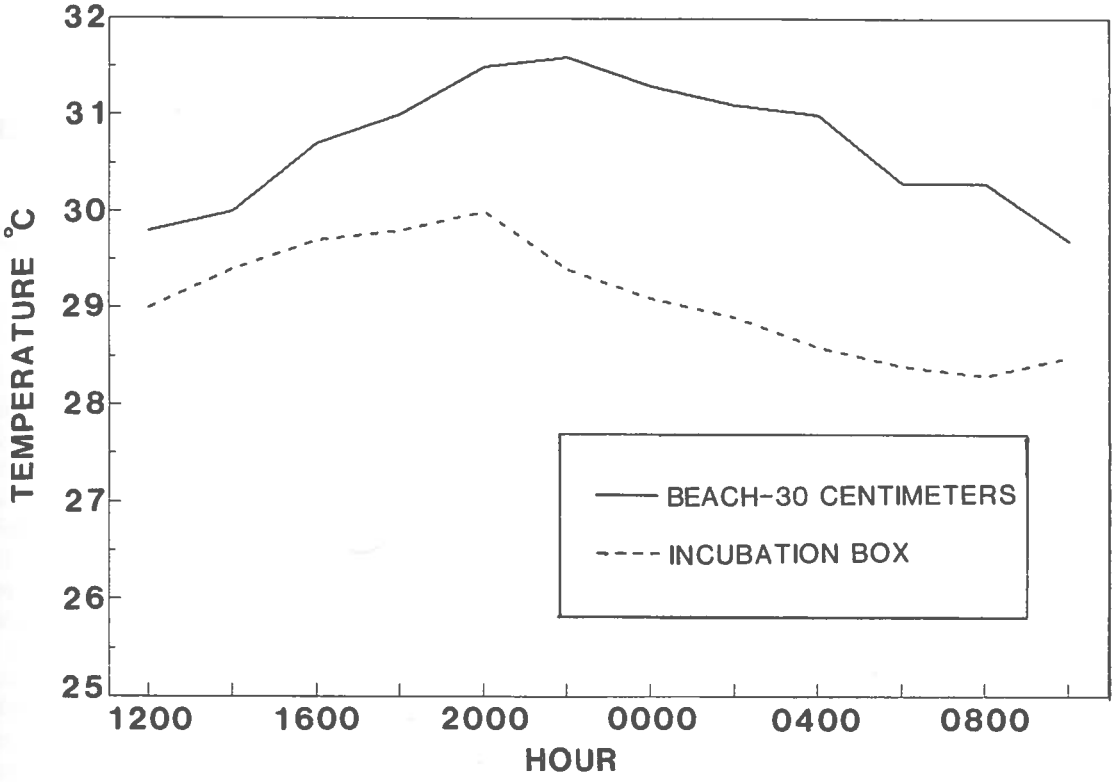

Figure 5. Padre Island beach sand temperature at 30 cm depth and incubation temperature for clutch 645 in a polystyrene foam box over a 24-hour period (incubation days 31 and 32, July 15-16, 1982).

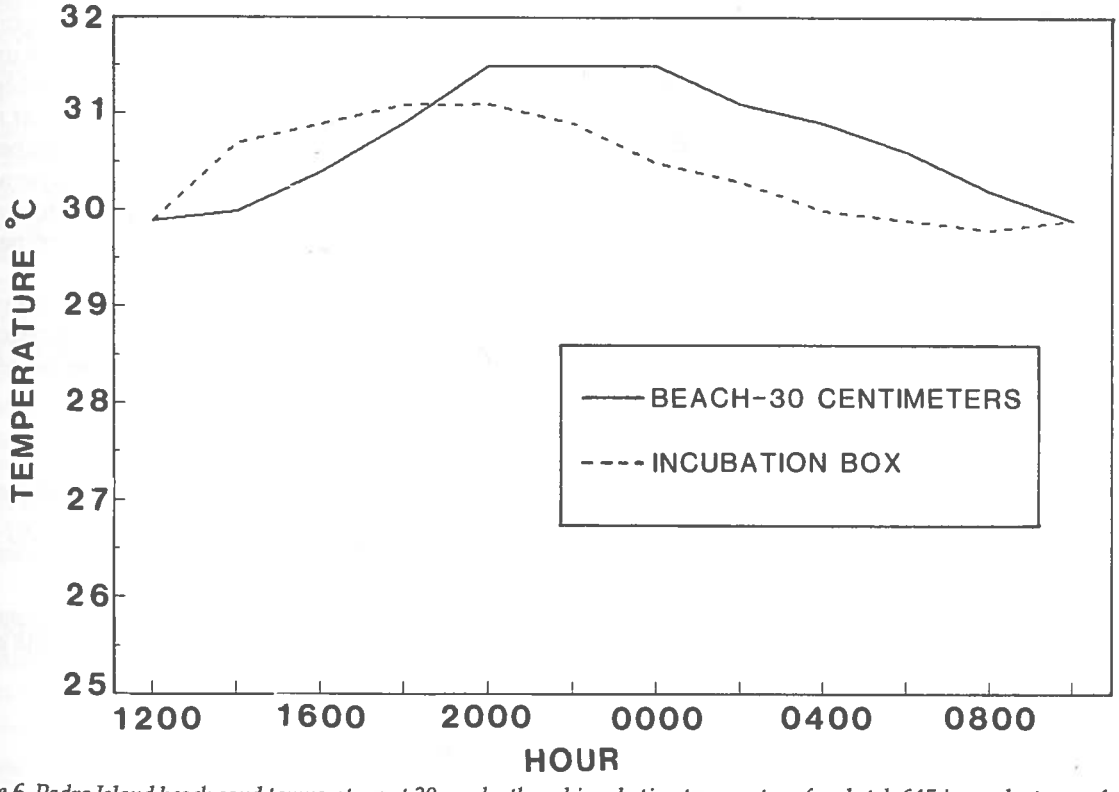

Figure 6. Padre Island beach sand temperature at 30 cm depth and incubation temperature for clutch 645 in a polystyrene foam box over a 24-hour period (incubation days 38 and 39, July 22-23, 1982).

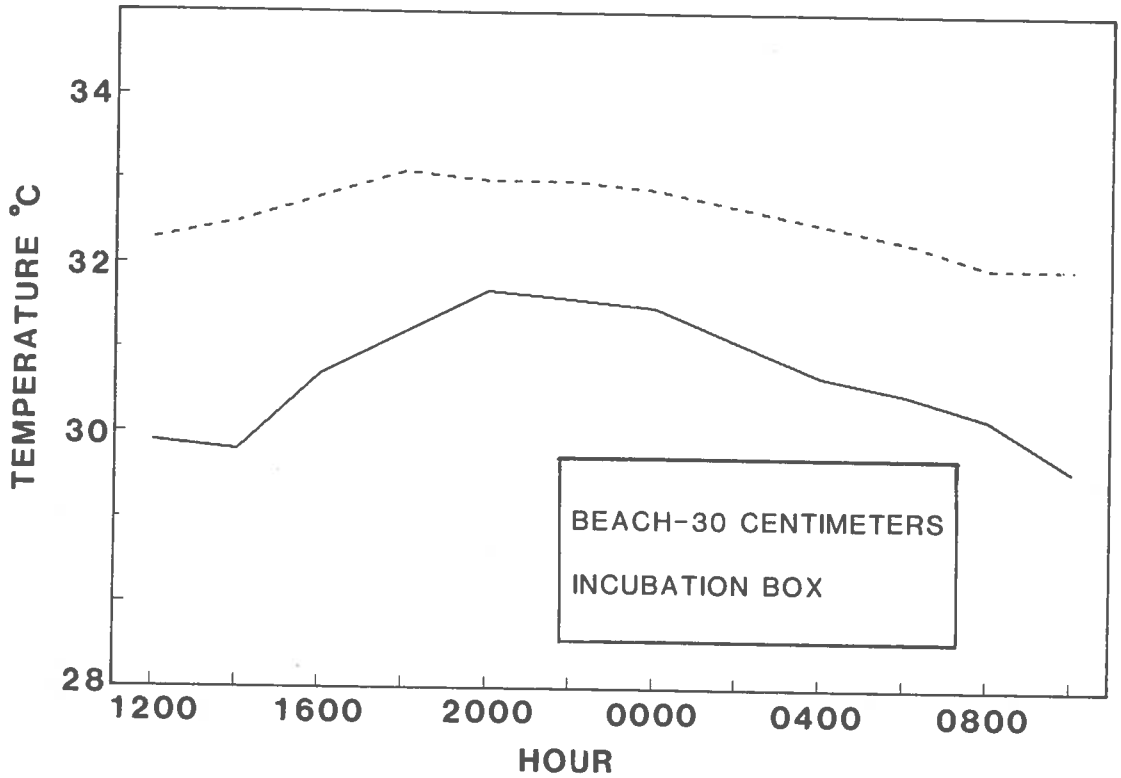

Figure 7. Padre Island beach sand temperature at 30 centimeter depth and incubation temperature for clutch 645 in a polystyrene foam box over a 24-hour period (incubation days 45-46, 29-30 July 1982).

Conclusion

Differences in incubation temperature between polystyrene foam boxes and natural beaches have important implications to sea turtle conservation programs. Incubation of Kemp's ridley eggs in polystyrene foam boxes under ambient conditions exposes the eggs to cooler temperatures during the first two trimesters of incubation (possibly the period when sex determination takes place), as compared to temperatures in sand on the Padre Island beach at mid-nest depth. Raising the temperature in the incubation shed could eliminate the lower-than-natural incubation temperature experienced by eggs in polystyrene foam boxes during the first two trimesters. Control of air temperature in the hatchery may be the only way to simulate the temperature pattern of the natural nesting beach during incubation of eggs in polystyrene foam boxes. Such control would be critical during the period of sex determination in incubating eggs.

In sea turtle conservation programs in which foam box incubation may be necessary, steps should be taken to control incubation temperature in ways that mimic the temperature pattern at nest depth on natural nesting beaches. If this cannot be done, eggs should not be removed from their natural incubation conditions until the period of sex determination has passed.

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Predicted Sex Ratios From the International Kemp's Ridley Sea Turtle Head Start Research Project

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Sex ratios were determined for groups of turtles from six year-classes of Kemp's ridley sea turtles (Lepidochelys kempi) *from the joint U.S.-Mexico Kemp's Ridley Sea Turtle Head Start Research Project. Gonadal histology, necropsy, laparoscopy, tail length evaluation and serum testosterone assays were used to determine sex.*

Turtles examined from the 1982 (n=92, 2.9M:1F) and 1984 (n=159, 2.5M:1F) year-classes were significantly male-dominated. The turtles examined from the 1978 (n=32, 1.9M:1F) and 1979 (n=22, 1.4M:1F) year-classes also were male-dominated, but not significantly so. Those examined from the 1983 (n=12, 1M:1F) year-class had equal representation of the sexes, and those from the 1981 (n=4, 0M:1F) year-class were all females. Data from the 1984 year-class also indicated that sex ratios of clutches from a given year-class can differ significantly from one another.

The significantly male-dominated groups of turtles from the 1982 and 1984 year-classes and the significant differences in sex ratios among clutches of the 1984 year-class are consistent with the hypothesis that the sex of Kemp's ridleys is determined environmentally. Because the number of turtles examined from most year-classes was small, our interpretations should be considered with caution. Conservatively, we concluded that relatively large numbers of both male and female Kemp's ridleys have been produced by the project in the past. However, a significant masculinization was evident in two of the year-classes. The implications of male-dominance in Kemp's ridley sex ratios are discussed.

All sea turtle species tested so far have been shown to possess environmentally dependent sex differentiation systems (Yntema and Mrosovsky, 1980, 1982; Miller and Limpus, 1981; McCoy, Vogt and Censky, 1983; Mrosovsky, Dutton and Whitmore, 1984). This fact has serious implications for present-day conservation programs incorporating artificial incubation under which biasing of sex ratios is possible (Mrosovsky and Yntema, 1980; Morreale et *al.*, 1982; Mrosovsky, 1983; Dutton, Whitmore and Mrosovsky, 1985).

Some sea turtle conservation programs use artificial incubation followed by short-term captive rearing and release of the turtles. Captive rearing is employed to reduce high natural mortality that occurs during the first year of life. The assumption is that the percentage of hatchlings surviving to reach sexual maturity could be increased by such programs. If short-term captive rearing proves to be an effective management technique, then artificial incubation of eggs in such cases could have a much greater effect on population sex ratios than when used in programs that release hatchlings immediately into the wild.

Kemp's ridley sea turtle (*Lepidochelys kempi*) is the most endangered species of sea turtle. Its current conservation program includes the Kemp's Ridley Sea Turtle Head Start Research Project that uses artificial incubation of eggs followed by captive rearing of the turtles for approximately one year (Klima and McVey, 1982). Head started Kemp's ridley sex ratios have a probability of being impacted by artificial incubation. The experimental head start project also involves imprinting in hopes of establishing a new nesting colony of Kemp's ridley on the Padre Island National Seashore near Corpus Christi, Tex.

Kemp's ridley apparently possesses environmentally dependent sex determination (Wibbels *et al.*, 1985; Shaver *et al.*, 1988). Therefore, the consequences of artificial incubation on Kemp's ridley sex ratios produced in the head start project require evaluation. The purpose of this paper is to review and evaluate sex ratio data from six year-classes (1978-1979 and 1981-1984) of Kemp's ridleys.

Sexing Techniques

Various techniques have been used by researchers to sex Kemp's ridley. Histological examination of hatchling and posthatchling gonads (as described by Yntema and Mrosovsky, 1980) was shown to be definitive in sexing Kemp's ridleys that died after hatching or during head starting (Wibbels *et al.*, 1985). Direct observation of the gonads during

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necropsy has been used to sex postyearling turtles (Wood, 1982). A testosterone sexing technique described by Owens *et al.* (1978) was used to predict sex of living Kemp's ridleys that were at least two years old (Wibbels *et al.*, 1985; Y. A. Morris and D. W. Owens, personal communication). The predicted sexes of 19 out of 55 turtles sexed by the testosterone method were verified via necropsy (in those that died), laparoscopy (described by Wood *et al.*,1983) or by tail length evaluation (Y.A. Morris and D.W. Owens, personal communication).

Results and Discussion

A summary of sex ratio data pertaining to the 1978-1979 and 1981-1984 year-classes of head started Kemp's ridleys is shown in Table 1. Data from the 1984 year-class supported the most comprehensive examination of a Kemp's ridley year-class to date, with 10 turtles sexed from each of 14 clutches, and from one to eight turtles sexed from each of the remaining five clutches. The aggregate sex ratio (n=159, 2.5M:1F) for the 1984 year-class samples was significantly male-dominated ($P<0.05$). If this sex ratio is representative of the entire 1984 year-class, it would seem that eggs from the 1984 year-class were incubated slightly below the pivotal temperature (i.e., that temperature that would produce a 1M:1F sex ratio; see Shaver *et al.*, 1988). Sex ratios of samples of turtles from 19 clutches of the 1984 year-class, are listed in Table 2. A Chi-square comparison among the sex ratios of the 14 clutches from which 10 turtles were sexed indicated that they were heterogeneous (i.e., sex ratios differed significantly at $P<0.05$). Such results could have derived from different incubation temperatures among the clutches. Sex ratio differences among clutches and the significant male-dominance of the aggregate sex ratio for the 1984 year-class are consistent with the hypothesis that Kemp's ridley possesses an environmentally dependent sex determination system. Furthermore, these results emphasize that sex ratios vary significantly among clutches of a year-class, so an aggregate sex ratio based on combined clutches would not be representative of all clutches of a year-class, and the particular choice of clutches in the aggregate could influence the sex ratio of the year-class as a whole.

One also must be concerned about adequacy of sample size within the chosen clutches in evaluating sex ratios and their relation to incubation temperature. Samples from the 1978, 1979, 1981 and 1983 year-classes (Table 1) are not adequate for all clutches in those year-classes. Conservatively, results for those samples suggest that relatively large numbers of both males and females were produced within those year-classes and that there was variation in incubation temperature among clutches within the year-classes.

Though 92 turtles of the 1982 year-class were sexed, all clutches were not represented. Those that were represented had only a few sexed individuals ($n<5$, Wibbels *et al.*, 1985). Furthermore, of the six clutches represented by the largest samples ($5\leq n\leq 11$), four contained only males (1M:0F) and one was male-dominated (4M:1F). This further exemplifies the problem associated with aggregating sex frequency data from various clutches when sample sizes for each clutch are inadequate. Therefore, the lack of samples from some clutches combined with insufficient sampling of others, and the male-dominance of clutches represented by the largest samples, make it difficult if not impossible to estimate with accuracy the sex ratio of the year-class. Nevertheless, these data suggest that relatively large numbers of both males and females were produced in the 1982 year-class. Assuming that a differential mortality between the sexes is not present, the significant ($P<0.05$) male-dominance of the 1982 year-class is noteworthy.

A significant male-dominance in head started Kemp's ridleys was indicated in the 1984 year-class and possibly in the 1982 year-class. This suggests that incubation temperatures were below the pivotal temperature for the species. Sex ratio data from other year-classes were inconclusive.

What should be the targeted sex ratio for the head start project, assuming that sex ratios can be manipulated by controlling environmental temperature during incubation? One strategy might be to duplicate the sex ratio in the natural population of Kemp's ridley. However, the natural sex ratio is unknown. Furthermore, the drastic decline in the Kemp's ridley population during the last four decades may have distorted the natural sex ratio, or the sex ratio may now be unstable. In addition, if the head start project succeeds in establishing a new breeding population that nests on Padre Island, the sex ratio for that population may differ from that of the population nesting in Mexico.

It might be possible to predict the sex ratio for the new population based on known characteristics of the Padre Island nesting beach, given that the pivotal temperature for sex determination in Kemp's ridley is around 30° C (Shaver *et al.*, 1988). Regardless, even if a temporally stable sex ratio could be predicted for the hypothetical population of Kemp's ridleys nesting at Padre Island and it was similar to that for Rancho Nuevo, such sex ratios may not be the ones that would maximize reproductive success within either of the two populations. In that case, a preferred strategy might be to manipulate sex ratio of head started Kemp's ridley in such a way that would enhance reproductive success.

Unfortunately, the relationship between sex ratio and reproductive success has not been studied in any sea turtle species. For that reason, the best strategy might be to hypothesize optimal sex ratios based on our current knowledge of reproductive ecology of sea turtles and status of Kemp's ridley in the wild. Sex ratios of naturally occurring Kemp's ridley have not been studied, but those of other sea turtle species have recently received attention. Standora and

Table 1. Sex ratios of head started Kemp's ridley sea turtles by year-class.

Year-class	Sex determination method	Sample size, n	Sex ratio	Chi square	Reference
1978	Testosterone[a]	32	1.9M:1F	3.1250	Morris *et al.* (per. com.)
1979	Necropsy	22	1.4M:1F	0.7272	Wood (1983)
1981	Histology	4	0M:1F	4.0000*	Wibbels *et al.*(1985)
1982	Testosterone	22	1.7M:1F	1.6364	"
1982	Histology	70	2.9M:1F	16.5142*	"
1983	Histology	12	1M:1F	0.0000	"
1984	Histology	159	2.5M:1F	29.9434*	"

[a] Sex predicted from testosterone titer was compared to known sex as determined through laparoscopy, gonad histology, or tail length for 19 of the 55 turtles from the 1978 and 1982 year-classes. All 19 of the predicted sexes were in agreement with the known sexes.
*Indicates significant difference from a 1M:1F sex ratio at $P<0.05$.

Table 2. Sex ratios of Kemp's ridley sea turtles of the 1984 year-class that died during head starting, by clutch.

Clutch[a]	Sample size, n	Sex ratio
512	10	0.4M:1F
513	10	1.5M:1F
514	10	2.3M:1F
515	10	0.4M:1F
765	4	3M:1F
766	10	4M:1F
767	10	1M:0F
768	8	1M:1F
769	10	2.3M:1F
770	10	1M:0F
771	10	2.3M:1F
772	10	1M:0F
773	2	1M:0F
774	4	1M:1F
775	10	1M:0F
776	10	2.3M:1F
797	10	9M:1F
798	10	1M:1F
799	1	1M:0F
Combined	159	2.5M:1F

[a]Clutch identification codes used at Rancho Nuevo, Tamaulipas, Mexico.

Spotila (1985) estimated that 71 percent of the hatchling green turtles (*Chelonia mydas*) produced at Tortuguero are female. Mrosovsky, Hopkins and Richardson (1984) estimated that the sex ratio of hatchling loggerheads (*Caretta caretta*) produced on several beaches in Georgia and North Carolina was close to 1M:1F. Mrosovsky, Dutton and Whitmore (1984) estimated hatchling sex ratios of green turtles and leatherback turtles (*Dermochelys coriacea*) from a beach in Suriname to be 0.9M:1F and 1M:1F, respectively.

Sex ratios have also been estimated for the subadult and adult portion of sea turtle populations. Limpus (1985) has found a significant male dominance in resident loggerheads on Heron Atoll on the Great Barrier Reef. Wibbels *et al.* (1987) found a significant female dominance in sex ratios of subadult loggerheads captured along the Atlantic coast of the U.S.

Studies mentioned above represent initial attempts at estimating sea turtle sex ratios in nature and are far from conclusive. They suggest that sex ratio varies widely (including both significant male or female dominances) in natural sea turtle populations. Thus, it would not be unreasonable to expect that male-dominated sex ratios could occur in natural populations of Kemp's ridley. Nevertheless, there is no reason to believe that male dominance of sex ratios would enhance reproductive success of Kemp's ridley or any other sea turtle species.

Female Kemp's ridleys are known to be annual and multiannual in their reproductive cycles (Pritchard and Márquez, 1973), but the reproductive cycle of males is not known. If males are primarily annual breeders and if only one male is required to fertilize one or more females, then sex ratios dominated by males or with equal numbers of males and females may represent surpluses of males. If this is true, the total egg production of the population might be increased by shifting the sex ratio toward more females. Obviously, a better understanding of reproductive ecology of both male and female Kemp's ridley is needed to determine the validity of this hypothesis. Until such information is available, a conservative approach might be to produce a 1M:1F sex ratio in head started Kemp's ridleys, thereby preventing departures from 1M:1F that might decrease reproductive success within the population. A 1M:1F sex ratio also would be consistent with that expected from classic theory on sex allocation (Fisher, 1930), assuming that species with environmentally dependent sex determination conform to classic theory.

We also offer the more controversial opinion that production of female-dominated sex ratios might be advantageous for several reasons. Any new population established by the head start project that nests on Padre Island probably would be composed predominantly if not totally of turtles from the project. Data reviewed in this paper indicate male-dominated sex ratios in the 1984 and possibly the 1982 year-classes. Therefore, temporary production of female-dominated sex ratios might compensate the imbalance created by past male-dominated sex ratios. Even if head started turtles nest on a natural nesting beach such as that at Rancho Nuevo, instead of Padre Island, a female-dominated sex ratio also could compensate for the possibly higher mortality experienced by adult females in the past due to their greater vulnerability to natural predators and to man when nesting. Finally, regardless of where head started females nest, if Kemp's ridley reproduction is female-limited, an increase in number of females in the population should directly increase total egg production.

Given the various considerations above, we suggest that it may be advantageous to increase incubation temperatures slightly for future year-classes of Kemp's ridley eggs, assuming a pivotal temperature of 30° C (Shaver *et al.*, 1988) as a guide. The amount of increase in incubation temperature needed could be based on the specific sex ratio desired as extrapolated from available sex ratio data (*ibid.*).

In closing, we hope this discussion with its focus on currently unanswered questions shows how critically important it is to continue and intensify studies on effects of incubation temperature on sex ratio in Kemp's ridley.

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An Analysis of Unhatched Kemp's Ridley Sea Turtle Eggs

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*Unhatched Kemp's ridley sea turtle (*Lepidochelys kempi*) eggs (3,656) from the 1980 and 1982-1987 year-classes were preserved after full-term incubation. Eggs were opened, examined to determine fertility, and embryos were removed. Embryo developmental stages were compared to those described by Cratz (1982) for olive ridley (*L. olivacea*) and were classified accordingly if they were compatible or were placed in additional erected stages if they were not. Obvious external deformities of embryos and hatchlings were noted and compared. Overall fertility of the eggs from the seven year-classes was at least 95 percent.*

Of all unhatched eggs examined, 19.9 percent were infertile, 38.8 percent were fertile but contained no identifiable embryos, and 38.5 percent contained embryos. Of the embryos found, 93.9 percent were staged. Most unhatched eggs and embryos of the 1982-1984 and 1986 year-classes ceased development during the first trimester of incubation, while most of the 1980, 1985 and 1987 year-classes succumbed during the last trimester. Deformities were observed in 8.3 percent of the staged embryos and 0.5 percent of the hatchlings examined from the 1982-1987 year-classes. Neither transport by aircraft nor low fertility were significant factors leading to the high mortality observed in eggs from the 1983 year-class.

The Kemp's ridley sea turtle (*Lepidochelys kempi*) is the most endangered species of sea turtle (Pritchard, 1969; Anonymous, 1978). In an effort to enhance the population and establish a second breeding colony, an international cooperative Restoration and Enhancement Program was undertaken in 1978. Participants in the program include the Instituto Nacional de la Pesca (INP) of Mexico, the U.S. Fish and Wildlife Service (FWS), the National Park Service (NPS) and National Marine Fisheries Service (NMFS). During each summer since then, approximately 2,000 eggs have been gathered at Rancho Nuevo, Tamaulipas, Mexico, packed in Padre Island, Tex., sand in polystyrene foam boxes (one clutch per box) and translocated to the Padre Island National Seashore near Corpus Christi, before hatching.

Yearly mean hatch rates for these eggs have ranged from 64 to 91 percent, except in 1983 when only 12 percent hatched (King *et al.*, 1982 and 1983; King, Shaver and Phillips, 1984; Leong, 1984; King *et al.*, 1985; Shaver *et al.*, 1986 and 1987). Several hypotheses were advanced regarding the cause of high mortality in eggs from the 1983 year-class including: (1) microbial invasion; (2) movement of the eggs during a critical phase of incubation; (3) non-fertilization of the eggs; (4) excessive sand moisture; and (5) egg contamination by chemical toxicants (Leong, 1984).

It was decided that examination of unhatched eggs might provide some insight into the critical periods of embryonic development and possible causes of embryo mortality. By staging embryos obtained from these eggs, we could estimate time of death, and relate it to the sequence of activities involved in the Restoration and Enhancement Program. Results could be used to evaluate procedures employed in the program, to aid in improving these procedures and to avoid excessively high mortalities such as occurred in 1983. Moreover, investigating embryological development and deformities in embryos from unhatched Kemp's ridley eggs could produce information enhancing our understanding of this critically endangered species.

The embryological stages of development of the olive ridley (*L. olivacea*), loggerhead (*Caretta caretta*), green (*Chelonia mydas*), flatback (*Chelonia depressa*), hawksbill (*Eretmochelys imbricata*) and leatherback (*Dermochelys coriacea*) sea turtles were examined and described by Cratz (1982) and Miller (1985) who sacrificed embryos systematically throughout the incubation period. It was hoped that developmental stages described for olive ridley could be used to stage Kemp's ridley embryos. However, Kemp's ridley eggs and embryos could not be sacrificed because its population is critically low. Unhatched eggs provided the material that could otherwise not be obtained by killing eggs or embryos.

The objectives of this study were: (1) to determine if embryos could be salvaged and valid information obtained from unhatched Kemp's ridley eggs that had been retained through full-term incubation; (2) to quantify the number of fertile and infertile eggs; (3) to determine if embryological stages of development for olive ridley (Cratz, 1982) could be applied to stage Kemp's ridley embryos, and if not, to develop any necessary modifications or additional stages; (4) to quantify embryonic deaths in terms of stage of development for unhatched eggs salvaged from clutches from each year-class; (5) to quantify and describe embryo deformities and compare them to deformities of hatchlings by clutch; and (6) to determine whether mortality and deformity rates were related to the methods employed for each year-class.

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Table 1. Hatched and unhatched eggs of Kemp's ridley sea turtle, by year-class.

Year-class	Hatched eggs		Unhatched eggs				Total
			Examined[a]		Not Examined		
	No.	%	No.	%	No.	%	
1980	2,502	84.1	450	15.1	24	0.8	2,976
1982	1,563	77.6	105[b]	5.2	349	17.2	2,017
1983	242	12.1	1,629	81.2	135	6.7	2,006
1984	1,792	90.7	184	9.3	0	0.0	1,976
1985	1,734[c]	83.6	340[d]	16.4	1	0.0	2,075[e]
1986	1,776	88.3	235	11.7	0	0.0	2,011
1987	1,288	64.4	713	35.6	0	0.0	2,001
Total	10,897	72.3	3,656	24.3	509	3.4	15,062

[a] To determine condition, fertility and embryonic stage.
[b] Represents all unhatched eggs from only seven of 20 clutches received from Rancho Nuevo in 1982.
[c] Includes 70 eggs from a natural nest laid on Padre Island National Seashore.
[d] Includes 27 eggs from a natural nest laid on Padre Island National Seashore.
[e] Includes 97 eggs from a natural nest laid on Padre Island National Seashore.

Materials and Methods

Out of 15,062 eggs from the 1980 and 1982-1987 year-classes, 4,165 (27.7 percent) did not hatch (Table 1). Of these unhatched eggs, 3,656 were preserved and examined. They were injected with and stored in F.A.A. solution, except for 600 eggs from 1983 that were fixed in 10 percent buffered formalin. The eggs were fixed and submerged in preservative within two days of hatching of a given clutch, except for 650 from the 1980 and 1983 year-class that first had been frozen for one to two years before injection.

Unhatched eggs that were examined were subjected to the same procedures. Each egg was opened and examined for signs of yolk absorption and presence of embryonic membranes. All embryos were removed, and the developmental stage of those not greatly deteriorated was compared to stages described for the olive ridley by Cratz (1982). If the Kemp's ridley embryo stages were comparable to those of olive ridley, they were so classified. If not, additional erected or modified stages were established and assigned. Embryos also were inspected for obvious external deformities, then were stored in 45 percent isopropyl alcohol. On the basis of these observations, eggs and embryos were classified according to the following categories (Tables 2 and 3):

1. Eggs in which no embryos were found
   a. Infertile — eggs showed no signs of yolk absorption or change in yolk texture, and exhibited no embryonic membranes
   b. Fertile — eggs contained embryonic membranes, showed signs of yolk absorption and changes in yolk texture, but ceased embryonic development early in incubation or eggs whose embryos were so deteriorated that they could not be found
   c. Rotten — eggs that could not be classified as either fertile or infertile because their yolks had either deteriorated or were consumed or disturbed by maggots
2. Eggs in which embryos were found
   a. Staged embryos — embryos assigned to one of the developmental stages described by Cratz (1982) for olive ridley or described in this study for Kemp's ridley
   b. Decomposed embryos — embryos that could not be staged because they had deteriorated

Results and Discussion

General

Condition of some of the eggs and embryos prior to preservation could have influenced the results. For example, eggs from clutches of the 1980 year-class were frozen for two years and inadvertently thawed twice before preservation, hence they generally were in poor condition when examined. Also, it was sometimes difficult to distinguish

Table 2. Categorization of unhatched Kemp's ridley sea turtle eggs examined, by year-class.

	Fertile Year-class		With embryos		Infertile Without embryos		Rotten		Total
	No.	%	No.	%	No.	%	No.	%	No.
1980	173	38.4	37	8.2	226	50.2	14	3.1	450
1982	47	44.8	25	23.8	28	26.7	5	4.8	105
1983	230	14.1	1,102	67.6	252	15.5	45	2.8	1,629
1984	75	40.8	59	32.1	39	21.2	11	6.0	184
1985	180	52.9	77	22.6	62	18.2	21	6.2	340
1986	113	48.1	51	21.7	67	28.5	4	1.7	235
1987	591	83.5	67	9.4	54	7.6	1	0.1	713
Total	1,409	38.5	1,418	38.8	728	19.9	101	2.8	3,656

Table 3. Condition of embryos in unhatched Kemp's ridley sea turtle eggs examined, by year-class.

Year-class	Staged		Decomposed[a]		Total
	No.	%	No.	%	No.
1980	115	66.5	58	33.5	173
1982	44	93.6	3	6.4	47
1983	213	92.6	17	7.4	230
1984	72	96.0	3	4.0	75
1985	178[b]	97.8	4	2.2	182[b]
1986	116[c]	98.3	2	1.8	118[c]
1987	595[d]	100.0	0	0.0	59[d]
Total	1,333[e]	93.9	87	6.1	1,420[e]

[a] Developmental stage could not be determined.
[b] Includes 2 sets of twin embryos.
[c] Includes 5 sets of twin embryos.
[d] Includes 4 sets of twin embryos.
[e] Includes 11 sets of twin embryos.

infertility from early embryonic death, and early embryos were difficult to find and stage in many instances because they were smaller and had been exposed to longer periods of deterioration prior to preservation.

Of the 4,165 unhatched eggs available from year-classes 1980 and 1982-1987, 3,656 (87.8 percent) were examined (Table 1). Of those examined, 101 (2.8 percent) could not be classified as infertile or fertile because they were rotten (Table 2). The annual percentage of unclassifiable eggs was relatively low and constant for all seven year-classes, ranging from 0.1 percent in 1987 to 6.2 percent in 1985. The annual percentage of infertile eggs varied widely from 7.6 percent in 1987 to 50.2 percent in 1980. However, it is likely that the numbers of unhatched eggs that were classified as infertile among those examined from the 1980 and 1983 year-classes were exaggerated by their poor condition. Fertility of marine turtle eggs typically exceeds 80 percent and, on an average, may exceed 95 percent (Miller, 1985). Considering all eggs from all seven study years, including those that hatched, only five percent were found to be infertile. However, one clutch had a 100 percent hatch and 24 percent of all 1982-1987 clutches examined were found to be 100 percent fertile.

The annual percentage of unhatched fertile eggs that contained no identifiable embryos ranged from 8.2 percent in 1980 to 67.6 percent in 1983 (Table 2). Of the 1,418 unhatched eggs classified as fertile but containing no embryos, 1,102 were from the 1983 year-class. Overall, 1,409 or 38.5 percent of all eggs examined contained embryos. Two eggs from the 1985 year-class, five eggs from the 1986 year-class and four eggs from the 1987 year-class contained twin embryos, so there were actually 1,420 embryos in the 1,409 eggs containing embryos. Overall, 1,333 (93.9 percent) of

Table 4. Embryological stages of development of embryos from 1980 and 1982-1987 Padre Island National Seashore unhatched Kemp's ridley eggs.

Approximate days of development		3	4	5	5	6	7	9	10	12	12	15	17	20	21	21	22	23	24	26	27	28	29	30	33	36	36 - 40	40	40 - 45	45	45 - 50	50	50 - 55	
Embryological stage of development		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	27 - 28	28	28 - 29	29	29 - 30	30	30 - 31	Total No. %
Year-class 1980	No.						1			1	2	4	5	1	1		2	3	8	3	4	6			1	2	6	4	12	7	27	15		115
	%						0.9			0.9	1.7	3.5	4.3	0.9	0.9		1.7	2.6	7.0	2.6	3.5	5.2			0.9	1.7	5.2	3.5	10.4	6.1	23.5	13.0		100.0
1982	No.							1		5	2	1	3	4		1		1						1			1	1	1	7	8	7		44
	%							2.3		11.3	4.5	2.3	6.8	9.1		2.3		2.3						2.3			2.3	2.3	2.3	15.9	18.1	15.9		100.0
1983	No.						3	3	2	10	12	14	7	4	6	7	5	7	3	4	1	1			1	6	6	11	26	35	38			213
	%						1.4	1.4	0.9	4.7	5.6	6.6	3.8	1.9	2.8	3.3	2.3	3.3	1.4	1.9	0.5	0.5			0.5	2.8	2.8	5.2	12.2	16.4	17.8			100.0
1984	No.	1							1	10	3	2	1	1	5		1	2		2	1					2	2	3	5	7	9	13	1	72
	%	1.4							1.4	13.9	4.1	2.8	1.4	1.4	6.9		1.4	2.8		2.8	1.4					2.8	2.8	4.1	6.9	9.7	12.5	18.1	1.4	100.0
1985	No.							1	6	4	4	2		2	1			1				2	1		1	3		5	11	9	44	80	1	178
	%							0.5	3.4	2.2	2.2	1.1		1.1	0.5			0.5				1.1	0.5		0.5	1.7		2.8	6.8	5.0	24.7	44.9	0.5	100.0
1986	No.	1	1				3	3	5	17	9	4	2	2	4	1	2	1				1	1				2	2	6	8	20	21		116
	%	0.9	0.9				2.6	2.6	4.3	14.7	7.7	3.4	1.7	1.7	3.4	0.9	1.7	0.9				0.9	0.9				1.7	1.7	5.2	6.9	17.2	18.1		100.0
1987	No.					1				7	1	2		1	1		1		1	2	2		1	1		2	6	4	70	123	256	110	3	595
	%					0.2				1.2	0.2	0.3		0.2	0.2		0.2		0.2	0.3	0.3		0.2	0.2		0.3	1..0	0.7	11.7	20.6	43.0	18.5	0.5	100.0
Total	No.	2	1			1	7	8	14	54	33	29	19	15	18	9	11	15	12	11	8	10	3	2	3	15	23	30	131	196	402	246	5	1,333
	%	0.2	0.1			0.1	0.5	0.6	1.0	4.0	2.5	2.2	1.4	1.1	1.3	0.7	0.8	1.1	0.9	0.8	0.6	0.8	0.2	0.2	0.2	1.1	1.7	2.3	9.8	14.7	20.2	18.5	0.4	100.0

all embryos were staged, and the other 87 (6.1 percent) were so decomposed that staging was impossible (Table 3). Of the latter, 58 (66.7 percent) were 1980 year-class embryos.

Embryological Staging

Staging of Kemp's ridley embryos was done according to Cratz (1982), except that four additional stages were erected. Stages 27-28, 28-29, 29-30 and 30-31 were established to classify Kemp's ridley embryos that possessed yolk sac and carapace measurements intermediate between those given for olive ridley embryo stages 27 through 31 by Cratz (1982). Each of the 1,333 staged embryos (Table 3) was assumed to have ceased development at the approximate day of development corresponding to the stage into which it was classified. The earliest dead embryo was placed in stage 3 corresponding to approximately 3 days of development and the latest in stage 30-31, approximately 50-55 days of development (Table 4).

The data for all fertile eggs (Table 2), including those without identifiable embryos and those with staged embryos, were combined to analyze overall egg and embryo mortality (Figure 1). Those eggs that were fertile but lacked identifiable embryos were included in the first third of incubation deaths. There was high mortality during early stages for all year-classes, especially for 1983. There were few deaths during middle stages, but deaths increased during later stages. Most embryos of the 1982-1984 and 1986 year-classes that died did so during the first third of development, while those of the 1980, 1985 and 1987 year-classes succumbed during the last third of development. Of 1,418 fertile eggs without embryos and 1,333 embryos that died and could be staged, 57.7 percent ceased development during the first third, 4.2 percent during the middle third and 38.1 percent during the last third of incubation. However, it is emphasized that the 1983 year-class, most of whose embryos died during early stages of incubation, and the 1987 year-class, most of whose dead embryos succumbed during late stages of incubation, dominated the results.

More embryo deaths occurred during later stages of development in 1985 and 1987 than during other years (Figure 1). However, 87 of 153 embryos that ceased development during the last third of incubation in 1985 were from two clutches, and 271 of 574 embryos that ceased development during the last third of incubation in 1987 were from three clutches. These were the only clutches in which incubation temperatures exceeded 38°C for prolonged periods of time. Only two of the 358 late stage embryos from these five clutches were obviously deformed. It appears that high incubation temperature may have contributed to these late stage mortalities (Shaver *et al.*, 1987). However, the relatively high late stage embryonic mortality in almost all of the other 1987 year-class clutches was not attributable to excessive incubation temperatures since the other clutches remained below 38°C. All 1987 clutches may have been adversely affected by a cold front or abruptly changing temperatures at Rancho Nuevo and possibly a bacterial infection transmitted by the nesting females (Shaver *et al.*, 1987).

Questions have been raised by Limpus, Baker and Miller (1979) as to the risks of air transporting or moving sea turtle eggs that are undergoing incubation. Air transport of Kemp's ridley eggs in our study occurred from incubation day 1 through 46 for various clutches during the seven-year study. However, after we examined laying dates, transport dates and stages of development, air transport was ruled out as a factor contributing to egg mortality. Air transport had been suggested as a possible causitive agent in the high mortality of the 1983 year-class clutches. However, 90 percent of the deaths in these clutches occurred before transport. Thus, both air transport and non-viability of eggs should be eliminated as possible factors leading to the exceedingly poor hatching success in the 1983 year-class. Other causes, such as excessive sand moisture, contaminated sand, or contaminated polystyrene foam boxes, must have acted on these early embryos. High incidences of fungi and bacteria were found in internal tissues of eggs from the 1983 year-class and it was concluded that *Fusarium solani* may have been responsible for the high mortality (Leong, 1984).

Deformities

Of the 1,333 embryos that could be staged (Table 3), 110 (8.3 percent) obviously were deformed (Table 5). Approximately half of all clutches examined from the combined year-classes contained deformed embryos. The earliest stage in which deformed embryos were noted was stage 10, but most deformed embryos occurred in stage 27 or later stages. Jaw deformities occurred most frequently, followed by deformities involving the eyes, pigmentation, carapace, flippers, twinning, head, skin, snout and other areas (Table 6). Certain deformities appeared more often in certain year-classes, such as longer lower jaw in the 1980 year-class, skin closure failure in the 1982 year-class, head malformations in the 1984 year-class, flipper abnormalities in the 1985 year-class and twinning in the 1986 and 1987 year-classes. The eleven sets of twins were obtained from unhatched eggs of the 1985, 1986 and 1987 year-classes. Twin embryos were most frequently classified in different embryological stages of development and usually possessed no other external deformities. The earliest twin embryo was stage 11 and the latest stage 29-30.

Only 39 (0.5 percent) of the 8,395 hatchlings of the 1982-1987 year-classes were deformed (Table 7). Approximately 18 percent of the clutches from these year-classes contained one or more deformed hatchlings. Carapace deformities

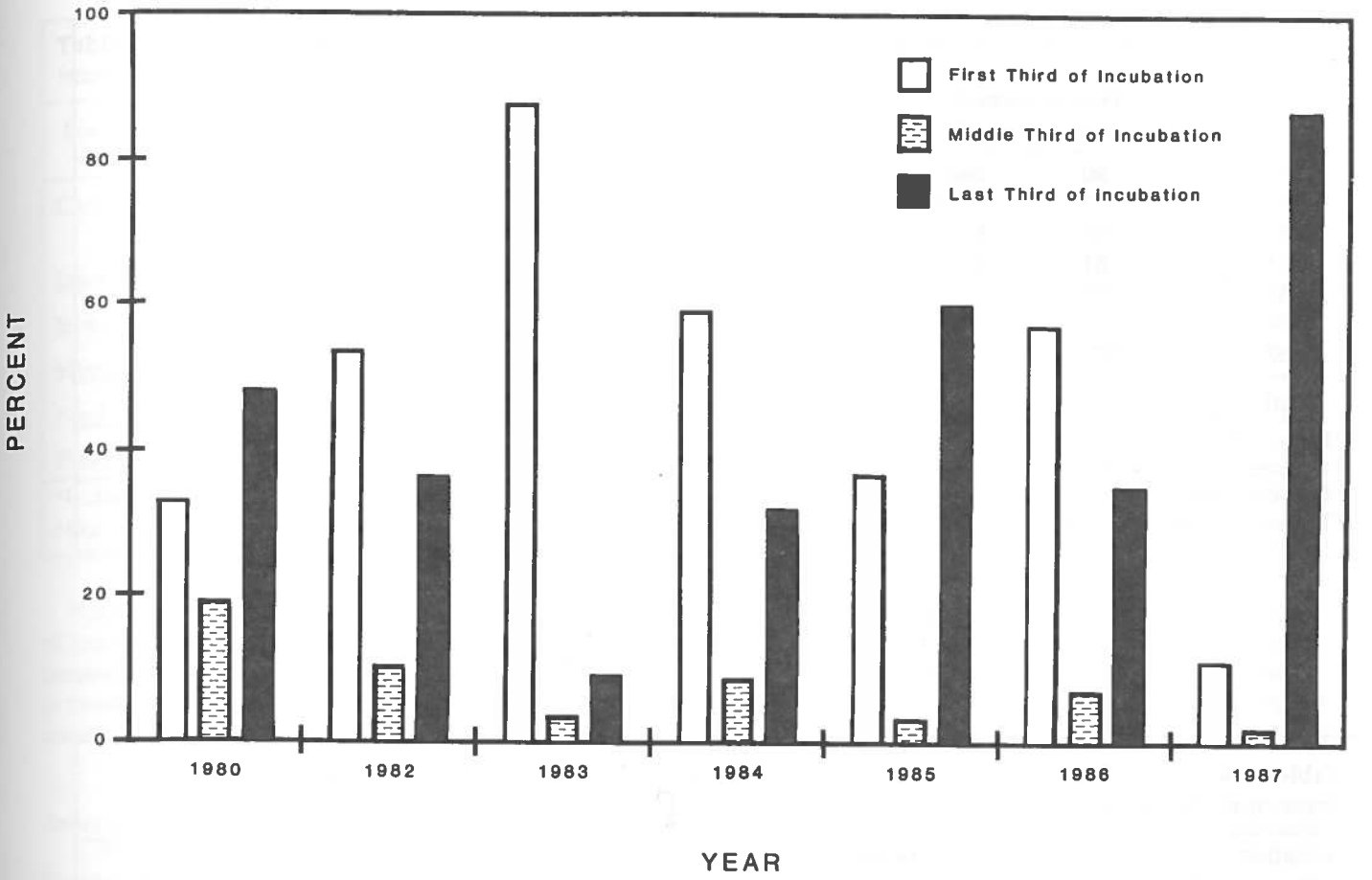

Figure 1. Frequency distribution of incubation trimester in which Kemp's ridley sea turtle embryos ceased development, by year-class.

occurred most frequently in these hatchlings followed by deformities of the jaws, eyes, flippers, neck and plastron. Almost all clutches with deformed hatchlings also contained deformed embryos, but the converse was not true. This could indicate that certain adults possessed a genetic trait that influenced embryonic development in their clutches. Also, because there were relatively more deformed dead embryos than deformed hatchlings, it appears that most of the aberrant Kemp's ridley embryos die before hatching. Variations in scute patterns were not included among hatchling and embryo deformities tabulated herein, although such variations frequently occurred. The rather low deformity rate of 1.2 percent for 11,485 hatched and unhatched eggs from the 1982-1987 year-classes that were examined and not rotten would be higher if scute deformities had been included. In any case, it is higher than the 1 percent deformity rate reported by McGehee (1979), Blanck and Sawyer (1981) and Miller (1985) for other marine turtles.

Conclusions

All procedures used in the international program to restore and enhance the Kemp's ridley sea turtle population must be monitored and evaluated constantly because of this species' critically endangered status. One means of evaluating procedures used in handling and incubating eggs is examination of unhatched eggs for signs of abnormal embryonic development and mortality. Unhatched eggs from each clutch can be preserved following the incubation period and can yield salvageable embryos. Eggs should not be frozen. F.A.A. is the preferred preservative. Embryological stages of development of the olive ridley can be used to stage Kemp's ridley embryos, provided modifications are made to account for slight differences in morphology and developmental rate between the species. Egg handling and incubation procedures can be evaluated by comparing their phases by date of occurrence with the time phasing of laying dates, translocation dates, embryological stages, embryonic death and hatching dates. Translocation of eggs by air apparently has not influenced embryonic development and its use should be continued as long as similar procedures and comparable care are maintained as in the past. Incubation temperatures should not be allowed to exceed 38°C or change abruptly. Contamination of sand and incubation boxes, and excessive sand moisture should also be avoided.

Table 5. Frequency of deformed embryos in unhatched Kemp's ridley sea turtle eggs, by year-class.

Year-class	Non-deformed No.	Non-deformed %	Deformed No.	Deformed %	Total No.
1980	99	86.1	16	13.9	115
1982	32	72.7	12	27.3	44
1983	207	97.2	6	2.8	213
1984	61	84.7	11	15.3	72
1985	155	87.1	23[a]	12.9	178[a]
1986	90	77.6	26[b]	22.4	116[b]
1987	579	97.3	16[c]	2.7	595
Total	1,223	91.7	110[d]	8.3	1,333[d]

[a] Includes 2 sets of twin embryos
[b] Includes 5 sets of twin embryos
[c] Includes 4 sets of twin embryos
[d] Includes 11 sets of twin embryos.

Table 6. Description, frequency and percent (%) of deformities in 1,333 staged Kemp's ridley sea turtle embryos from the 1980 and 1982-1987 year-classes combined.

Location	Description	Frequency No.[a]	Frequency %[b]
Jaws	Both lacking, lower lacking, lower much longer or shorter than upper, split, crossed, both too long or too short	31	2.3
Eyes	True or false cyclopia, both lacking, both joined, both too large or too small, lacking pupils	24	1.8
Carapace	Saddleback, indented on one or both sides, curved upward, contorted, too small, too narrow, posterior portion missing	24	1.8
Pigment	Lacking on part or all of body, lighter than normal on part of body	24	1.8
Flippers	All lacking, all too short, both front or both rear lacking, both front too narrow or too wide at tips, both rear too short, notch in right or left front, right front too short, both front with 6 or 7 claws, right rear margin indented, right or left rear small and clawless	23	1.7
Twins	Twin embryos	22	1.7
Head	Lacking, two-headed, too wide, too large, encephalocoele, pointed or lumped on top	21	1.6
Skin	Patch lacking on back of neck or head	8	0.6
Snout	Too short, too long	8	0.6
Other	Plastron incomplete, lump under throat	3	0.2

[a] Out of a total of 110 deformed embryos. Some of the embryos had more than one type of deformity.
[b] Out of 1,333 staged embryos.

Table 7. Description, frequency and percent (%) of deformities in 8,395[a] Kemp's ridley sea turtle hatchlings from the 1982-1987 year-classes combined.

Location	Description	Frequency No.[a]	Frequency %[b]
Carapace	Sides curved upward, contorted, very small and round, constricted or indented laterally	25	0.30
Jaws	Crossed, too long	7	0.08
Eyes	One or both lacking	6	0.07
Flippers	Front with 6 claws and very wide at tips	1	0.01
Neck	With a ventral and dorsal lump	1	0.01
Plastron	Center lacking bone and scutes	1	0.01

[a] Includes 70 hatchlings from a natural nest on Padre Island National Seashore in 1985.

[b] Out of a total of 39 deformed hatchlings. Some of the hatchlings had more than one type of deformity.

The data gathered in this study can be compared to similar data from future year-classes, both under conditions of artificial incubation and incubation in natural nests. Systematic sacrificing and staging of embryos throughout incubation might be useful in providing a picture of normal development for comparison. However, special permit provisions will be required for such studies. Nevertheless, such studies could lead to improvements in procedures used to enhance and restore the Kemp's ridley population.

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A Further Evaluation of Imprinting in Kemp's Ridley Sea Turtle

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Attempts to delineate mechanisms associated with the remarkable homing abilities of sea turtles have proven to be elusive endeavors. For example, the olfactory imprinting hypothesis was proposed more than 30 years ago. To date, olfactory imprinting has been neither demonstrated directly nor refuted. The failure to demonstrate whether or not sea turtles imprint is due in part to several difficulties associated with using sea turtles as experimental animals. The most noteworthy of these problems include long periods of time required for the turtles to reach sexual maturity and presumed high predation rates on hatchlings.

*Laboratory experiments designed to circumvent these problems were conducted using several sea turtle species including Kemp's ridley (*Lepidochelys kempi*). The first experiment involved quantifying the chemosensory choice behavior of juvenile ridleys that had been artificially imprinted to Padre Island, Tex. Ridley turtles exposed to Padre Island seawater preferred this seawater compared to other seawater samples. Based on the assumption that mechanisms subserving this chemosensory choice behavior similarly function to facilitate homing in adults, it was suggested that the turtles were imprinted to Padre Island.*

In the first experiment the possibility of a generalized preference for Padre Island seawater independent of imprinting could not be ruled out. However, if the observed choice behavior reflected an underlying imprinting mechanism, turtles "imprinted" to Padre Island and Rancho Nuevo might be expected to prefer cues from their respective natal beaches. A second experiment designed to test this hypothesis revealed no significant preferences for either Padre Island or Rancho Nuevo seawater by either turtle group. However, it is suggested that low turtle activity brings the validity of this result into question.

Sea turtles, especially green turtles (*Chelonia mydas*), are renowned for their long-distance homing migrations from feeding grounds to far-away beaches for mating and nesting. For example, the green turtles that feed off the Brazilian coast nest on Ascension Island in the mid-Atlantic Ocean (Carr, 1967; Koch, Carr and Ehrenfeld, 1969). Kemp's ridley sea turtles (*Lepidochelys kempi*) must also migrate long distances to mate and nest. Non-reproductive individuals of this species range throughout the Gulf of Mexico and are also found along the eastern coast of the United States. Because almost the entire reproductive population nests on a short section of beach near Rancho Nuevo, Mexico, ridleys exhibit precise nest-site fidelity. Furthermore, because an extremely high proportion of all ridley turtles nest at Rancho Nuevo, the vast majority of nesting turtles very likely hatched many years earlier from eggs in nests laid at Rancho Nuevo.

These observations raise intriguing questions regarding the mechanisms subserving sea turtle homing behavior. Of the mechanisms proposed to be involved (Owens, Grassman and Hendrickson, 1982) only chemical (olfactory) imprinting will be discussed for the following reasons:

1. The chemical imprinting hypothesis is mechanistically simple. Briefly, the imprinting hypothesis states that hatchling turtles imprint to chemical cues characteristic of their natal beach, retain this information and use it as adults many years later to aid in their return to their natal beach for mating and nesting.
2. Examination of nasal morphology and investigation of chemosensory behavior suggest that sea turtles possess acute chemical senses (Grassman, 1984). In turtles, both olfactory and vomeronasal sensory systems are anatomically well developed. However, with respect to turtles, the functions of these two distinct chemosensory systems have never been rigorously investigated. For example, turtle imprinting could involve the vomeronasal system to the exclusion of olfaction. For this reason "chemical imprinting "more accurately reflects the current understanding of turtle chemosensory biology and behavior as contrasted with the idiom "olfactory imprinting" traditionally used by turtle biologists.
3. The chemical imprinting hypothesis has a long history and is widely believed by sea turtle biologists and conservationists to be the most likely mechanism subserving sea turtle homing. The imprinting hypothesis with respect to sea turtle homing was first proposed in the early 1950s by Dr. Archie Carr (Carr, 1967). Because of several difficulties associated with sea turtle natural history, investigations of chemical imprinting have been unsuccessful (Owens *et al.*, 1982) until recently. Although chemical imprinting as a homing mechanism has never been demonstrated for adult turtles, conservation projects often include attempts at artificially

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imprinting turtles in hopes of establishing new reproductive populations. For example, the Kemp's Ridley Recovery Program is possibly the most extensive sea turtle conservation program ever attempted, and seeks among other goals to establish a ridley breeding rookery on North Padre Island, near Corpus Christi, Tex. by transferring eggs from Rancho Nuevo, Mexico, hatching them at Padre Island where the hatchlings are imprinted, then rearing them in Galveston, Tex. for a year or less before releasing them into the Gulf of Mexico (Klima and McVey, 1982). This attempt to establish a new ridley breeding population is based on the as yet undemonstrated chemical imprinting hypothesis. Indeed, the authors have argued that the Kemp's Ridley Sea Turtle Head Start Research Project (Caillouet, 1984) constitutes the best designed experiment of turtle imprinting ever attempted (Owens *et al.*, 1982). However, even if the project is successful in establishing a new ridley breeding population, the possibility of imprinting to cues other than chemical cues could not be ruled out.

Chemical imprinting can be delineated into several components, some of which suggest tests of imprinting (Hasler, 1966; Hasler and Scholz, 1983):

1. Turtle hatchlings must imprint to chemical cues characteristic of their natal environment.
2. At least within the context of migration, but not necessarily exclusive of migration, chemical imprinting cues must be relevant only to turtles imprinted to them as hatchlings. General turtle attractants or repellents would be ineffective chemical imprinting cues.
3. Imprinting requires a long term chemical memory.
4. Relevant chemical signals must be sufficiently stable over the turtles' life spans.
5. Adult turtles must be able to detect chemicals relevant to imprinting and use them to facilitate homing. This final component can only be tested by experiments such as the Kemp's Ridley Head start Research Project. However, it is suggested that the second component (item 2 above) can be tested in the laboratory using juvenile turtles. The chemical imprinting experience of hatchlings does not necessarily influence migratory behavior only. Thus, it was postulated that imprinting could be tested by examining the effects of early chemosensory environment on subsequent behaviors relevant to juvenile turtles. Chemical imprinting, which could be important in the context of adult migration, also might affect juvenile behaviors such as chemosensory choice and orientation behaviors. A demonstated response by juvenile turtles to chemical cues to which they had been exposed as nestlings, hatchlings, or both, would constitute strong indirect evidence supporting the chemical imprinting hypothesis.

An experiment was conducted to determine whether or not early chemosensory environment affects subsequent choice and orientation behavior in Kemp's ridley (Grassman *et al.*, 1984). Turtles were artificially imprinted to Padre Island in the head start project. The response of these turtles to Padre Island-treated, Galveston-treated and untreated seawater was compared. Padre Island-imprinted turtles exhibited a response to Padre Island seawater in the form of increased average time spent in that seawater as compared to the other two. It was suggested that this response was likely a demonstrated preference for a chemical cue affected by the turtles' earlier exposure; i.e., chemical imprinting. Although chemical imprinting is the most parsimonious explanation of this result, the possibility of a general attraction to Padre Island seawater could not be eliminated. The possiblity of a generalized response to a chemical cue can be addressed by comparing the responses of turtles that were exposed to the chemical cue as neonates to turtles that were not exposed to the cue as neonates. Thus, two experiments, one involving Kemp's ridley and another using green sea turtles (Grassman and Owens, 1987), were conducted to test juvenile turtle imprinting.

Materials and Methods

An automatic data acquisition system consisting of a circular tank (Figure 1) with 16 peripheral compartments was used to monitor turtle movements. Synthetic seawater (salinity 25 ppt and temperature 26-29 C) flowed from a moat, through siphons and into the back (outer end) of each compartment. Each compartment emptied into a central pen area, and the tank drained through a centrally located standpipe to a biological filtering system and reservoir. The centripitally located open end of each compartment was equipped with a photoelectric gate which was electronically interfaced to a clock. The basic system was designed to monitor the behavior of fish that are inherently more active than sea turtles. Thus, in the present context, in order to ensure sufficient turtle activity in the compartments to facilitate statistical comparisons, the tank was partitioned into four quarters instead of 16 compartments. This converted the tank into a four-choice, pie-shaped tank and effectively increased the quantity of activity per compartment. Suspected chemical cues used to artificially imprint turtles were pumped into the back of the four compartments with a constant-rate infusion pump. And each test animal's movements into and out of each compartment, and hence responses to chemical cues, were automatically recorded.

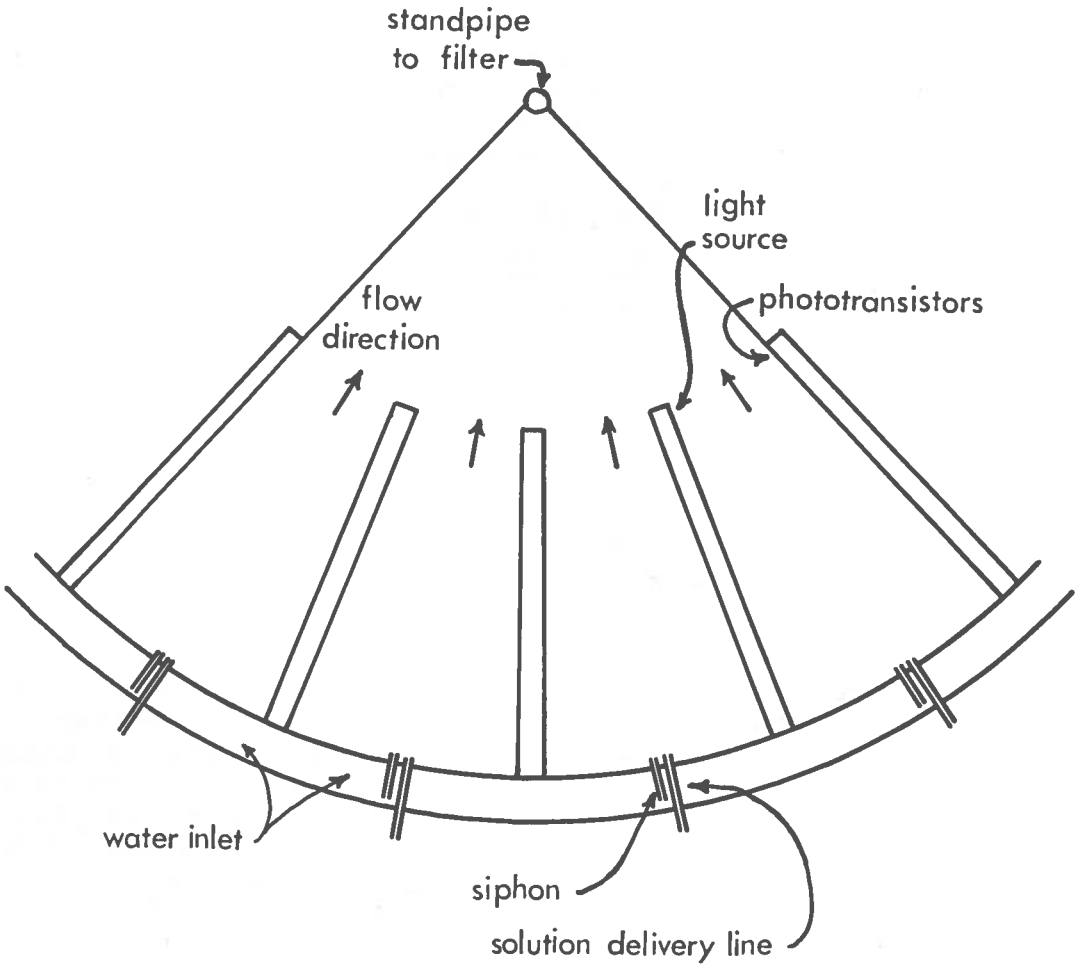

Figure 1. Circular tank used in testing responses of sea turtles to chemicals.

Repeated tests of an animal's responses to natural seawater containing potential imprinting cues were conducted by placing it in the center of the tank and allowing it to swim freely for four hours. Seawater solutions were prepared according to the following protocol: one kilogram of sand was washed with one liter of seawater collected from the same locale. Sufficient seawater volume was then added to bring the total volume to four liters. Equal volumes of synthetic seawater were added at concentrations appropriate to equilibrate salinity of the solutions to each other and the holding tank. Because equal volumes of synthetic seawater were added to each sample, the concentrations of possible chemical cues (except for ions) in the two samples did not change relative to each other. Synthetic seawater was siphoned into each compartment at a rate of 0.72 liter per minute.

Responses of 24, 4-month-old ridleys, which had previously been artificially imprinted to either Rancho Nuevo or Padre Island by exposure to solutions prepared from sand and seawater from their respective imprinting sites, were compared. Padre Island (PI) ridleys were artificially imprinted in the head start project. The eggs were collected at Rancho Nuevo during oviposition and placed in polystyrene foam boxes containing Padre Island sand. The eggs were transported to Padre Island National Seashore where they were hatched. The hatchlings were released on the Padre Island beach near where the sand had been collected originally, and they were allowed to enter the surf momentarily. They were recaptured in dip nets and shipped to the National Marine Fisheries Service, Southeast Fisheries Center's Galveston Laboratory to be reared (head started) in captivity for not more than one year. Ridleys also were hatched and released to the beach and surf at Rancho Nuevo (RN), then recaptured using large dip nets. Both groups were reared at the Galveston Laboratory under similar conditions. Rancho Nuevo sand and seawater, and Padre Island sand and seawater were collected from the imprinting sites, transported to the laboratory at Texas A&M University in College Station and refrigerated for later use. Padre Island test solution was metered into one compartment and Rancho Nuevo test solution was metered into another at a rate of one liter per hour. Two compartments were left untreated as controls. Individual turtles were placed into the center of the monitoring tank and presented simultaneously with choices among the four compartments. Responses (dependent variables) measured by total entries, time

spent and average time spent in each compartment by each turtle were automatically recorded for later analysis.

Standard parameteric statistical analyses were performed. Single-classification analyses of variance (ANOVA) with completely randomized design (i.e., individual turtles considered as random effects), factorial arrangement of treatments, and nesting (subsampling) were followed by the Tukey-Kramer comparisons of means (Hicks, 1973). Expected mean squares were examined to determine the appropriate experimental error (residual) mean square for testing each main effect and interaction. Where no exact F-tests were indicated by the expected mean squares, "nt" (no test) is shown under columns labeled mean square and F-value in Tables 1-3. The effects of greatest interest were testable. Significance of differences among means was accepted at $P \leq 0.05$. Preliminary investigations suggested the possibility that turtles might be more likely to respond to chemosensory cues that were metered into the edge compartments (perhaps they were more likely to encounter them). Thus, a "pattern" effect was included in the ANOVA model.

Patterns were as follows:

1. Padre Island solution metered into an edge compartment and Rancho Nuevo solution metered into a middle compartment.
2. Rancho Nuevo solution metered into an edge compartment and Padre Island solution metered into the middle.
3. Both solutions metered into edge compartments.
4. Both solutions metered into middle compartments.

Results

There were no significant differences attributable to imprinting with respect to any of the dependent variables examined. Thus, only results for average time spent (ATS) will be discussed in detail because it was found to be of interest in the previous ridley experiment described above (Grassman *et al.*, 1984). Analyses of variance of ATS responses of ridley turtles to solutions are presented in Tables 1-3. There were no significant main effects or interactions with respect to either PI or RN turtles. Furthermore, the F-value for the Group x Water interaction was less than 1.00 indicating that there were no differences comparing the responses of PI and RN turtles to the solutions presented in the test situation (Table 3).

During the course of this experiment it became apparent that turtle activity was low compared to our other experiments using this paradigm. Twenty-four ridleys entered four compartments 580 times. This was one-third the activity per individual seen in the previous experiment involving Kemp's Ridley Head Start Research Project turtles (Grassman *et al.*, 1984).

Discussion

There were no consistent responses to chemical cues in the experimental situation that would indicate chemical imprinting. Because the behavior monitoring system depends on animal activity, low turtle activity suggests that the experiment was likely flawed. Although accurate hourly temperature records were not kept, holding tank and experimental tank temperatures were maintained between 26 and 29 C. The low turtle activity was noted early in the experiment and tank temperatures were not low. In 1983, there was a high mortality (approximately 90 percent of the eggs did not hatch) of embryos at the Padre Island National Seashore. Poor health of the turtles may have adversely affected the experimental results. However, PI turtles were almost three times as active in experiments as RN turtles (427 and 153 entries, respectively). Based on personal observation, the hatching success appeared to be excellent at the Rancho Nuevo rookery during one week in 1983. Finally, this is the only experiment of the five we have conducted to date, using the artificial imprinting-behavior monitoring paradigm, that has failed to detect differences in turtle responses to treated tank water.

Previous experiments suggest that juvenile turtles imprint to chemical cues to which they were exposed as neonates (Grassman *et al.*, 1984; Grassman and Owens, 1987). First, Kemp's ridleys artificially imprinted to Padre Island demonstrated a preference for Padre Island seawater compared to other seawater samples to which they were previously unexposed. Second, green turtles exposed either to morpholine or phenylethanol as neonates demonstrated responses to these chemicals that were dependent upon their earlier experience. Furthermore, for green turtles, only those that were exposed in their nests, including an approximately 5-day period after hatching, and for three months in their holding tank water, responded to chemical imprinting cues. Together these experimental results support the hypothesis that juvenile sea turtles imprint to chemosensory cues to which they were exposed as neonates.

Although juvenile turtles apparently imprint to chemical cues, only the documented return of reproductive adults to an artificial imprinting site that was previously devoid of nesting would prove that imprinting facilitated homing. However, this would not delineate the possible sensory systems involved. If chemical imprinting were determined to be of primary importance to sea turtle homing this would not guarantee the successful establishment of new turtle

Table 1. Analysis of variance of average time spent (ATS) responses of Padre Island-imprinted Kemp's ridley sea turtles to water treatments.

Source of variation	Degrees of freedom	Mean square	F
Model	35	0.0358	0.53
Pattern	3	nt	nt
Individuals (within Pattern)	8	nt	nt
Water	2	0.0100	0.22
Pattern x Water Interaction	6	0.0458	1.33
Individuals (within Pattern) x Water Interaction	16	0.0345	0.51
Error	12	0.0673	
Total	47		

nt = no test.

Table 2. Analysis of variance of average time spent (ATS) responses of Rancho Nuevo-imprinted Kemp's ridley sea turtles to water treatments.

Source of variation	Degrees of freedom	Mean square	F
Model	35	0.0333	1.53
Pattern	3	nt	nt
Individuals (within Pattern)	8	nt	nt
Water	2	0.0007	0.03
Pattern x Water Interaction	6	0.0264	1.53
Individuals (within Pattern) x Water Interaction	16	0.0173	0.79
Error	12	0.0218	
Total	47		

nt = no test.

Table 3. Analysis of variance of the average time spent (ATS) for interactions between two groups (Rancho Nuevo-imprinted and Padre Island-imprinted) of Kemp's ridley sea turtles and water treatments.

Source of variation	Degrees of freedom	Mean square	F
Model	71	0.0342	0.77
Group	1	nt	nt
Pattern (within Group)	6	nt	nt
Individual (Group x Pattern Interaction)	16	nt	nt
Water	2	0.0051	3.89
Group x Water Interaction	2	0.0056	0.06
Pattern (within Group) x Interaction	12	0.0361	1.39
Individual x Water (Group x Pattern) Interaction	32	0.0259	0.05
Error	24	0.0446	
Total	95		

nt = no test.

populations using artificial imprinting protocols. The relative importance of imprinting as compared to other possible homing mechanisms is unknown but it appears possible that social facilitation could be important in species that nest and possibly migrate *en masse* such as is the case with ridleys. Furthermore, chemical imprinting might be expected to be most important as turtles neared the nesting beach. In such a case, oceanic currents involved in delivering chemical cues could be significant. With respect to artificially imprinting neonates, little is known concerning appropriate chemical stimuli in terms of quantity, quality and the timing of exposure to stimuli relevant to the possible turtle imprinting mechanism.

Increasingly, behavioral experiments suggest the importance of sea turtle chemosensory systems (Grassman *et al.*, 1984; Manton, 1979; Owens *et al.*, 1982; Grassman and Owens, 1987). Because chemical senses may be of primary importance in turtle natural history, the impact of continued chemical pollution of the marine environment may have serious consequences for sea turtle conservation and ultimately species survival.

Acknowledgements

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Kemp's Ridley Sea Turtle Head Start Operations of the NMFS SEFC Galveston Laboratory

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The Kemp's Ridley Sea Turtle Head Start Research Project is part of the U.S.-Mexico Kemp's Ridley Recovery Program, and has as its main objective the establishment of a new nesting colony at the Padre Island National Seashore near Corpus Christi, Tex. As of October 1988, 13,572 tagged Kemp's ridley sea turtle (Lepidochelys kempi) *juveniles had been released into the Gulf of Mexico after being reared in captivity at the National Marine Fisheries Service (NMFS), Southeast Fisheries Center (SEFC), Galveston Laboratory in Galveston, Tex.*

Each year during the nesting season, approximately 2,000 eggs are collected by the U.S. Fish and Wildlife Service and its contractor, Gladys Porter Zoo, from the beach at Rancho Nuevo, Tamaulipas, Mexico. The eggs are placed in Padre Island sand within polystyrene foam boxes for incubation. Once all the eggs have been collected, the boxes are flown to the National Seashore where the eggs are further incubated and hatched, and the hatchlings imprinted on the beach and in the surf at Padre Island, under surveillance by National Park Service personnel.

The imprinted hatchlings are transferred to the NMFS SEFC Galveston Laboratory where they are reared in sea water raceways, in isolation from each other in individual containers, for 9 to 11 months. Survivors in good condition are tagged, weighed and measured, and released into the Gulf of Mexico, usually off Padre and Mustang Islands.

Feeding, maintenance and health care of the turtles, the major activities of captive-rearing, are described. Other activities described include: (1) monthly weighings of samples of turtles to obtain average body weight from which feeding ration is determined as a percentage of body weight; (2) tagging by three methods (living tags, internal tags and flipper tags); (3) removal and preservation of kidneys and gonads (from turtles that die) for sex determination; and (4) final weighing and measuring of each turtle before it is released.

Hatchlings weigh around 14 grams when received in July and August. By late May or early June of the following year, the captive turtles have increased in average weight to 0.8 kg, at which size they are released into the Gulf.

Kemp's ridley sea turtle (*Lepidochelys kempi*) is listed as endangered under the U.S. Endangered Species Act of 1973. Its primary nesting site is a beach bordering the Gulf of Mexico near the village of Rancho Nuevo, in the State of Tamaulipas, Mexico (Chávez, Contreras and Hernandez, 1968). Hildebrand (1963) estimated that 40,000 female Kemp's ridleys nested on this beach on one day in June 1947, but by 1982 the number had declined to about 1,500 (Márquez, Villanueva and Sanchez, 1982; Márquez, 1983). The primary cause of the population decline has been overexploitation of the turtles (both directed and incidental) and the eggs by man. Since 1966, the beach near Rancho Nuevo has been protected during the nesting season from April to July by Mexican Marines and personnel of the Instituto Nacional de la Pesca (INP) of Mexico, with assistance from the U.S. Fish and Wildlife Service (FWS) and others. This protection has reduced the poaching by man (Márquez *et al.*, 1982).

Since 1978, the National Marine Fisheries Service (NMFS), Southeast Fisheries Center (SEFC), Galveston Laboratory has participated in an international program to save Kemp's ridley from extinction (Klima and McVey, 1982). The program is a joint conservation effort among the INP, FWS, NMFS, National Park Service (NPS) and Texas Parks and Wildlife Department (TPWD), with assistance from Gladys Porter Zoo, Brownsville, Tex. and others. The goal of the Kemp's ridley recovery program is to increase the Kemp's ridley population. The approach includes protection of nesting turtles and their eggs on the beach at Rancho Nuevo, prohibitions on the capture, possession and sale of the turtles, their eggs and turtle products, promotion of use of trawling efficiency devices (TED) to allow escapement of turtles captured incidentally in shrimp trawls, and experimental head starting of Kemp's ridley in captivity during its criticial first year of life. The head started turtles are released into the Gulf of Mexico in hopes of establishing a new nesting colony at the Padre Island National Seashore, near Corpus Christi, Tex. For the latter purpose, most of the head started Kemp's ridley are imprinted as hatchlings at Padre Island, but others have been imprinted at Rancho Nuevo in hopes of supplementing that breeding colony as well.

Imprinting is defined as species-specific, rapid learning during a critical time of early life in which social attachment

**National Marine Fisheries Service*

and identification are established. One working hypothesis of the head start project is that imprinting occurs during incubation and hatching of the eggs in beach sand, during exposure of hatchlings to the beach and adjacent surf, or both. Imprinting is assumed to act through memory to guide adult turtles back to their natal beach. At Rancho Nuevo each season, a small proportion of the eggs is taken for head starting. These eggs are collected in plastic bags as they are laid so they do not touch the local beach sand. They are placed in polystyrene foam boxes containing beach sand from Padre Island and are flown to the Padre Island National Seashore where they are placed in a hatchery and allowed to continue incubation. NPS biologists carefully monitor environmental conditions in the boxes during the incubation phase that normally takes 43 to 53 days (Robert King, NPS, personal communication, July 1984). Hatchlings are taken to the beach and allowed to crawl across the sand to the surf to enhance their opportunity for imprinting. The hatchlings are collected from the surf, placed in boxes lined with water-saturated, polyurethane foam cushions and transported by NPS personnel to Galveston.

Head starting undoubtedly increases survival of the young Kemp's ridleys during their first year, and their larger size upon release is thought to give them a subsequent survival advantage as compared to their natural counterparts (Márquez, 1972; Klima and McVey, 1982; Fontaine, Leong and Caillouet, 1983; Caillouet, 1984; Fontaine *et al.*, 1985). Natural survival of this turtle during its critical first year of life in the wild may be less than 1 percent. Survival during head starting the 1978-1987 year-classes has ranged from 67.8 to 98.4 percent. Of the total of 16,538 hatchlings received alive from year-classes 1978 to 1987, 13,572 (82.1 percent) had been reared, tagged and released as of October 1988.

This paper describes the facilities and methods used to rear, tag and release head started Kemp's ridleys (see also Fontaine *et al.*, 1985; Fontaine *et al.*, 1989).

Facilities

Quonset Huts

The sea turtle head start research facilities at the Galveston Laboratory consist of three, 9 x 20 meter, aluminum-framed quonsets huts manufactured by X. S. Smith, Inc., Red Bank, N.J. Each is covered by inflated, double-layered white polyethylene sheathing (Figure 1). The long axis of each quonset hut is situated on an northeast-southwest orientation parellel to the coastline so that prevailing winds provide cross-ventilation to cool the interior during summer. Sides of the quonset huts are equipped with lateral vent-rails located 1.2 meters above ground level. Panels of polyethylene sheathing attached to the rails can be removed during summer to allow ventilation. The quonset huts also are equipped with ventilation fans at one end. The space between the double-layered, polyethylene covers is inflated by small blowers to approximately 20 cm. This air-space between the layers provides insulation. The tops normally last only 12 to 18 months, so they are replaced annually following the hurricane season and before winter. Gas-fired, forced air heaters are used during the winter to maintain warm temperatures.

Seawater Supply

Seawater is pumped through submerged well-points located approximately 200 meters seaward of the surfline of Galveston's beach bordering the Gulf of Mexico. The seawater is stored initially in an underground, concrete sump (113,460 liters) and then pumped into two above-ground, fiberglass-lined redwood storage tanks (each 94,550 liters). Seawater is then delivered from the redwood tanks to eight, above-ground, insulated, fiberglass reservoirs near the head start facilities. Figure 2 shows the four smaller reservoirs, each with a capacity of 28,390 liters, and two of the larger ones, each with a capacity of 37,850 liters. The other two reservoirs (not shown) also have a 37,850 liter capacity. During cold weather, seawater is heated by thermostatically-controlled, immersion heaters (Table 1) to maintain temperatures at 25° to 28° C.

Raceways

The 27 fiberglass raceways used to rear the turtles were manufactured by Red Ewald, Inc., Karnes City, Tex. The raceways are rectangular (Figure 3), measuring 6.1 meters long x 1.8 meters wide x 0.6 meters deep. They are filled to a depth of 30 cm, providing a seawater volume of 3,140 liters per raceway.

Isolation Rearing Containers

Hatchling Kemp's ridley are aggressive and will attack and injure each other (Klima and McVey 1982; Bjorndal and Balazs, 1983). Consequently, they cannot be reared together without high mortality. Therefore, each turtle is reared in isolation either in plastic buckets or boxes. Each raceway usually contains 18 rows of six plastic buckets, 28 cm deep x 22 cm (inside top diameter), suspended with 10-gauge galvanized wire from 18 5.1 cm x 5.1 cm wooden poles, placed across the width of the raceways (Figure 4). The 18 rows are lettered A-R from southeast to northwest, and the six columns are numbered 1-6 from northeast to southwest, providing a total of 108 buckets per raceway. The bottom of each bucket is drilled with 12 holes, each 2.5 cm in diameter, to allow water exchange and liberation of turtle excrement and uneaten food. A raceway can contain 16 rows of five plastic boxes (not shown; see Caillouet *et al.*, 1988) of the kind

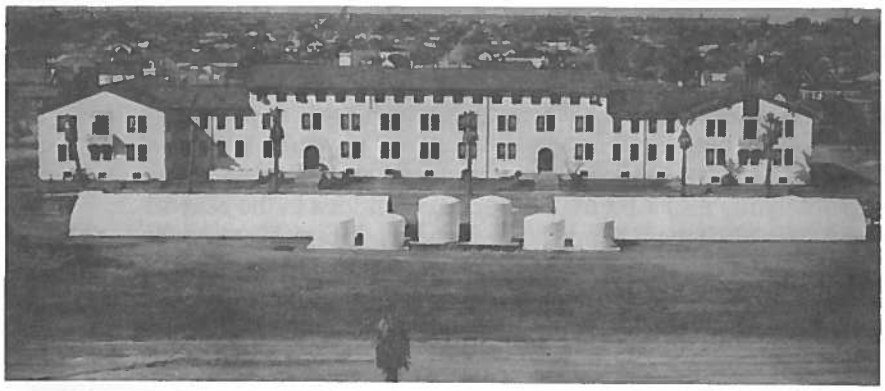


Figure 1. Kemp's ridley sea turtle head start research facilities (quonset huts and sea turtle reservoirs in middleground), NMFS SEFC Galveston Laboratory.

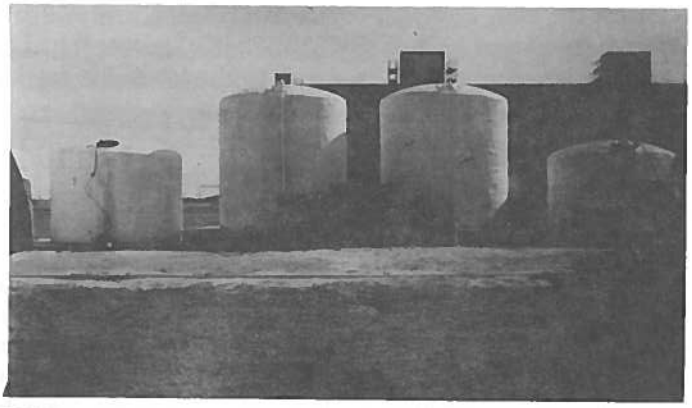


Figure 2. Insulated, fiberglass seawater reservoirs supported by 15 cm thick, steel-reinforced, concrete pads (four additional reservoirs are not shown).

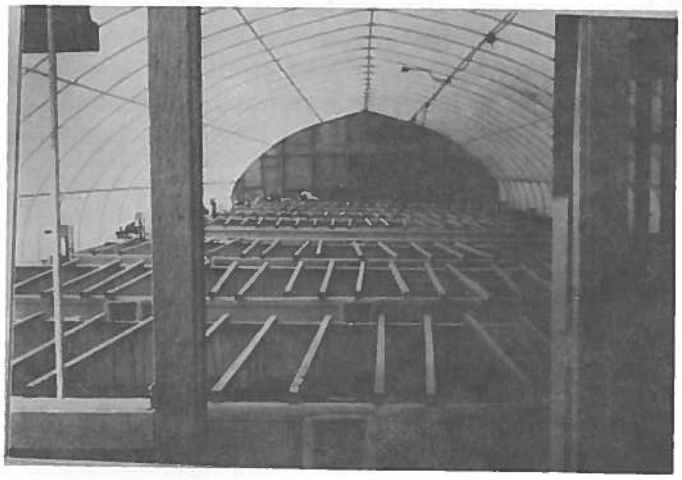


Figure 3. Raceways (viewed from the side) used in rearing Kemp's ridley sea turtles.

Figure 4. The buckets used for isolation rearing of Kemp's ridley sea turtles to prevent aggressive attacks.

Table 1. Specifications, uses and suppliers of equipment and materials.

Description	Use	Supplier
Fiberglass raceways, basins, digestion tanks, and seawater reservoirs	Holding turtles, treating wastewater, and storing seawater	Red Ewald, Inc. PO Box 519 Karnes City, TX 78118
Positive air-blowers, 2.7 HP (Cyclonair #CH5)	Aeration of digestion tanks	Rotron, Inc. Mansfield, OH
Centrifugal pump, 2 HP (Gorman-Rupp #B0024FGF2A4)	Seawater delivery	Pump & Power Equipment 800 Harwin, Dr., Ste. 370 Houston, TX 77036
Submersible sump pump, 496 liters/min at 1.5 m head (Teel pump #3P650)	Pumping untreated wastewater	Granger, Inc. 7777 Parnell St. Houston, TX
Plastic buckets, 10 liter volume 22 cm inside top diameter, 28 cm depth	Containers for individual sea turtles	Loma Plastics, Inc. Fort Worth, TX
Quonset hut covers (Loratex, UV Treated)	Tops for quonset huts	Farms Supply Co. 500 Clarkesville St. Cornelia, GA 30351
Titanium immersion heaters	Heating seawater in reservoirs	Glo-Quartz Electric Heater 7074-7190 Maple St. Mentor, OH 40051

used to transport plastic, 3.8-liter milk jugs. Dimensions of these boxes are 33.0 cm long x 31.1 cm wide x 30.5 cm deep.

Each turtle remains in its assigned bucket or box throughout the head start process, unless it dies or becomes ill. The raceway and bucket or box locations provide codes used as identifiers for individual turtles throughout head starting. In this way, the clutch-of-origin identity of each turtle is maintained, and can be linked through records to the female that laid the clutch.

Turtles that outgrow their containers are transferred to plastic laundry baskets suspended in a raceway or to fiberglass basins (Figure 5). These hemispherical basins are 61 cm in diameter and 25 cm deep and usually filled with 26.5 liters of seawater. The seawater is exchanged and the basins cleaned on a daily basis.

When ill, a turtle is transferred to sick bay (Figure 6) where it is treated, then returned to its bucket or box if it is cured. The sick bay (Figure 6) where sick turtles are isolated for observation and treatment contains fiberglass basins similar to those described in the previous paragraph. When in use, the basins are drained, scrubbed with a heavy brush, rinsed, and filled with clean seawater on a daily basis.

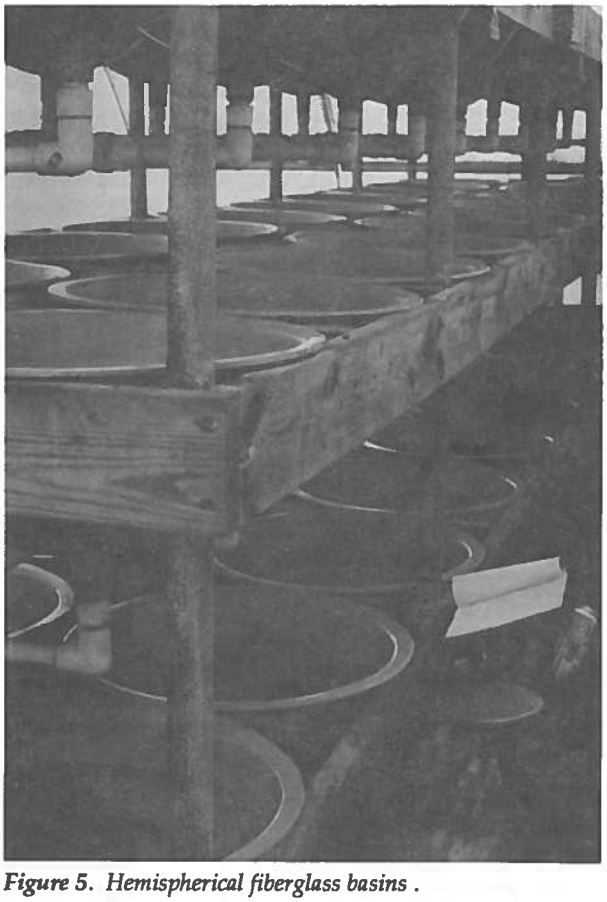


Figure 5. Hemispherical fiberglass basins .

Seawater Exchanges and Cleaning

All raceways are drained and seawater replaced three times a week (Monday, Wednesday and Friday). Once a week, each raceway is thoroughly cleaned by draining the seawater, washing down the turtles, buckets and raceway with freshwater (tapwater), rinsing out the raceway with freshwater, scrubbing the inside walls of the raceway with heavy-duty brushes or power sprayers to remove attached algae, rinsing the raceway once again with freshwater, and refilling the raceway with

Figure 6. Sick-bay (for isolation and treatment) containing hemispherical basins.

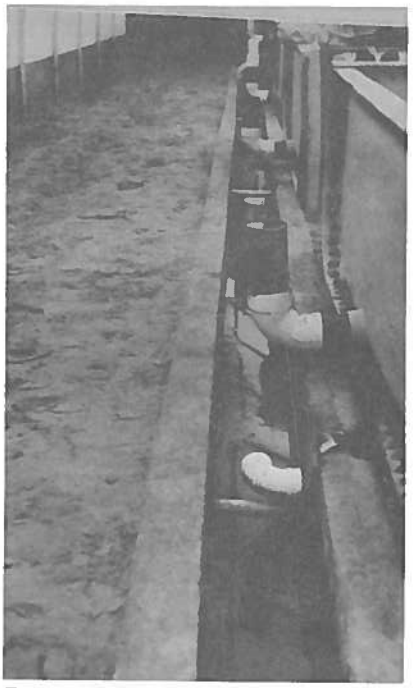


Figure 7. Raceway standpipe system that prevents overfilling of raceways and allows quick drainage.

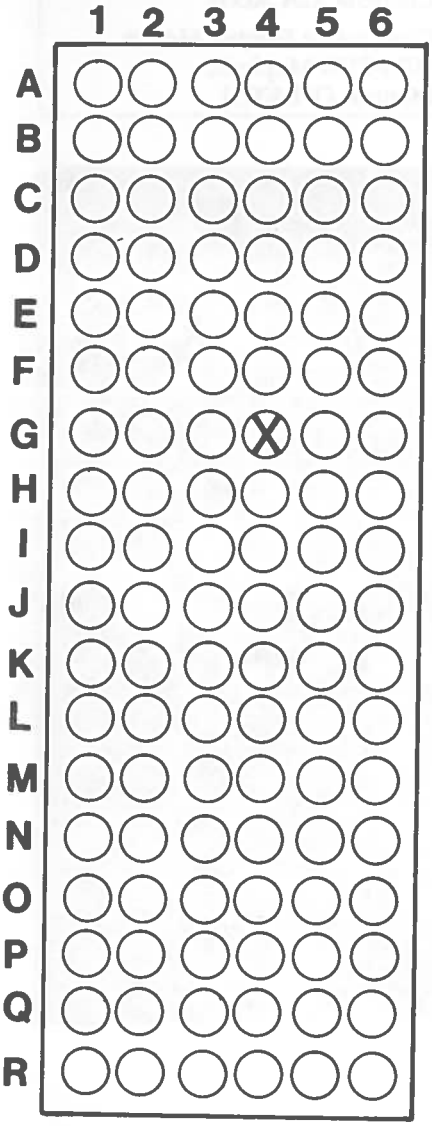


Figure 9. Code system used for eighteen rows (lettered A-R) and six columns (numbered 1-6) of buckets. X marks bucket location 83-1-G-4 (for 1983 year-class, raceway 1, row G and column 4).

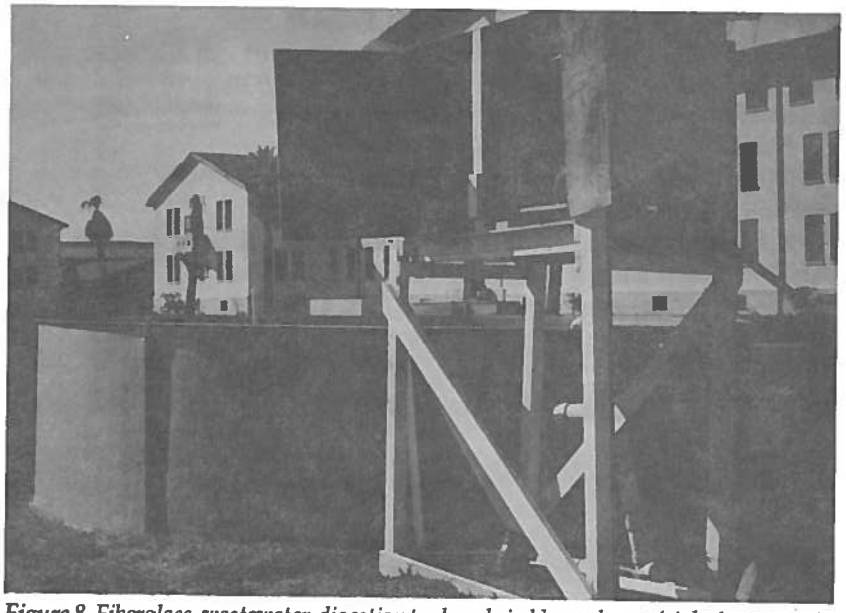


Figure 8. Fiberglass, wastewater-digestion tank and air-blower house (right foreground). The air-blower is elevated to prevent back-siphoning of wastewater into the blower.

clean seawater. The tapwater is not heated in the winter time prior to use, but usually remains around 21 °C. Its use has caused no apparent ill effects to the turtles.

The raceways are fitted on one end with a 10.2 cm (inside diameter) standpipe drain (Figure 7) and a 3.8 cm (inside diameter) drain pipe on the bottom at the same end as the standpipe. The raceways are drained by rotating the 10.2 cm standpipe downward and by opening the valve to the 3.8 cm bottom drain.

The drained seawater and water from scrubbings and rinsings are collected in concrete troughs (Figure 7) that empty into 0.9 meter x 1.8 meter fiberglass sumps located outside the quonset huts. Solid-waste sump pumps transfer this water into two cylindrical, fiberglass, digestion tanks (Figure 8), each 1.5 meters high x 6.1 meters in diameter and holding a volume of 44,570 liters. The waste water from the digestion tanks is drained intermittently into the City of Galveston domestic sewerage system. At the end of each annual head start period, the residual sludge is washed from the digestion tanks into the sewerage system.

Head Start Operations

Hatchlings

Before the hatchlings are transported from Padre Island National Seashore to Galveston they are weighed (wet weight) and measured [carapace length and width, as recommended by Bjorndal and Balazs (1983)] by NPS personnel. The hatchlings are packed in plastic tubs containing polyurethane foam padding soaked with water to prevent dessication of the hatchlings. They arrive at Galveston after two to six hours in transport. NPS personnel pack the boxes in such a way that each clutch is kept segregated from others. Upon arrival at the head start facilities, the hatchlings are first rinsed with seawater and then inspected closely for abnormalities and mortality.

There have been few turtles with abnormalities, but the most common abnormalities that have been observed are: "cross-beak" (upper and lower jaws grossly malformed, left eye missing); concave plastron (plastron grossly depressed); curvature of the spine; shortened spine (turtle much greater in width than in length); plastron improperly healed (unclosed yolk-sac attachment site) and deformed flippers. Turtles with abnormalities are isolated in the sick bay. Turtles with improperly healed plastrons are treated with a topical antibacterial ointment (Terramycin, Gentamycin, Neomycin or Furacin), and in most cases the plastron eventually heals. Abnormal turtles that survive the usual head starting of 9 to 11 months have been transferred to Texas A&M University, to The University of Texas Medical Branch in Galveston or to The University of Texas Institute of Marine Science, Port Aransas to be used for research. Small numbers of these have been transferred by Texas A&M University to Sea Turtle, Inc., directed by Mrs. Ila Loetscher, South Padre Island, Tex.

Clutches of hatchlings are usually assigned to raceways more or less sequentially from raceway to raceway as they are received from NPS. However, in some cases, the turtles have been distributed according to an experimental design (e.g., Caillouet *et al.*, 1989). Clutch identity of each turtle in a raceway is kept track of through the bucket or box location code (Figure 9). For example, the bucket marked with an X in Figure 9 is labeled 83-1-G-4, indicating that the turtle in this bucket was from the 1983 year-class and that the bucket was located in raceway 1, in bucket row G and in bucket column 4. Once an individual turtle is assigned to a container, it usually stays there throughout head starting so that it can be linked through records to its clutch-of-origin and to the female that laid its clutch. In any case, a given turtle can be linked through its container code to recorded details about oviposition, egg collection, incubation, hatching, growth, amount of food fed, health care, etc. One exception is that four hatchlings can be held temporarily within four smaller containers (plastic flower pots) placed in a plastic box. As the turtles grow they are redistributed to larger containers. Another exception is when turtles outgrow their containers. In any case, they are traced according to the code for the container they spend the most time in. For tagged turtles released, the tag number can be linked with the container identification code used during head starting. Computerized data files carry the tag number and container identification code to track data for each turtle.

Foods and Feeding

The food currently in use in the head start research project is a commercially prepared, dry, floating, pelleted diet (Table 2) manufactured by Purina. In 1978, the first year of head start operations, foods such as lettuce and fillet of fish were tried (McKey, J.P., J.K. Leong, R.S. Wheeler and R.M. Harris, unpublished manuscript on culture of Kemp's ridley sea turtle), but the cost and inconvenience of using such foods were prohibitive. A dry, pelleted food manufactured by Central Soya and Subsidiaries of Fort Wayne, Ind., was used between 1979 and 1984 (Caillouet *et al.*, 1986b). After encountering problems with the pellets (they no longer floated), we substituted the Purina diet (Caillouet *et al.*, 1989). The diet prepared by Purina contains 40 percent crude protein, 8 percent crude fat, 5 percent crude fiber, and 47 percent other ingredients (Table 2). This diet provides good growth and survival of the turtles.

Feeding of hatchlings and juveniles must be carefully monitored as overfeeding can result in compaction of the gut and, in extreme cases, death. Because sacrificing live, healthy hatchlings is prohibited, no direct way can be used to

Table 2. Ingredients[a] of the dry, floating, pelleted diet manufactured by Purina, Richland, Indiana.	
Ground yellow corn	Ascorbic acid
Fish meal	Biotin
Soybean meal	Choline chloride
Corn Gluten meal	Folic acid
Meat and bone meal	Pyridoxine hydrochloride
Dried whey	Thiamine
Soybean oil	Niacin supplement
Dehydrated alfalfa meal	Calcium phosphate
Animal fat preserved with BHA_1	Riboflavin supplement
Salt	Magnesium oxide
Brewer's dried yeast	Copper sulfate
Dicalcium phosphate	Manganous oxide
Ethoxyquin (a preservative)	Calcium iodate
Vitamin A supplement	Ferrous carbonate
D activated animal sterol (source of vitamin D-3)	Calcium carbonate
Menadione sodium bisulfite (source of vitamin K-activity)	Cobalt carbonate
	Zinc sulfate
DL-methionine	Zinc oxide
Vitamin E supplement	Copper oxide
Vitamin B-12 supplement	

[a]Quantities not available. Proprietary information of Purina.

determine when the yolk has been absorbed as a guide to when feeding should start. However, this can be estimated indirectly with samples of hatchlings from each clutch weighed daily. When hatchlings from a clutch start losing weight, as indicated by changes in average weight for the sample, feeding of that clutch is commenced. The time lapse to initiation of feeding is approximately one to two weeks from the hatch date.

The rate at which head started turtles are fed is based on the average weight of a random sample of turtles selected from each raceway at monthly intervals from those surviving during head starting. An adequate sample size was determined to be 25 turtles per raceway (Caillouet *et al.*, 1986b). During the weighings, no attempt is made to dry the turtles. After consecutive weighings of three turtles, the balance pan is dried and re-zeroed. Both mechanical and electronic balances have been used. The initial rate of feeding for hatchlings is roughly five percent of body weight. This rate is gradually changed each month until a rate of roughly 1.5 percent body weight is reached for yearlings. The daily food ration is usually divided into two equal portions, one fed in the early morning and the other in late afternoon. The rations of food are distributed to the turtles using small plastic cups that hold the measured volume of feed required to deliver a given weight of feed. Geometric mean weights are preferred to arithmetic mean weights for setting feeding rates, because it has been found that the variances of weights of head started Kemp's ridleys are heterogeneous and a logarithmic transformation alleviates this problem (Caillouet *et al.*, 1986b; Caillouet *et al.*, 1989).

Health Care

During head starting, each turtle receives a precursory examination for evidence of disease during the twice daily feeding. Any turtle displaying signs of disease or injury is isolated at that time in the sick bay. Others with more serious problems are submitted to Joseph Flanagan, DVM, Houston Zoo, for clinical diagnosis and treatment (see also Clary and Leong, 1984; Leong *et al.*, 1989).

Necropsy

If a turtle dies, its kidneys and gonads are removed and preserved in 10 percent buffered formalin for sex determination (Wibbels *et al.*, 1989). If several die at once or from the same raceway the turtles are put on ice and taken to the Texas Veterinary Medical Diagnostic Laboratory Systems in College Station for a thorough necropsy. Treatments recommended for remaining sick turtles can then be implemented.

Tagging

The head started turtles are tagged by three different methods (Fontaine *et al.*, 1989) before being released into the Gulf of Mexico:

1. A living-tag technique developed by Dr. John and Mrs. Lupe Hendrickson, University of Arizona, Tucson involves surgical removal of small pieces of plastron and carapace, interchanging the grafts, and securing them with histological glue. As the turtles grow, the lighter colored plastron transplant makes a vivid mark on the otherwise darker background of the carapace (Figure 10). By placing the tag on a different scute each year, the year-class can be determined for turtles later recaptured or found (Caillouet *et al.*, 1986a; Fontaine, Williams and Caillouet, 1988)). We do not expect anyone but the informed observer to recognize such a tag.
2. An internal, binary coded, magnetic tag, manufactured by Northwest Research Technology Corporation, Shaw Island, Wash., is injected into the tip of the right front flipper (Figure 11). The tags are 2 mm in length. They are sterilized and the area of flipper where the tag is to be injected is swabbed with tincture of iodine. Once in the turtle, the tag is magnetized by running a magnet over the flipper. The tag can be detected by a magnetometer. The flipper can also be X-rayed to determine the exact location of the tag. If the turtle is dead when found, the tag can then be surgically removed and the year-class determined. We do not expect anyone but those equipped with magnetometer or X-ray devices to detect and locate such tags. However, if the carcasses of tagged turtles that are found dead are made available to us, we can check for presence of the tags. It is also possible that a hand-held magnetometer may be developed for future use in field studies. In any case, these internal tags are expected to be life-time tags and should remain in place for future reference.
3. Flipper tags (Figure 12) are the most frequently used tags, and are easily recognizable as tags by the public, but we do not consider them to be lifetime tags. Flipper tags used for head started Kemp's ridley are Hasco type, style 681, self-piercing, self-clinching, ear tags, manufactured from monel or inconel by National Band and Tag Company, Newport, Ky. They are inscribed with a sequential letter-number code as well as the message "Send NMFS Lab, Virginia Key, Miami, FL 33149." Tagging with this tag is usually done about 30 days prior to release of the turtles to allow remedial action in case of tag loss or infection, and to allow time for tag-related mortality, if any, to be observed. The tags are normally inserted on the trailing edge of the right front flippers. The tags are first soaked in gasoline for 24 hours to remove any oil or grease, then in 90 percent ethanol for 24 hours and, finally, they are sterilized by autoclaving prior to tagging. The area of tag insertion on the flipper is swabbed with tincture of iodine prior to tagging. Neosporin, a broad-spectrum anti-bacterial ointment, is applied to the tip of the sharp clasping device of the tag before the tag is inserted. A cast-iron, tagging tool (National Band and Tag Company) is used to affix the tag to the flipper. It is sometimes necessary to recrimp the tag with pliers to secure it. Careful observations of tag codes, body weight, carapace length and width (straight line), and gross observations of general condition and health of each turtle are made and recorded as each tag is applied. This usually is the last time that measurements and weights of the head started turtles are recorded before the turtles are released. Turtles do not actively feed for one to two days after tagging, so feeding is discontinued for 48 hours. This procedure prevents fouling the water with uneaten food.

Release

Head started Kemp's ridleys are transported to release sites in wax-coated, cardboard boxes. The boxes are modified by partitioning them with plywood to make two horizontal layers within each box (Figure 13). Two 1.3 cm air-holes are drilled at each end of the box, and the floor of each layer is covered with a piece of 1.3 cm thick polyurethane foam to cushion the turtles. The foam is moistened with water to prevent dessication of the turtles during transit. Eight yearling turtles are transported in each box, four turtles to a layer. Turtles are oriented with their heads toward the corners of the box to prevent them from biting each other, and to place their heads nearer the air-holes. The lid of the box is secured with gray duct tape, one piece completely around the length of the box and another completely around the width.

Copies of federal and state permits are attached to each box. Normally, a crew of 10 persons requires three hours to pack and load the yearling turtles for shipment. Packing and loading should be done as quickly as possible and at night to reduce the amount of time that turtles are held in the boxes and to prevent their becoming over-heated. The turtles remain in the boxes until released from a vessel.

Since 1981, the release site for the 9- to 11-month-old turtles has been offshore of Padre Island (Fontaine *et al.*, 1989). This site was chosen to reinforce any imprinting the turtles might have received as eggs and hatchlings at Padre Island. Transit by truck and vessel to the release site takes about 10 hours. Either U.S. Coast Guard cutters or The University of Texas' R/V LONGHORN have been used in most of the releases.

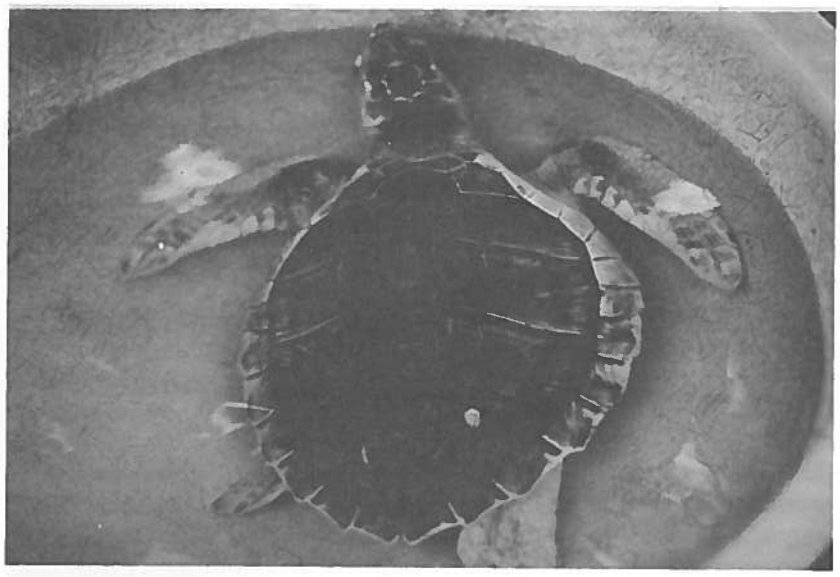


Figure 10. Living tag on a 1984 year-class Kemp's ridley sea turtle. The tag is on left costal scute 5.

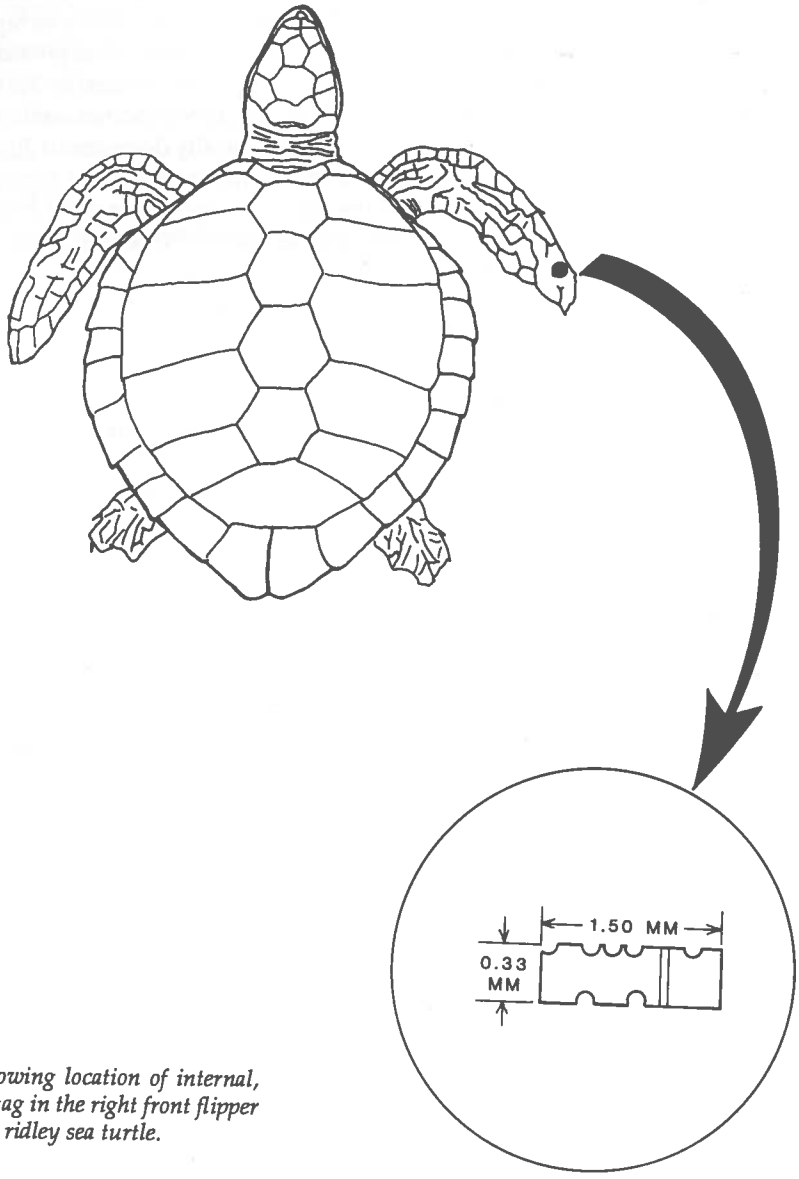


Figure 11. Diagram showing location of internal, binary-coded, magnetic tag in the right front flipper of a head started Kemp's ridley sea turtle.

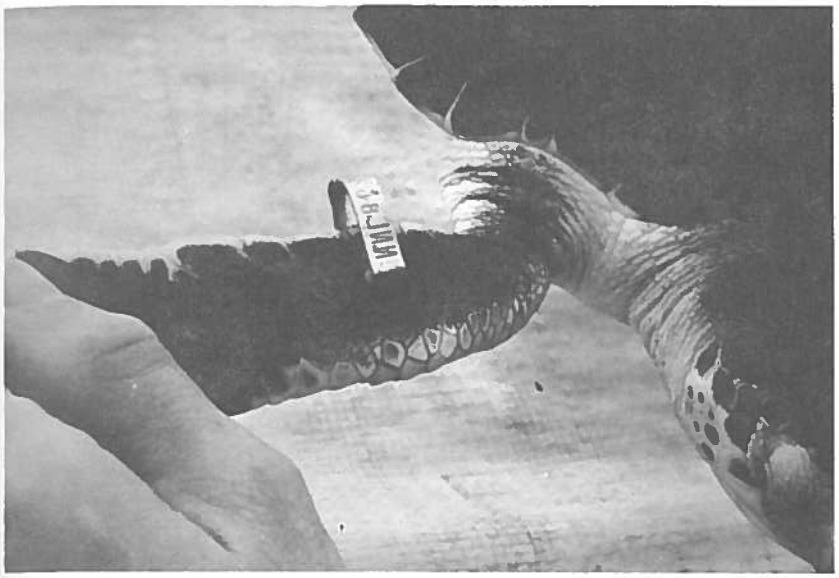
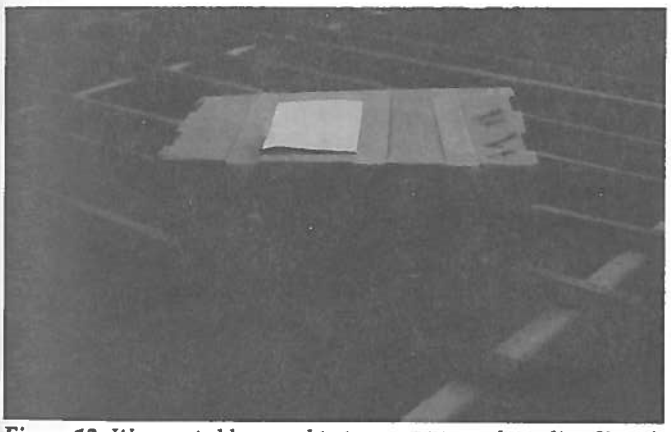


Figure 12. Flipper tag (Hasco type, style 681, self-piercing, self-clinching) used on head started Kemp's ridley sea turtles.



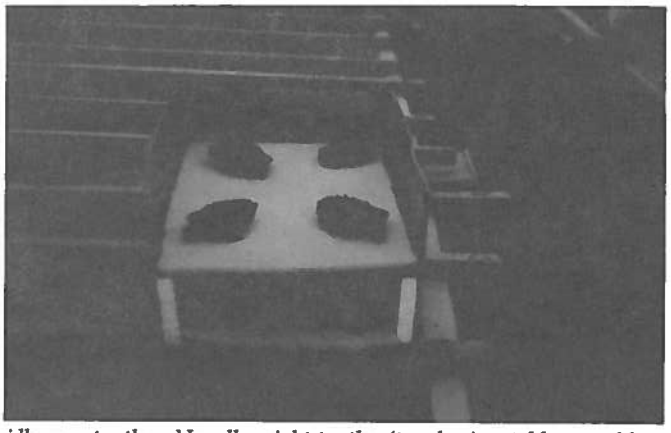


Figure 13. Wax-coated box used to transport tagged yearling Kemp's ridley sea turtles. Usually, eight turtles (two horizontal layers of four each; right photo, cutaway) are transported in this manner to the release site.

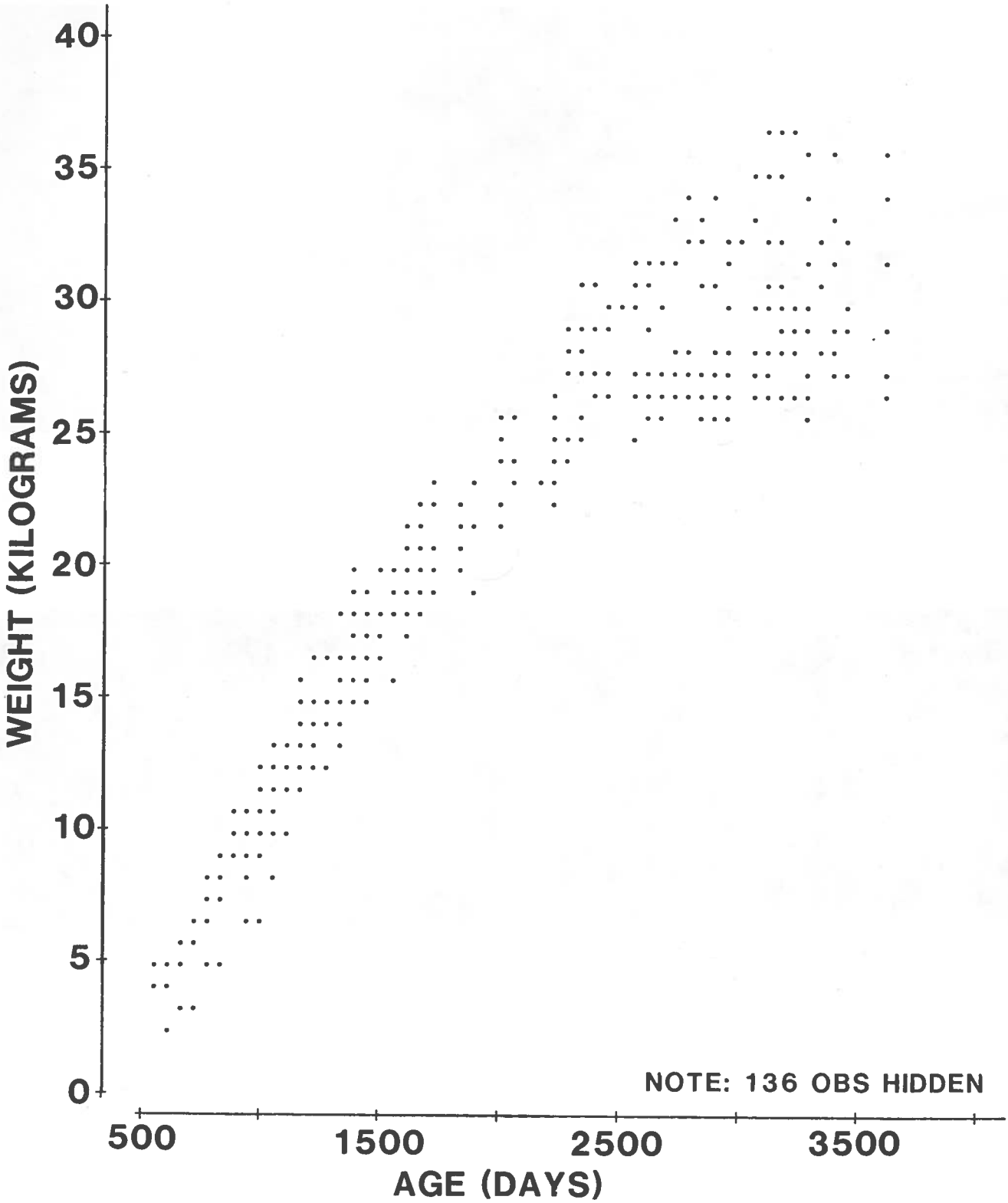


Figure 14. Weight (kg) versus age (days) for 10 head started Kemp's ridley sea turtles of the 1978 year-class held in captivity at Sea-Arama Marineworld.

Table 3. Summary of Kemp's ridley sea turtle head start results for year-classes 1978-1988 [a]

Year-class	Number of live hatchlings received	Number of dead hatchlings received	Mortality during head starting	Number of survivors	Percent survival[b]	Number of turtles held back for research[c]	Number of tagged turtles released	Percent released[b]
1978	3,080	1	992	2,088	67.8	42	2,019 [d]	65.6
1979	1,843	3	315	1,528	82.9	166	1,345 [e]	73.0
1980	1,815	7	84	1,731	95.4	0	1,723 [f]	94.9
1981	1,864	1	225 [g]	1,639	87.9	0	1,639	87.9
1982	1,524	0	171	1,353	88.8	28	1,325	86.9
1983	250	0	58	192	76.8	2	190	76.0
1984	1,441	106	361	1,080	74.9	63	1,017	70.6
1985	1,684	8	138	1,546	91.8	12	1,534	91.1
1986	1,759	0	29	1,730	98.4	50	1,680	95.5
1987	1,278	4	126	1,152	90.1	50	1,100 [h]	86.1
1988	925	0	14	911	98.5	-	-	-
Total	17,463	130	2,513	14,950	84.9[i]	413	13,572	82.1[i]

[a]As of 31 October 1988, except for the 1988 year-class which status is as of 13 October 1988.
[b]Based on number of hatchlings received alive. See footnote a.
[c]Included abnormal, injured or sick individuals that could not be released and normal, healthy animals held for extended head starting and captive propagation experiments.
[d]27 turtles died in transit.
[e]17 turtles died in transit.
[f]8 turtles died in transit.
[g]Included 2 turtles unaccounted for but presumed dead.
[h]2 turtles died in transit.
[i]Based on 1978-1987 year-classes only.

Results

As of October 31, 1988, 13,572 Kemp's ridley sea turtles had been head started, tagged and released into the Gulf of Mexico (Table 3). This represents 82.1 percent of the 1978-1987 year-class hatchlings received alive from the NPS. As of October 31, 1988, 589, or 4.3 percent, had been recaptured. Distribution, growth and survival of head started turtles in the wild were described by Fontaine *et al.* (1989) and Manzella, Caillouet and Fontaine (1988). Growth and movements of head started Kemp's ridleys in the wild also have been described by McVey and Wibbels (1984).

Since 1978, 264 head started Kemp's ridley have been transferred to oceanaria for extended head starting or captive propagation. As of the end of October 1988, 100 survivors remained in captivity. Growth in weight of head started Kemp's ridley of the 1978 year-class at Sea-Arama Marineworld, Galveston, Tex., is shown in Figure 14 (see also McVey and Wibbels, 1984; Caillouet *et al.*, 1986b).

A summary of head starting Kemp's ridleys in captivity is shown in Table 3. Survival and growth of head started Kemp's ridleys in captivity have been described by Caillouet *et al.* (1986b). The combined survival rate for the seven year-classes was 84.9 percent (Table 3). Survival and growth of head started Kemp's ridleys in the wild appear to be good (Fontaine *et al.*, 1989), but we cannot gauge the success of maturation, copulation and nesting of such animals in the wild as none of the released turtles have been reported to have nested.

In 1984, egg laying was reported in two 5-year-old, head started Kemp's ridleys maintained in captivity at Cayman Turtle Farm (Wood and Wood, 1984). According to Wood and Wood (1984), more than 60 eggs were laid by the sea turtles in May 1984. Three of the eggs in one clutch hatched, indicating that copulation and fertilization had occurred. Unfortunately, the three hatchlings did not live. Successful reproduction (that which produces viable hatchlings) has since occurred in the captive stock of Kemp's ridleys at the turtle farm in 1986, 1987 and 1988, and some of the hatchlings were head started in Galveston. These events indicate that captive propagation of Kemp's is feasible, and could provide a safety net for the species (Caillouet, 1984).

Public awareness of the head start project is so great that the turtles have become celebrities on the Texas coast. The facilities provide a common site for field trips for many local schools in the Houston-Galveston area. A book (Phillips, 1989) recently has been published popularizing the project. Annually, thousands of visitors tour the project site. HEART (Help Endangered Animals - Ridley Turtles), a special committee of the Piney Woods Wildlife Society, North Harris County College, Houston, Tex., sponsors a one day open house in February that attracts hundreds of visitors to the facility. The annual release of turtles also is a very much publicized event. Local and national news teams cover the release. Such media coverage helps convey the message of the need for sea turtle conservation to the public.

Recommendations

We believe there are four areas of research that should be emphasized in furture work:

1. Tags and tagging of sea turtles – None of the tags presently being used adequately meet the need. A tag or mark is needed that will last the entire life of the tagged turtle, and that can be easily recognized and identified by whomever recaptures a Kemp's ridley. The PIT (passive integrated transducer) tag shows promise as a permanent tag, and we are testing it. Further, through publicity and through changes in the message on the flipper tags, the finders of a tagged turtle could be encouraged to take the needed observations and report them in a timely manner without removing the tag from live animals. Carcasses of tagged animals that die in the captive stock or are found dead after release should be saved for examination, as these specimens provide a means of evaluating tag recognition and retention, as well as provide valuable information on possible causes of death.
2. Sex determination – A simple technique must be developed to determine the sex of live hatchlings and juveniles without injuring them. Sex determination is essential for proper management and conservation of this endangered species, because sex ratios of hatchlings are affected by incubation temperature. The hormonal studies by Dr. David Owens, Texas A&M University, and his students are encouraging in this regard. Laparoscopy also has been used successfully by Dr. Owens and his students on large juvenile and adult turtles, but neither technique is simple nor applicable to hatchlings and small juveniles. However, the non-injurous approach used by Demas *et al.* (manuscript) shows promise.
3. Reproductive physiology and behavior – Additional information is needed on reproduction in the wild and in captivity.
4. Prevention, recognition, diagnosis and treatment of diseases – These must be improved for captive stocks of Kemp's ridley. The successful captive-rearing of Kemp's ridleys depends to a large extent upon prevention and control of diseases encountered in the husbandry of this species. Improvements in seawater systems that provide high quality seawater for captive rearing of sea turtles go far toward reducing disease problems. Other

environmental influences (e.g., temperature, sunlight, etc.) also may affect the incidence of diseases. Good nutrition is another important factor.

Acknowledgements

Head starting of Kemp's ridleys was conducted under INP permits, FWS Endangered and Threatened Species Permits, CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) permits and scientific permits issued by TPWD and Florida Department of Natural Resources.

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Dr. James P. McVey, Mr. Ray S. Wheeler, and Mr. Larry Lansford worked diligently to establish the sea turtle head start research facilities and initiate the project from 1978 to 1981. Bonnie Cockrell, Thane Wibbels, Jean McDonald, Diana Nunez, Jody Gruber, Joey Cheeks and Cornelius Mock contributed much to establishment and improvement of systems, methods and equipment. Dr. Jorge K. Leong was instrumental in developing the facilities for and in recommending treatments for diseases of head started turtles, as well as providing health care for the 1978-1981 year-classes, along with his staff including John Clary, III and Dickie Revera. The administrative guidance and support provided by Drs. Edward F. Klima and Walter Nelson have been both stimulating and encouraging. The assistance of Kathy Indelicato, Marcel Duronslet, Joanne Williams and many others is appreciated.

A special thanks goes to Mrs. Carole H. Allen and the many supporters of HEART whose diligent and conscientious efforts have enhanced public awareness and support for the conservation of Kemp's ridley sea turtles. HEART collects donations from children, school groups and interested people, and each quonset hut has its own HEART wall that displays red plastic hearts, each marked with the name and address of the person who made a donation for the turtles. HEART is also involved in educating the public on the plight of the Kemp's ridley.

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Questions and Answers

Sally Murphy: *I am not quite sure I understood what you said about hatchling emergence - that hatchlings were emerging in the morning and that this is different from the natural condition. When do they normally emerge?*

King: Pat Burchfield mentioned that he was watching normal emergence at the Rancho Nuevo beach just prior to sunrise.

Burchfield: René Márquez and I decided, in light of some of the experimental imprinting work that is being done, that during the 1985 nesting season we wanted to determine whether there were any relationships between hatchling emergence times and beach temperatures, incubation and so on. Unfortunately, we did not have our data analysis complete for this meeting. About 70 percent of the hatchling ridleys that emerged out of 117 nests from June 13, 1985 to the end of the season would have essentially been in the water before sunrise. Hatchling emergence started about 2300 hours the preceeding evening and continued through 0900 hours the following morning. But the majority of the turtles would have been in the water before sunrise.

Peter Pritchard: *You mentioned that the hatchlings needed to be heated up a little before they were active enough to walk down the sand, and the general opinion from Mrosovsky's* et al. *observations was that sea turtles tend to slow down in activity when temperature rises above a certain critical level about 29° C, if I recall correctly. Are these compatible with each other? In other words, at what temperature did you find they were active? How low was the temperature when they were too cold to move?*

King: During the night, when the hatchlings are in the transfer boxes prior to their transfer from the incubation shed to the beach for imprinting, the temperature drops to 72°-74° F (22°-23° C). I would imagine that the hatchlings were at that same temperature. At 0800 hours, when the sun is rising, the hatchlings are still at the lowered temperature. On exposure to the sun, their temperature begins to rise. I would guess that by the time they start moving down to the water, the temperature, in most cases, is somewhere between 75° F and 85° F (24° - 29°C).

Pritchard: *Do you think you could lower the peak temperature in the egg boxes and perhaps make it occur later in the day by using thicker boxes or double boxes?*

King: The holes that must be put through the boxes to ensure good ventiliation throughout the sand probably would counteract any benefits of thicker walls. Thickness of the foam material does not seem to make a difference. For example, we doubled the thickness of the foam walls changing from the old boxes used in 1982 to the newer boxes used in 1983, and this did not seem to change the temperature curve at all. This change was from 1/2 inch (1.3 cm) to 1 inch (2.5 cm) thick.

Caillouet: It is generally accepted that incubation temperature affects the sex ratio in sea turtles. However, it seems to me that two quite different results might derive from this. Either sea turtles that become male or female have identical sex genotypes and their phenotypic sex is somehow induced by incubation temperature or they have male and female genotypes that can be overcome by temperature. If the latter were true, then it follows that a certain proportion of the animals would become sex-reversed in the process of incubation at temperatures conducive to induction of the sex that is inconsistent with the sex genotype. We should be concerned about the possible affects of such sex reversal. For example, it may be that sex-reversed animals, even though they are phenotypically females, may not have the same biotic potential or survivability as females that are not sex-reversed.

John Carr: *Do you have an idea at which stage of development the carapacial scutes pattern is determined or finalized?*

Shaver: I did not examine the scutes because oftentimes the embryos were in very bad condition. They were frequently deformed. If I recall correctly, it is approximately at stages 25 and 26 that the scutes begine to appear.

Carr: *What is the full number of stages in development?*

Shaver: Cratz described 31. We added four more because his stages left out a lot of measurements. Applying his stages to our embryos would have made it impossible to characterize some of our embyros.

Pritchard: *How many days would that be, when scutes first can be seen, more or less?*

Shaver: It is about 33 days.

Status of Satellite Tracking of Kemp's Ridley Sea Turtles

John O. Mysing and Thomas M. Vanselous*

*Two Kemp's ridley sea turtles (*Lepidochelys kempi*) were tagged with specially developed, satellite transmitters that operate through NIMBUS/ARGOS receiving/processing systems. The turtles were tagged in 1985 during the annual nesting season at Rancho Nuevo, Tamaulipas, Mexico. The experiment was curtailed because of the separation of the transmitters from the turtles. Although the feasibility of the concept of tracking turtles via satellite has been established, additional development work is needed to enhance the performance of the system.*

The Kemp's ridley sea turtle (*Lepidochelys kempi*) is the species most in danger of extinction of the extant marine turtles in the world. The only known primary nesting area of this species is a stretch of beach near Rancho Nuevo, Tamaulipas, Mexico. Virtually the entire world population of adult females of this species nests in broad daylight at this single locality (Pritchard, 1969).

The passage of the Endangered Species Act of 1973 offered protection of Kemp's ridley in U.S. waters. Similar legislation by the Mexican government led to protection of turtles on the nesting beach and protection of the eggs from both human and canine predators (Pritchard and Márquez, 1973). While these measures appear to have slowed the nesting population decline, future efforts to enhance survival potential of the species are hampered by lack of information concerning the basic life history of the animals at sea. A major lack of information involves post-nesting movement patterns of the adult females.

Development of satellite tracking systems made it possible to monitor the wide ranging migration habits of sea turtles for the first time on a comprehensive basis. Prior observations were limited to visual sightings, random recovery of tagged animals, and radio beacon tracking with a limited range.

Background and Rationale

The National Marine Fisheries Service (NMFS), Southeast Fisheries Center's Fisheries Engineering Laboratory at Bay St. Louis, Miss. and the U.S. Fish and Wildlife Service (FWS), Denver Wildlife Research Center, Denver, Col. jointly sponsored a marine turtle migration research project in 1985. Orginally a transmitter (Figure 1) compatible with the NIMBUS-6/Random Access Measurements System (RAMS) and capable of receiving a signal and determining a position within 5 km was attached to a 96-kg female loggerhead turtle (*Caretta caretta*). Signals were received through the National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center (GSFC). Following a series of behavioral studies on this turtle, dubbed "Diane," in captivity, the turtle was released into the Gulf of Mexico off Gulfport, Miss. on October 16, 1979. She remained offshore from southeast Louisiana until mid-December, during which time periodic overflights by aircraft verified her position. In the latter half of December, she began westward migration around the mouth of the Mississippi River, along the Louisiana coast, southwest along the Texas coast to her last reported southern position offshore of Brownsville, Tex. The turtle then headed northward to a position near Sabine Pass, between Texas and Louisiana where she and the transmitter became separated (Figure 1). Periodic monitoring of her movement had occurred over an 8-month period during which she had traveled a distance exceeding 2,200 km.

Several other tracking experiments were conducted with the NIMBUS-6 transmitter, and all were relatively successful except for one involving a female Kemp's ridley with 67-cm carapace length tagged at the Rancho Nuevo nesting beach. The turtle was captured a few days after release by a local fisherman, presumably because of difficulty the turtle was having with the large transmitter package.

Argos System Development

The relative success of these pioneering experiments encouraged development of a transmitter that would work with the newer ARGOS system when the NIMBUS/RAMS system degraded due to old age. The ARGOS system is a platform location and data acquisition system aboard NOAA satellites and is operationally similar to NIMBUS/

*National Marine Fisheries Service

RAMS with several significant advantages. The first is a short message format that is available where "position only" operation is desired. This means that there can be approximately 67 percent power savings as compared to operation with a RAMS transmitter. The second advantage is that there are always two satellites in orbit, effectively doubling the probability of receipt by the satellite of a transmission. Also, additional backup satellites are available for deployment in the event that a replacement is needed. This provides assurance that a newly developed transmitter can be used for the foreseeable future.

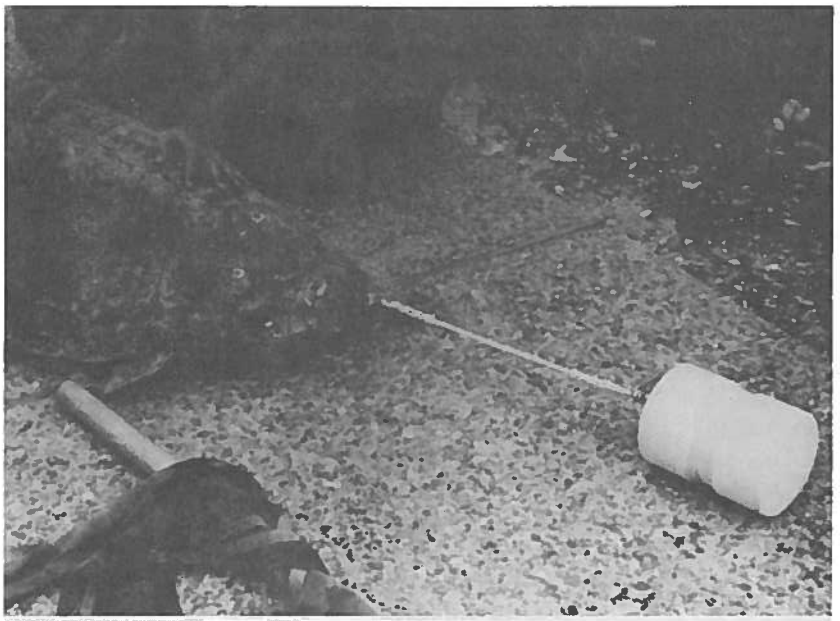

Figure 1. Female loggerhead sea turtle with NIMBUS-6/RAMS transmitter attached.

A contract was awarded to Wood-Ivey Systems Corporation (WISCO), Orlando, Fla. to develop an ARGOS transmitter suitable for attachment to and tracking of marine animals. Two prototypes delivered during the third quarter of 1982 were fully certified by Service ARGOS for satellite beacon performance and represent the baseline design. By comparison, they are 41 percent of the weight (in air), 22 percent of the displacement volume, and 13 percent of the buoyancy of the NIMBUS-6 transmitters. The NIMBUS-type tag weighed about 3.1 kg (about 3.2 percent of "Diane's" body weight) compared to the ARGOS-type tag weight of 1.25 kg (about 2.7 percent of the average adult female Kemp's ridley's body weight). The towing resistance (drag) of the ARGOS-type tag is less than one-half that of the NIMBUS-type tag. Extensive laboratory testing (e.g., shock, pressure, temperature and vibration) was conducted with the ARGOS-type transmitters. One controlled field test was completed using a captive loggerhead turtle. Release of a tagged loggerhead into the Gulf of Mexico was attempted in 1982, but the transmitter failed for unknown reasons.

Figure 2. ARGOS tag (foreground) and short-range receiver (background).

Rancho Nuevo Study

In June 1985, two WISCO-manufactured ARGOS tags were transported to Rancho Nuevo for attachment to Kemp's ridley females in coincidence with the nesting season. The objective was to establish the development and operational feasibility of the ARGOS tags as a means of tracking Kemp's ridley. The tags also included an auxiliary short-range transmitter to be used to aid in location and recovery of the unit (Figure 2). The tag was attached as shown in Figure 3.

The first tag (#3176; Table 1) was attached on June 7 at about 1530 Central Standard Time (CST) to a Kemp's ridley with a 72-cm carapace length while she was nesting. She returned to the water immediately afterward, towing the tag without apparent difficulty. A satellite location was obtained on June 9 at 22.77°N, 97.69°W, or about 40 km south of the release point and on the 18-m depth contour. A 19-minute transmission on June 23 led to the conclusion that the transmitter was on the beach approximately 40 km south of Tampico, Mexico. Subsequently, a Mexican fisherman found the tag on the shore and returned it. The system was still operational and showed little or no damage and a minimum of marine growth.

A second ARGOS-tagged (#3177; Table 1) Kemp's ridley nester was released on June 10 at Rancho Nuevo, and this turtle was caught by shrimp fishermen off Freeport, Tex., on July 19. The crew removed the tag and released the turtle

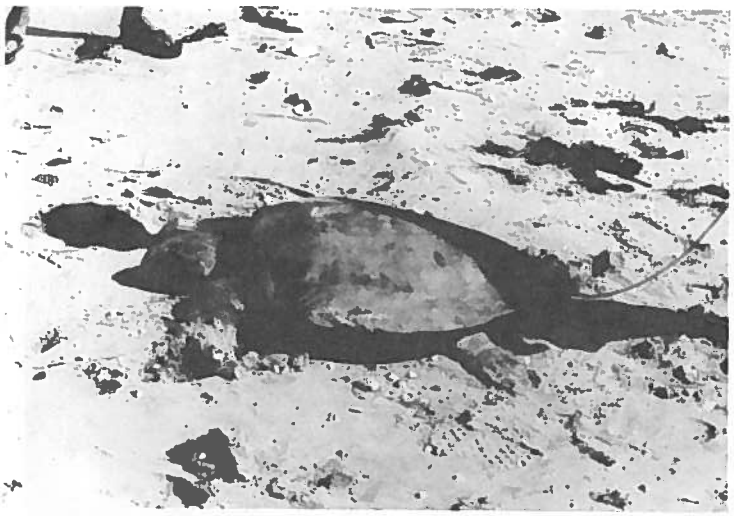

Figure 3. Kemp's ridley nester with ARGOS tag (upper right) attached at Rancho Nuevo, Tamaulipas, Mexico, June 1985.

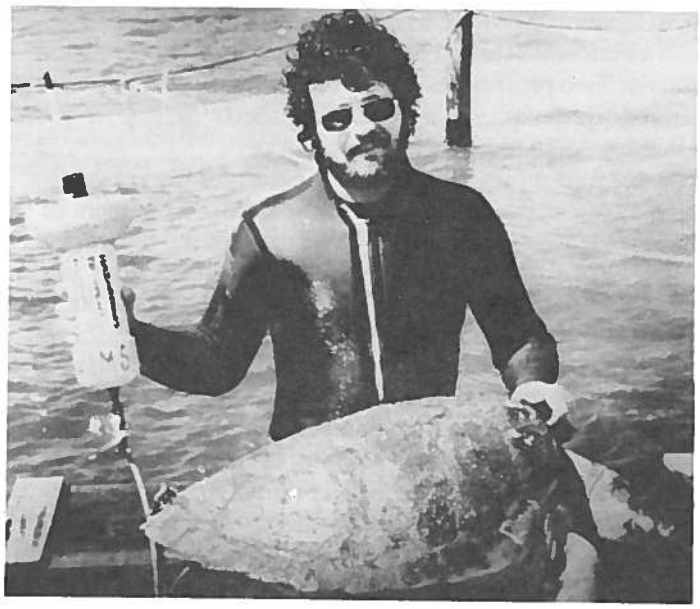

Figure 4. Richard Byles holding satellite tag developed for NMFS by Virginia Institute of Marine Sciences.

Table 1. Number of messages transmitted by tags placed on two nesting female Kemp's ridley sea turtles at Rancho Nuevo, Tamaulipas, Mexico, and received through ARGOS.

Tag Number	Date	Number of Messages Received
3176	June 9, 1985	5
	11	-[a]
	13	3
	15	-
	16	-
	17	-
	19	-
	21	-
	23	29
3177	June 13, 1985	1
	16	2
	19	-
	22	5

[a]No transmissions received.

in apparently good condition. The tag was inoperative upon receipt. Testing indicated that the circuitry was functional, and that the problem was related to premature failure of the battery. No satellite positions were received for this tagged turtle, but it traveled 672 km with the tag in 39 days, before the tag was removed.

In this experiment, observed surfacing time ranged from 40 seconds to 320 seconds. Standard data processing techniques used by Service ARGOS require a minimum span of 420 second transmissions.

An alternate tag developed for NMFS by the Virginia Institute of Marine Science (VIMS; Figure 4) uses a transmitter unit produced by Telonics, Inc. The unit was not available for use during the 1985 Kemp's ridley nesting season, so it was evaluated on a captive loggerhead turtle at the VIMS facility. This unit has a somewhat different packaging and antenna configuration, but it meets the standard ARGOS specifications.

Summary and Conclusions

The data obtained from this experiment on Kemp's ridley nesters were severely limited by the brief duration of the tests. Nonetheless, messages were received from the ARGOS transmitters by the satellite while the turtles were at sea, several accurate location fixes were processed (Table 1), and the results can be used to guide further development of satellite tags.

More development work is needed to achieve the goals of daily position updates and determination of surfacing time. Surfacing times and satellite visibility remain as areas of concern. Specialized software needs to be developed incorporating position processing algorithms that trade off accuracy to maintain tracking continuity in a manner tailored to the requirements of this type of experiment. Improved transmitter control, through the use of a surface sensing switch, will also help raise the number of successful transmissions. Additionally, the radiation pattern of the antenna used needs to be verified in the marine environment to assure signal continuity over an extended period of marine growth and fouling.

Tagged turtles, such as the ones used in this study, are vulnerable to the actions of local fishermen. Improved attachment and better identification methods, and increased public awareness may alleviate the unnecessary separation of the tags from the turtles by those who catch sea turtles, but this will probably remain a problem. Rescue of the turtle and tag from threatening situations might be enhanced by incorporation of sensors that would detect continued surfacing and/or removal from the water. Such information can be transmitted through the ARGOS net to alert the experimenter. Even faster response could be achieved by use of a Local User Terminal (LUT) for immediate relay of this information.

Finally, although the present tag package appears to be small enough, improved and lighter electronics should be incorporated as they become available to reduce even further the weight and size of the satellite package.

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Distribution of Juvenile and Subadult Kemp's Ridley Turtles: Preliminary Results from the 1984-1987 Surveys

Larry H. Ogren*

*Juvenile life stages of Kemp's ridley turtle (*Lepidochelys kempi*) are widely distributed throughout the coastal waters of the United States from Texas to New England. For the most part, these individuals could be described as post-pelagic "yearlings" that have left the pelagic habitat for the nearshore benthic habitat to forage primarily on motile forms of crustaceans such as portunid crabs. Historical records from the turn of the century characterize the ridley as a common inhabitant of North Carolina bays and estuaries. Kemp's ridley was the second most abundant sea turtle caught in the Cedar Key, Fla., turtle fishery, but this may reflect fisherman bias for the green turtle.*

Following the drastic decline in the size of the Rancho Nuevo, Mexico, rookery over the past four decades, a similar decrease in numbers of juveniles and subadults in our coastal waters would be expected. Early surveys conducted in the northern Gulf of Mexico substantiated that this was the case. However, occurrences of unusual numbers of juvenile Kemp's ridleys captured in relatively restricted areas have been recently reported in Louisiana, Alabama and, to some extent, in northwest Florida. In two cases, the most significant biological factor associated with these frequent captures was the abundance of portunid crabs. In some cases, cold-stunned turtles were obtained from both coasts of Florida following episodes of severe winter temperatures.

Records of Kemp's ridleys collected or observed, weighed and measured, and tagged and released are presented. Anecdotal information from various informants and miscellaneous observations are summarized.

The early life history stages of Kemp's ridley turtle (*Lepidochelys kempi*) have not received as much attention by biologists as have studies of the older, reproductively active adults. This was probably due to their small size, reduced numbers and cryptic habits in the extensive marine environment of the Gulf of Mexico and North Atlantic, and was compounded by their being frequently misidentified (Brongersma, 1982). However, adults, as well as juveniles, were relatively common years ago and well known to the trawlermen of the Gulf of Mexico (Liner, 1954; Carr, 1977). After the nesting beach at Rancho Nuevo, Mexico was discovered by scientists in 1961 (Hildebrand, 1982), ridleys became highly visible and relatively accessible to biologists at the rookery. That was the situation until their numbers declined to the low levels reported today (Márquez, Villanueva and Burchfield, 1989). Before their numbers decreased to present levels, tagging studies conducted by Mexican biologists at Rancho Nuevo revealed that females returned to crab-rich foraging grounds either south of the rookery in the Tabasco-Campeche Bay region or north, primarily off the Louisiana coast, after the nesting season (Chávez, 1969; Pritchard and Márquez, 1973; Márquez, 1984). It was also determined that the majority of tag returns came from shrimp fishermen trawling in those two areas (Márquez, 1984; National Marine Fisheries Service, 1987).

Nothing is known about the distribution, or even the occurrence, of Kemp's ridley hatchlings in the pelagic stage in the Gulf of Mexico. A few are sometimes observed swimming in the surf zone off Padre Island, Tex., and some have been tossed up on the beaches of Mustang Island, Tex. during storms (Anthony Amos, The University of Texas, and National Park Service personnel, Padre Island National Seashore, personal communication). In either case, the littoral zone, with its attendant predators, is clearly not the appropriate habitat of these young turtles. Paradoxically, the smallest post-hatchlings recorded were two specimens found in the Atlantic (Schmidt and Dunn, 1917; Deraniyagala, 1939). One was from the Azores and the other from an unknown locality identified only as "United States."

The juvenile life history stage, not including the hatchlings or the post-hatchling pelagic stage (Carr, 1986), is best described as the post-pelagic or coastal benthic stage that feeds primarily on crustaceans such as portunid crabs, bivalves, and a variety of other invertebrates (Dobie, Ogren and Fitzpatrick, 1961). This developmental stage is widely distributed throughout the Gulf of Mexico and northward along the Atlantic coast from Florida to New England. Kemp's ridley has also been recorded from Bermuda (Mowbray and Caldwell, 1958), but nowhere else in the western North Atlantic, and that includes the Bahamas and Antilles (Carr, 1980).

In the eastern Atlantic, Kemp's ridleys include a wide range of size classes, from small post-hatchlings to larger juveniles with carapace lengths from 10 to 25 cm (Carr, 1980). In the western Atlantic only one adult size individual (66 cm) has been captured at Cape Canaveral, Fla. (Henwood and Ogren, 1987). Other records showed that Kemp's ridleys from the western Atlantic ranged in size from 20 to *circa* 60 cm carapace length (Table 1). Several more adult

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Table 1. Size distribution of Kemp's ridley turtles from the Atlantic coast.

Straight line[a] carapace length, centimeters Mean	Range	n[b]	Locality	Date	Source
30	27-33	7	Cape Cod Bay, Mass.	Nov. 1978	Lazell (1980)
35.6	26.5 - 43	7	Sandy Hook Bay/ New York Bight	Jun. - Nov. 1973-1975	Tom Azarovitz (unpublished)
*41	27-62	21	Chesapeake Bay, Va.	May - Nov. 1979-1981	Lutcavage and Musick (1985)
34.8	20.3 - 57.2	21	S.C. and Ga. coastal zones	Jun. - Nov. 1978-1983	Henwood and Ogren (1987)
38.6	24.1 - 66	40	Cape Canaveral, Fla.	Dec. - Mar. 1978-1984	Henwood and Ogren (1987)

[a] Except as noted by asterisk (*) indicating curved measurement. Curved carapace length measurements are approximately 2 centimeters greater than straight line measurements.
[b] Sample size.

size individuals have been found stranded on Atlantic coast beaches of South Carolina, Georgia and Florida (Barbara Schroeder, National Marine Fisheries Service, personal communication), and René Márquez (Instituto Nacional de la Pesca, personal communication) reported the capture of two adult females offshore the Dry Tortugas and the upper Florida Keys. With the discovery of the rookery at Rancho Nuevo, a postulated old world origin for these individuals was laid to rest (Brongersma, 1972). However, the fate of these turtles in the North Atlantic remains undetermined. Some obviously die from exposure to low temperatures if they venture too far north (Lazell, 1980; Meylan and Sadove, 1986). Whether all are lost never to enter the breeding population, or whether they return to the Gulf of Mexico to mature, breed or both is not known.

Historical records from the turn of the century characterize juvenile Kemp's ridleys as common inhabitants of North Carolina bays and sounds (Coker, 1906). Kemp's ridley was the second most abundant sea turtle caught in the Cedar Key, Fla., turtle fishery (Carr and Caldwell, 1956). However, this might not reflect the natural conditions concerning the species' abundance at that time because of the fishermen's bias for the green turtle (*Chelonia mydas*). Elsewhere in the United States, unusual numbers of small Kemp's ridleys were found cold-stunned in Vineyard Sound, Mass., and were reported to be a common inhabitant of New York Harbor (Babcock, 1930; Carr, 1980).

The nesting population of Kemp's ridley at Rancho Nuevo was first observed by biologists in the early 1960s when it was determined that numbers of nesters estimated from a single *arribada* in 1947 had been reduced by more than 92 percent (Márquez, 1984). A corresponding decrease in the number of hatchlings produced would be expected, and the number that survived the pelagic stage and entered the coastal benthic population as juveniles would therefore also be lowered. This decline was the result of systematic and intensive egg harvest over a period of many years (Hildebrand, 1982), in addition to other natural causes and continuing incidental catch primarily by shrimp trawlers elsewhere in the species range.

During the last two decades, increasing beach protection provided by the Mexican government and a very successful hatchery program operated by Mexican and American biologists at Rancho Nuevo produced an average of 20,000 hatchlings annually the first decade and 50,000 annually thereafter (Márquez, 1984). This can be expected to have resulted in a major demographic change for Kemp's ridley in the Gulf of Mexico, and possibly the western Atlantic region as well. However, the adult population continued to decline steadily during 1978 to 1985 (Frazer, 1986), and only about 600 females nested at Rancho Nuevo in 1986 (Richard Byles, U.S. Fish and Wildlife Service, personal communication; National Marine Fisheries Service, 1987). Observations or incidental captures of adult ridleys at sea have become rare events. Conversely, juveniles in the post-pelagic benthic stages are now commonly found at various localities in coastal waters from Texas to New England, probably as a result of the protection afforded the nesters and nests at Rancho Nuevo for two decades.

The following account presents capture, tagging and recapture results and size distribution data obtained in recent years. These studies are part of the long-term effort to determine migratory patterns, seasonal occurrence and distribution and growth of foraging populations of juvenile sea turtles in coastal waters. They provide support for the overview I will give of the early life history of Kemp's ridley.

Table 2. Size distribution of Kemp's ridley turtles from the northern Gulf of Mexico.

Straight line carapace length, centimeters Mean	Range	n[a]	Locality	Date	Source
53.5	38-64	72	Cedar Key, Fla.	Apr. - Nov. 1955	Carr and Caldwell (1956)
45.9	35.5-57	36	Cedar Key, Fla.	May - Nov. 1984 - 1987	NMFS[b]
35.5	20.3-55.9	30	Apalachicola - Apalachee Bays, Fla.	Mar. - Jan. 1970 - 1985	Jack Rudloe (unpublished) NMFS
37.4	20.3-53	53	Apalachicola - Apalachee Bays, Fla.	Jan. - Dec. 1985 - 1987	Jack Rudloe (unpublished) NMFS
31	25.8-39	7	Mississippi Sound & coastal zone, Ala.	Feb. - Oct. 1966-1983	Carr (1980) NMFS
23.7	21.6-26.3	5	Terrebonne and Caillou Bays, La.	Jun. 1984	NMFS
32.3	20.3-45.7	61	Sea Rim State Park, Tex.	Apr. - Nov. 1983 - 1985	Texas Parks & Wildlife Dept. STSSN[c]
31	24.1-39.8	6	La. coastal zone and eastern Tex.	Mar. - Nov. 1978	NMFS

[a] Sample size.
[b] National Marine Fisheries Service.
[c] Sea Turtle Stranding and Salvage Network.

Capture, Tagging and Recapture

At-sea capture of sea turtles continues to be the most important and productive source of information from which we at the National Marine Fisheries Service, Panama City, Fla., Laboratory ascertain the distribution and abundance of sea turtles in coastal waters. This is especially true when a turtle biologist or a similarly trained person is directly involved in collecting or handling the turtles and in recording the species identification and morphometrics. In addition, references dealing with significant numbers of juveniles turtles and meristic data have been selected from other sources to complement our limited data (Tables 1 and 2).

In general, most of our sea turtle capture efforts in the southeast region of the United States are either by active fishing gear, such as trawls and strike gill nets, or more passive methods such as turtle entanglement nets. The primary objective of capturing turtles is to tag and release them. In certain areas along the coasts of the Gulf of Mexico and Atlantic Ocean, turtles are sometimes captured in pound nets, by hook and line, and fortuitously when they are immobilized by cold temperatures (Ogren and McVea, 1982; Ehrhart, 1983). Some stranding records also were included in the size distribution examples discussed, but most captures were made by shrimp trawls.

Juvenile Kemp's ridleys are not the only species collected during our capture efforts. Adult and subadult loggerheads (*Caretta caretta*) dominate the catch on the Atlantic coast, and juvenile green turtles, although less abundant in our catches than are loggerheads and Kemp's ridleys, are found in both areas in the Gulf and Atlantic. Other areas along the Gulf Coast of Florida south of Cedar Key are reported to have significant numbers of juvenile green turtles (Paul Raymond, National Marine Fisheries Service, personal communication). An expansion of our netting activities at Cedar Key is being planned to include sampling in the Homosassa, Fla., area. New netting methods are being developed for sampling Corrigan and Waccasassa reefs, and sampling areas will be extended to Homosassa, Fla., where conditions appear to be more favorable for capturing subadult green turtles.

Most of the capture and tagging efforts take place along the northwest and east-central coasts of Florida, with considerable seasonable (summer) effort in Winyah Bay, S.C. The most productive method of capture has been with shrimp trawls, but "run-around" gill nets and, more recently, turtle entanglement nets have accounted for an increasing number of captures on the west coast of Florida. More than 600 turtles have been captured, tagged and

Table 3. Recent recaptures of Kemp's ridley turtles along the Atlantic coast.

Tag Code	Date tagged	Capture locality	Capture gear	Date of recapture	Recapture locality	Recapture gear
PPF 541-542	Nov. 29, 1986	Cape Canaveral, Florida	Shrimp trawl	Dec. 13, 1986 & Mar. 23, 1987	Cape Canaveral, Florida	Shrimp trawl
PPF 542-54	Jan. 25, 1987	Cape Canaveral, Florida	Shrimp trawl	Jul. 28, 1987	Glynn County, Georgia	Shrimp trawl

Table 4. Recaptures of Kemp's ridley turtles in the northern Gulf of Mexico.

Tag Code	Date tagged	Capture locality	Capture gear	Date of recapture	Recapture locality	Recapture gear
NNJ 253	Nov. 7, 1984	Mississippi Sound, Biloxi, Miss.	Shrimp trawl	Sept. 16, 1985	Sabine Pass Jetties, Tex.- La. boundary	Shrimp trawl
NNZ 674-907	Jul. 6, 1985	Fidlers Point, Wakulla County, Fla.	Gill net	Jul. 9, 1985	Fidlers Point, Wakulla County, Fla.	Seine net
NNW 701-702	Nov. 18, 1985	1.6 km offshore Shell Island, Bay County, Fla.	Shrimp trawl	Apr. 1986	4.8 km offshore Marsh Island, Iberia Parish, La.	Shrimp trawl
NNZ 219-220	May 31, 1986	Mud Cove, Franklin County,Fla.	Shrimp trawl	Jun. 26, 1986	Mud Cove, Franklin County, Fla.	Shrimp trawl
NNJ 266	Jul. 15, 1986	Mississippi Sound (released 40.3 km offshore Horn Island), Miss.	Shrimp trawl	Aug. 4, 1986	East Deer Island, Mississippi Sound, Miss.	Shrimp trawl
NNJ 267	Jul. 15, 1986	Horn Island, Mississippi Sound, Miss.	Shrimp trawl	Oct. 23, 1986	Dauphin Island, Mississippi Sound, Ala.	Shrimp trawl
NNW 729-730	Jul. 30, 1986	Corrigan Reef, Levy County, Fla.	Turtle net	May 21, 1987	Corrigan Reef, Levy County, Fla.	Turtle net
NNZ 231-232	Dec. 7, 1986	St. George Island, Franklin County, Fla.	Shrimp trawl	Apr. 3, 1987	Alligator Point, Franklin County, Fla.	Shrimp trawl
NNZ 252-253	Apr. 13, 1987	Shell Point, Wakulla County, Fla.	Shrimp trawl	Apr. 16, 1987	Shell Point, Wakulla County, Fla.	Shrimp trawl

released. Of this total, 376 loggerheads, 146 Kemp's ridleys and 22 green turtles have been captured on the Atlantic coast. During 1978 to 1984, approximately 60 juvenile Kemp's ridleys and 20 green turtles were tagged and released on the Atlantic coast (Henwood and Ogren, 1987), and these included a significant number of juvenile and subadult turtles from the coastal waters of the United States offshore the Indian River estuarine system of east-central Florida as reported by Ehrhart (1983). Recent recaptures of Kemp's ridleys on the Atlantic coast are shown in Table 3.

On the west coast of Florida, capture efforts have resulted in the tagging of more than 100 juvenile sea turtles, primarily Kemp's ridleys. The species composition was 110 Kemp's ridleys, 10 green turtles and 7 loggerheads. The capture methods included gill and entanglement nets as well as shrimp trawls. Recent and significant recaptures of Kemp's ridleys in the Gulf of Mexico have been reported (Table 4). One tagged Kemp's ridley was at large at Cedar Key from July 1986 until May 1987, and another migrated eastward from Biloxi, Miss., to Dauphin Island, Ala. Two other tagged Kemp's ridleys were recaptured in Louisiana, a considerable distance westward of their original capture sites at Panama City and Biloxi, respectively.

Figure 1 gives the carapace length-frequency distribution of Kemp's ridleys captured by shrimp trawls during our sampling effort in the northeast Gulf of Mexico from 1984 to 1986.

Overview

Juvenile Kemp's ridley turtles are widely distributed throughout U.S. coastal waters from Maine to Texas. The

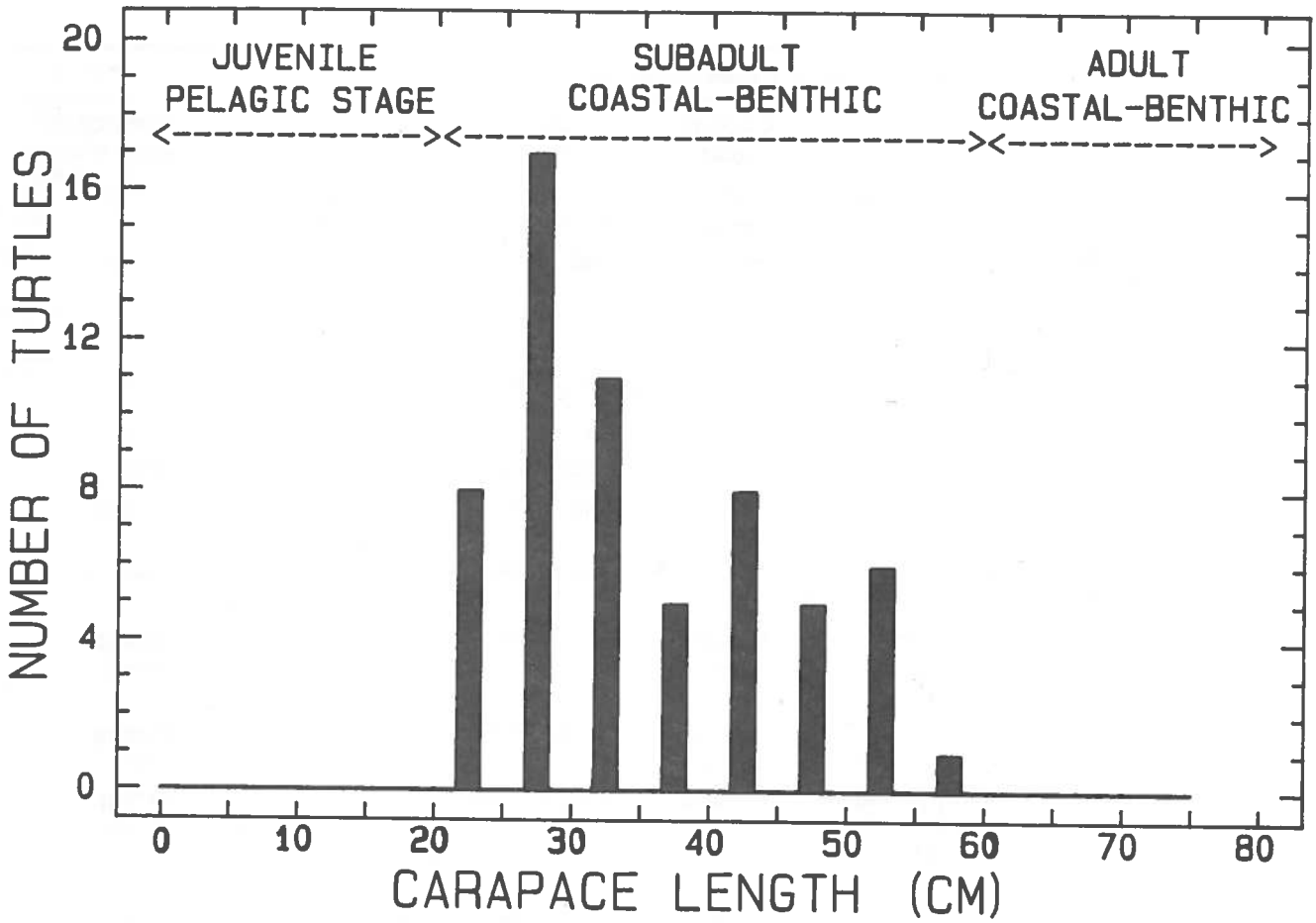

Figure 1. Straight line carapace length-frequency of 61 Kemp's ridley turtles captured in shrimp trawls in the northeastern Gulf of Mexico, 1984-1986.

smallest individuals, ranging in carapace length from 20 to 25 centimeters, are probably post-pelagic stage individuals entering shallow coastal zones of bays, sounds and estuaries (Figure 1). In these developmental habitats, their ecologic niche changes to that of a benthic carnivore. The 20 to 25 cm size class is apparently most numerous in the Gulf of Mexico, giving credence to speculation that the entire life cycle occurs entirely within the Gulf of Mexico for some unknown proportion of the population.

Historically, the smallest post-hatchling Kemp's ridleys were reported only from the New England states and the eastern North Atlantic (Brongersma, 1972; Carr, 1980). However, the ridleys that are found in the Atlantic states to the north and that have a carapace length greater than 25 cm are still relatively small individuals whose movements are most likely mediated by ocean currents. Because of the greater distance from their natal beach, Kemp's ridleys in North Atlantic waters may take a little longer to complete the pelagic development stage than their cohorts in the Gulf of Mexico, and thus they enter the coastal zone at a larger size than those in the Gulf.

Examination of previously published data on sizes of Kemp's ridleys along the U.S. Atlantic coast (Table 1) reinforces earlier comments on the possibility of a north to south increase in size (Carr, 1980), a phenomenon that has also been observed for green turtles (Carr, 1952). This gives support to the idea that the smallest Kemp's ridleys transported out of the Gulf of Mexico are carried by currents northward to New England and then shoreward across the continental shelf via Gulf Stream gyres (Carr, 1980 and 1986). Carr (1980) and others (Lazell, 1980; Meylan, 1986) have proposed this, and the data presented herein agree with such an explanation. Some of these Gulf of Mexico expatriates do not leave the Gulf Stream off New England, but continue their journey to northern Europe and points south in the eastern North Atlantic (Brongersma, 1972 and 1982; Pritchard and Márquez, 1973; Carr, 1980).

There has been considerable debate as to whether or not these Atlantic expatriates survive in the North Atlantic and live long enough to return to the Gulf of Mexico to breed, and conversely as to whether or not they are all doomed waifs, destined either to become cold-stunned in the winter or permanently isolated in the Atlantic (Carr, 1980). Historical records and scientific data strongly suggest that some mortality occurs when young Kemp's ridleys are carried into northern latitudes on either side of the Atlantic and are exposed to the lethal effects of winter temperatures (Lazell, 1980; Meylan and Sadove, 1986). However, some individuals apparently manage to survive, either by being

carried farther downstream to warmer latitudes in the eastern Atlantic, or by some unknown migratory route southward along the coast of the United States to Florida, or both.

In the above case of Atlantic expatriates, our data support the possibility of a seasonal migration south from northern latitudes in the fall, and a subsequent return to northern foraging grounds with the warming of the waters in the spring (Henwood and Ogren, 1987). Other workers studying sea turtle populations along the Atlantic coast have also postulated a seasonal migration among New York Bight, Chesapeake Bay and Florida (Lutcavage and Musick, 1985; Byles, 1989). A similar migratory pattern has been suggested for the loggerhead as well. Otherwise, it is difficult to explain the regular occurrence of significant numbers of viable and healthy sea turtles in northern waters in the warmer months. We have a few Kemp's ridley tag returns from specimens tagged in Florida and recaptured as far north as Chesapeake Bay, and vice versa (Table 3) (Henwood and Ogren, 1987). These could be indicative of what some members of the population do to exploit the crustacean-rich and mollusc-rich foraging grounds north of Florida and to avoid being exposed to the low temperatures that occur for part of the year. Seasonal migrations by other marine poikilotherms are not unusual.

Size distribution of Kemp's ridley along the northern Gulf of Mexico is more or less unremarkable as compared to that along the Atlantic (Table 2). However, some significance should be given to two areas: the smallest Kemp's ridleys found in Gulf coastal waters occur in (1) western Louisiana and eastern Texas and (2) Wakulla and Franklin counties in northwest Florida. These turtles have carapace lengths (20 to 25 cm) that one would expect them to have attained during the time between that when the hatchlings first enter the pelagic stage offshore of the natal beach and the time juveniles enter the coastal benthic stage. However, their precise age is not known. Although we have no documented records of Kemp's ridleys from the pelagic stage, conversations with tuna long-line fishermen indicate that "baby" turtles do occur in the Gulf. In either case, favorable onshore currents exist that could bring them ashore to these two areas east and west of the Mississippi Delta. Wind-driven surface currents west of the Mississippi River and the deeper, more permanent but variable loop current in the eastern Gulf may be the hydrographic features involved in transporting Kemp's ridleys from the pelagic to the coastal benthic habitat. In any event, we have recorded this size class of small Kemp's ridleys as being present in the shallow waters of the upper Texas coast and inshore waters of Louisiana and northwest Florida, and its presence supports the belief that some proportion of the population spends its entire life cycle within the Gulf of Mexico (Table 2, Figure 1).

Other physical and biological factors such as temperature, water depth and food items were studied during the course of our investigations, but the data are scanty and more data will have to be collected before we can discuss their relationships to the distribution of juvenile Kemp's ridleys with any certainty. However, a brief outline will serve to identify some of the more interesting aspects that require further study:

1. Distribution of Kemp's ridleys along the coastal United States is frequently correlated with areas abundant in portunid crabs, their primary prey species (Dobie *et al.*, 1961; Hildebrand, 1982). These areas include blue crab nursery grounds; i.e., shallow seagrass beds and shallow mud bottom bays of coastal marshes, two distinctly different coastal habitats.
2. Localities where numerous juvenile Kemp's ridleys have been reported as captured in trawls since the mid-1970s are:
   (a) Sabine River offing - Sea Rim State Park, Texas (Jake Dameron, Texas Parks and Wildlife Department, personal communication);
   (b) Caillou Bay, Terrebonne Parish, Louisiana (Larry H. Ogren, National Marine Fisheries Service, unpublished data); and
   (c) Big Gulley, east of the Mobile Bay offing, Alabama (Larry H. Ogren, National Marine Fisheries Service, unpublished data; Carr, 1980).

   These events, referred to as "jubilees" by coastal Alabamians when applied to other demersal organisms, may have been unusual in that they are thought to be correlated with high concentrations of blue crabs resulting in concentrations of foraging Kemp's ridleys. The displacement of deeper hypoxic water landward by offshore winds and a subsequent shoreward migration of demersal prey species is the most logical explanation for this phenomenon. These physicobiological events are not necessarily regular occurrences but appear to be episodic in nature (May, 1973; Renaud, 1986).
3. The shallow coastal waters of the Gulf of Mexico serve as the foraging habitat for Kemp's ridleys throughout the year. A seasonal offshore movement in response to low water temperatures is suggested. Three juvenile Kemp's ridleys, 20.0 to 47.5 cm in carapace length, were captured by trawling at depths of 21 to 29 meters during late winter to early spring (January to April) off Apalachicola Bay, Fla. Data on such offshore movement to deeper and warmer water for northern Gulf Kemp's ridleys are scanty, however.

On the Atlantic coast, coastal habitats as far north as Massachusetts are utilized by Kemp's ridleys during summer. The New England Kemp's ridleys frequently succumb to cold temperatures during November and December. Other Kemp's ridleys occurring south of Cape Cod may survive and some may migrate south to Florida to overwinter (Ogren and McVea, 1982; Henwood and Ogren, 1987).

4. Preliminary findings, albeit qualitative, suggest that the northern Gulf coast from Port Aransas, Tex., to Cedar Key, Fla., is the foraging habitat for subadult Kemp's ridleys. Historically, Florida Bay in southeastern Florida was identified as subadult Kemp's ridley habitat, but recent information is lacking in this regard (Carr, 1952).

   On the southeast coast of the U.S., Kemp's ridleys are apparently common from Cape Canaveral north to Chesapeake Bay, but they are less abundant than in the Gulf. They are found inshore only during spring, summer and fall north of a latitude *circa* 20°N. During winter they apparently migrate either south or offshore to warmer waters and are apparently much more abundant at Cape Canaveral during December to February than at any other time.

5. Turtle size and water depth relationships were observed for a large sample (n = 79) of juvenile Kemp's ridleys from northwest Florida. Most (91 percent) were captured in depths 6.1 meters or less, but all of the Kemp's ridleys less than 25 cm in carapace length, except one, were collected from depths 0.9 meters or less. This supports the belief that their exploitable foraging habitat is restricted to shallow depths because of the feeding energetics of these small individuals; i.e., their high specific metabolic rate and an aerobic diving strategy (Peter Lutz, University of Miami, personal communication).

6. Kemp's ridley captures were associated with a variety of substrates and bottom types including mud, sand, oyster shell and turtle grass (*Thalassia*). No preference was indicated except when associated with portunid crab distribution (see above).

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Distribution, Growth and Survival of Head Started, Tagged and Released Kemp's Ridley Sea Turtles (*Lepidochelys kempi*) from Year-Classes 1978-1983

Clark T. Fontaine, Sharon A. Manzella, Theodore D. Williams, Richard M. Harris and William J. Browning*

A cooperative program between the United States and Mexico was initiated in 1978 in an effort to save the Kemp's ridley sea turtle (Lepidochelys kempi) *from extinction. Participating agencies include the Instituto Nacional de la Pesca of Mexico, National Marine Fisheries Service, U.S. Fish and Wildlife Service, National Park Service and Texas Parks and Wildlife Department.*

Part of the cooperative program includes an experiment in head starting Kemp's ridleys to increase their survival during the first year of life in captivity and to establish a new nesting colony on Padre Island, near Corpus Christi, Tex. The head start research project involves removing eggs from the nesting beach at Rancho Nuevo, Mexico, hatching the eggs and imprinting the hatchlings at Padre Island, rearing the hatchlings to yearlings at Galveston, Tex., then releasing the tagged yearlings into the Gulf of Mexico. This paper discusses the releases and recaptures of the 1978 to 1983 year-classes of head started Kemp's ridleys as of September 30, 1985.

By the end of September 1985, 8,241 head started and tagged Kemp's ridleys had been released, and there had been 399 reported recoveries. Included were reports from the east coast of Mexico, the coast of the northern half of the Gulf of Mexico, the east coast of the United States as far north as New York, and from France and Morocco.

Growth of the released Kemp's ridleys was slower than that of Kemp's ridleys of the same ages held in captivity. Head started turtles survived and grew well after release, though those recovered in the Atlantic Ocean grew slower than those recovered in the Gulf of Mexico. Further, when recovery data were compared to the historical distribution of Kemp's ridleys as reported in the literature and by the Sea Turtle Stranding and Salvage Network, Archie Carr's speculation about a northern West Africa nesting site was resurrected.

The Kemp's ridley sea turtle (*Lepidochelys kempi*) is listed as endangered under the United States Endangered Species Act of 1973. In 1978, a multiagency, cooperative, conservation effort was initiated by the Instituto Nacional de la Pesca (INP) of Mexico, the U.S. Fish and Wildlife Service (FWS), the National Park Service (NPS), the National Marine Fisheries Service (NMFS) and the Texas Parks and Wildlife Department (TPWD) to work toward Kemp's ridley recovery (Klima and McVey, 1982). This program included intensive protection of eggs and turtles at the primary nesting beach near Rancho Nuevo, Tamaulipas, Mexico, and a project whose objective was to establish a second breeding colony at Padre Island National Seashore near Corpus Christi, Tex. The latter project was based on annual translocation of eggs from Rancho Nuevo to the National Seashore, incubating them there, imprinting the hatchlings to Padre Island beach and surf, then head starting the hatchlings at the NMFS Southeast Fisheries Center's (SEFC) Galveston Laboratory (Anonymous, 1978; Wauer, 1978; Klima and McVey, 1982; Caillouet, 1984; Fontaine and Caillouet, 1985). Head started Kemp's ridleys were tagged and released into the Gulf of Mexico. This paper reports observations on the distribution, survival and growth of head started and tagged Kemp's ridleys from year-classes 1978 to 1983. Manzella, Caillouet and Fontaine (1988) have recently updated the recovery information by including later year-classes.

Materials & Methods

Rearing

During each nesting season beginning in 1978, a small portion (less than 5 percent) of the eggs laid by Kemp's ridley nesters at Rancho Nuevo have been collected by personnel of the INP and FWS and their cooperators and transferred to the Padre Island National Seashore. The eggs were not allowed to touch the Rancho Nuevo sand but were caught in plastic bags then placed in polystyrene foam boxes containing Padre Island sand in hopes of imprinting the eggs

* *National Marine Fisheries Service*

to Padre Island. After incubation of the eggs in boxes within a hatchery at the National Seashore, the hatchlings that emerged were allowed to crawl across the Padre Island beach to enter the surf in hopes of strengthening or reinforcing the imprinting process. NPS personnel then collected the hatchlings with dipnets and put them in boxes to be transported by U.S. Navy or Coast Guard aircraft to the NMFS SEFC head start research facilities in Galveston where they were reared in captivity usually for 10 to 11 months before being released usually offshore of Padre Island. These yearlings had been tagged in several ways before being released into the Gulf of Mexico.

Head start facilities and husbandry methods have been described in detail by Fontaine *et al.* (1985) and Fontaine *et al.* (1989). First-year growth and survival during head starting have been described by Caillouet *et al.* (1986).

Tagging

Usually about 30 days before the annually scheduled release of head started Kemp's ridleys, all yearlings in good health and physical condition are tagged with metal flipper tags. This allows time for observations to be made on tag retention and on possible infection caused by tagging, as well as for appropriate remedial actions. It also allows time for tag-related mortality, if any, to occur before the release.

Flipper tags used on head started turtles (Table 1) were purchased from the National Band and Tag Company and were Hasco type, style 681, self-piercing, self-clinching tags. All tags were monel metal except for inconel tags used on 100 turtles of the 1980 year-class (the latter tags were obtained from George Balazs, NMFS, Southwest Fisheries Center, Honolulu Laboratory). The G- and F-series tags used on the 1978 year-class, and the K-series tags used on the 1980 year-class, were obtained from Dr. Archie Carr, and were inscribed with the message "Reward Primio Remite, Send Dept. Biol., U.F., Gainesville, Fla. U.S.A." The NNA-series through NNQ-series tags, used on the 1979 to 1983 year-classes and on one turtle of the 1978 year-class were inscribed with the message "Send NMFS Lab, Virginia Key, Miami, FL 33149." The 800-series inconel tags from Hawaii were inscribed with the message "Write H.I.M.B. University, Hawaii 96744." Two odd tags, No. 13582 (one turtle of the 1978 year-class) and J0096 (one turtle of the 1979 year-class) were also used.

Flipper tags used on the 1978 to 1981 year-classes were first soaked in gasoline for 24 hours then in 90 percent alcohol for 24 hours prior to use, without apparent problems. Tags used with the 1983 year-class were sterilized by autoclaving. The tags were applied to each turtle using a standard Hasco tag applicator. The area of tag insertion was swabbed with tincture of iodine. Neosporin, a topical antibacterial ointment, was placed on the sharp point of the tag and the tag was inserted on the trailing edge of the right front flipper. Some of the turtles were double-tagged with flipper tags; i.e., a second flipper tag was attached to the left front flipper. The double-tagging was done in hopes of increasing the chances that one of the flipper tags would be retained. However, it was recognized that if each tag had the same probability of loss, then, on the average, both would be lost about the same time. For this reason, additional tag types (internal magnetic tags and living tags) were also used on some year-classes. However, only recapture results for flipper tags are reported herein, because recovery reports from the internal tags and living tags are indeed rare events, as they require special equipment (magnetometer) or expertise to be recognized.

Release weight of each head started turtle was taken at the time of tagging so some growth could have taken place between the time the turtles were tagged and the 30 or 50 days thereafter when they were released. An O'haus "Dial-o-gram" beam balance was used for weighings to the nearest 0.1 gram. Measurements of carapace length and width were also made and were straight line measurements as recommended by Pritchard *et al.* (1983). Measurements were made to the nearest 0.1 cm, initially with a hard plastic rule and later with calipers. Data on length and width measurements are available, but only weights are included in our analyses herein.

Release

Turtles were transported to release sites (Table 1) in cardboard boxes described by Fontaine *et al.* (1985, 1989). All turtles were released in the Gulf of Mexico or in adjacent bays. Most turtles of the 1978 and 1979 year-classes were released in Florida waters, 113 of the 1978 year-class and six of the 1979 year-class were released off Texas and 197 turtles of the 1980 year-class were released from the NOAA research vessel *Oregon II* in the Bay of Campeche, Mexico. All the rest were released in Texas waters, either offshore or inshore. In 1983, 96 of the 1982 year-class turtles were released in Nueces Bay, Tex., part of the Corpus Christi Bay system near the Padre Island National Seashore. Other releases of small groups or individual turtles represented turtles held back from the major releases for a variety of reasons (e.g., due to injuries or illnesses, being too small at times of major releases, or because they were used for potential brood stock). The total tagged turtles released was 8,241, or 79.4 percent of the 10,376 imprinted hatchlings of the 1978 to 1983 year-classes received alive from NPS for head starting (Table 2).

Sources of Recoveries

Reports of head started Kemp's ridleys found in the wild were received by telephone and from correspondence from the public, the Sea Turtle Stranding and Salvage Network, Dr. Archie Carr's office at the University of Florida

Table 1. Summary of imprint groups, release sites, dates of release, numbers of turtles released and tag code series used for head started Kemp's ridley sea turtles of the 1978-1983 year-classes.

Year-class	Imprint group[a]	Release site	Release date Dy/Mn/Yr	No. Released	Tag code series[b]
1978	PINS[a]	Sandy Key, Fla.	22/02/79	135	G——
	PINS	East Cape, Fla.[c]	22/02/79	52	G——
	PINS	East Cape, Fla.	28/02/79	1	13582
	PINS	East Cape, Fla.	28/02/79	166	G——
	PINS	Sandy Key, Fla.	05/03/79	172	G——
	RN	Homosassa, Fla.	08/05/79	751	G——, F——
	PINS	Homosassa, Fla.[c]	08/05/79	628	G——, F——
	PINS	Padre Island, Tex.	07/07/79	112	G——, F——
	RN	Padre Island, Tex.	07/07/79	1	G0985
	PINS	Homosassa, Fla.	03/06/80	1	NNA260
	Subtotal			2,019	
1979	PINS	Homosassa, Fla. (offshore)[c]	03/06/80	665	NNN—
	RN	Homosassa, Fla. (nearshore)	05/06/80	66	NNA—
	PINS	Homosassa, Fla. (nearshore)[c]	05/06/80	608	NNN—, NNA—
	PINS	Padre Island, Tex.	02/06/81	5	K——
	PINS	Galveston, Tex.	28/09/81	1	J0096
	Subtotal			1,345	
1980	PINS	Padre Island, Tex.	02/06/81	1,426	NNB—, K——
	PINS	Padre Island, Tex.	02/06/81	100	8001-8100 (Inconel)
	RN	Campeche, Mexico	03/03/81	197	NNB—, K——
	Subtotal			1,723	
1981	PINS	Padre Island, Tex.	02/06/82	1,521	NNG—, NNH—
	PINS	Sabine Pass, Tex.	14/07/82	118	NNG—, NNH—
	Subtotal			1,639	
1982	PINS	Padre & Mustang Islands	07/06/83	1,159	NNL—, NNM—
	PINS	Nueces Bay, Tex.	07/06/83	96	NNL—, NNM—
	PINS	Sabine Pass, Tex.	15/07/83	69	NNL—, NNM—
	PINS	Mustang Island, Tex.	05/06/84	1	NNM428
	Subtotal			1,325	
1983	PINS	Mustang Island, Tex.	05/06/84	172	NNQ—
	RN	Mustang Island, Tex.	05/06/84	18	NNQ—
	Subtotal			190	
Year-classes Combined					
	RN			1,033	
	PINS			7,208	
Total				8,241	

[a] PINS = imprinted at Padre Island National Seashore, and
RN = imprinted at Rancho Nuevo.

[b] Monel metal tags, unless noted otherwise. Each dash represents three or four numerical digits from 0-9; actual numerical series are not given because they were mixed. Details concerning numerical series can be obtained from Sharon A. Manzella, NMFS SEFC Galveston Laboratory, 4700 Avenue U, Galveston, Tex., 77551.

[c] This release included turtles also tagged with radio-transmitters (see Klima and McVey, 1982; Wibbels, 1984).

and the Endangered Species Program Office, NMFS, SEFC, Miami, Fla. Unfortunately, in many cases, complete information was not available for each recovery.

Results

Recoveries by Year-class

Out of 399 recoveries (Table 2), 88 were excluded from subsequent summary tables and figures. These 88 turtles had been recovered in 10 or fewer days of their release. Therefore we believed such turtles were not representative due to disorientation, weakness, illness or other problems at the time of release. The remaining 311 recoveries included some turtles recovered more than once.

The condition of each turtle as to whether live or dead at recovery is shown by year-class in Table 3. Most (60.8 percent) were reported to have been alive and returned to the environment. Unfortunately, the flipper tags were removed from some of the turtles recaptured alive before they were returned to the water, so they could not be recognized and reported again as tagged turtles if recaptured. For this reason, we recommend that the message on the flipper tags be changed so that the finder clearly understands that it is important to leave the tag affixed to the turtle if it is alive. Several head started turtles whose flipper tags were not removed on first recapture were recaptured on one or more occasions.

Geographic Distribution

Reported recoveries by year-class and state or country indicated diverse geographical distribution (Table 4). The geographical distribution of recoveries was related in part to the release location (Tables 1, 5-7). For example, of the 89 recoveries from turtles released in southern Florida (1,906 from the 1978 year-class and 1,339 from the 1979 year-class) 70 (78.6 percent) were from the Atlantic Ocean, along the eastern coast of the United States as far north as New York, and at least two crossed over to Europe and North Africa. Of the turtles released in Texas (4,794 from all six year-classes), 208 (95.8 percent) were recovered from the Gulf of Mexico (Table 6). Of the 197 turtles of the 1980 year-class released off Mexico, four (80.0 percent) were recovered in the Gulf of Mexico, but one was recovered in New York (Table 7).

The wide dispersal of head started Kemp's ridleys also can be discerned by comparing same day recoveries. For instance, two turtles were recaptured on June 15, 1983, one from the 1979 year-class at Core Sound, N.C. and the other from the 1981 year-class within the Galveston Bay near Texas City, Tex. On June 4, 1981, a turtle from the 1980 year-class was recovered at Galveston and another from the 1978 year-class was recovered at Bradley Beach, N.J. On November 1, 1981, a turtle from the 1980 year-class that had been released in the Bay of Campeche was recaptured at Morgan City, La., while another from the 1980 year-class that had been released off Padre Island was recovered south of Tampico, Mexico. On November 20, 1982, a turtle from the 1979 year-class that had been at large for 893 days was recaptured in a lagoon near El Jadida, Morocco, another from the 1980 year-class that had been at large for 536 days was found stranded on the beach at Panacea, Fla., and a third from the 1981 year-class that had been at large for 171 days was recovered at South Pass, Ala.

Table 2. Summary of releases of head started Kemp's ridley sea turtles by year-class[a].

Year-class	Number of live hatchlings received	Number of tagged turtles released	Percent released[b]	Number of tagged turtles recovered[a]	Percentage recovered
1978	3,080	2,019	65.6	76	3.8
1979	1,843	1,345	73.0	21	1.6
1980	1,815	1,723	94.9	86	5.0
1981	1,864	1,639	87.9	50	3.0
1982	1,524	1,325	86.9	155	11.7
1983	250	190	76.0	11	5.8
Combined	10,376	8,241	79.4	399	4.8

[a] As of September 30, 1985, with no exclusions.
[b] Based on number of hatchlings received alive.

Table 3. Numbers of head started Kemp's ridley sea turtles of the 1978-1983 year-classes recovered live, dead or in unknown condition[a].

Year-class	Condition	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Total	Percentage by condition
1978	Live	5	27	19	9	60	83.3
	Dead	0	3	5	1	9	12.5
	Unknown	0	3	0	0	3	4.2
	Total	5	33	24	10	72	
	Percentage by season	6.9	45.8	33.3	14.0		
1979	Live	0	5	4	5	14	70.0
	Dead	0	1	1	1	3	15.0
	Unknown	0	0	1	2	3	15.0
	Total	0	7	6	8	22	
	Percentage by season		30.0	30.0	40.0		
1980	Live	4	20	18	6	48	57.1
	Dead	0	4	4	7	15	17.9
	Unknown	0	9	7	5	21	25.0
	Total	4	33	29	18	84	
	Percentage by season	4.8	39.3	34.5	21.4		
1981	Live	2	14	7	4	27	54.0
	Dead	3	8	4	3	18	36.0
	Unknown	1	1	3	0	5	10.0
	Total	6	23	14	7	50	
	Percentage by season	12.0	46.0	28.0	14.0		
1982	Live	3	21	10	1	35	44.9
	Dead	2	13	15	0	30	38.5
	Unknown	1	5	4	3	13	16.6
	Total	6	39	29	4	78	
	Percentage by season	7.7	50.0	37.2	5.1		
1983	Live	0	3	2	0	5	71.4
	Dead	0	2	0	0	2	28.6
	Unknown	0	0	0	0	0	0
	Total	0	5	2	0	7	
	Percentage by season	0	71.4	28.6	0		
Combined							
	Live	14	90	60	25	189	60.8
	Dead	5	31	29	12	77	24.8
	Unknown	2	18	15	10	45	14.4
	Total	21	139	104	47	311	
	Percentage by season	6.8	44.7	33.4	15.1		

[a] As of September 30,1985, and excluding all recoveries that occurred 10 days or less after release.

Table 4. Geographical distribution of recoveries of head started Kemp's ridley sea turtles of the 1978-1983 year-classes[a].

State or Country	Year-Class 1978	1979	1980	1981	1982	1983	Total
Mexico			3	2			5
Texas	4	2	54	21	69	5	154
Louisiana	3		17	18	9	2	49
Mississippi	1	1	2	1			5
Alabama	1			3			4
Florida	25	13	2	3			43
Georgia	6		2	1			9
S. Carolina	9	1	1	1			12
N. Carolina	17	1	1				19
Virginia	2						2
Maryland	2						2
New Jersey	1	1					2
New York	1		1				2
France		1					1
Morocco		1					1
Unknown			1[b]				1
Total	**72**	**20**	**84**	**50**	**78**	**7**	**311**

[a] As of September 30, 1985, and excluding all recoveries that occurred 10 days or less after release.
[b] An indefinite LORAN reading was the only recapture location reported for this turtle from the 1980 year-class; therefore it could not be assigned geographically.

Table 6. Relationship between recovery location (state or country) and days at large for head started Kemp's ridley sea turtles of the 1978-1983 year-classes released in Texas[a].

Days at Large	State or Country Mexico	Tex.	La.	Miss.	Ala.	Fla. (Gulf)	Fla. (Atl.)	Ga.	S.C.	N.C.	NR[b]	Total
11-49		40	2								1	43
50-99		14	1									15
100-149	1	11	1			1						14
150-199	2	3	3		1	1						10
200-249		2			1							3
250-299	1	7	2									10
300-349	1	16	9	1	1							28
350-399		26	13	1								40
400-449		10	3	1				2				16
450-499		11	3						1			15
500-549		1	3			1			1	1		7
550-599		1					1					2
600-649			1									1
650-699		1	1									2
700-749		4					1	1				6
750-799		1										1
800-849		1										1
1150-1199			1									1
1200-1249		2										2
Total	**5**	**151**	**43**	**3**	**3**	**3**	**2**	**3**	**2**	**1**	**1**	**217**

[a]See Table 1 regarding releases; recoveries as of Sept. 30, 1985, excluding all recoveries that occurred within 10 days or less after release.
[b]Not reported

Table 5. Relationship between recovery location (state or country) and days at large for head started Kemp's ridley sea turtles of the 1978 and 1979 year-classes relased in Florida.[a]

Days at large	State or Country of Recovery															
	Tex.	La.	Miss.	Ala.	Fla. Gulf	Fla. Atlantic	Ga.	S.C.	N.C.	Va.	Md.	N.J.	N.Y.	France	Morocco	Total
31-49	1				5	12										18
50-99			1		1	7										9
100-149					1	1										2
150-199					1	3										4
200-249					1		2									3
300-349	1				1											2
350-399		2				1		2	1							6
400-449		1		1	1	1		1	1	1		1				8
450-499					1	1	3		3	1						9
500-549									5				1			6
550-599														1		1
600-649									1							1
700-749								1								1
750-799			1					2	2		1					6
800-849							1	1			1	1				4
850-899								1	2						1	4
950-999								1								1
1100-1149									1							1
1200-1249									1							1
1500-1549									1							1
1550-1599								1								1
Total	2	3	2	1	12	26	6	10	18	2	2	2	1	1	1	89

[a]See Table 1 regarding releases; recoveries as of Sept. 30, 1985, excluding all recoveries that occurredin 10 days or less after release.

Table 7. Relationship between recovery location (state or country) and days at large for head started Kemp's ridley sea turtles of the 1980 year-class released in Mexico[a].

Days at large	State or Country of Recovery				
	Mexico	Texas	Louisiana	New York	Total
50-99			2		2
200-249			1		1
500-549		1		1	2
550-599					
Total		**1**	**3**	**1**	**5**

[a] See Table 1 regarding releases; recoveries as of September 30, 1985, excluding all recoveries that occurred in 10 days or less after release.

Geographical distribution of recoveries of head started turtles was compared with that of stranded Kemp's ridleys in Figure 1. The stranding data were obtained from monthly reports published by the Sea Turtle Stranding and Salvage Network (STSSN), NMFS Southeast Fisheries Center, Miami Laboratory. The stranding data in Figure 1 do not include strandings of head started turtles. In general, the pattern of geographical distribution of Kemp's ridley recoveries and that of strandings appears to be similar, with some departure for Louisiana, Florida, Virginia and Massachusetts. Only those states in which both recoveries of head started Kemp's ridleys and strandings of Kemp's ridleys had been reported were included in this comparison, although the other states in the geographic series are shown in Figure 1. Monthly frequency distributions of recoveries and strandings also were similar (Figure 2). Strandings from Massachusetts in November and December of 1981 and 1982 were excluded from this comparison because we believed at the time of writing this paper in 1985 that the sporadic occurrence of Kemp's ridley there represented aberrant behavior. Similarities in distributions of strandings and recoveries suggest the head started turtles successfully integrate themselves into the natural Kemp's ridley population after release.

When recoveries are viewed with respect to the relationships among release area (Table 1), state or country of recovery (Table 4) and days at large (grouped by 50-day intervals), interesting patterns emerge (Tables 5-7). As one might expect, dispersion widened as days at large increased. There also was an annual resurgence of recoveries (Tables 5-7), probably reflecting a seasonal phenomenon related to behavior of the turtles, seasonal fishing activity, or recreational pursuits that bring people to the coasts.

The Florida releases (Table 1) produced recoveries with the widest dispersion and greatest days at large (Table 5), as these were the oldest turtles of all year-classes. Escapement from the Gulf of Mexico to the Atlantic Ocean characterized the Florida releases, whereas the Texas and Mexico releases were characterized by a predominance of recoveries within the western Gulf of Mexico (Tables 5-7). These results became the primary rationale for discontinuation of Florida releases after the first two years of head starting in favor of releases off Padre and Mustang Islands, Tex., in hopes that the turtles would remain and mature in the Gulf of Mexico. Florida releases had been urged by some turtle biologists in the early years, because turtles of yearling size are known to have been abundant in Florida waters in the past.

Seasonal Distribution

Recoveries showed a definite seasonality (Table 3). This may be related to seasonality in commercial and sports fishing activities, environmental conditions and recreational activities along beach fronts, or a combination of these variables.

Recoveries by Year-Class

1978 Year-Class

The release and subsequent recovery of the 1978 year-class has been discussed by McVey and Wibbels (1984). Because turtles from this year-class have been at large the longest time, we examined recoveries from this year-class in greatest detail. Most (1,906 turtles, or 94 percent) of the turtles released from this year-class were released in the Gulf of Mexico off Florida (Table 1) because this area had been identified as a typical habitat of juvenile Kemp's ridleys. Of the 76 recoveries from this year-class, 57 (75 percent) were made on the Atlantic coast of the United States. As of September 30, 1985, the latest recovery from this year-class had occurred on August 18, 1983 at Hunting Island, S.C., and the turtle was alive and released. This turtle had been released into the Gulf of Mexico on May 8, 1979 at Homosassa, Fla., and had been at large for 1,563 days. Unfortunately, no lengths or weights were reported.

Recoveries of the 1978 year-class, as with other year-classes, evidently were seasonal, with most recoveries reported

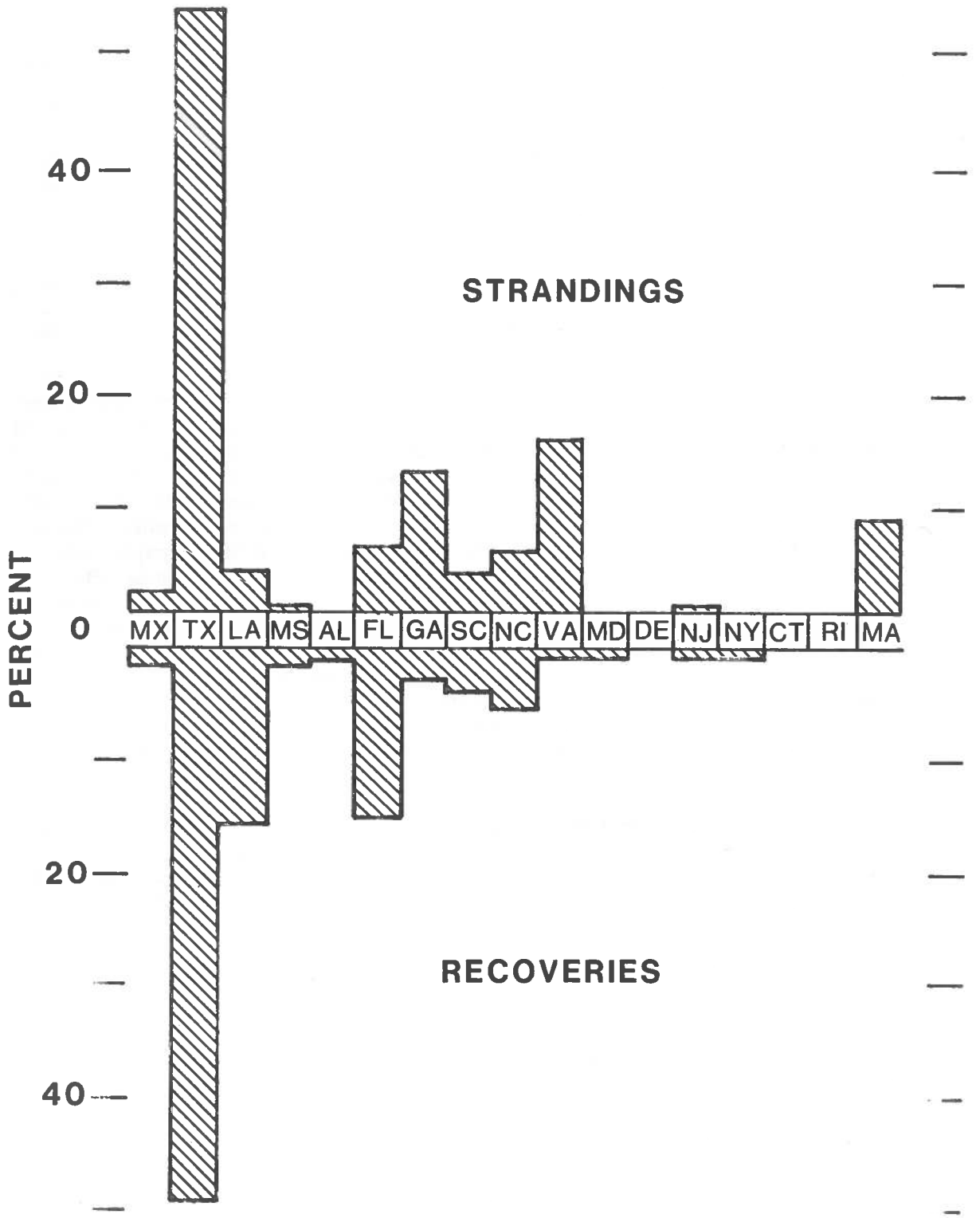

Figure 1. Comparison of geographic distributions of recoveries of head started Kemp's ridley sea turtles and Kemp's ridley strandings (data from the Sea Turtle Stranding and Salvage Network) during calender years 1979-1984.

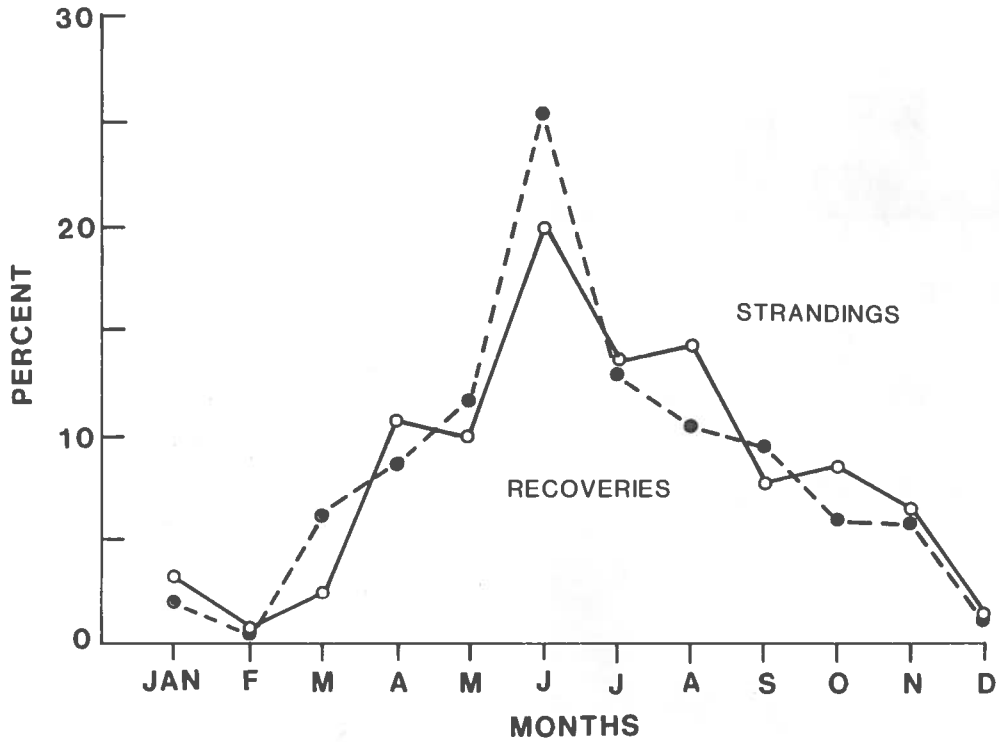

Figure 2. Comparison of monthly distributions of recoveries of head started Kemp's ridley sea turtles and Kemp's ridley strandings (data from the Sea Turtle Stranding and Salvage Network) during calender years 1979-1984.

during warm months (Table 3, Figure 3). The paucity of reported recoveries during the cold months may be linked to reduced commercial and recreational fishing and other outdoor activities, as well as possible seasonal movements of sea turtles.

Annual recoveries from the 1978 and other year-classes declined from year to year as would be expected due to mortality, but the decline could also have reflected tag loss (Figure 3). Observations on tagged turtles at private marine aquaria (Larry Ogren, NMFS, SEFC, Panama City, Fla., personal communication, October 1985) and from metal flipper tag loss studies (Henwood, 1986) on loggerhead sea turtles (*Caretta caretta*) indicate high rates of tag loss during the first two years after tagging. Such loss of flipper tags may be due to one or a combination of factors: (1) improper initial application of the tag, (2) deterioration of the tag from the corrosive action of seawater, and (3) tag sloughing due to rapid growth of the turtle in relation to size of the tag, infection leading to necrosis, or both. Nevertheless, two recoveries of the 1978 year-class were reported in 1983, five years after release (Figure 3), so the metal tags can be retained in some cases.

During 1979, turtles of the 1978 year-class were recovered only in Florida and only during the first three quarters of the year. Few recoveries were reported from October 1979 through March 1980, then in spring (April-June) and summer (July-September) of 1980 the number of recoveries increased, particularly along the east coast of the United States. Three recoveries were reported from North Carolina during winter (October-December) 1980, and none during spring (January-March) 1981. Turtles of the 1978 year-class reappeared from Georgia to New Jersey during summer-fall 1981, a period of 768 to 950 days after release and following two winters at large. Only one recovery from the 1978 year-class was reported during 1982. One recovery was reported from South Carolina in 1983 after three winters at large.

Five turtles from the 1978 year-class were recovered more than once. One (tag G0104) was recovered along the U.S. east coast on three different occasions after its release on February 22, 1979, at Sandy Key, Fla., at a weight of 0.7 kg. It was recovered 47 days later on April 10 near Miami, Fla., and weighed 0.6 kg, 0.1 kg less than at release. The turtle was in good condition and was re-released on the same day. It next appeared 730 days later on April 9, 1981 near Ocean City, Md. It again appeared in good health and was re-released on the same day (no weight or measurements were taken). The turtle was recovered a third time 56 days later on June 4, 1981 at Bradley Beach, N.J. At that time it was reported to weigh 4.5 kg, and was released on the same day. This turtle traveled from Sandy Key, Fla., to Bradley Beach, N.J., over an 833 day sojourn spanning two winters.

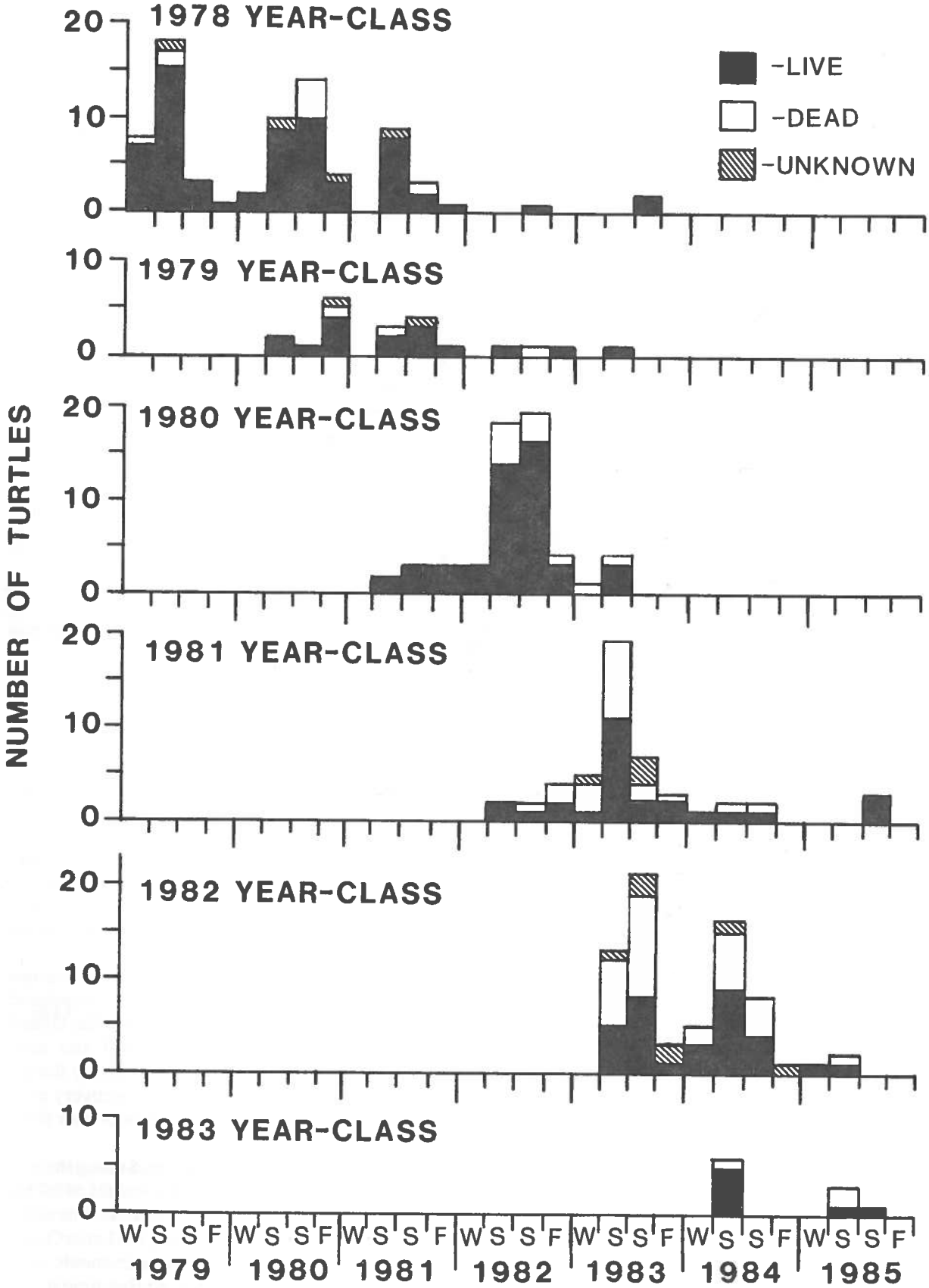

Figure 3. Seasonal distribution of recoveries of head started Kemp's ridley sea turtles, by year-class and calender year of recovery.

Four turtles of the 1978 year-class were recovered twice. One (tag G0460) was recovered first on September 25, 1979, 209 days after release at Jekyll Island, Ga., and was released; 26 days later it was recovered at the same location and weighed 3.9 kg. Another (tag G0904) was recovered on August 25, 1980, 475 days after release, at Colonel Island, Ga. It was re-released and recovered again 14 days later at the same location on September 8, 1980. The turtle was re-released in good condition, but no measurements or weight were taken. A third turtle (tag G2385) was recovered on April 4, 1980, 352 days after release, at Holly Beach, La. It was re-released and again recovered 59 days later on June 22, 1980 at Johnson Bayou, La., at which time it weighed 2.7 kg. On September 2, 1981, the fourth turtle (tag G2830) was recovered at Edisto Beach, S.C., 848 days after release. After re-release on the same day, it was found dead 20 days later on September 22 on the same beach and in the same location. It weighed 4.5 kg when found dead. From the time of its release on May 8, 1979 until it was found dead, this turtle had survived two winters.

1979 Year-Class

As of September 30, 1985, 21 (1.6 percent) recoveries had been reported from the 1979 year-class. One recovery (tag K1773) was from a turtle held into its second year in captivity before being released in 1981 with the 1980 year-class offshore of Padre Island, Tex. By September 30, 1985, the most recently recovered turtle (tag NNA001) from the 1979 year-class was recovered alive and re-released at Core Sound, N.C. on June 15, 1983. It originally had been released offshore of Homosassa, Fla., on June 5, 1980.

Two of the most interesting recoveries of head started Kemp's ridleys were from the 1979 year-class. One (tag NNN893) released offshore of Homosassa, Fla., on June 5, 1980 was recovered 568 days later at Biarritz, France on December 25, 1981 (Wibbels, 1983). It weighed 2.0 kg at the time of recovery. Another (tag NNN678) released with the first was recovered 893 days later on November 20, 1982 at El Jadido, Morocco. This turtle was found in a lagoon, wrapped in a fisherman's net, and was measured before being released. The turtle reportedly weighed 20 kilograms, and was the largest of all head started Kemp's ridley reported as of September 30, 1985.

1980 Year-Class

Included among the head started turtles released from the 1980 year-class were 197 that had been imprinted as hatchlings on the Rancho Nuevo beach. They were released in the Bay of Campeche near Arrecife Alacran, Mexico, on March 3, 1981, from the NOAA research vessel *Oregon II*. From this Bay of Campeche release, five (2.5 percent) recoveries had been reported, as of September 1985 (Table 7). Two were reported from Louisiana, within 99 days after release (Table 7). Between 200 to 249 days at large, onr more was recovered from Louisiana. The last two from this group were recovered 500 to 599 days after release; one of these was recovered at Fire Island, N.Y. on August 14, 1982.

Of the turtles released from the 1980 year-class, 1,526 (88.6 percent) were released offshore of Padre Island on June 2, 1981. All but two of the recoveries reported from this release were made in the Gulf of Mexico. One of the exceptions (tag K1495) was recovered alive at Ossabow Island, Ga. on August 19, 1982, 443 days after release, and it was re-released on the same day. The other (tag K1625) was recovered alive at Hunting Island, South Carolina on September 9, 1982 and was re-released on the same day.

The preponderance of recoveries from the 1980 year-class have been made in Texas and Louisiana (Table 4), although a few migrated to the south and east. The single most frequent number of recoveries (12) taken in one location from this year-class was near Matagorda, Tex., approximately 161 kilometers east of the release site, between 43 and 454 days after release.

1981 Year-Class

The 50 (3.0 percent of those released) reported recoveries from the 1981 year-class were made from the northeast coast of Mexico to South Carolina, but the majority of these, 39 (78.0 percent of the recoveries), were made in Texas and Louisiana (Table 4).

1982 Year-Class

Most turtles (1,159 turtles or 87.5 percent of those released) of the 1982 year-class were released offshore of Padre and Mustang Islands into drifting sargassum weed patches, with the intent of providing them with cover and an immediate food supply (Carr, 1986). However, within 10 days of release, 77 of these turtles had been found stranded on beaches within 32 kilometers of the release site. All showed evidence of contact with oil to varying degrees, and 20 were found dead. All of the dead turtles examined appeared to have ingested tar or crude oil. The 56 turtles found alive were cleansed of oil and rehabilitated, either at the Padre Island National Seashore or The University of Texas Marine Science Institute, Port Aransas, Texas. They were subsequently released offshore of Mustang Island by Anthony Amos. None of the 77 turtles stranded within 10 days of release were included in our data summaries.

Out of the total of 1,159 Kemp's ridleys released from the 1982 year-class off Padre and Mustang Islands on June 7, 1983, 24 were recovered from the Corpus Christi Bay area, one from Galveston Bay and one from Brownsville, Tex. Two of the turtles from this offshore release were recovered virtually at the exact site of the inshore release within

Nueces Bay (Table 1), one at 20 and the other at 28 days after release offshore. This suggests a selection of inshore habitat by head started Kemp's ridleys.

Seasonal distribution of recoveries of the 1982 year-class shown in Figure 3 is much like that of other year-classes. Recoveries of head started turtles from the 1982 year-class began to be reported on the western Gulf coast in March 1984 and reporting continued through the warm months of that year. This year-class was foremost among the year-classes for which reported recoveries were confined almost entirely to the western Gulf of Mexico (Table 4).

1983 Year-Class

There was a poor hatch (12 percent) in the 1983 year-class at the Padre Island National Seashore. Only 250 hatchlings that had been imprinted at Rancho Nuevo were received for head starting.

Within 10 days of the release of 190 tagged survivors on June 5, 1984, four recoveries were made. From that time to September 30, 1985, seven more recoveries were reported from the 1983 year-class (Table 4).

Growth

Growth in weight (g) was examined in head started Kemp's ridleys that were recovered after release. When carapace length but not weight was reported, the following weight-length equation from McVey *et al.* (manuscript), based on 5,064 pairs of weight and length from head started turtles ranging in size from hatchlings to 20.0 kilograms in weight, was used to estimate weights from lengths:

$$W = 0.2301\ (L^{2.882})$$

where

W = weight in grams
L = straight line carapace length in centimeters

Weights of recovered turtles are plotted against years at large (Figure 4), for two different groupings of points, one for turtles recovered in the Gulf of Mexico and the other for turtles recovered in the Atlantic Ocean. Separate exponential growth curves, one for the Gulf and the other for the Atlantic, were fitted to the data points using the following model (in logarithmic form):

$$\ln W = \ln a + bt,$$

where

W = weight in grams,
t = years at large, and
a and b are estimated parameters.

The exponential curves derived therefrom are shown in Figure 4. The slopes, b, were significantly different ($P<0.05$), and growth rate was greater in the Gulf of Mexico than in the Atlantic.

Growth in weight of captive-reared Kemp's ridleys over a six-year period at Sea-Arama Marineworld in Galveston was examined by Caillouet *et al.* (1986), and the fitted growth curve for the captive-reared turtles is drawn in Figure 4 for comparisons with curves fitted to recapture weights. Growth in captivity was more rapid than growth of head started turtles released into the wild.

Growth in turtles from different year-classes could not be validly compared because it was confounded with the effects of location (Gulf of Mexico vs. Atlantic Ocean) and because the growth histories of the different year-classes spanned different years (Figure 3).

Condition of turtles and location and method of recovery information on whether or not the animal was alive or dead at recovery was lacking in some cases, but the majority were reported to have been found alive and released (Table 3).

Recovery location of head started turtles was 54.0 percent offshore and 46.0 percent inshore, despite the fact that 98.8 percent of the turtles were released in waters seaward of the barrier islands. Only the 96 turtles released in Nueces Bay represented an inshore release (Table 1). This suggests that the turtles seek out the inshore environment, even when released offshore. The dominant methods of recovery were unknown (33.1 percent), shrimp trawl (28.9 percent), stranded dead (15.1 percent) and stranded alive (10.4 percent) (Table 8).

Percentage recovery (Table 2) probably reflects some tag loss. Also, all recoveries are not reported, and reporting rates for recoveries are not constant, either spatially and temporally, or among year-classes. We had no information to test the various effects on recovery rates. In some cases (e.g, 1982 year-class) the recovery was high (11.2 percent) because of oiling of the turtles shortly after their release. Thus, we can consider the observed recoveries to represent an underestimate for head started Kemp's ridleys released into the wild. Figure 3 depicts seasonal variation in recoveries as well as the year to year decline in recoveries.

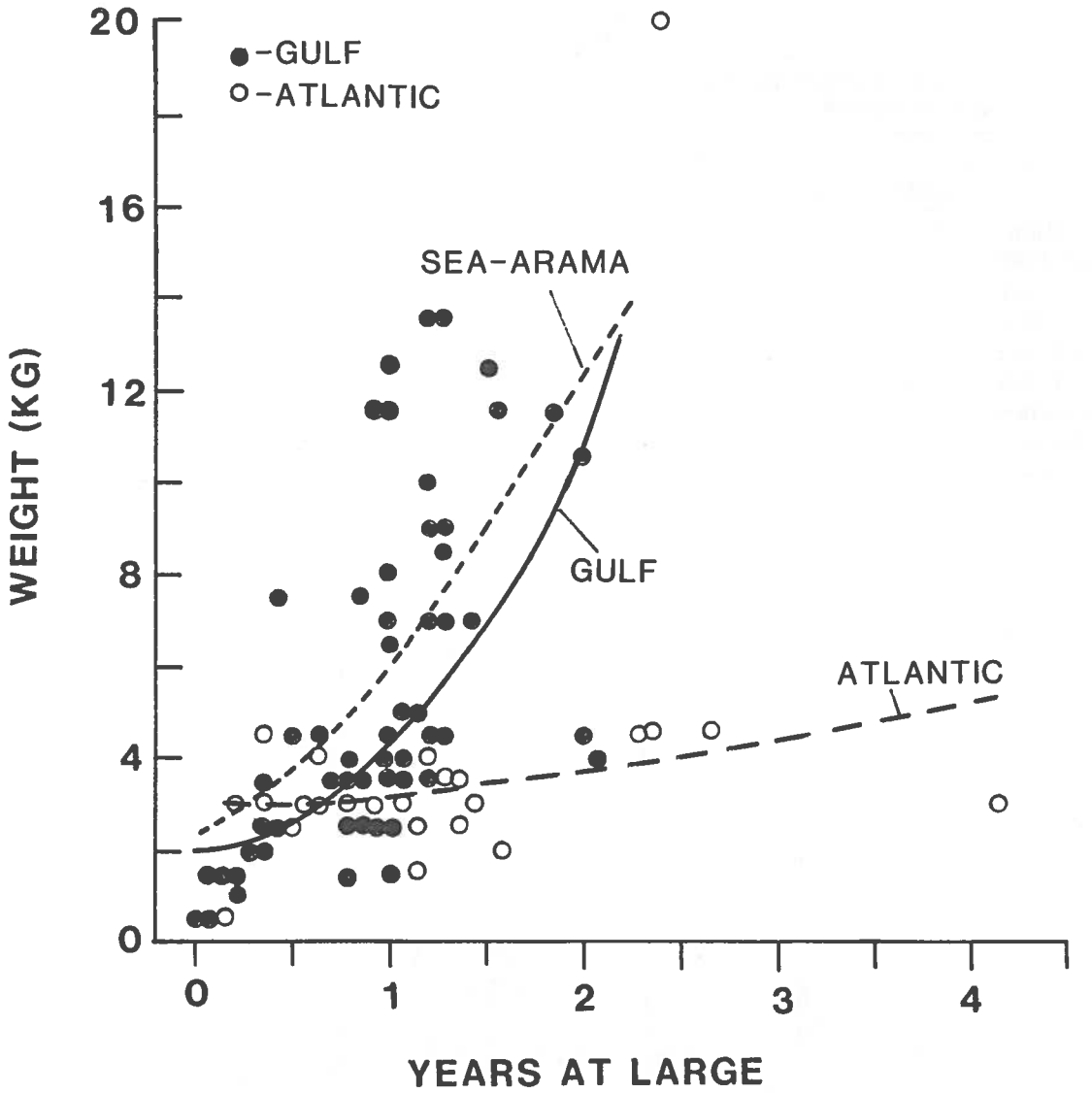

Figure 4. Scatter diagram and fitted exponential relationships between recapture weight and years at large for head started Kemp's ridley sea turtles recaptured in the Gulf of Mexico (dots and solid line) and Atlantic Ocean (circles and dashed line) as compared to growth curve for Kemp's ridleys in captivity (small short-dashed line) at Sea-Arama Marineworld, Galveston, Tex.

Discussion

Carr and Caldwell (1958) suggested that Kemp's ridley may be endemic to the Gulf of Mexico, and that records of its occurrence on the Atlantic coasts of North America and Europe are based on stragglers lost to the Gulf via the Florida current and Gulf Stream. Two major forage grounds for mature Kemp's ridleys have been identified, one in Campeche, Mexico and the other off western Louisiana (Chávez, 1968; Pritchard and Márquez, 1973). In Massachusetts waters, Kemp's ridley appears to be more common than the loggerhead, and this also seems to be the case in Nova Scotia (Dodge, 1944; Bleakney, 1965). In Virginia (Musick, 1979), most ridleys were small (<18 kg). Lazell (1976) suggested that Kemp's ridley's occurrence off New England may be cyclic and that this may be true for Virginia as well.

Carr (1963, p. 300) stated: "It is possible, for example, that the European ridley records represent waifs permanently lost to the breeding population." Carr (1967), apparently reconsidering the possibility of a nesting location south of European Atlantic waters, stated that: "no ridley of any kind is known from Morocco, Spanish Sahara, and the Canary and Cape Verde Islands, or from anywhere in the open ocean from Mauritania up to Azores." Later, Brongersma (1972) stated that: "Kemp's ridley has not been found in the southern area of France but has been recorded from Ireland, Scotland, England, Wales, Channel Islands, the Netherlands, Azores, and Madeira." All specimens from European waters have been classified as being young to about half grown. A specimen recorded from the Azores in

Table 8. Summary of recovery location, method, tag status, and turtle condition for head started Kemp's ridley sea turtles from year-classes 1978-1983[a].

	Year-class						
	1978	1979	1980	1981	1982	1983	Combined
Recovery Location							
Offshore							
Beach	9	1	11	10	43	2	76
Surf	0	1	2	1	2	2	8
Open Water	16	5	21	15	7	1	65
Other	4	1	0	2	2	0	9
Unknown	2	1	5	2	0	0	10
Inshore							
Beach	5	3	3	2	5	1	19
Surf	2	1	2	2	0	0	7
Open Water	10	0	15	5	0	0	30
Other	16	3	7	6	13	1	46
Unknown	8	4	18	5	6	0	41
Method of Recovery							
Shrimp trawl	13	1	34	24	16	2	90
Gill net	7	0	0	1	3	0	11
By hand	2	0	0	0	0	0	2
Hook and line	3	1	10	1	2	1	18
Stranded dead	5	3	10	7	20	2	47
Stranded alive	7	7	5	2	7	4	32
Unknown	35	8	26	14	20	0	103
Other	3	1	1	1	1	1	8
Tag Status[a]							
Tag left on turtle	51	14	44	25	38	6	178
Tag removed/alive	11	1	12	3	5	1	33
Tag removed/dead	0	0	4	8	10	3	25
Double tags	0	0	0	0	25	0	25
Unknown	13	6	26	14	16	0	75

[a] The listed categories are not always mutually exclusive.

1939 was estimated to be 4 months old. Mowbrag and Caldwell (1958) referred to a Kemp's ridley from Bermuda that was captured on March 31, 1949, and weighed 6.8 kilograms. However, its species identification is in doubt (Pritchard, 1969).

Brongersma (1972) stated that: "*L. kempi* breeds in the Gulf of Mexico and, as far as we know, only there. All specimens found along the North America east coast, in European Atlantic waters, in the Azores and off Madeira must have come from the Gulf of Mexico. The fact that in American Atlantic coastal waters *L. kempi* seems to be more common than *C. caretta* may perhaps be explained by *C. caretta* being a more oceanic species, the young of which at a very early age already move out into the open ocean, while *L. kempi* tends to keep to shallower water, closer to the coast. This may be one of the reasons too that fewer Kemp's ridleys than loggerheads reach European Atlantic waters. Another reason may be that the nesting beaches of *L. kempi* are further away from Europe."

On the basis of data from tagging, shrimp trawler catches, and extensive observations, Hildebrand (1982) suggested that the entire life cycle of Kemp's ridley may be completed within the Gulf of Mexico. Carr (1980) also thought this to be a definite possibility but also that it was probable that the entire population was not so contained. Small ridleys occur frequently on the coast of New England (Lazell, 1979) and Virginia (Lutcavage and Musick, 1985) which might represent a regular station in the developmental ecology of a part of the species. Carr (1980) and Witham (1980) both believed that the warm waters of the Gulf Stream supplied the northern waters with ridleys regardless of whether the young turtles emerged from the current farther south and swam north, or were transported into New England coastal waters by local eddies of, or separated from, the Gulf Stream. Unless the northern ones are lost to the population they must swim to Florida under their own motivation and efforts. Carr (1980) theorized: "The alternative possibility, that

they never go back at all, that all post-Florida ridleys may be lost waifs, is reinforced by the occurrence in European waters of juveniles even smaller than the average for the U.S. Atlantic coast. Most European specimens range in shell length from 10 to 25 cm, and they are derived from Old World nesting grounds, but *L. kempi* has none there." Carr (1980) further reinforced his belief that the Atlantic Kemp's ridleys are lost waifs never to return to the Gulf of Mexico, and concluded that if the life cycle of the Kemp's ridley is completed within the Gulf of Mexico, then "the lost year puzzle is confirmed as the most substantial of all obstacles to understanding the ecology of sea turtles." However, Carr (1986) relaxed his position regarding the lost year hypothesis after recognizing an association between juvenile sea turtles, sargassum weed and oceanic convergence zones.

Witham (1976) argued strongly for ocean current transport of young sea turtles and suggested that such currents might also be important to adult sea turtle dispersal. It has been estimated (Hughes, 1974) that hatchling sea turtles entering the sea at a Caribbean site would require four to seven years to circumnavigate the North Atlantic and return to their natal beach. On the other hand, Witham (1976) and Witham and Futch (1977) indicated that such circumnavigation could take less than one year in the North Atlantic gyre, which includes the Florida Current and Gulf Stream.

Obviously, not everyone agreed with Carr's (1955) "lost waif" theory. Pritchard and Márquez (1973) postulated that most of these young ridleys that leave the Rancho Nuevo nesting beach and are carried around the Gulf of Mexico to the Florida Keys then up the U.S. east coast as far as Canada eventually migrate back to the Gulf of Mexico to Rancho Nuevo to reproduce, even though a few are carried by the Gulf Stream to European waters. Lazell (1980) stated that "New England's sizable aggregations of marine turtles have been known to be regular, healthy migrants, rather than waifs, in New England waters since Bleakney (1965) first called attention to their robust, aggressive, and good condition." At the time Carr (1975) wrote his paper the greatest concentration of positively identified Kemp's ridleys that he had heard of, other than that at the nesting beach at Rancho Nuevo, occurred in Martha's Vinyard, Mass. Lazell (1976) noted that *L. kempi* was a regular migrant to Massachusetts waters, and Lazell (1980) wrote: "The vast majority of ridleys seen by me in New England waters were active, healthy, and fed voraciously at ambient water temperatures. The evidence available for the natural, normal, and regular presence of ridleys in summer and autumn is inferential, of course. The alternative is to believe the ridleys come here to die, or perhaps hibernate. Records for Kemp's ridleys in the Gulf of Maine region are substantial. With eight salvaged in 1978 alone, the weight of evidence argues well for these waters as a critical habitat for this desperately endangered species. It is now incumbent upon those who disagree with my interpretation of the data to muster some contrary evidence." Shoop (1980) further reinforced the idea that New England waters are potential developmental habitat by stating that: "Each year several juvenile ridleys wash up on the shore of Cape Cod Bay, apparently drowned after becoming too cold. Perhaps they are trapped in the geographical hook of the Cape as they try to migrate southward. Our guess is that the small ridleys are pushed northward in the Gulf Stream, from which they make their way to shallow bays, sounds, and estuaries where they feed on mussels and other invertebrates and then move south, perhaps maturing in the Gulf of Mexico and never returning to northern waters."

Chesapeake Bay is a seasonal foraging area for juvenile loggerheads (*Caretta caretta*) and Kemp's ridleys (Byles, 1982; Lutcavage and Musick, 1985). Stranding and sighting reports documented by Lutcavage (1981) indicated that both species are present in the bay from April through November and disappear with the advent of cold weather. Byles (1982) observed: "The turtles in the Chesapeake Bay and along the Virginia coast cannot survive the cold winter temperatures and so must either migrate to warmer waters or overwinter submerged in the sediment. The latter method of survival seems unlikely due to penetration of cold water (1-5°C) to the bottom over most of the bay and nearshore shelf."

A decline in turtle abundance during winter was apparent in the turtle fishery in West Florida (Fritts *et al.*, 1983). It was suggested that the turtles bury themselves in the mud and become dormant in the winter (Carr and Caldwell, 1956; Pritchard and Márquez, 1973). Winter dormacy of Kemp's ridleys was evident when turtles were found with mud on their backs (Ehrhart, 1980; Carr, Ogren and McVea, 1980). Kemp's ridleys have been found with loggerhead turtles in an apparent state of winter dormancy in water of 11°C in Florida (Carr *et al.*, 1980; Ogren and McVea, 1982). Dormant periods in the mud may be an adaptive response to avoid cold shock. In water temperatures of 10°C or less, ridleys become stunned and float immobile at the surface (Ehrhart, 1980; Schwartz, 1978). Ridley turtles died within 24 hours during exposure to water temperatures of 5-6°C (Schwartz, 1978). No evidence has been found of sea turtles wintering in Virginia waters (Musick *et al.*, 1983; Lutcavage and Musick, 1985).

Chesapeake Bay Kemp's ridleys are all small immatures, most being between 30 and 45 cm. Beginning in 1979, 47 ridleys were documented in Chesapeake Bay, 30 dead and 17 alive, and none between November and May (Musick *et al.*, 1983). One was a head started turtle (tag G0080) released at Homosassa, Fla., on February 22, 1979. It had traveled 2,277 kilometers, moving at an average of 5.3 kilometers per day, to Hampton Roads, Va. where it was captured alive after approximately 14 months at large (Musick *et al.*, 1983).

Of the three ridleys reported from the Indian River, Fla., (Ehrhart, 1983), two were only slightly shorter than the

smallest adult females reported by Pritchard (1969), and the third was well within the size range of adults. According to Ehrhart (1983) it seemed unlikely that these individuals could have returned to Rancho Nuevo to breed by the following spring, but a later return to the natal beach was neither suggested nor denied.

During the first Western Atlantic Turtle Symposium in San Jose, Costa Rica, in 1983, the following comment was made to the panel of sea turtle experts by Dr. C. R. Shoop (Márquez, 1983): "Since most Kemp's ridley strandings in the U.S. are along the Atlantic Coast, does the panel actually believe all of the animals are waifs? The number of juveniles along the eastern U.S. is substantial, almost all are very healthy, and the observations have been made every year. Surely, some emphasis in research on these eastern U.S. animals is in order." The discussion panel's response (Márquez, 1983) was that: "The panel does not have data to reach conclusions on the question of Kemp's ridleys on the Atlantic coast. Are they, or are they not waifs? Research is in order." A statement made by Musick *et al.*, (1983) emphasized: "Since there is a great difference in habitat preference and feeding habit (between the various sea turtles), planning should address the individual species rather than sea turtles as a general category."

The number of head started Kemp's ridleys found on the east coast of the United States is not surprising when compared to the distribution shown by the literature we reviewed and by records from the Sea Turtle Stranding and Salvage Network. Multiple recoveries of some head started turtles raise a number of questions. For instance, one head started Kemp's ridley (tag G0045) was recovered on November 25, 1980, at Core Sound, N.C. after 642 days at large. The turtle was alive and was released in good condition. It was recovered again at Core Sound 208 days later on June 21, 1981. What happened to this turtle during the winter of 1980-1981? Did it migrate to warmer waters before winter, then return to the same area when waters warmed, or did it overwinter at Core Sound? Another (tag G0104) was recovered and released on three different occasions, the first at Miami, Fla., on April 9, 1979, the second at Ocean City, Md., on April 9, 1981, and the third at Bradley Beach, N.J. on June 4, 1981. Where was this turtle during the winters of 1979-1980 and 1980-1981? A third head started turtle (tag G0914) was recovered at Beaufort, N.C. on August 20, 1980, after 470 days at large. This turtle was recovered again 1,052 days later on July 9, 1983 at Hampstead Bay, N.C. Again, where was this turtle during the intervening four winters? It was recovered twice in the same general area and dates 1,052 days apart! The turtles may migrate to warmer areas when colder weather begins to occur in the fall and then return in the spring, or they could conceivably burrow into the mud of deep bays and sounds to overwinter. It is important to conservation of Kemp's ridley to determine whether one, the other, or both occur.

The head started turtle (tag NNN893) of the 1979 year-class recovered in Biarritz, France on December 25, 1981, had been at large 568 days, for one winter and a portion of another. This turtle was small (2.0 kg) and cold-stunned when found. However, the most interesting of all recoveries occurred at El Jadida, Morocco on November 20, 1982 after the turtle had been at large for 893 days. This turtle (tag code NNN678) had survived two winters, was alive and in excellent condition when captured in a fisherman's net in a lagoon, and was reported to have weighed 20 kg Unfortunately, the flipper tag was removed and sent with the recovery information to Miami.

Another head started turtle from the 1979 year-class, held in captivity at Cayman Turtle Farm (1983), Ltd., laid eggs there in the spring of 1984. This turtle also weighed 20 kg at the time (Wood and Wood, 1984). The Rancho Nuevo nesting beach is located at 23° 11'N latitude and 97° 46'W longitude. This latitude strikes the northwestern coast of Africa just south of Golfo de Cintra, Spanish Sahara (Figure 5), approximately 1,127 kilometers south of the lagoon where the head started turtle (tag NNN678) was recovered. Carr (1957) hypothesized an Old World colony of "five-scaled" ridleys (implying Kemp's ridley) on the northern coast of West Africa, and made a flight along the uninhabitated coast from Mauretania to Morocco in search of Kemp's ridleys, but to no avail. In his continuing commentary on Kemp's ridley nesting beaches during the 1950s, Carr (1957) observed that although this species was apparently absent from the Caribbean, there is some unexplored territory there, and it still seems possible that "part of the American Atlantic ridley population could be derived from West Africa – either from somewhere within the range of the form that lives about and below the bulge, and in the Gulf of Guinea and which has predominantly six lateral laminae, or from the long extent of shore from Port Etienne to Morocco, where nothing is known of the turtle fauna."

We suggest that the area from Port Etienne to Morroco should be reinvestigated as a possible nesting site for Kemp's ridley. Not only is this area near the same latitude as that of Rancho Nuevo, Mexico, but many of the nesting prerequisites listed by Pritchard (1969) for Kemp's ridley occur there; e.g., numerous, shallow, warm water lagoons. Similar habitat exists along the northern coast of West Africa, and the numerous islands of the Arquipelago de Madeira and the Islas Canarias could provide sanctuary for small turtles.

It is clear that young juvenile Kemp's ridley sea turtles can and do exit the Gulf of Mexico and escape into the Atlantic. There they possibly enter the Gulf Stream where they can become entrapped in eddies that spin off from the main current toward estuarine areas along the east coast of the United States (Carr, 1986). Our recovery data for head started Kemp's ridleys, the published distribution records, and strandings reported by the Sea Turtle Stranding and Salvage Network all show that Kemp's ridley is common to the east coast of the United States. We do not believe that

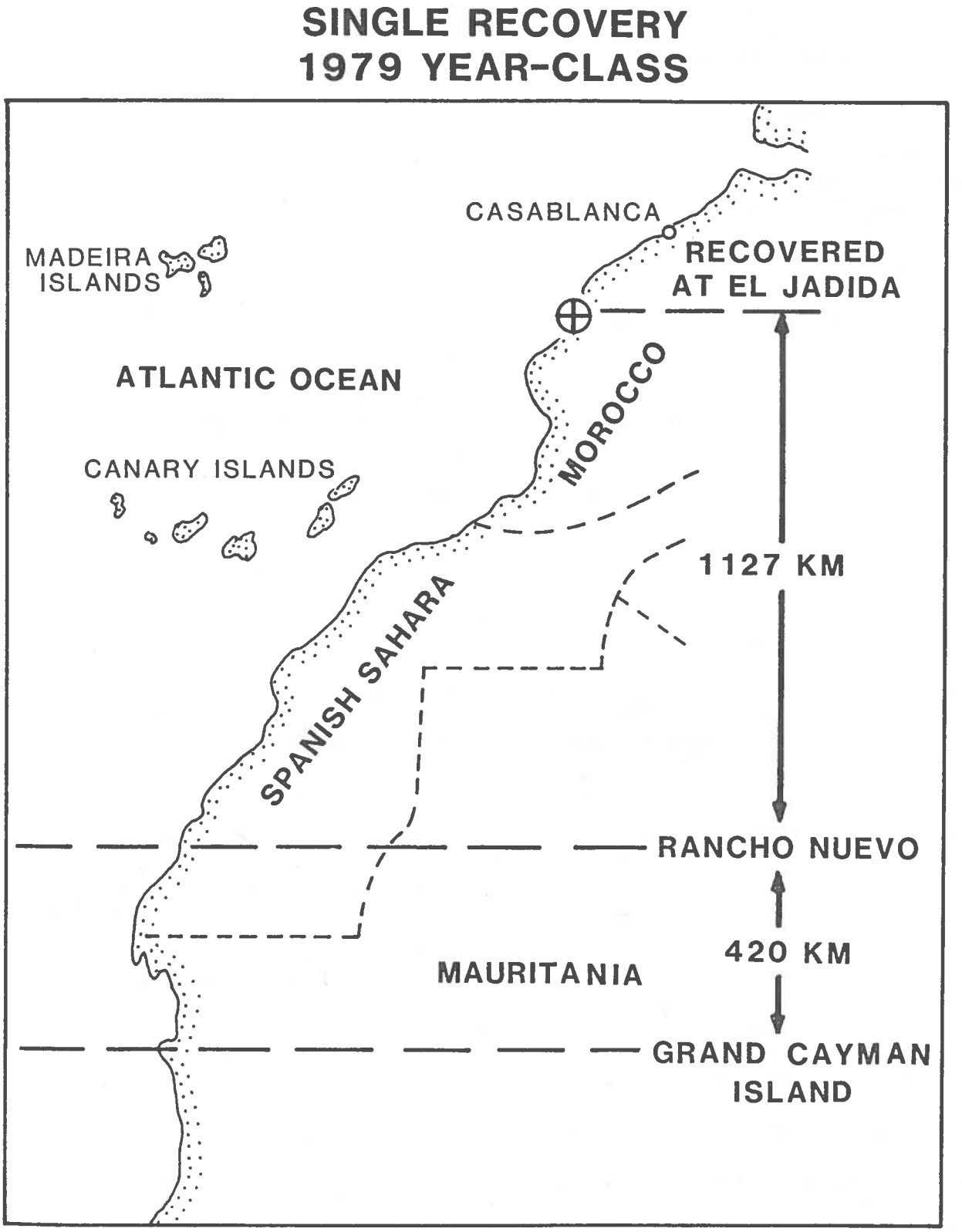

Figure 5. The northwest coast of Africa showing the northward location (latitude 33°4′ N) of the recovery of a 1979 year-class head started Kemp's ridley sea turtle as compared to locations of the Rancho Nuevo nesting beach (latitude 23°11′ N), Tamaulipas, Mexico, and the Cayman Turtle Farm (1983) Ltd. (latitude 19°3′ N), Grand Cayman Island, B.W.I.

smaller Kemp's ridleys found on the Atlantic coast are "lost waifs," but that these east coast turtles represent an integral part of the life cycle of this species. Further, from previous records and ours we know that Kemp's ridley occurs in European waters, and one of our head started turtles has been reported from the northern coast of West Africa at a reported size comparable to one that matured and nested in captivity. Therefore, it is tempting to resurrect Carr's (1955) speculation of an Old World nesting site on the northern coast of West Africa. The search should continue.

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Distribution and Abundance of Kemp's Ridley Sea Turtle, *Lepidochelys kempi*, in Chesapeake Bay and Nearby Coastal Waters

Richard A. Byles*

*Immature Kemp's ridley sea turtles (*Lepidochelys kempi*) are found on the entire Atlantic Coast of the U.S., while adults are conspicuously scarce. Ridleys in the 30-45 cm straight-line carapace length range migrate annually to Chesapeake Bay to forage, primarily on blue crabs (*Callinectes sapidus*). Differences in prey items and habitat effectively partition ridleys from co-occurring immature loggerheads (*Caretta caretta*). Ridleys inhabit extensive grass beds (*Zostera marinas *and* Ruppia maritima*) and shoal areas in the lower Bay, while the loggerheads tend to occupy deeper channels and orient toward river mouths. The extent of the grass bed utilization by ridleys throughout the entire Bay has not been examined. Both species must leave the Bay before cold winter temperatures render the Bay and nearshore Atlantic waters uninhabitable, and evidence favors overwintering areas south of Cape Hatteras, N.C. There is no evidence of brumation in Chesapeake Bay or the mid-Atlantic Bight, and bottom water temperatures of 1-4° C seem to preclude successful brumation.*

Abundance of Kemp's ridley is difficult to assess by aerial survey due to this species' small size and coloration, which blends with the aquatic background. However, abundance can be extrapolated by other means. From 1979 through 1985, among the live and dead sea turtles observed, there were 540 loggerheads and 54 ridleys, a ratio of 10:1. Loggerhead abundance in the lower Bay is conservatively estimated from aerial surveys to be 2,000-3,000 individuals per summer. Therefore, an estimate of 200-300 ridleys occupying the lower Bay per summer can be obtained as 1/10 of the loggerhead abundance in the same area per summer.

The paucity of records for adult Kemp's ridleys along the Atlantic coast of the U.S., the apparent good health of the immature specimens captured, and southerly migration during autumn lend support to the conjecture that Atlantic coastal ridleys are not waifs and may eventually return to the Gulf of Mexico. In view of the apparently low number of adults in the Kemp's ridley population, managers need to be aware of considerable numbers of juvenile ridleys that occur on the east coast of the U.S. We need to determine their contribution to the population that nests in the Gulf of Mexico. I consider the Atlantic stock of Kemp's ridley a significant portion of the genetic reservoir of the species.

* *U.S. Department of the Interior, Fish and Wildlife Service*

Dermatoglyphic Patterns on Kemp's Ridley Sea Turtle Flippers: Can They be Used to Identify Individuals?

Charles W. Caillouet, Jr., Dickie B. Revera, Marcel J. Duronslet and John Brucks *

Dermatoglyphic patterns encompass the configurations formed by dermal ridges on the palms, fingers, toes and soles of all primates. Fingerprints are the most widely known example. As applied to sea turtles, dermatoglyphic patterns are those formed by scales and intervening spaces between them on the tops and bottoms of front and rear flippers. These patterns can be replicated, examined and compared as flipper-prints.

Impressions (negatives) of flippers of 50 yearling Kemp's ridley sea turtles (Lepidochelys kempi) *of the 1984 year-class were made in moist clay, then reproductions (positives) were cast in plastic. Selected reproductions were photographed to produce flipper-prints that were compared visually.*

Introduction

Dermatoglyphics refers to patterns of the skin. The word is derived from the greek words "derma," meaning skin, and "glyphe," meaning carved work. It encompasses the configurations formed by dermal ridges of the palms, fingers, toes and soles of all primates (Ausherman *et al.*, 1973). Fingerprints are the most widely used and familiar examples. As applied to sea turtles, dermatoglyphics refers to flipper-prints.

In hopes of developing a lifetime tag for individual Kemp's ridley sea turtles (*Lepidochelys kempi*) we have been investigating the use of dermatoglyphic patterns formed by scales and intervening spaces on the tops and bottoms of front and rear flippers. Replicas (plastic casts, photographs and computer-digitized images) of flipper dermatoglyphics provide permanent records that can be examined in detail and compared. Our paper describes the preparation of such replicas and our plans for their examination and comparison.

Materials and Methods

Clay impressions were made of flippers of 50 Kemp's ridley yearlings of the 1984 year-class. They were among the same turtles designated for transfer to marine aquaria and the Cayman Turtle Farm (1983) Ltd., for extended head starting and captive propagation (Caillouet *et al.*, 1986). Therefore, captive survivors of this group are available for flipper-printing again in the future. The clay was a mixture of Velvetex and Marblex. Velvetex is a moist, white, smooth-bodied modeling clay containing no grog. It is formulated by V. R. Hood, Inc., San Antonio, Tex. for Houston Arts and Crafts, Inc., Houston, Tex. Marblex is a self-hardening clay manufactured by American Art Clay Co., Inc., Indianapolis, Ind. The mixture consisted of three parts Velvetex to one part Marblex blended to a smooth, homogeneous consistency. Blending was facilitated and proper consistency achieved by the addition of approximately 130 mm of warm tap water for each kilogram of clay used. A precise quantity of water needed cannot be given, because the amount depends on the moisture content present in the individual clays at the time of mixing. We used a Hobart model A/200 mixer to blend the Velvetex and Marblex clays. Mixing can be done by hand, but it is difficult and tiring. Once mixed, the clay can be used over and over if kept moist. The clay mixture was stored in a plastic bucket with a layer of plastic film pressed over its surface and with the lid of the bucket firmly secured as an additional safeguard against loss of moisture. In a vapor tight container, the clay will remain workable for six to eight weeks.

Clay was divided into 550-600 gram portions, each formed into a ball. Care was taken to work out any trapped air bubbles. Forming the clay into balls was facilitated by having a container of water available so that hands could be kept wet during the forming process, then in the final step the ball could be smoothed onto a shiny wet surface. The ball was placed on the shiny side of a 25 x 25 cm square of heavy freezer (wrapping) paper, and another square of the same size was placed on top of the ball, shiny side against the surface of the ball. The ball was then flatted by firm but gentle pounding with the bottom of a 25 cm cast-iron skillet (Figure 1). Any heavy, smooth-surfaced object having a diameter 5 cm greater than the desired diameter of the clay disk to be produced may be used.

* *National Marine Fisheries Service*

The flattening process produced a clay disk of uniform thickness, sandwiched between two layers of freezer paper. A 550-600 g clay ball produces a disk approximately 18 cm in diameter and 7 to 9 mm thick. The freezer paper was left in place. Two clay disks were stacked on top of one another and slipped into a 3.8 liter capacity, self-sealing, plastic (freezer) bag (Figure 2). The bags were stacked in plastic boxes with tight fitting lids. The disks may be stored in this manner in an air-conditioned room for a week or in a refrigerator for two to three weeks before use. The disks were allowed to come to room temperature before use.

Impressions of the dorsal and ventral sides of the left front flipper were made in clay. To make a flipper impression, the clay should be firm but not excessively sticky. Proper consistency may be tested by forming a smooth, marble-sized ball, then pressing it gently with a clean, dry fingertip. The clay should not stick to the fingertip and the resulting flipperprint should be well defined. At the time a flipper impression was made on a clay disk, the top sheet of freezer paper was removed, and the clay surface was smoothed with a spatula (Figure 3). The smoothed surface was then sprinkled with pure talcum powder as a mold release (Figure 4). The powder was smoothed with clean, dry fingertips so that the surface was evenly covered with a thin film of powder. The flipper from which the impression was to be made was wiped clean and gently blotted dry. A very light coating of talcum powder was applied to the flipper (this was washed off immediately after the impression was made). The code from the monel flipper tag, which uniquely identified the turtle, was written on a square of paper that remained attached to the bottom of the clay disk. The turtle was supported by one person who also held a folded paper towel against the side of the head adjacent to the flipper being impressed to prevent possible biting while the impression was being made. The impression was made by another person who positioned the flipper on the surface of the clay and applied gentle, even, downward pressure with the fingertips (Figure 5). The thicker anterior edge was pressed down first and the fingertips were carefully worked back to the thin posterior edge to avoid distortion of the impression. The soft consistency of the clay allowed the flipper to be pressed into the disk without application of undue pressure on the flipper. The person supporting the turtle then lifted the animal so that the flipper was lifted vertically from the newly formed mold to avoid smearing or distorting the impression. The designation of the side (V=ventral, D=dorsal) of the flipper so molded was written next to the impression (negatives) on the freezer paper extending beyond the perimeter of the disk (Figure 6).

The clay disks containing the impressions (negatives) were placed individually in plastic boxes with tight-fitting lids, and the junction of the lid and box was sealed with masking tape. Impressions that were to be cast within 36 hours were stored at room temperature. It is possible to store clay impressions of flippers for 7 to 10 days if they are refrigerated. However, care must be taken to prevent moisture condensate from dripping from the box lid onto the impressions during refrigerated storage.

We did not experiment with casting materials. Instead, a local representative, Ms. Deanna Hunter, of Patty Cakes, Inc., made casts (positives) from the flipper impressions. The Patty Cakes process is patented by Ms. Irene Theis of Denver, Col. It produces a plastic cast of extremely fine detail without distortion of dermal configurations (Figure 8). Before the cast was removed from the clay mold, the information written on the attached paper square was duplicated on the back side of the plastic relica. This was accomplished by using a heat-pen of the type used in wood or leather burning. A vibrating engraving tool also works well. The hardened plastic casts were removed from the mold and excess powder was removed from the clay surface with a wet towel. The paper square was removed from the back and the used disks were stored in a plastic bucket to be reworked as needed. The finished casts were stored in envelopes bearing the tag code, flipper and surface designations and date of the impression. They were filed in order by tag code.

Comparison of Flipper-prints

Initial inspection of the plastic models revealed easily discernable differences in the dermal patterns (Figure 8). Both ventral and dorsal aspects appeared equally suitable for comparison. Since it was obvious that obtaining flipper-prints from large animals and from animals in the field would ultimately require development of techniques for obtaining sharply-defined scale patterns in black and white photographs, it was decided to use the dorsal aspect of the flipper. Photographing the dorsal side would involve the least amount of effort for the photographer and, more importantly, the least amount of disturbance for the turtle.

It was difficult to obtain photographs of the plastic models with sufficient contrast to define the dermal configurations. This difficulty was overcome by using a size 4X0 Rapidograph pen to ink the indentations outlining the scales. The enhanced plastic models (Figure 8) were reproduced on acetate transparencies using an IBM photocopier (Model 20). The transparencies were superimposed on an overhead projector and projected onto a screen. This procedure allowed rapid visual comparison for differences in size, shape and arrangement of the dermal configurations. Initially, 10 prints were compared. Each print appeared to be unique to the individual sea turtle. Figure 9 is a photograph of a computer-digitized image of a flipper-cast.

Future efforts should be directed toward finding a casting plastic of equal quality and reproductive integrity to that

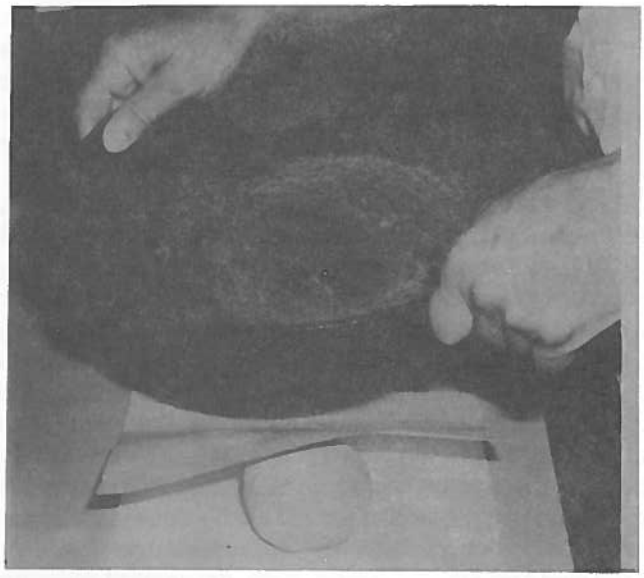

Figure 1. Flattening a clay ball with a cast-iron skillet.

Figure 2. Preparing clay disks for storage.

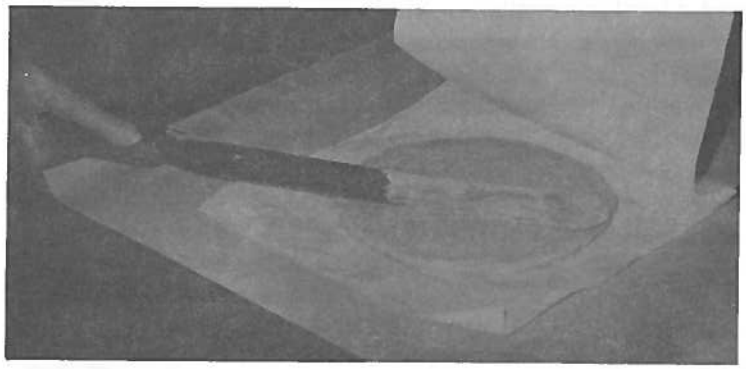

Figure 3. Preparing the surface of a clay disk at room temperature for making a flipper impression.

Figure 4. Application of talcum powder to the smooth surface of a clay disk (powder on disk and flipper surface serves as a mold release).

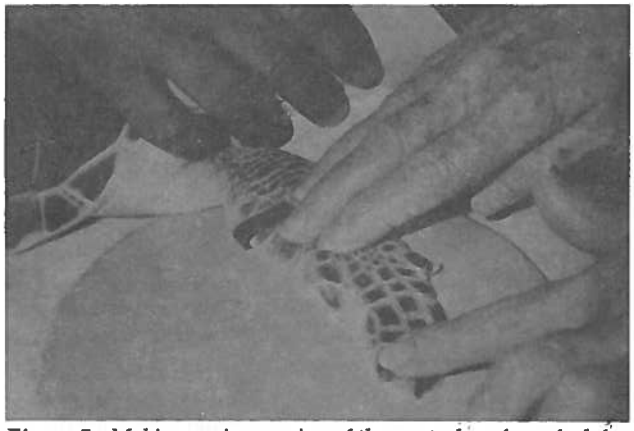

Figure 5. Making an impression of the ventral surface of a left foreflipper.

Figure 6. Impressions of ventral and dorsal surfaces of the left foreflipper of a Kemp's ridley sea turtle (flipper tag code NNT-140).

Figure 7. Reverse side of plastic models. Note flipper tag code and letter (D=Dorsal V=Ventral).

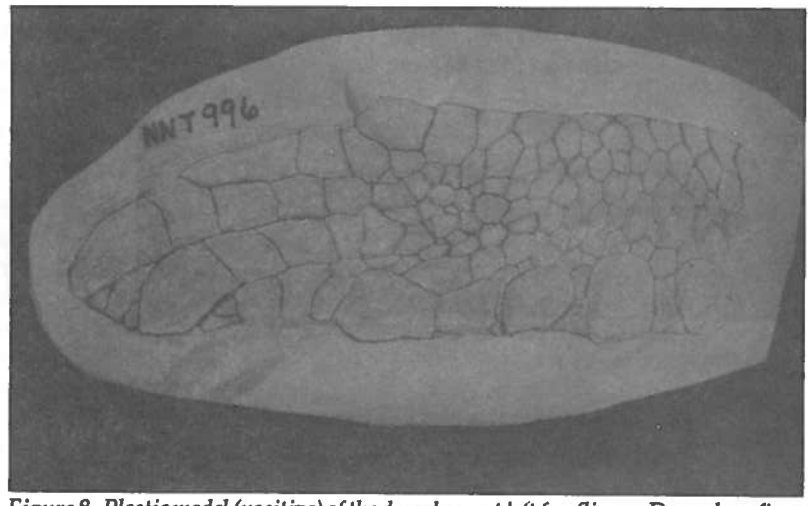

Figure 8. Plastic model (positive) of the dorsal aspect left foreflipper. Dermal configurations have been outlined, using a 4X0 Rapidograph pen, to enhance contrast for photography or computer-digitization.

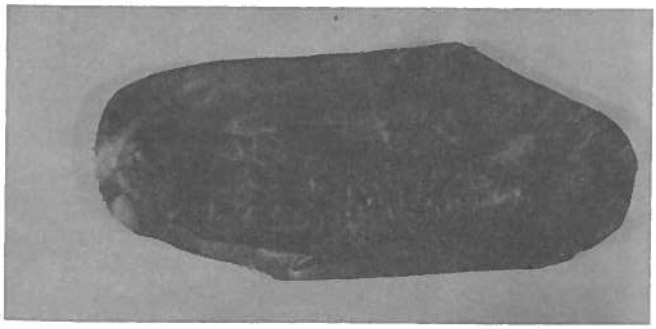

Figure 9. Photo of an unenhanced plastic model of a turtle flipper as seen by the NASA/NSTL/ERL EIKONIX Digitizer. Plastic model was made from clay impression of a foreflipper of a hatchling that was dead on arrival at the NMFS Galveston facility after transport from Padre Island National Seashore (age at time of death was three days post-hatching).

of Patty Cakes, Inc. Casts should be lightweight, durable and non-brittle, and they must harden in moist clay but not shrink or expand during hardening.

Future comparisons between flipper-prints of an individual sea turtle taken at different times must take into consideration whether growth in the flippers is isometric or allometric. Milford Fletcher's (National Park Service, personal communication) preliminary observations suggest that growth is allometric. Allometric growth will require mathematical (or graphical) transformations of flipper images prior to comparisons among prints of flippers of different sizes.

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Questions and Answers

Sally Murphy: What kind of verifications do you have that the transmitter is still attached to the turtle and is not floating or beached?

Mysing: At present, the only information that would be indicative is movement. The rate of movement of the tag and the amount of surfacing would suggest that the tag is still on the turtle. When the satellite tag was beached, I did not want to believe it, but I knew immediately because I got about 21 messages in one day. Only five messages per day is more like what one would expect. If the turtle (or tag) were adrift, the same thing would occur; i.e., more than the expected number of messages per day.

Murphy: What about cost?

Mysing: Cost is dropping. I think with two vendors we have a more competitive situation. A finished package should cost under $4,000 per unit, but cost per unit depends on the number of units one would buy.

Murphy: How many sea turtles has National Marine Fisheries Service instrumented to date?

Mysing: I am not sure, but I would say four or five. I have not been with this program the whole time it has existed. Some of the turtles were observed in captivity. I think there were only four released into the wild.

Murphy: Does that include the two Kemp's ridleys?

Mysing: Yes.

Henry Hildebrand: Did the turtle recovered off Freeport, Tex., stay in shallow water? What was the greatest water depth in which it was found?

Mysing: It was reported in about 20 feet (6.1 m) of water.

Clark Fontaine: On the two turtles you numbered one and two, you indicated that they overwintered. Do you know that they overwinterd?

Ogren: No, such data are like your recapture data. We assume the turtles stayed in the Atlantic. We do not suppose they went around here (referring to a map). We show these kinds of movements here. It might be a regular thing, but we have no way of knowing for sure what other routes they are traveling.

Fontaine: Of the turtles that go out into the North Atlantic, are they lost to the general population in the Gulf of Mexico, never to return?

Ogren: I think both happen. How was I going to state that in my summary here? We have two things going on. Those turtles that end up at Cape Cod Bay are washed ashore cold-stunned, or dead. The ones in Northern Europe are dead, cold-stunned. Those turtles that get caught up in the upper latitudes in wintertime, the ones that do not get stopped in time – I believe they are gone. These turtles that get in the Atlantic here and stay in this area manage to survive by migrating out of the coastal area and into the warmer deeper water moving south. And over on the eastern Atlantic, those turtles that go into the Canary current system and continue on downstream of the Gulf Stream get around the Azores. The loggerheads are out there living well, and there is no doubt that somehow, constantly, some of those turtles will survive also. We do not know how they get back, or which route they take back to the western Atlantic. I think we have a percentage of mortality, called waifs or whatever you want, that also have a percentage of survivors.

Captive-Reared Kemp's Ridley Sea Turtle Data Base Management

Dennis B. Koi*

Effective care of Kemp's ridley sea turtles (Lepidochelys kempi) *held in captivity for head starting depends in part on collection and maintenance of complete and accurate records covering many aspects of the turtles' lives during that period. Growth, environmental and other types of data were collected and archived since the inception of the head start project. The methods of collection of data varied with less emphasis placed on data collection in the early years of head starting compared to recent years. This was due to emphasis in early years on learning about husbandry of Kemp's ridley.*

With increasing opportunities for research in recent years, data management by computer has played an essential role, and the efficiency of collection, management and subsequent analyses of data has improved dramatically. However, due to the dynamic needs of researchers, no complete system could be developed to manage all data aspects.

The monthly system currently in use tracks each turtle's status, selects random samples for weighings, and manages the data. Frequent review and modification of computer-based data management systems are required until such time as the raising of sea turtles in captivity becomes routine.

Involved in the efforts to save Kemp's ridley sea turtles from extinction are various federal and state agencies, and private organizations, each with its own tasks and data needs. With few exceptions, regular and routine communication and sharing of data among these entities make the best and widest possible use of the information and data. As these entities' data needs are different, their needs for exchanging data may vary. The advantages and disadvantages of centralized versus distributed data management were discussed.

**National Marine Fisheries Service*

Marine Turtle Data Base Management: National Marine Fisheries Service - Miami Laboratory

Barbara A. Schroeder*

The Miami Laboratory of the National Marine Fisheries Service (NMFS), Southeast Fisheries Center, is responsible for maintaining and managing several large data bases that contain information on marine turtles. Data applicable to Kemp's ridley turtle (Lepidochelys kempi) *are found in three data bases: (1) stranding; (2) tagging (release and recapture); and (3) Western Atlantic Turtle Symposium (WATS). The stranding data base contains records of stranded sea turtles reported through the Sea Turtle Stranding and Salvage Network. The tagging data base contains release and recapture records of sea turtles tagged primarily with tags supplied by NMFS. Data included in the WATS data base were collected from countries throughout the Caribbean basin and summarized for the WATS I and WATS II symposia held in 1983 and 1987. Keeping these data bases current and maintaining their validity is largely dependent upon receiving timely and accurate records from the many sources that provide data. Status of the data bases is discussed.*

Sea turtle data bases created, maintained and managed within the Miami Laboratory of the National Marine Fisheries Service (NMFS), Southeast Fisheries Center (SEFC) were established to compile and make available data on all species of sea turtles. Availability, status and potential uses of these data are not limited to one species. Hence, it is difficult to address Kemp's ridley turtle (*Lepidochelys kempi*) specifically when discussing the data bases. For this reason the data bases are discussed herein in general terms, and specific references to Kemp's ridley are made when appropriate.

Sea Turtle Stranding and Salvage Network

The Sea Turtle Stranding and Salvage Network (STSSN) was informally organized at a special session of the World Conference on Sea Turtle Conservation held in November 1979 in Washington, D.C. A coordination and planning meeting was held during the Symposium on Behavioral and Reproductive Biology of Sea Turtles at the American Society of Zoologists meeting held in Tampa, Fla., in December 1979. The STSSN was designed to function as a cooperative effort among the U.S. Fish and Wildlife Service (FWS), the NMFS and state coordinators from various public and private agencies and universities.

The primary purpose for establishing the STSSN was to coordinate the collection and centralized management of data on sea turtles stranded along the Atlantic and Gulf of Mexico coasts of the United States. A secondary purpose was to compile and periodically distribute summary reports of reported strandings, thus making the information available to researchers and managers upon request.

Prior to the establishment of the STSSN, stranding records were compiled independently in some states, so limited data records are available in the data base for strandings during the late 1970s. In terms of more comprehensive data, 1980 was the first functional year for the STSSN. From inception of the network in January 1980 until August 1982, the NMFS SEFC was responsible for data compilation and data base management. In August 1982, under contract to NMFS, Dr. D. K. Odell, University of Miami, Rosenstiel School of Marine and Atmospheric Science (RSMAS) took over these responsibilities. Dr. Odell continued to function as the STSSN coordinator, although NMFS discontinued contract funding of the network. In 1985, NMFS again assumed responsibility for STSSN management including all data compilation.

The basic flow of information, from stranding event to data requests by users, is depicted in Figure 1. Upon notification of a sea turtle stranding, the network volunteer closest to the stranding is responsible for locating and documenting it. Documentation includes accurately recording all pertinent data on a standardized stranding data report form and disposing or permanent marking of the carcass. All or part of the specimen may be salvaged for further study, if appropriate. Live turtles are handled in a manner appropriate to the situation, but this should include an attempt to rehabilitate the turtle for future release. Completed report forms are submitted to the appropriate state coordinator who verifies the data and periodically forwards the report along with an accumulation of similar reports to the network coordinator at the Miami Laboratory.

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* *Florida Department of Natural Resources*

Numerous versions of the STSSN data report form have been used during the years the network has been in existence, and this has complicated standardization of data collection. In 1985, with input from the state coordinators and other interested parties, I revised the data report form based primarily on the format utilized in Florida and North Carolina. Acceptance and utilization of this standardized stranding report form greatly improved the quality of the stranding data. Information collected on each stranding report includes: observer, stranding date, state/county of occurrence, species, reliability of species identification, sex, sex determination method, stranding location including latitude and longitude, carapace length and width measurements, condition of turtle, tag information (if present), disposition of carcass and remarks.

As stranding reports are received at the Miami Laboratory, they are edited, coded and entered into the STSSN data base, and the original reports are filed for future reference. Quarterly stranding summaries, including an annual report, are compiled by the STSSN coordinator. These reports are distributed to STSSN participants and other interested parties.

The STSSN data base is maintained in a dBASE III Plus™ format on microcomputer. Editing of the data base began with the most recent years, progressing back in time. This back editing includes the assignment of county and remark codes to individual records. Additionally, statistical zones (shrimp statistical subareas) as defined by the current Trawling Efficiency Device (TED) regulations have been assigned to each stranding record.

A time series of sea turtle stranding records for the U.S. Atlantic and Gulf of Mexico coasts provides a valuable source of information that offers many realized and potential uses. However, certain limitations must be considered when the stranding data are analyzed and interpreted. Changes in frequency and range of beach survey coverage over time are difficult to quantify. Coverage ranges from systematic weekly (or more frequent) sampling in some areas to infrequent or no monitoring in other areas. Thus, data contained in the STSSN data base are considered minimum stranding figures, as they are reported strandings only, not all stranding events. Additionally, the relationship between reported strandings and actual at-sea mortality has not been quantified. Preliminary information suggests that a significant percentage of the coastal marine turtle mortality may not be documented by the STSSN (Ulrich, 1978; S. Murphy, South Carolina Wildlife and Marine Resources Department, personal communication).

Nevertheless, the data collected enable determination of trends based on reported strandings, and provide a wide variety of biological information about the turtles themselves. Significant changes in frequency of reported strandings or identification of areas of high numbers of strandings may indicate problems in need of attention.

Measurements of stranded turtles provide information upon which size frequencies can be compiled, but such frequencies should be interpreted in the context that some mortalities may be size-selective, thus biasing size distribution data derived from reported strandings. Strandings do indicate presence of turtles in specific areas, and such information may be useful in assessing impacts of man's activities in the coastal zone as well as natural causes of sea turtle mortality.

Stranding reports may also include information on tagged turtles that become stranded, providing an additional source for documenting recaptures. Collection of sea turtle carcasses (or parts) by network volunteers provides specimens for research (e.g., necropsies, stomach contents, museum collections, age-growth studies), and information on the incidence of such things as propeller wounds, entanglement in fishing gear, ingestion of debris or tar, external fouling by oil or tar, and fibropapillomas or other abnormalities.

It is hoped that the continuity of the stranding data base can be maintained through continued cooperation and participation of the coastal states. Both general and specific summaries of stranding data can be obtained by request from the STSSN coordinator at the NMFS SEFC Miami Laboratory.

Cooperative Marine Turtle Tagging Program

The need for a centralized clearinghouse for marine turtle tags was formally stated at the World Conference on Sea Turtle Conservation held in November 1979. The recommendation is listed as an action project under management techniques in the proceedings of the conference and reads: "Encourage the establishment of a world clearinghouse for data on all tag series used by all investigators throughout the world. To facilitate exchange of data on tag returns, and to avoid confusion resulting from duplication of tag numbers, this information should be made available to all parties involved in turtle research and conservation" (Bjorndal, 1982). In response, the NMFS SEFC Miami Laboratory, in cooperation with the Panama City Laboratory, established and maintains the cooperative marine turtle tagging program. Efforts have focused primarily on those tags carrying a NMFS return address. A tag distribution data base is maintained that logs specific tag series in use and the researcher to whom those tags were issued. We welcome and encourage others to submit information on all tag series produced and distributed, to make this data base as comprehensive as possible.

Two additional tagging data bases are compiled and maintained at the Miami Laboratory: (1) tag release records on individual turtles and (2) recapture records on individual turtles. These data files primarily contain NMFS tag

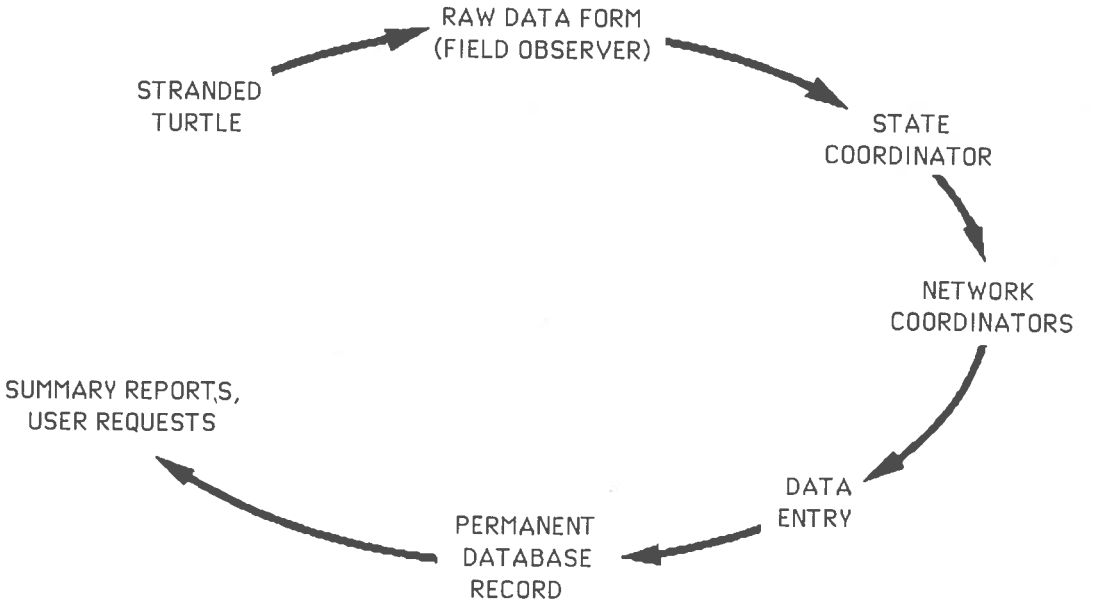

Figure 1. Sea Turtle Stranding and Salvage Network flow of data from stranding event to requests by users.

records, but we encourage the archival of non-NMFS tag series release and recapture records as well. Information contained in the tag release data base includes: data source, tag number(s), release date, state/country, county, release latitude and longitude, project type, species, sex, condition of turtle, straight line and curved carapace measurements, weight, capture latitude and longitude, coded notes, and other uncoded remarks. Recapture data base records include: tag number(s), species, recapture date, state/country of recapture, recapture county, region and statistical zone, recapture latitude and longitude, recapture method, condition of turtle, disposition of turtle, tag status, report category, original release date, release location, original tagger and remarks.

Upon notification of a recapture of a tagged turtle, we search the tag release data base for the original tagging record, send a reply letter thanking the finder for reporting the tagged turtle and providing him or her with background information on the recaptured turtle. The tag return data are entered into the recapture data base, and the recapture information is forwarded to the researcher who originally applied the tag.

The release and recapture data bases are maintained in a dBASE III Plus™ format. The NMFS SEFC Galveston Laboratory maintains independent data bases for release and recapture records of head started Kemp's ridleys. It is hoped that the existence and expansion of these data bases, especially the tag series in use data base, will bring us closer to the goals that were set forth at the World Conference in 1979.

Western Atlantic Turtle Symposium

Data on many aspects of marine turtle biology were gathered from 38 countries in the Caribbean basin by way of their submission of national reports prior to the first Western Atlantic Turtle Symposium (WATS I) held in San Jose, Costa Rica, in July 1983. Data were compiled on such topics as coastal shoreline habitat, known nesting beaches, aerial and ground surveys of nesting beaches, numbers of nesting females, numbers of foraging sea turtles, natural mortality rate estimates, utilization and socio-economic statistics, and head start and culture activities. These data constitute the WATS data base and were utilized to produce the summary tables published in the WATS I symposium proceedings. The data base was revised in February 1984 based on comments and updates resulting from the symposium. A second symposium, WATS II, was held in Mayaguez, Puerto Rico, in October 1987. The WATS data base was expanded as new national reports and data were received.

Southeast Turtle Surveys

In addition to the data bases discussed previously, information derived from a three-year pelagic aerial survey program conducted from North Carolina to Key West, Fla., is archived in the Southeast Turtle Surveys (SETS) aerial survey data base. This data base primarily contains data on loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*) turtles. Our aerial survey data base is not applicable to Kemp's ridley, except to strengthen the conclusion that Kemp's ridley is not a good subject for pelagic aerial survey work, at least not in the southeastern U.S., because of its coloration, small size, and nearshore distribution.

Summary

Development of the various sea turtle data bases maintained by the NMFS SEFC Miami Laboratory evolved from information needs related to sea turtle conservation and management. The data bases on sea turtle strandings, tagging (release and recapture), biology (WATS I and II), and aerial surveys (SETS) can contribute valuable data toward evaluating, conserving and managing sea turtle populations. We encourage participation in expansion of these data bases to make them as comprehensive and accurate as possible.

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Evolutionary Relationships, Osteology, Morphology and Zoogeography of Kemp's Ridley Sea Turtle

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Kemp's ridley (Lepidochelys kempi) *is a member of the subfamily Carettinae of the family Cheloniidae. The genus includes two species,* L. kempi *and* L. olivacea *and the subfamily also includes* Caretta caretta *and certain fossil forms. It should probably also include* Eretmochelys imbricata. *The two species of* Lepidochelys *are considered distinct at the species level on the basis of meristic differences in scutation, proportional differences in components of the skull and carapace, and no evidence of intergradation despite the presence of both species in the Atlantic system.*

Osteologically, L. kempi *is of interest in that the carapace is more completely ossified than that of other living cheloniids, with the intercostal fontanelles closing completely with maturity and the plastral fontanelles reduced to a small area around the entoplastron. Furthermore, the peripheral bones near the middle of the series on each side are unusually well-developed and wide, so that the overall carapace shape is almost circular — in many juveniles, the carapace is actually longer than wide. Zangerl argues that the small adult size, well-ossified carapace, and circular form are primitive characteristics, typical of early sea turtles lacking advanced marine specializations. However, Kemp's ridley is actually a highly migratory species, well adapted for marine life, and the broad and well-ossified shell, far from being primitive, may be widened and reinforced so that the animal can use the sides of the shell for closure of the nest. The vigorous lateral rocking of the female during nest closure is a very conspicuous trait, and one peculiar to* Lepidochelys. L. kempi *and its congener show more neural bones than any other living turtles. The primitive series of around eight neural elements is increased, usually by transverse division of individual elements, to as many as 15. Few fossil turtles show this feature; indeed, it is only known in the extinct cheloniids,* Glyptochelone suyckerbuyki *and* Procolpochelys grandaeva *from the Cretaceous and the Miocene, respectively, and conceivably was monophyletically derived in all these forms. The function of this development, if any, is unknown. Possibly the additional neural elements were introduced to reinforce the vertebral tubercles typical of half-grown* Lepidochelys *(though absent in adults). Certain fossil toxochelyids (e.g.,* Prionochelys *and* Ctenochelys*) are known in which the vertebral tubercles were extremely well developed, and each bore an additional, seemingly neomorphic, "epithecal" bone at the tip.*

Another unique feature of Lepidochelys *is the extraordinary development of the Rathke's glands, present in the inguinal region of many turtles, but present as a series of glands whose outlets penetrate each of the four inframarginal scutes on each side in* Lepidochelys. *The function of these glands is still uncertain, and their product has not been adequately analyzed, but it has been speculated that they may play a role in olfactory detection of conspecific turtles in the area, which in turn may assist in the coming-together of animals in the extraordinary simultaneous nesting assemblages or* arribadas *for which this genus is famous.*

Kemp's ridley only nests in the western Gulf of Mexico, with virtually all nesting occurring in central to southern Tamaulipas, Mexico. Adults apparently spend their lives in the Gulf, but juveniles are not infrequently encountered in U.S. Atlantic waters, and even as apparent waifs in western Europe. However, the species apparently fails to enter the Caribbean. The congeneric L. olivacea, *widespread on mainland coasts of the Indian and Pacific Oceans, also occurs in West Africa and the Guianas, from where occasional individuals swim as far west as the Lesser Antilles. No major geographic variation has been documented between* L. olivacea *populations in the three oceans where it occurs, constituting an example of the curious phenomenon that sometimes oceans seem to be more trenchant barriers than continents in sea turtle zoogeography.*

Kemp's ridley (*Lepidochelys kempi*) was described by Samuel Garman, of the Museum of Comparative Zoology at Harvard, in 1880 (Garman, 1880). He based the new species upon two adult specimens from Key West, Fla., that had been sent to him by Richard M. Kemp, a man whose name has been immortalized in the name of the species that is the subject of this symposium. Garman actually named the new species *Thalassochelys (Colpochelys) kempi*, *Thalassochelys* being the generic name then in use for the loggerhead turtle. Garman thought that his new species might be distinct at a level above that of the species, which is why he placed it in a separate subgenus, or (in the same paper) even a full genus. Garman noted that it was a widespread belief that this new turtle was commonly considered a cross between a green turtle and a loggerhead, being known as "bastard" in the Gulf of Mexico, an epithet that persists to the present in the German vernacular for the species (Wermuth and Mertens, 1961). This persistent belief in the hybrid origins of the ridley derived not just from the morphology of the animal, which in some respects might be superficially judged to be intermediate between the two species, but also because it was not known to nest, which seemed to support the

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"sterile hybrid" theory. Archie Carr (1956), in his book "The Windward Road," had to report that the nesting habits of Kemp's ridley were still unknown, and the unusual breeding habits of the species were indeed not revealed until 1961 as reported by Hildebrand (1963) and Carr (1963). Garman (1880), however, while reporting the folk beliefs of the hybrid nature of the ridley, did not subscribe to them himself. In naming the species, he considered it distinct from the loggerhead in having a short, round shell, low "humps," marginal "plates," narrow head and swollen jaws, and these are indeed good characters for recognizing the species.

Loggerheads have wider, more triangular heads, a hump or thickened area above the tail, and lack the distinctive broadening of the shell, which in Kemp's ridley apparently assists in the nest-closing process. Garman also wrote that the species was distinguished from the olive ridley (then called *Thalassochelys olivacea*) by the shape of the head, swollen jaws and the carapace scutes, although it is now known that the first two characters only separate the adults of the two species. However, the costal scute count — nearly always five on each side in *L. kempi*, but generally six to nine, and only occasionally five, in *L. olivacea* — will distinguish even the hatchlings.

Garman (1880) correctly recognized all the species of sea turtle considered valid today, and recognized none that today are considered invalid. Indeed, in addition to *L. kempi*, he described *Chelonia depressa*, although his professional interests were primarily ichthyological. However, his example was not followed by many subsequent authors. In particular, the olive ridley and the loggerhead were confused for decades in the late 19th and early 20th centuries, a misconception that perhaps reached its zenith in a paper by Gadow (1899), in which the author attempted to explain the apparent loss of scutes with ontogeny in loggerheads. Actually, his hatchlings were the multiscutate *L. olivacea* and his adults the pentecostal *Caretta caretta*.

Today, the two ridleys are considered full species, *kempi* and *olivacea* within the genus *Lepidochelys*, this generic name being considerably senior to Garman's (1880) *Colpochelys*. The specific epithet cannot be displaced by the discovery of senior synonyms since it has been officially conserved by the International Commission for Zoological Nomenclature (Opinion 660, 1963).

For example, one such senior synonym, *Testudo mydas minor* Suckow 1798, was thought by Wermuth (1956) to be based on a specimen of Kemp's ridley, although Pritchard and Trebbau (1984) summarize why it was probably based, in fact, on a specimen of the olive ridley.

Evolutionary Relationships

The genus *Lepidochelys* is placed within the Order Chelonia or Testudines (or, increasingly, the Chelonii since Chelonii Latreille, 1800, has priority over Chelonia Macartney, 1802, and Testudinata Oppel, 1811). Testudines Linnaeus, 1758, is simply a Latin plural form of *Testudo*, and thus lacks suprageneric nomenclatorial rank. Testudines Batsh, 1788, is clearly presented as a familial, not an ordinal, name, and the suborder Cryptodira. The latter allocation could be challenged, since the cryptodires are defined on the basis of certain characteristics, such as the retractile neck, not shown by sea turtles. Zangerl (1969), for example, placed the Cheloniidae in a Suborder that he called Metachelydia, whereas Gaffney (1984) proposed a complex new hierarchial classification, in which the Cheloniidae were placed in the Microorder Chelonioida, Infraorder Procoelocryptodira, Suborder Polycryptodira, Parvorder Eucryptodira, Hyperorder Daiocryptodira, Megaorder Cryptodira, and Gigaorder Casichelydia, of the Order Testudines.

The family Cheloniidae is considered not to include natural subfamilies by many authors (see Pritchard and Trebbau, 1984, for discussion). The family as a whole includes 31 genera, of which only four have living representatives. Some of the fossil genera are known from extremely fragmentary material, and in some cases names were published in the form of preliminary notices (e.g., Dollo, 1909) never followed up by a description.

There is some justification for allocating the living cheloniid genera (*Chelonia, Eretmochelys, Caretta* and *Lepidochelys*) to two subfamilies, the Cheloniinae and the Carettinae. The former subfamily would include, as a minimum, *Chelonia*, and the latter *Caretta* and *Lepidochelys*. The latter two genera show a number of distinctive common features including the triangular head, presence of two pairs of prefrontal scales, somewhat similar scalation of the crown of the head, and the insertion of an additional pair of costal scutes at the front of the series. The two genera are also linked by shared behavioral traits, such as the alternating terrestrial gait, similar egg size, and certain stereotyped features of the nesting process, such as the symmetrical, widely-spaced posture of the hindlimbs during oviposition. The placement of the hawksbill (*Eretmochelys*) however, is less clear. Some authorities place this genus close to *Chelonia* largely because of the presence of only four pairs of costal scutes and the clear-cut, non-fragmented head scales. The former character also correlates with certain other differences, such as the presence of additional anterior peripheral bones in *Caretta* and *Lepidochelys*, and the nuchal scute having contact with the first costals. However, as early as 1942, Carr (1942) pointed out a series of characteristics that linked *Eretmochelys* with *Caretta* and *Lepidochelys* rather than with *Chelonia*, and this argument remains persuasive (see Pritchard and Trebbau, 1984, for discussion).

The allocation of *Lepidochelys* to the Cheloniidae appears to be unassailable. Other sea turtle families, such as the

Dermochelyidae, Protostegidae or Toxochelyidae show different key characteristics, such as the layer of mosaic carapacial bones of the Dermochelyidae, the highly fontanelled shell, nasal bones and often absent epiplastra of the Protostegidae, and the cruciform plastron of the Toxochelyidae. The rounded, thoroughly ossified carapace of *Lepidochelys* does show strong similarity to that of *Toxochelys* and some other toxochelyid genera, but this appears to be a case of parallelism rather than of evolutionary relationship.

As has been discussed by Zangerl (1980), tracing the evolutionary history of the Cheloniidae from the Cretaceous to the present leads to the odd conclusion that the most advanced forms occurred early in the fossil record, whereas the living cheloniids are remarkably generalized in their morphology, and are seemingly primitive. This suggests that the more specialized forms were ill-adapted for changing environmental conditions, and that the unspecialized central stem of the evolving cheloniids represented the formula for survival. Moreover, among the living genera, *Lepidochelys* seems to be the most primitive on morphological grounds, although not on behavioral grounds. In this genus, for example, the gigantic size of many of the specialized sea turtles is not expressed, whilst the rounded, ossified carapace and generalized food habits mark this as an unspecialized genus. In connection with the generalized diet, *L. olivacea* appears to be quite opportunistic in its feeding habits, often being almost exclusively herbivorous in the Indian Ocean (Biswas, 1982), but in the Eastern Pacific it is generally carnivorous (see Pritchard and Trebbau, 1984, for review). However, the fragmentation of the neural bones discussed below is a rare development and almost certainly a specialized rather than a primitive one, even though a dominant theme in vertebrate evolution has been reduction rather than proliferation of discrete bony elements.

Few fossil turtles show fragmented neurals. The two fossil forms with this condition (the cheloniids *Glyptochelone suyckerbuyki* and *Procolpochelys grandaeva*, from the Cretaceous and the Eocene to Miocene, respectively, of Europe and North America) may or may not be monophyletic with *Lepidochelys*.

Osteology and Morphology

Carapace

The carapace of *L. kempi*, cordiform in the hatchlings, widens dramatically with growth, sometimes even becoming wider than long in the half-grown, and even in adults the shell width is very close to the length. The mean carapace length and width of 50 hatchling L. *kempi* were 42.05 and 33.79 mm respectively (Pritchard, 1980), giving a ratio of 1.24:1. The mean carapace length of nesting females was found to be 64.64 cm in 1966, 64.52 in 1979 and 64.85 in 1980 (Chávez, Contreras and Hernandez, 1967; Pritchard, 1981). Pritchard (1969) found the shell width of adults to average 0.969 of shell length. The overall range of carapace length for nesting females was 59-71 cm in 1980 (Pritchard, 1981). The longest carapace lengths recorded for adult females measured 74 to 74.9 cm (Pritchard, 1969).

Intercostal fontanelles are evident in the shells of subadult *L. kempi*, but they close as maturity is approached, and the carapace of the adult is thick and lacks any trace of fontanelles. There are ten rib-bearing dorsal vertebrae. In the first pair the ribs are short and extend parallel to the second pair of ribs, instead of converging and ankylosing with them as they do in many non-marine turtles. Ribs of the first pair terminate distally in a broad but non-ankylosing contact with the visceral surface of the first pleural bones.

The carapace includes eight pairs of costal bones and 11 to 13 pairs of peripheral bones. Meristic variation in the peripheral series is concentrated in the area between the wide nuchal bone and the peripheral bones perforated by the rib-tip extending from each of the first pleural bones. This section of the periphery of the carapace may be spanned by two to four peripheral bones on each side. In addition to these, the peripheral bones third-from-last in the series, situated between the rib-tips of costals VI and VII, do not make contact with any of the rib tips, and this insertion corresponds to a wider than usual separation between the rib tips of costals VI and VII. Otherwise, each peripheral bone makes contact with a corresponding costal bone via the exposed rib tip.

The neural bone series in highly variable. In general, *Lepidochelys* shows a higher neural count than any other genus of living turtles. Typically, there is alternation between octagonal and squarish or rounded neural elements, but there is much variation in shape as well as in number. On occasion there may be as many as 14 neurals. Sometimes, asymmetrical or fragmentary azygous bones may be intercalated at the sides of the neural series, or isolated neurals may be longitudinally divided. On rare occasions (Pritchard, 1969), there may be a slight posterior interruption of the neural series, with median contact between pleurals VIII, but, in sharp contrast to the situation in *Caretta*, the nuchal series is usually continuous from the nuchal bone to the suprapygals. In post-hatchlings and juveniles, the neural series is strongly tuberculate, reaching high, somewhat elongate prominences at positions corresponding to the rear of vertebral scutes I and II and a lower one at the rear of vertebral scute III. These eminences disappear entirely in adults as do the serrations along the periphery of the posterior half of the carapace.

There are two suprapygals. The suture between them is anteriorly strongly convex. In juveniles, the suprapygals, especially the rear one, are narrow, but with growth the anterior suprapygal progressively embraces the posterior one between its extending posterolateral rami. Initially, the rear suprapygal makes sutural contact posteriorly only with

the single pygal bone, but with growth it expands and makes progressively increasing sutural contact with the posteriormost pair of peripherals. The space posterior to the last pair of ribs is thus closed even when the intercostal fontanelles are still quite open.

Functional interpretation of the rounded, highly ossified carapace and the unique proliferation of the neural bones remains conjectural. Perhaps the former characteristics, as suggested above, are merely primitive. Certainly they are shared by such early sea turtles as the toxochelyids *Osteopygis*, *Thinochelys* and*Toxochelys*, as well as by the Eocene cheloniid *Puppigerus camperi* (see Weems, 1974; Zangerl, 1980). On the other hand, these two features together create a very strong and unusually extended mid-peripheral section of the carapace, and those who have watched the vigorous nest-closing behavior of this species, in which the shell is rocked from side to side so that the lateral margins of the shell alternately thump the substrate, might conclude that the development indeed had considerable functional significance. The supernumerary neurals have no obvious function in adult *Lepidochelys* and may simply reflect the action of some harmless gene, perhaps associated with the tendency towards a parallel fragmentation of scutes and scales manifested in the carapace of the congener *L. olivacea*, or in the head scales of all the Carettinae. However, it is conceivable that the additional neurals might play a role in stabilizing the vertebral tubercles that are such a striking characteristic of immature *Lepidochleys*. Certain fossil toxochelyids (e.g. *Prionochelys* and *Ctenochelys*) are known in which the vertebral tubercles were extremely well developed, and each bore an additional, seemingly neomorphic, "epithecal" bone near its tip (see Zangerl, 1953 and 1980).

Plastron

Like the carapace, the plastron of *L. kempi* is extensively ossified, so that in adults the only persistent cartilaginous areas are along the midlines of the hyo-, hypo- and xiphiplastra, and each side of the posterior dagger-like process of the entoplastron. Retention of cartilage in these areas allows the plastron a modest degree of longitudinal flexibility along the midline and along the sides where the hyo- and hypoplastra meet the mid-peripheral bones. The hyo-hypoplastral sutures in adult *Lepidochelys* develop distally to a degree that completely eliminates the lateral fontanelles present in the plastra of almost all other sea turtles. In mature *Lepidochelys*, these large plastral bones lose all of the proximal and distal interdigitations that characterize the hyo- and hypoplastra of most sea turtles, their flanks being separated from adjacent bones only by a narrow strip of gelatinous cartilage. In visceral view, the xiphiplastra can be seen to develop a process that penetrates deeply into the posterior margins of the hypoplastra. The medial junction of the epiplastra does not ankylose, presumably because of the need to retain some midline flexibility, but this junction is stabilized by considerable thickening, in a visceral direction, of the juxtaposed ends of these bones. The entoplastron remains thin and dagger-like throughout life, with a median visceral ridge in adults and extensive but non-ankylosing anterior contact with the inner edge of the proximal ends of the epiplastra. A single pair of narrow, contiguous mesoplastra has been reported as an anomaly in *L. olivacea* (Pritchard, 1966), but this has not been reported for *L. kempi*.

The plastral formula for *L. kempi*, defined as 100 times the shortest distance across the bridge (between the axillary and inguinal notches) divided by half the width of the plastron, averaged 65.0 for 11 mature females (Pritchard, 1969). Zangerl (1958) found even lower indices for two immature specimens, 55.0 and 61.9, respectively. These are unusually low values for any cheloniid, and they provide a good index to the unusually short, broad shell of *L. kempi*. Other cheloniids, from the Cretaceous to the present, may show plastral formulae of more than 90 or even more than100 (Zangerl, 1958). However, plastral formulae even lower than those for *L. kempi* were shown by some of the toxochelyids, the cruciform plastron (with very narrow bridge) being an important diagnostic of this family.

The outer margins of the hyo- and hypoplastra of *L. kempi* are penetrated by a series of pores, each of which perforates one of the inframarginal scutes (which almost always number four pairs in this species; see Pritchard, 1969), and opens into a small chamber within the bone of the plastron. These openings correspond to the Rathke's glands, present in the inguinal and/or axillary regions of many turtles, but present as a complete series of glands spanning the width of the bridge only in *Lepidochelys*. The function of these glands in *Lepidochelys is* still uncertain, although their homologues in other turtles, including the chelydrids and kinosternids, chelids such as *Chelodina*, and even emydids such as *Melanochelys*, produce a very odiferous musky secretion, instantly detectable by humans. It has been speculated that the glands of *Lepidochelys*, even though their product has no obvious odor to humans, may play a role in the turtles' detection of conspecific animals in the vicinity, which in turn may assist in the coming-together of turtles in the extraordinary simultaneous nesting assemblages or *arribadas* for which the genus is famous. The recent observation of a completely eyeless adult female *L. olivacea* participating in an *arribada* in Costa Rica (Mora and Robinson, 1982) certainly suggests that non-visual senses play an important role in *arribada*-formation.

Extremities

The forelimbs of *L. kempi* are relatively short, as compared to those of cheloniines or dermochelyids. Zangerl (1953)

reported the femur of a near-adult *L. kempi* to be 92.1 percent as long as the humerus, a ratio much higher (i.e. reflecting relatively shorter forelimbs) than those (71.8 to 79.8 percent) found for representatives of three other families of sea turtles. However, it is important to remember that this ratio changes with ontogeny, juvenile sea turtles having relatively long forelimbs. In a 26.2-cm specimen (PCHP 1978) of *L. kempi* from Barnegut Bay, New Jersey, the proportion was much lower (79 percent).

Zangerl (1953) discussed other aspects of the relative limb proportions of *L. kempi*, as well as details of the proportions of the shoulder girdles. He found the length of the scapular neck to be 46.7 percent of the length of the ventral prong of the scapular fork, and the length of the dorsal prong of the scapular fork and the maximum length of the coracoid to be 118.4 percent and 155.2 percent, respectively, of the length of the ventral prong of the scapular fork. The last ratio was much higher in the more streamlined and faster-swimming *Chelonia* and *Eretmochelys*.

The hindlimb skeleton of *L. kempi* is similar to that of other living cheloniids, and different from the fossil forms of the family, in having these limbs modified to form steering rudders (and nest hole diggers) instead of paddles to assist in propulsion. Skeletally, such a change manifests itself in a near-union of the two trochanters on the femur, which are separated by a deep valley in the fossil forms. The limbs of the living cheloniids also differ from those of the fossil ones in bony proportions and in organization of the carpus and tarsus.

Skull and vertebrae

The skull of *L. kempi* differs from that of the congener *L. olivacea* in many details (Pritchard, 1969). These include: the generally more massive construction, with heavier rhamphothecae bearing a triturating ridge on each upper tomial surface that is also reflected in the underlying bone; the smaller orbit (perhaps correlated with the diurnal nesting habit) as well as the heavier maxillae; the slight bulging of the maxillary area, a feature noticed by Garman (1880) in his original description; the much narrower pterygoid "waist" (presumably corresponding to more bulky *levator mandibulae* muscles); the more extensive secondary palate; the heavier ventrally flanged supraoccipital process; and the greater relative width of the adult skull (width averages 0.988 of the basicranial length in adult *L. kempi* and 0.909 to 0.914 in different populations of *L. olivacea*, with all *L. kempi* having a ratio of more than 0.95 and all *L. olivacea* less than this).

The lower jaws of the two species of *Lepidochelys* show numerous differences. In *L. kempi*, characteristics of the lower jaw include:

1. a bony point toward the rear of the mandibular symphysis;
2. a concave bony alveolar surface (flat in *L. olivacea*);
3. greater overall depth than in *L. olivacea;*
4. a bluntly pointed tip of the coronoid bone (rounded off in *L. olivacea)* ;
5. a relatively small *Fossa meckelii;*
6. articular surfaces somewhat backwardly directed (more vertical in *L. olivacea*); and
7. well fused bones forming the articular surfaces (the articular, prearticular, and angular) (loosely sutured and tending to be open at their antero-dorsal end in *L. olivacea*).

The cervical vertebrae of *L. kempi* are illustrated by Williams (1950). The only ginglymoidous articulation is that between cervicals VII and VIII. However, the character of this joint is variable and sometimes ill-defined. The anterior facet may be laterally cylindrical rather than truly doubled, and it is even possible for a double convex facet to articulate with a single (laterally elongated) concave facet, presumably because the ginglymoidous bony articular surface had a cartilaginous surface in life, whose contours masked the separation of the paired bony convexities. Other features of the morphology of *L. kempi* are presented elsewhere (Caillouet *et al.*,1986; Landry, 1989; Mast and Carr, 1989), and need not be discussed further here.

Zoogeography

Most sea turtle species are nearly circumglobal in distribution, and *L. kempi* is thus a conspicuous exception. It apparently replaces *L. olivacea* in the Gulf of Mexico and northwestern Atlantic, much as *Chelonia agassizi* replaces *C. mydas* in the eastern Pacific. As is now well known, the nesting distribution of *L. kempi* is uniquely concentrated. Carr (1963) used the term "panspecific reproductive convergence" to refer to the extraordinary gathering of mature females of this species each spring along the coast near the village of Rancho Neuvo in the south of Estado Tamaulipas, Mexico to nest along a few tens of kilometers of the almost continuous sand beach that fronts the western Gulf of Mexico. Sporadic and individual nesting emergences have been reported from Padre Island, Texas and the coast of Estado Veracruz, but even collectively these nestings represent a very low level of activity. It remains possible that another *arribada* of *L. kempi* exists somewhere in the world. For example, the small group of nesting animals that emerged at Washington Beach just south of the Rio Grande some years ago would have gone unnoticed had this not

been a resort beach, as the tracks are so ephermal and the nesting emergences themselves so brief that nesting can easily be overlooked. However, for the time being, we must proceed on the assumption that the Rancho Nuevo site is the only location where *L. kempi* nests regularly and in significant numbers.

Mature *L. kempi* have been found only in the Gulf of Mexico. The report by Chávez and Kaufmann (1974) of an individual nesting in Caribbean Colombia almost certainly represented a misidentified *L. olivacea* tagged in the Guianas (Pritchard and Trebbau, 1984). Moreover, such adults are not uniformly distributed in Gulf waters, as outside the nesting season they are commonly encountered in biologically productive, estuarine situations such as the coast of Louisiana near the mouth of the Mississippi River, or the Laguna del Carmen area of Estado Campeche, as evidenced by tag returns of individuals tagged while nesting (Chávez, 1968; Pritchard and Márquez, 1973). The immature animals, on the other hand, frequently leave the Gulf of Mexico, and are (or were) commonly found on the Atlantic coast of Florida, and in appropriate embayments and protected coastal habitats as far north as New England (Pritchard, 1969). Bleakney (1955) even reported four specimens from Nova Scotia. Occasionally, individuals may reach Europe. Brongersma (1972) listed 25 records of *L. kempi* in European Atlantic waters, and it is of interest that two of the animals head started in Galveston were picked up in France and Morocco (Fontaine *et al.*, 1989). Brongersma and Carr (1983) discussed the single known Mediterranean record, a 29.4 centimeter specimen from Malta.

There continues debate as to whether the animals in U.S. Atlantic waters, especially in the northern section, are lost to the population, or are indulging in a normal (or at least optional) part of their developmental odyssey. Specimens as far north as Chesapeake Bay are known to travel out of the Bay to Florida waters as part of a seasonal migration to escape winter temperatures (Musick *et al.*, 1983). Musick *et al.* (*ibid.*) identified 47 *L. kempi* (as well as 664 *Caretta caretta* and eight *Dermochelys coriacea*) in a study of sea turtles in Chesapeake Bay. Many of these animals they found dead; fewer than 20 percent of the mortalities could be attributed positively to entanglement or incidental catch in fishing operations, although doubtless this occurred in many other cases but proof was lacking. Winter strandings were almost non-existent, but there was a minor surge of strandings in June of each year, which to Musick *et al.* (1983) was possibly attributable to poor physical condition of many turtles resulting from suboptimal conditions during winter followed by an arduous migration to the bay. These authors found no evidence of turtles overwintering in Virginia waters, and although winter torpor has now been documented for both *Caretta caretta* (in Florida) and *Chelonia agassizi* (in the Gulf of California), the evidence for this in *L. kempi* remains anecdotal and unproven. A series of 29 Virginia *L. kempi* showed an average carapace length of 40.0 cm, with 75 percent between 30 and 45 cm.

Ridleys occur regularly, although infrequently, in waters north of Virginia. Carr (1957) reported an extraordinary observation made by W. Schevill of Woods Hole Oceanographic Institution, of several dozen yearling ridleys, out of "a whole fleet of such turtles," being stranded on Woods Hole beaches while travelling out of Buzzards Bay into Vineyard Sound. Lazell (1976) reported 16 specimens of *L. kempi* from waters of Cape Cod and associated islands, and he commented that presence of large numbers of immature *L. kempi* in Massachusetts waters may have been cyclic, adding that the last major inundation was in 1961, a time, he postulated, that corresponded to the beginnings of the decline of the great *arribadas* at Rancho Nuevo.

Nevertheless, such invasions may still occur on a limited scale. An anonymous reporter (Anonymous, 1985) related that no fewer than 36 *L. kempi* as well as three *C. caretta* and three *Chelonia mydas*, were found in Long Island Sound, New York, in fall of 1985, and doubtless more were found during the ensuing winter. The largest ridley was reported as less than 30 centimeters in "diameter". No mention was made of their being tagged, so they probably did not derive from the Galveston head start project. Maigret (1983) gave a brief description of an enormous flotilla, numbering thousands of *L. kempi* each about 30 cm in carapace length, of which 75 were captured for examination. This was reported to have occurred in May 1982 at a location defined by the coordinates 33°N, 74°W, which corresponds to the northwestern Atlantic, between North Carolina and Bermuda. However, subsequent correspondence between Dr. Maigret and myself first revealed to me that this concentration of turtles was on the other side of the Atlantic, off northwestern Africa (as the title of the paper implied). The given latitude of 74 °W had been a misprint for 14°W, deriving perhaps from the European custom of writing the number "1" similar in form to the number "7" in U.S. or British orthography. Moreover, Dr. Maigret kindly agreed to seek confirmation of the identity of the turtles, and was ultimately able to locate a specimen that had been kept and preserved. He sent me a series of photographs, and the specimen shown was unquestionably a loggerhead (*Caretta caretta*)!

Whether *L. kempi* is evolutionarily closer to the ancestral generic stock than is *L. olivacea* is a matter for conjecture. However, while many of the differences between the species are a reflection of the more durophagous diet of *L. kempi*, the difference in the scute configurations is more difficult to explain. Certainly the multiscutate condition of *L. olivacea* appears to be the derived condition — it is indeed unique, both in the high numbers of scutes (especially costals) borne by almost any representative of this species, and in the extraordinary degree of intraspecific variability. The subject is discussed further by Pritchard (1969), Hill (1971), and Mast and Carr (1989). On the other hand, this proliferation of scutes can occur in other turtle species, including freshwater and land forms, in cases where the animals were

hatched artificially under stressful conditions of temperature or humidity.

Pritchard (1969) presented some conjecture as to how *L. kempi* may have arisen by isolation of an early *Lepidochelys* stock in the Gulf of Mexico following the closure of the Isthmus of Tehuantepec. Although the Caribbean route remained theoretically open to reinvasion (or escape), this was not utilized because of the long reach of inappropriate habitat in the Caribbean, *Lepidochelys* flourishing in areas little frequented by *Caretta* and requiring productive estuarine conditions for optimal feeding. Between the mouth of the Orinoco (an important feeding ground for *L. olivacea*) and the Laguna del Carmen in the Gulf of Mexico, a stretch of thousands of kilometers, there are no major estuaries, the rivers of the Caribbean Islands being too small to produce them, the mainland shores of western Venezuela, Colombia, and the Yucatan Peninsula too dry, and the watersheds of Caribbean Central America too restricted by the narrowness of the coastal lowlands in these countries.

Hendrickson (1980) presented an intriguing hypothesis regarding the zoogeography of *L. kempi*, arguing that the species was isolated in Gulf waters following the relatively recent closure of the marine passage through Panama, 3.5 to 4 million years ago, rather than that of the Isthmus of Tehuantepec. Hendrickson also hypothesized that the closing of the Panamanian portal may have been accompanied by a major redirection of ocean currents, the Atlantic North Equatorial Current now being denied access to the Pacific and instead sweeping northward and clockwise with greatly increased force. He further theorized that the presence of this new current might have constituted a chronic stress upon populations of *L. kempi* by sweeping relatively large numbers of immatures completely out of the Gulf of Mexico, to the eastern seaboard of the U.S. and ultimately, in some cases, to the British Isles and northern Europe. He expressed doubt that these individuals were ever able to make their way back to the Gulf of Mexico to join in the reproductive effort of the species.

The last question remains open. Certainly the adults of *L. kempi* seem to be able to resist drifting outside the Gulf of Mexico, and not a single adult has been reliably recorded from extra-Gulf waters. It is possible that juveniles that are not carried too far north on the Atlantic seaboard are ultimately able to return to the Gulf and reproduce, but perhaps specimens in Canadian or European waters are truly lost. If specimens in U.S. Atlantic waters were able to survive but were not able to return to the Gulf the question arises as to what they would do when they reached maturity, as regards egg production and oviposition. In other words, why do they not nest alongside *Caretta* on southeastern Atlantic beaches? A fair proportion of the specimens of *L. kempi* found in Atlantic waters of Florida are healthy animals only a few centimeters short of mature carapace lengths, and it seems unlikely that such individuals would inevitably die before actually reaching maturity, having survived all dangers up to that point. However, since they do not occur in Atlantic waters as adults, I am inclined to believe that they are capable of returning to the Gulf to reproduce. Sea turtles have evolved with ocean currents as a constant factor in their lives ever since their ancestors first took to the sea, and it seems improbable that *L. kempi* has not yet learned to cope with them. Additional efforts to tag Kemp's ridleys on the Atlantic seaboard may help settle this long-standing issue.

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Feeding, Growth Rate and Survival of the 1984 Year-Class of Kemp's Ridley Sea Turtles (*Lepidochelys kempi*) Reared in Captivity

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*A feeding experiment was conducted between August 22, 1984 and February 28, 1985 on the 1984 year-class of Kemp's ridley sea turtles (*Lepidochelys kempi*). Hatchlings were assigned to three treatments in a randomized block design. The treatments included two levels of feeding, high and low, represented by feeding rate (percentage of body weight per turtle per day) and food ration (weight of food per turtle per day). The high level began at 1.3 times the low level in terms of weight of food per turtle per day, and reached 2.5 times the low level by the end of the experiment. At the high level, two feeding frequencies were tested, once-daily in the morning versus twice-daily in morning and afternoon. For twice-daily feeding, the daily ration was divided into two equal portions. At the low level, only once-daily feeding was tested. Response variables included feeding rate, food ration, survival, gross food conversion efficiency, weight gain and a growth rate index. Temperature, salinity and pH were monitored during the experiment.*

Turtles that received the most food had the highest weight gains and growth rate indices. However, for the high level of feeding, turtles receiving the entire daily ration in one feeding per day had a smaller daily weight gain than those in which the daily ration was divided into two separate feedings. There was no apparent difference in the response to once-daily vs. twice-daily feeding (at the high level) as measured by the growth rate index.

Gross food conversion efficiency was either better (lower amount of food fed per unit increase in weight of turtle) at the low level of feeding or did not differ from that at the high level of feeding.

The experimental feeding levels and frequencies had no apparent effect on survival, and overall survival during the experiment was very high (95.8 percent).

Approaches used in the Kemp's ridley sea turtle (*Lepidochelys kempi*) recovery program include experimental head starting to establish a new nesting colony of Kemp's ridleys at the Padre Island National Seashore bordering the Gulf of Mexico near Corpus Christi, Tex. (Klima and McVey, 1982). Head starting involves collecting, incubating and hatching the eggs, imprinting the hatchlings and rearing the turtles from hatchlings to yearlings (9 to 11 months of age) in captivity (Mrosovsky, 1983; Caillouet, 1984; Fontaine *et al.*, 1985). Survivors in good condition and health are tagged and released into the Gulf at a size that, according to the current working hypothesis, improves their chances of survival as compared to that of wild hatchlings.

Among the objectives of experimental head starting has been the improvement of captive rearing methods. This paper describes a feeding experiment conducted on Kemp's ridleys of the 1984 year-class to determine the effects of feeding level and frequency on their growth rate, gross food conversion efficiency and survival in captivity.

Hatchlings

Padre Island-imprinted Kemp's ridley hatchlings from 19 clutches of the 1984 year-class (see Caillouet *et al.*, 1986a, Tables 3-13 and 15) were transferred from the Padre Island National Seashore to the head start facilities at the Galveston Laboratory from July 24-27, 1984. The eggs from which these hatchlings were obtained had been collected in the usual way from the beach at Rancho Nuevo. The eggs were packed in polystyrene foam boxes containing sand from the Padre Island National Seashore, with one clutch per box. Boxes containing the eggs and sand were flown by single-engine aircraft to the National Seashore were they were tended by NPS personnel during incubation. Upon emergence, the hatchlings were imprinted by brief exposure to the Padre Island beach and surf.

Clutches of hatchlings were placed in wax-coated, corrugated cardboard boxes for shipment to Galveston. Some of the boxes containing hatchlings were transported by NPS station wagon from the National Seashore to the U.S. Navy Base at Corpus Christi, and thence to Galveston's Schole's Airfield aboard a U.S. Navy aircraft. The boxes were then transferred by pick-up truck to the head start facilities. Other boxes were transported by NPS station wagon from

* *National Marine Fisheries Service*

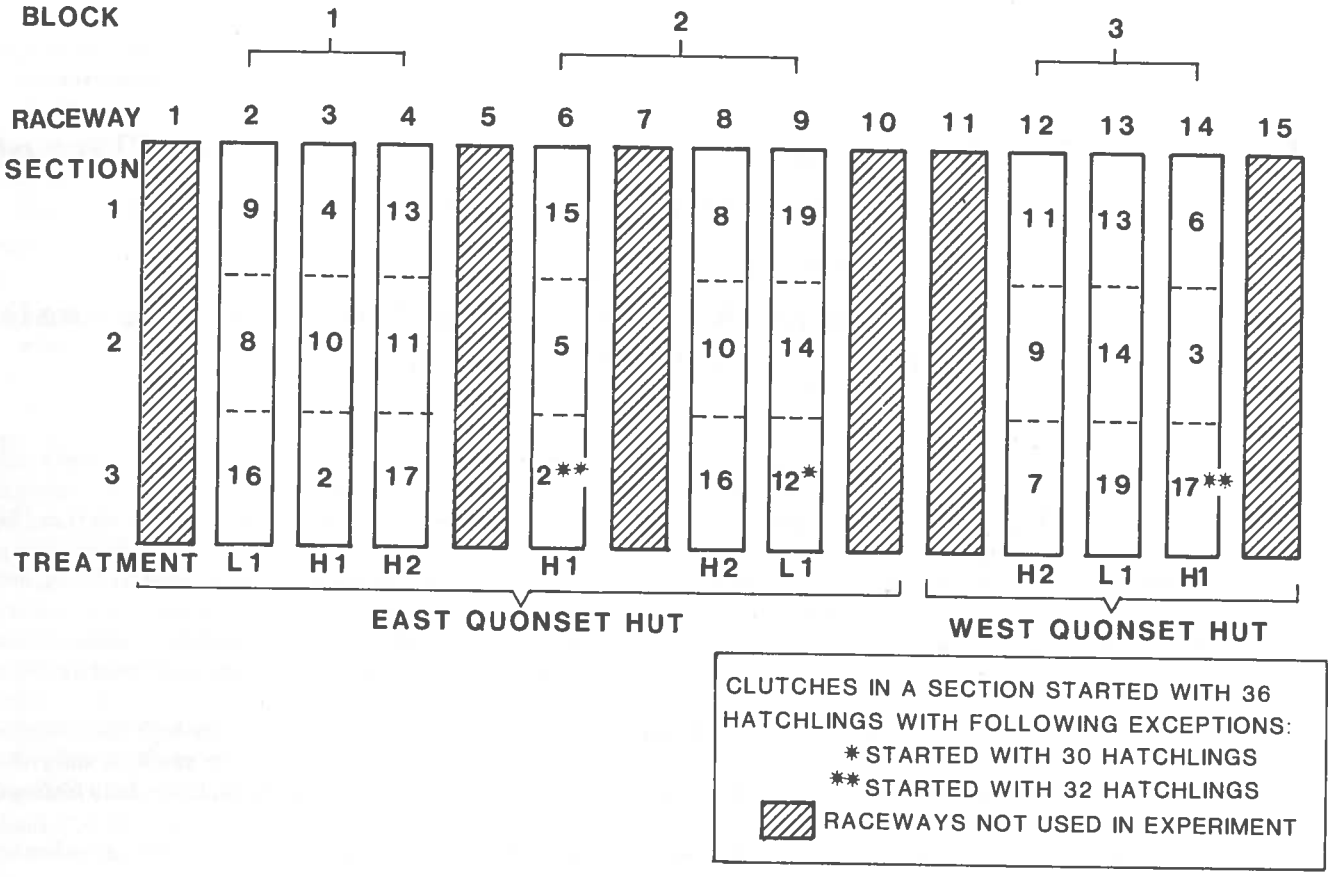

Figure 1. Physical layout of the randomized complete block design for the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class (three blocks of three raceways with three treatments [H1, H2 and L1] randomly assigned to each; clutch numbers are shown by section within raceways).

the National Seashore to the head start facilities. All boxes contained a 2.5 cm layer of moistened polyurethane foam to cushion the hatchlings and prevent their desiccation during transport.

Rearing Facilities

Hatchlings in the experiment were reared in buckets placed in nine rectangular (1.8 x 6.1 m), fiberglass raceways (Figure 1) located in two polyethylene sheeting-covered quonset huts (Fontaine *et al.*, 1985, 1989). Each raceway contained approximately 3,140 liters of seawater. Suspended within each raceway were 108 yellow, plastic buckets (9.5-liter capacity). Turtles were reared in isolation from each other in these buckets, one turtle per bucket, to prevent their attacking, biting and injuring one another, as they are very aggressive (Klima and McVey, 1982; Clary and Leong, 1984). The bottoms of the buckets were perforated with 1.3-cm diameter holes, to allow exchange of seawater and liberation of turtle excrement and uneaten food. Forced-air, gas-fired heaters maintained warm air and water temperatures within the quonset huts during the winter.

Turtles in a raceway were all treated similarly with regard to feeding, cleaning of the raceway and management of seawater and wastewater. Raceways were drained, flushed by hosing with fresh (tap) water, and refilled with clean seawater three times a week. Once each week, all raceways were drained, scrubbed with brushes and flushed to remove attached algae, uneaten food and accumulated waste materials. Temperature, salinity and pH were monitored in the nine raceways used in the experiment.

Seawater for the raceways was pumped from the Gulf of Mexico through well-points buried in the sand below water at the Galveston beachfront (Fontaine *et al.*, 1985, 1989). After a period allowed for settling of particulates, the seawater was stored in fiberglass reservoirs near the quonset huts, and was used as needed. The reservoirs were shrouded with insulation and were outfitted with emersion heaters to keep the seawater warm during winter.

Feeding Experiment

Experimental Design

The experiment was conducted in parallel with that of Landry (1989). A randomized complete block design was used for the experiment to isolate possible microenvironmental variation among raceways from the treatment effects

(Table 1, Figure 1). For this purpose, the nine raceways used in the experiment were divided into three adjacent groups of three raceways each, and these groups were treated as blocks numbered 1 - 3. One of the three treatments (Table 1) was randomly assigned to each raceway within each block.

Prior to receiving the hatchlings, we anticipated that we could reduce possible effects of variation in age and other characteristics of clutches on the treatment effects by distributing the hatchlings in such a way that each raceway contained three different clutches, with the constraint that clutches assigned to a given raceway were as close in age as possible. Location of clutches within each raceway was randomized among three sections of 36 buckets each (Figure 1). Variation among clutches within raceways was treated as a random nested effect within raceways. All clutches except clutches 1 and 18 contributed hatchlings to the experiment.

Clutches hatched between July 15-23, 1984, so they varied in age only slightly more than a week. Therefore, all clutches were considered the same age, and their age in days was calculated from the mean hatch date of July 18. To calculate the mean hatch date, each date was weighted according to the number of hatchlings that emerged on that date. The modal and median hatch dates also were 18 July.

Seven clutches (3-7, 12 and 15) used in the experiment did not contain enough hatchlings to be assigned randomly to more than one block, but the remaining 10 clutches (2, 8-11, 13, 14, 16, 17 and 19) were large enough to be divided between two raceways, with each of the two raceways being in different blocks (Figure 1). However, section 3 of raceways 6, 9 and 14 contained fewer than the full complement of 36 hatchlings, because clutches 2, 12 and 17 were not large enough to provide full complements of 36 each to these raceways.

Foods and Feeding

Two commercial diets were used in head starting the 1984 year-class (see Fontaine *et al.*, 1985; Caillouet *et al.*, 1986a). Both were dry, floating, pelleted diets. The experiment began on August 22, 1984 , with a diet manufactured by Central Soya and Subsidiaries, Decatur, Ind. This diet had to be replaced after November 10 because the new batch we received did not have the same floating characteristics of the earlier batches. We switched to a sea turtle chow (a modified trout chow) manufactured by Purina, Richland, Ind. The latter was the same diet used by the Cayman Turtle Farm (1983), Ltd., Grand Cayman, B.W.I., for rearing green turtles (*Chelonia mydas*), and it had been recommended earlier by the farm's director, James Wood (personal communication, August 1984).

The standard feeding technique developed by Fontaine *et al.* (1985) in head starting Kemp's ridleys of the 1981-1983 year-classes was to set the food ration per turtle as a percentage of the arithmetic mean weight per turtle, determined by weighing samples of turtles at roughly monthly intervals during head starting. The procedure was modified for the experiment by substituting geometric mean weight for arithmetic mean weight in the calculations of food ration. This was done because the variance in weight among head started Kemp's ridleys increases with average weight in such a way that a logrithmic transformation of weights eliminates such heterogeneity of variance (Caillouet *et al.*, 1986b). Once the weight of food per turtle was calculated for a given raceway, the food was distributed to each turtle by volumetric measure based on the weight: volume ratio for the food.

Through September 4, 1984, all hatchlings received the same daily ration based on approximately 10 percent of their initial arithmetic mean weight (see Caillouet *et al.*, 1986a, Table 15). Feeding under the experimental protocol (Table 1) began on September 5, but August 22 was considered the start of the experiment because it was the date on which the turtles were first weighed for the experiment (Table 2). Weighings continued at 22-29 day intervals (Table 2) until February 28, 1985, when the experiment was terminated as a consequence of some turtles having outgrown their buckets.

Two experimental feeding levels were tested in the feeding experiment (Tables 1 and 3). Feeding level was represented in two ways: (1) feeding rate expressed as a percentage of geometric mean body weight per turtle and (2) food ration expressed as the weight of food fed per turtle per day. At the beginning of the experiment, the high feeding level represented approximately 1.3 times as much food by weight as the low level, and it reached approximately 2.5 times the low level by the end of the experiment. This shift merely reflected the differences in growth among turtles in the different treatments. Because day to day conditions in the raceways were affected by temperature, the amount of uneaten food, and the amount of turtle excrement, the experimental daily food rations had to be altered from time to time. For example, when bloating caused by overfeeding occurred, feeding was interrupted for a day or two to allow the turtles to recover. After the experiment, the actual rations as well as the feeding rates in percentage of body weight were recalculated for each interval between weightings (Table 3). While the feeding rate was reduced gradually over the period of the experiment, the food ration increased because the turtles were growing.

Because feeding rates were controlled as a percentage of mean body weight during the experiment (Table 3), for any given feeding rate the actual food ration received by each turtle in a given raceway varied depending upon the weight per turtle in that raceway at the beginning of each interval when feeding rate was adjusted (see Fontaine *et al.*, 1985; Caillouet *et al.*, 1986b). For this reason, analyses of variance were conducted on daily food ration (Table 4) and

Table 1. Treatments in the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Daily feeding frequency	Daily feeding levels[a] High	Low
Once: in the morning	Treatment H1	Treatment L1
Twice: once in the morning and once in the afternoon	Treatment H2 (Control)[b]	(not tested)

[a]See Table 3 for food rations and feeding rates.
[b]This was comparable to the old system of feeding as regards feeding level and frequency (Fontaine *et al.*, 1985; Caillouet *et al.*, 1986b).

Table 2. Sequence and dates of weighings and time intervals between weighings in the feeding experiment on Kemp's ridly sea turtles of the 1984 year-class.

Weighing sequence	Date	Time interval	Duration of time interval, Days[a]
1	August 22, 1984		
		1	22
2	September 13		
		2	28
3	October 11		
		3	28
4	November 8		
		4	28
5	December 6		
		5	27
6	January 2, 1985		
		6	29
7	January 31		
		7	28
8	February 28		

[a]Represents the number of days lapsed from and including one date of weighing to the day prior to the next consecutive date of weighing.

Table 3. Daily food ration (grams)[a] and daily feeding rate (%)[b] averaged by treatment and time interval during the feeding experiment on the 1984 year-class of Kemp's ridley sea turtles.

Phase	Time interval	Inclusive dates	Treatment: High level once/day H1 grams (%)	High level twice/day H2 grams (%)	Low level once/day L1 grams (%)	Diet
	1	Aug. 22-Sept. 12, 1984	2.0 (6.3)	2.1 (6.0)	1.6 (4.7)	Central Soya
1	2	Sept. 13 - Oct. 10	1.9 (3.3)	2.2 (3.3)	1.2 (1.9)	"
	3	Oct. 11 - Nov. 7	4.3 (4.6)	5.0 (4.4)	2.6 (2.9)	"
NA[c]	4	Nov. 8 - Dec. 5	3.9 (2.5)	4.8 (2.6)	2.1 (1.6)	Central Soya – Purina
	5	Dec. 6, 1984 - Jan. 1, 1985	2.3 (1.4)	2.5 (1.3)	1.2 (0.8)	Purina
2	6	Jan. 2 - Jan. 30	2.9 (1.5)	3.1 (1.3)	1.4 (0.9)	"
	7	Jan. 31 - Feb. 27	3.0 (1.2)	3.5 (1.2)	1.3 (0.7)	"

[a]Daily food ration was determined for each raceway (because all turtles in a given raceway received the same ration) by dividing the total grams of dry food per turtle per day during a given time interval between weighings by the number of days in the interval.
[b]Daily feeding rate was determine for each clutch within a given raceway by expressing daily food ration for a given time interval between weighings as a percentage (%) of the geometric mean body weight (wet) at the beginning of each time interval.
[c]NA = not applicable as a separate phase. This was a transition period in which the diet was changed from Central Soya to Purina pellets after 10 November 1984 due to problems encountered with the former diet (see text).

Table 4. Analysis of variance of daily food ration[a] in the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Source of variation	Degrees of freedom	Mean square	F
Blocks	2	0.36412	5.31 *[b]
Treatments, T	2	16.26393	237.26 *
H1 & H2 vs. L1	(1)	(30.94249)	451.39 *
H1 vs. H2	(1)	(1.58537)	23.13 *
Time interval, I	6	6.46791	94.35 *
T x I interaction	12	0.51202	7.47 *
Experimental error	40	0.06855	

[a]Daily food ration was determined for each raceway (because all turtles in a given raceway received the same ration) by dividing the total grams of dry food per turtle per day during a given time interval between weighings by the number of days in the interval.

[b]* = significant at $P \leq 0.05$.

Table 5. Analysis of variance of transformed[a] daily feeding rate[b] in the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Source of variation	Degrees of freedom	Mean square	F
Blocks	2	0.05513	0.20 ns[c]
Treatments, T	2	74.79456	271.81 *[d]
H1 & H2 vs. L1	(1)	(148.48420)	539.61 *
H1 vs. H2	(1)	(1.10494)	4.02 ns
Time interval, I	6	249.54165	906.86 *
T x I interaction	12	0.89448	3.25 *
Experimental error	40	0.27517	
Clutches within raceways	126	0.53264	

[a]Angular (arcsine) transformation (see Sokal and Rohlf, 1981, p. 427-428).
[b]Daily feeding rate was determined for each clutch within a given raceway by expressing daily food ration for a given time interval between weighings as a percentage (%) of the geometric mean body weight (wet) at the beginning of each time interval.
[c]ns = non-significant at P = 0.05.
[d]* = significant at $P \leq 0.05$.

Table 6. Analysis of variance of transformed[a] proportion of survivors[b] in the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Source of variation	Degrees of freedom	Mean square	F
Blocks	2	219.00704	2.42 ns[c]
Treatments, T	2	79.30744	0.88 ns
H1 & H2 vs. L1	(1)	(0.01040)	0.00 ns
H1 vs. H2	(1)	(158.60448)	1.75 ns
Experimental error	4	90.44190	
Clutches within raceways	18	137.91116	

[a]Angular (arcsine) transformation (see Sokal and Rohlf, 1981, p. 427-428).
[b]Determined for each clutch within a raceway by dividing the number or survivors at the end of the experiment by the number of hatchlings at the beginning of the experiment.
[c]ns = non-significant at P = 0.05

on transformed daily feeding rate (Table 5). An angular transformation (Sokal and Rohlf, 1981, p. 427-428) was used for daily feeding rate because percentages usually require such transformation to meet assumptions of analysis of variance.

Two feeding frequencies were tested at the high feeding level (Tables 1 and 3, Figure 1): once-daily in the morning (Treatment H1), and twice-daily, once in the morning and once in the afternoon (Treatment H2). For twice-daily feeding, the daily ration was divided into two equal portions, so the turtles in Treatments H1 and H2 received the same amount of food per day. The low level of feeding was only once-daily in the morning (Treatment L1). Treatment H2 was considered a control as it represented the old system of feeding (Fontaine *et al.*, 1985; Caillouet *et al.*, 1986b). The combination of low feeding level and twice-daily feeding was not tested.

Sampling for Weighings

To determine growth and adjust feeding rates, wet body weights were determined from random samples of 10 turtles per clutch in each raceway at each weighing during the experiment (Table 2). Weighings were made to the nearest 0.1 gram on an O'Haus, triple-beam balance. The balance pan was dried and the balance re-zeroed after consecutive weighings of three turtles. The geometric mean weight of the combined samples within a raceway was used as the basis for adjusting feeding rate.

Survival

Survival from the beginning to end of the experiment was calculated for each clutch in each raceway and was expressed in percentage.

Results

Feeding Rations and Rates

In the analysis of variance for daily food ration (Table 4), all main effects and the treatment x time interval interaction were significant (refers throughout this paper to the critical region of rejection of null hypotheses at $P \leq 0.05$). Orthogonal contrasts among treatments (Table 4) showed that the daily food ration was significantly and substantially higher at the high feeding level (as expected), but also that the ration for twice daily feeding was significantly and slightly higher when split into twice-daily feedings than when given in only one feeding (Table 3), probably an artifact of the pellet size in relation to the use of two different sizes of volumetric measures to dole out the pellets for the two feeding levels. The significant differences in food ration among time intervals and the significant interaction between treatments and time intervals (Table 4) simply reflected the effects of differential growth of the turtles from different clutches and raceways within treatment-time interval combinations, which in turn influenced the adjustment of feeding rates.

As expected, daily feeding rate differed significantly between the high and low levels of feeding but not between the two frequencies of feeding at the high level (Table 5). As with daily food ration, there were significant differences in feeding rate among time intervals and a significant interaction between treatment and time interval. Again, this reflected differential growth of the turtles which in turn influenced the subsequent amounts of food they received. Daily feeding rate was reduced over time, because the turtles require a decreased feeding rate as they grow larger (Fontaine *et al.*, 1985). The analysis of variance for daily feeding rate included the random nested effect of clutches within raceways, because feeding rate was recalculated on a clutch-within-raceway basis retrospectively to assess variability generated by differences in growth from clutch to clutch.

Survival

Analysis of variance of transformed proportion of survivors detected no significant differences in main effects or interaction (Table 6), so the treatments had no significant effect on survival. Overall survival was 95.8 percent for the experiment.

Gross Food Conversion Efficiency

Gross food conversion efficiency, C, was calculated for each clutch in each raceway over the intervals between weighings as follows:

$$C = F/G$$

where

F = food ration in grams of dry food fed per turtle per day, and
G = weight gain (wet) per turtle per day.

G was calculated by dividing the change in geometric mean weight per turtle between two consecutive weighings by the number of days in the interval between weighings. Usually this resulted in a weight gain, but in some cases there

was a weight loss so the weight change was negative. The food ration, F, was calculated by dividing the sum of the daily quantities of food fed per turtle during an interval between weighings by the number of days in the interval. Gross food conversion efficiency does not represent actual food intake and assimilation, because some of the food was not eaten. It is only an index.

Gross food conversion efficiency is summarized in Table 7. Time interval 4 produced aberrant conversion efficiencies because of the problems that began to develop in time interval 3 with the Central Soya diet. In interval 4, growth slowed and at the low level of feeding some of the clutches lost weight producing negative efficiencies. Food was in excess because the turtles were not utilizing it and were either growing slowly or losing weight. Therefore, conversion efficiencies in interval 4 were disregarded (Table 7), and separate analyses of variance were conduced for two phases of the experiment, the first involving only the Central Soya diet and the second involving only the Purina diet (Table 8).

In phase 1, the gross food conversion efficiency was significantly higher at the high level of feeding than at the low level of feeding, and it varied significantly among time intervals (Table 8). No other main effects nor the interaction were significant. During phase 2, none of the main effects nor the interaction were significant, so the differences observed in phase 1 apparently had no significant residual or carry-over influence on those of phase 2.

Weight Gain

Weight gain, G, is summarized in Table 9. Analysis of variance detected significantly greater weight gain at the high level of feeding than at the low, but in addition the twice-daily feeding produced significantly greater weight gain than the once-daily feeding at the high feeding level (Table 10). There also were significant differences in weight gain among time intervals. Interval 4 had the smallest average weight gain.

Growth Rate Index

The growth rate index, b, was calculated by linear regression analysis for each clutch in each raceway. This was done separately for the two phases of the experiment, so each line was based on 40 paired observations (10 per weighing for four consecutive weighings per phase). Each line was fitted to logarithmically transformed weights regressed on the square roots of age as follows:

$$\ln(W) = \ln(a) + bT^{1/2}$$

where,

W = wet weight in grams,
T = age in days from the mean hatch date,
b = slope (an index of growth rate), and
a = empirical constant.

This growth model is similar to that derived by Caillouet *et al.* (1986b) to describe first-year growth in weight per turtle for year-classes 1978-1983 of head started Kemp's ridleys. The exponential equivalent of the model is:

$$W = ae^{bT^{1/2}}$$

where,

e = base of natural logarithms.

Growth rate index is summarized in Table 11, and analyses of variance detected significantly greater growth rates at the high level of feeding than at the low in both phases of the experiment (Table 12). Again, the transitional and aberrant time interval 4 was disregarded in the analyses. There were no significant differences in growth rate between once and twice daily feedings at the high level in either of the two phases of the experiment.

Environmental Variables

Average seawater temperature, salinity and pH were calculated for each of the nine raceways for each of the seven time intervals. Analyses of variance detected significant differences among time intervals for all three environmental variables (Table 13). Variations in temperature, salinity and pH probably reflected seasonal changes. Treatments had no significant effect and there were no significant interactions between treatments and time intervals for these variables. Time interval 4 had the lowest temperature and salinity in the time series which may have contributed to the aberrant gross food conversion efficiencies and low or negative weight gains in interval 4.

Discussion

There have been numerous studies of growth of sea turtles of various species on artificial diets in captivity (Hildebrand and Hastel, 1927; Caldwell, 1962; Uchida, 1967; Stickney, White and Perlmutter, 1973; Kaufmann, 1975; LeBrun, 1975; Witham and Futch, 1977; Whitaker, 1979; Witzell, 1980; Wood and Wood, 1981; Nuitja and Uchida, 1982;

Table 7. Gross food conversion efficiency, C[a], averaged by treatment and time interval during the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Phase	Time interval	Inclusive dates	Treatment: High level once/day H1	High level twice/day H2	Low level once/day L1	Diet
			C[a]	C	C	
	1	Aug. 22 - Sept. 12, 1984	1.8	1.3	1.3	Central Soya
1	2	Sept. 13 - Oct. 10	1.6	1.5	1.2	"
	3	Oct. 11 - Nov. 7	1.9	2.1	1.7	"
NA[b]	4	Nov. 8 - Dec. 5	16.0	183.7	-0.3	Central Soya-Purina
	5	Dec. 6, 1984 - Jan. 1, 1985	2.3	0.8	3.6	Purina
2	6	Jan. 2 - Jan. 30	1.8	1.8	2.2	"
	7	Jan. 31 - Feb. 27	2.6	2.0	2.1	"

[a]C was determined for each clutch within a given raceway by dividing F, the food ration in grams of dry food per turtle per day during a given time interval between weighings by G, the weight gain (wet) per turtle per day during the interval. Daily weight gain was determined for each clutch within a given raceway by dividing the change in geometric mean weight per turtle during a given time interval by the number of days in the interval. Note that averages in this table are not the same as those one might obtain by dividing average daily food rations in Table 3 by corresponding average daily weight gains in Table 9, because C was determined for every clutch in each raceway and for each time interval before being averaged herein.
[b]NA = not applicable as a separate phase. This was a transition period in which the diet was changed from Central Soya to Purina pellets after 10 November 1984 due to problems encountered with the former diet (see text).

Table 8. Analysis of variance of gross food conversion efficiency [a] for the two phases of the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Phase 1

Source of variation	Degrees of freedom	Mean square	F	
Blocks	2	0.27881	0.88	ns[b]
Treatments, T	2	1.05733	3.33	ns
H1 & H2 vs. L1	(1)	(1.72356)	5.43	*[c]
H1 vs. H2	(1)	(0.39111)	1.23	ns
Time interval, I	2	1.94480	6.13	*
T x I interaction	4	0.22622	0.71	ns
Experimental error	16	0.31723		
Clutches within raceways	54	0.27108		

Phase 2

Source of variation	Degrees of freedom	Mean square	F	
Blocks	2	0.34443	0.04	ns
Treatments, T	2	8.58744	1.11	ns
H1 & H2 vs. L1	(1)	(10.27210)	1.33	ns
H1 vs. H2	(1)	(6.90277)	0.89	ns
Time interval, I	2	0.67243	0.09	ns
T x I interaction	4	5.55306	0.72	ns
Experimental error	16	7.73725		
Clutches within raceways	54	4.79946		

[a]C was determined for each clutch within a given raceway by dividing F, the food ration in grams of dry food per turtle per day during a given time interval between weighings by G, the weight gain (wet) per turtle per day during the interval. Daily weight gain was determined for each clutch withing a given raceway by dividing the change in geometric mean weight per turtle during a given time interval by the number of days in the interval.
[b]ns = non-significant at P = 0.05.
[c]* = significant at $P \leq 0.05$.

Table 9. Daily weight gain[a] averaged by treatment and time interval during the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Phase	Time interval	Inclusive dates	Treatment: High level once/day H1	High level twice/day H2	Low level once/day L1	Diet
			grams	grams	grams	
	1	Aug. 22 - Sept. 12, 1984	1.2	1.6	1.3	Central Soya
1	2	Sept. 13 - Oct. 10	1.2	1.6	1.0	"
	3	Oct. 11 - Nov. 7	2.3	2.8	1.6	"
NA[b]	4	Nov. 8 - Dec. 5	0.4	0.5	0.4	Central Soya-Purina
	5	Dec. 6, 1984 - Jan. 1, 1985	1.2	1.8	0.6	Purina
2	6	Jan. 2 - Jan. 30	1.9	2.1	0.9	"
	7	Jan. 31 - Feb. 27	2.1	2.5	0.6	"

[a]Daily weight gain was determined for each clutch within a given raceway by dividing the change in geometric mean weight per turtle during a given time interval by the number of days in the interval.
[b]NA = not applicable as a separate phase. This was a transition period in which the diet was changed from Central Soya to Purina pellets after 10 November 1984 due to problems encountered with the former diet (see text).

Table 10. Analysis of variance of daily weight gain[a] during the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Source of variation	Degrees of freedom	Mean square	F	
Blocks	2	1.04346	1.64	ns[b]
Treatments, T	2	12.96030	20.41	*[c]
H1 & H2 vs. L1	(1)	(22.56014)	35.52	*
H1 vs. H2	(1)	(3.36046)	5.29	*
Time interval, I	6	8.39384	13.22	*
T x I interaction	12	1.11699	1.76	ns
Experimental error	40	0.63505		
Clutches within raceways	126	0.37152		

[a]Daily weight gain was determined for each clutch within a given raceway by dividing the change in geometric mean weight per turtle during a given time interval by the number of days in the interval.
[b]ns = non-significant at $P = 0.05$.
[c]* = significant at $P \leq 0.05$.

Table 11. Growth rate index, b[a], averaged by phase and treatment during the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Phase	Time interval	Inclusive dates	Treatment: High level once/day H1	High level twice/day H2	Low level once/day L1	Diet
			b[a]	b	b	
1	1-3	Aug. 22 - Nov. 7, 1984	0.327	0.354	0.286	Central Soya
2	5-7	Dec. 6, 1984 - Feb. 27, 1985	0.201	0.196	0.115	Purina

[a]The slope of the regression of the natural logarithm of weight (grams) on the square root of age (days). Growth rate index was determined for each clutch within a given raceway.

Table 12. Analysis of variance of growth rate index, b[a], during the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

Phase 1 Source of variation	Degrees of freedom	Mean square	F	
Blocks	2	0.000429	0.48	ns[b]
Treatments, T	2	0.010610	11.84	*[c]
H1 & H2 vs. L1	(1)	(0.017858)	19.93	*
H1 vs. H2	(1)	(0.003362)	3.75	ns
Experimental error	4	0.000896		
Clutches within raceways	18	0.000752		
Phase 2 Source of variation	Degrees of freedom	Mean square	F	
Blocks	2	0.003689	3.24	ns
Treatments, T	2	0.021075	18.54	*
H1 & H2 vs. L1	(1)	(0.042056)	36.99	*
H1 vs. H2	(1)	(0.000093)	0.08	ns
Experimental error	4	0.001137		
Clutches within raceways	18	0.000904		

[a]The slope of the regression of the natural logarithm of weight (grams) on the square root of age (days). Growth rate index was determined for each clutch within a given raceway.
[b]ns = non-significant at P = 0.05.
[c]* = significant at $P \leq 0.05$.

Hadjichristophorou and Grove, 1983; Frazer and Schwartz, 1984; Rajagopalan, 1984; LeGall, 1985; and Lebeau, 1986), but few such studies have been conducted on Kemp's ridley (Caldwell, 1962; Pritchard and Márquez, 1973; Klima and McVey, 1982; Caillouet and Koi, 1985; Caillouet *et al.*, 1986b and Landry, 1989). Our study on Kemp's ridley was a logical sequel to that of Caillouet *et al.* (1986b) because it stressed statistical design and analysis not possible under the uncontrolled conditions of the previous head starting efforts involving this species.

Our results showed clearly that the Kemp's ridleys receiving more food exhibited the highest weight gains and growth rate indices, as might be expected. However, for the high level of feeding, the turtles receiving the entire daily ration in one feeding per day had a smaller daily weight gain than those in which the daily ration was divided into two separate feedings. Again, this was not surprising because the turtles fed twice-daily grew faster and therefore received more food based on a percentage of their body weight under the feeding technique developed by Fontaine *et al.* (1985). Also, this may have been due in part to an artifact of using different size volumetric measures to dole out feed pellets to the turtles, with resulting difficulty in measuring out small quantities of pellets by volume. While this is a practical technique which saves time in feeding large numbers of turtles, it is obviously inadequate for definitive studies of food intake and growth. There was no apparent difference in the response to once-daily vs. twice-daily feeding (at the high level) as measured by the growth rate index developed by Caillouet *et al.* (1986b). This was probably due to the fact that there were fewer degrees of freedom for the experimental error mean square in analyses of variance of the growth rate index as compared to degrees of freedom for experimental error in the analyses of variance of weight gain.

Gross food conversion efficiency was best (lowest amount of food fed per unit increase in weight per turtle) at the low level of feeding, but only during the first phase of the experiment during which the Central Soya diet was being used. During the second phase in which the Purina diet was used, the effects of the two different feeding levels on gross food conversion efficiency were indistinguishable.

The shift in diet during the experiment was an unplanned event, a consequence of unanticipated problems with the Central Soya diet that had not occurred in prior years of its use. Because the shift in diet occurred sequentially, the experiment did not provide a comparison of the two diets. The main consideration was the health and safety of the endangered Kemp's ridley turtles, so the experimental protocol had to be subservient.

A slowing of growth in captive-reared Kemp's ridleys during winter, associated with cooling of the water, has been observed (Caillouet and Koi, 1985; Caillouet *et al.*, 1986b). Lowered temperature may account in part for the slowing of growth and the poorer food conversion efficiencies observed in the experiment during time interval 4 (November 8 - December 5, 1984) which had the lowest average temperature and salinity of any of the time intervals. Nonetheless,

Table 13. Means[a] (A) and analyses of variance for temperature (B), salinity (C) and pH (D) during the feeding experiment on Kemp's ridley sea turtles of the 1984 year-class.

A. Means

Time interval	Mean temperature, °C	Mean salinity, ppt	Mean pH
1	25.7	29.1	-[b]
2	22.7	29.3	7.2
3	24.1	24.6	7.3
4	21.1	23.6	7.4
5	22.9	27.2	-
6	21.9	26.2	-
7	23.1	28.8	7.5

B. Temperature, °C

Source of variation	Degrees of freedom		Mean square	F	
Blocks	2		0.01300	0.23	ns[c]
Treatments, T	2		0.07889	1.40	ns
H1 & H2 vs. L1		(1)	(0.08770)	1.56	ns
H1 vs. H2		(1)	(0.07008)	1.24	ns
Time interval, I	6		19.56146	347.51	*[d]
T x I interaction	12		0.00354	0.06	ns
Experimental error	40		0.05629		

C. Salinity, ppt

Source of variation	Degrees of freedom		Mean square	F	
Blocks	2		0.12749	2.14	ns
Treatments, T	2		0.01892	0.32	ns
H1 & H2 vs. L1		(1)	(0.02388)	0.40	ns
H1 vs. H2		(1)	(0.01397)	0.23	ns
Time interval, I	6		46.91016	786.03	*
T x I interaction	12		0.00395	0.07	ns
Experimental error	40		0.05968		

D. pH

Source of variation	Degrees of freedom	Mean square	F		
Blocks	2		0.00330	4.23	*
Treatments, T	2		0.00046	0.59	ns
H1 & H2 vs. L1		(1)	(0.00086)	1.10	ns
H1 vs. H2		(1)	(0.00007)	0.09	ns
Time interval, I	3		0.16910	216.79	*
T x I interaction	6		0.00022	0.28	ns
Experimental error	22		0.00078		

[a]Based on observations taken from each raceway, but not necessarily on every day within the time intervals. Averaged over raceways and days of observation within time intervals.
[b]– = insufficient number of observations.
[c]ns = non-significant at P = 0.05.
[d]* = significant at $P \leq 0.05$.

temperature was better controlled in 1984 than in previous years.

The experimental feeding levels and frequencies had no apparent effect on survival, and overall survival during the experiment was very high (95.8 percent). Therefore, the turtles that received the least food showed no greater mortality than those that received the larger amounts based on our results.

Our results have considerable practical significance to the head starting of large numbers (1,000 to 2,000 per year) of Kemp's ridleys in captivity. Twice as much labor is required to feed the turtles twice per day than to feed them once per day. The turtles seem to be opportunistic feeders and will eat as many pellets as provided them until they are satiated. Additional food is wasted and causes problems in deterioration of seawater quality (Fontaine *et al.*, 1985; Caillouet *et al.*, 1986b). Perhaps a single feeding per day would be adequate if the feeding rate were somewhat higher than the low feeding rate but lower than the high feeding rate used in our experiment.

Feeding rate expressed as a percentage of body weight provides a handy *rule of thumb* for feeding large numbers of Kemp's ridleys in mass production head starting. However, its use results in heavier feedings for faster-growing turtles. Some clutches exhibit better growth than others. With the typical mixture of several clutches in a single raceway, the practical question arises as to whether or not the feeding rate should be adjusted according to the average weight of a sample of turtles representing the raceway or samples from each clutch within the raceway. Our conventional practice has been to feed by raceway, basing the feeding rate on the average weight of turtles representing all clutches in the raceway. To do otherwise would be impractical. However, this restricts growth in faster growing clutches and may result in overfeeding of slower growing clutches. The problem can be lessened by putting clutches of equal age in a raceway, but this does not accommodate genetic differences that might affect growth performance of different clutches.

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Health Care and Diseases of Captive-Reared Loggerhead and Kemp's Ridley Sea Turtles

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*During 1977 to 1983, Kemp's ridley (*Lepidochelys kempi*) and loggerhead (*Caretta caretta*) sea turtles were reared for one year or less at the National Marine Fisheries Service, Southeast Fisheries Center, Galveston Laboratory. Many of the diseases, malformations and injuries observed in captive-reared sea turtles were named and classified into 27 major categories. The categories were: sudden hatchling death syndrome, papillary dermatitis, emaciation, focal erosive dermatitis, injuries from aggressive biting, focal dermal granulosis, scolecobasidiosis, white-suture syndrome, yolk sac mycosis, internal nodular mycosis, hypernecrotic warts, malabsorption of yolk sac, urolithiasis, duodenal ulceration, hemorrhagic bacteriosis, mycobacterial pneumonia, swollen-eye, intussusception, curved-back, soft shell, coelomic edema, lung aplasia, flipper malformation, cross-beak, congenital blindness, intestinal prolapse, and prolapse of the urinary bladder. Each category of ailment is described with respect to etiology, symptomatology, occurrence and suggested remedy if known. Current levels of our knowledge of diagnosis and control of diseases during captive-rearing of these two species of turtle are discussed. Recommendations are made on perspectives and needs in sea turtle pathology research.*

Numerous kinds of diseases and physical injuries occurred in Kemp's ridley (*Lepidochelys kempi*) and loggerhead (*Caretta caretta*) sea turtles reared for one year or less at the National Marine Fisheries Service (NMFS), Southeast Fisheries Centers Laboratory in Galveston, Tex. Rearing Kemp's ridleys from hatchlings to yearlings is a feasibility study of the head starting concept, part of a broader conservation program aimed at preventing extinction of this critically endangered species (Klima and McVey, 1982).

Information on nesting sites and population decline in Kemp's ridley has been summarized in several papers (Klima and McVey, 1982; Mrosovsky, 1983; Caillouet, 1984; Caillouet *et al.*, 1986; Fontaine *et al.*, 1985). To recapitulate, there is only one known primary nesting beach located near the village of Rancho Nuevo, in the State of Tamaulipas, Mexico. The number of nesters at that beach has declined from an estimated 40,000 reported to have nested in a single day in June 1947 to some 1,200 in 1974 and then to 500 or so in 1977. It is hoped that head starting will prove useful as one among several methods to help preserve and augment the population. In head starting, the turtles are reared in captivity from hatchlings to about one year or less of age, then tagged and released into the Gulf of Mexico or adjacent estuaries.

To gain experience before attempting to rear Kemp's ridleys, the Galveston Laboratory staff obtained 1,160 loggerhead hatchlings, a species which had not yet been listed as threatened under the Endangered Species Act of 1973. Experimenting first with the loggerheads proved beneficial, because almost all of the loggerhead hatchlings became ill at some time during head starting, so the staff at the Galveston Laboratory was able to derive important information on sea turtle pathology and health care methods without jeopardizing Kemp's ridleys. Only about 9 percent of the loggerheads survived after a 10-month rearing period. The knowledge, experience and information gained on prophylaxes, diagnoses and therapeutics for loggerheads were applicable in part to Kemp's ridleys in subsequent years. Pathology studies and observations on loggerheads and Kemp's ridleys contributed greatly to the high survival rates of six year-classes (1978-1983) of head started Kemp's ridleys: 68 percent, 83 percent, 95 percent, 88 percent, 89 percent and 77 percent, respectively (Fontaine *et al.*, 1985).

This paper is a review of some of the diseases and injuries suffered by captive loggerhead and Kemp's ridley sea turtles at the Galveston Laboratory. It also describes remedies or prophylaxes that we have found useful in resolving or preventing some of the problems. The diagnostic, prophylactic, therapeutic and health-care methods that we adopted represent the best approaches that we could undertake, given the constraints on funding, personnel and other resources. In addition, we were constrained by our U.S. Fish and Wildlife Service Permit, which prohibited deliberate sacrificing or injuring of live, normal sea turtles. To secure baseline, in-depth pathological information essential to development and refinement of diagnostic, prophylactic and therapeutic methods will require controlled experiments necessitating sacrificing or injuring some test animals.

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With few exceptions, there was a paucity of documented information on diseases and causes of death in sea turtles and efficient remedies, especially those applicable to mass-culture situations such as ours. The information in this paper may be useful both to those interested in rearing sea turtles from hatchling to yearling stages and those concerned with their morbidity and mortality.

Materials and Methods

Sources of Hatchlings

In September 1977, 1,160 loggerhead hatchlings were supplied by the Florida Department of Natural Resources, Jensen Beach, Fla. (Clary and Leong, 1984). Approximately 200 loggerhead hatchlings were received from the same source in July 1978. Kemp's ridley hatchlings were obtained each summer, beginning in 1978, through the joint efforts of the Instituto Nacional de la Pesca of Mexico, U.S. Fish and Wildlife Service, National Park Service, Texas Parks and Wildlife Department and Gladys Porter Zoo in Brownsville, Tex. (Fontaine *et al.*, 1985). The number of Kemp's ridley hatchlings received annually at the Galveston Laboratory for 1978-1983 were 3,081, 1,846, 1,822, 1,865, 1,524 and 250, respectively (Fontaine *et al.*, 1985).

Rearing of Turtles

Turtles were reared at the Head Start Research Project facilities of the Galveston Laboratory until they were 7 to 12 months old. They were then tagged and released offshore at preselected locations off Texas, Florida and Mexico (Klima and McVey, 1982; McVey and Wibbels, 1984; Wibbels, 1984; Fontaine *et al.*, 1985).

Two major concepts of maintenance and rearing were tried by the Galveston Laboratory: (1) free-contact by group-rearing in raceways or tanks, and (2) individual-rearing in isolation (Clary and Leong 1984; Caillouet, 1984). The first concept was implemented in 1977 and 1978. Hatchlings were divided into groups of about 50 to more than 550 turtles, depending on the size of rearing tanks, and the hatchlings were allowed to swim freely in contact with one another.

A variety of holding vessels was used, including: concrete raceways, fiberglass-lined wooden raceways and fiberglass tanks. Seawater in the concrete raceways was either recycled (non-flow-through) to remove wastes via a biodisc (Mock, Ross and Salser, 1977), or was constantly replaced by flow-through. Oyster-shell filters were used to remove wastes from recycled seawater in the fiberglass-lined, wooden raceways. Static water in the fiberglass raceways was replaced three times per week.

Initially, the incidence of disease, traumatic injuries and death was very high, indicating inadequacy of the group-rearing method. Laboratory and tankside observations revealed that hatchlings faired better when isolated from one another in small containers and when the culture water was replaced frequently with clean seawater. Not only were traumatic injuries caused by mutual biting and scratching eliminated, but morbidity and mortality were also greatly reduced. Based on these findings, isolation-rearing was implemented in January 1979, after the 1978 year-class of Kemp's ridleys had been reared for six months.

The isolation-rearing system (Klima and McVey, 1982; Fontaine *et al.*, 1985) was employed in the same kinds of holding tanks already described. Each hatchling was raised in isolation from others in a 10-liter plastic bucket, with holes in the bottom to allow seawater exchange and removal of feces and surplus food. The waste materials would fall through the holes to the tank floor and would be eliminated when the tanks were drained during routine cleaning operations. The seawater was completely changed daily for rearing the 1978 year-class, but the frequency was reduced to two to three times a week for subsequent year-classes.

Raw fish flesh was the primary food used for rearing the 1977 year-class of loggerheads. Feeding of the Kemp's ridleys has been described by Fontaine *et al.* (1985) and McVey, Leong, Wheeler and Harris (unpublished manuscript on the culture of young Kemp's ridley sea turtles). Kemp's ridleys were fed a synthetic, floating, pelleted diet (Fontaine *et al.*, 1985). In general, two meals per day were provided, one in early morning and one in late afternoon. The daily amount of pelleted feed ranged from roughly five percent of wet body weight for hatchlings to roughly 1.5 percent of body weight for yearlings.

Maintenance of Sick or Injured Turtles

In general, sick or injured turtles were removed from their rearing tanks and maintained separately for observation and medication until recovery. Two different systems, collective isolation and individual isolation, were used for holding sick or injured turtles.

Collective isolation was used for some of the sick loggerhead turtles of the 1977 year-class. Two or more turtles having similar signs or symptoms of illness were held together in one container. The number of animals placed in each container was dependent on the sizes of container and animals. In general, no less than 300 square cm of seawater surface area were provided for every 100 square cm of turtle carapace area. Water depth was at least twice the thickness of the body of the turtle, except in the specific situation in which an animal was unable to raise its head above the water due to physical weakness. In the latter cases, shallower water was used to prevent drowning. The kinds of

containers used for collective isolation of sick or injured turtles included 2,100-liter circular fiberglass tanks (1.83 m inside diameter, I.D.), 190-liter rectangular fiberglass tanks 0.83 m x 0.5 m (upper-rim dimensions) x 0.5 m deep, and 19-liter circular plastic tubs (0.46 m I.D.).

In individual isolation, used for both loggerhead and Kemp's ridley turtles, each sick or injured turtle was held singly in a separate container. Containers included 4-liter glass jars, 10-liter plastic buckets, 19-liter tubs, and 190-liter rectangular tanks. When there were only a few sick turtles, the containers were placed on the floor or bench tops, and seawater was manually replaced daily. However, within the 1978 year-class of Kemp's ridleys, there were routinely from 800 to 1,000 sick or injured turtles to be cared for at a time. Under these circumstances, 10-liter buckets with holes in their bottoms were suspended in a concrete raceway, and each contained a sick or injured turtle. Each day the seawater was drained, the buckets and turtles were washed with fresh water from a hose, the turtles were given the appropriate medication, and the raceway was refilled with clean seawater to the appropriate level. This method also reduced the labor required to clean individual buckets manually.

Feeding sick turtles varied according to the nature of the illness. The animals were either fed food similar to that given to healthy turtles, or they were given a special diet such as a dry breakfast cereal (rice or wheat) or commercial baby food (used for human infants), supplemented in some instances with multivitamins. When semi-solid food was used, it was fed to the turtle via intraesophageal intubation by means of plastic tubing attached to a graduated medical syringe. In general, sick animals had reduced appetites. Therefore, the amount of food was about one-half to one-third of normal feeding rate. On many occasions, sick turtles were not fed at all because of the nature of certain illnesses such as suspected intestinal perforation. To sustain the life of non-feeding or anorexic turtles, subcutaneous injection of a sterile dextrose-multivitamin solution (10 percent dextrose + 10 percent multivitamin infusion concentrate, U.S. Pharmaceutical) was administered at the rate of 0.25 ml per 50 mg wet body weight per day. Daily injection continued until the animal regained its appetite or for as long as seemed necessary.

Drug Administration

At least four methods of administering therapeutic chemicals to sick or injured turtles were studied as follows:

1. For medicated baths the calculated dose of a water-soluble drug or antibiotic was added to the seawater. The turtle was then placed in the medicated seawater for a period of time, either predetermined or on an as-needed basis, depending on the nature of the illness or injury, the progress of recovery, and the kind of medication used. Examples of medicated baths were formalin (50 to 100 ppm), potassium permanganate (2 to 5 ppm), malachite green (0.1 to 0.2 ppm), Cutrin-Plus (Applied Biochemist, Inc., Wisconsin; 0.3 ppm copper), minocyclin hydrochloride (0.3 to 0.6 ppm), erythromycin (2 to 4 ppm), and furanace (Dainippon Pharmaceutical Co., Osaka, Japan; 0.05 to 0.1 ppm).
2. For oral administration a drug was fed to the turtle either through intraesophageal intubation or by incorporating it into the feed or agar carrier. For the latter, two methods were tried. The first was to spray by means of an atomizer a predetermined volume of solution of the drug onto a premeasured quantity of dry pelleted food. The second was to mix the drug with a one percent solution of heat-melted Bacto agar (DIFCO) which had cooled to 45-50°C. After solidification, the medicated agar was diced and offered to the sick turtles. It was necessary that the agar pieces floated on the surface for the turtle to bite and swallow them. If they did not float, the quantity of agar in the solution was reduced until the diced pieces would float. In a liquid medium of a given salinity, diced pieces having a lower concentration of Bacto agar will float more readily than those having a higher concentration. Nevertheless, both methods of incorporating drugs into the food were discontinued in favor of intraesophageal intubation, because effectiveness of drugs in the feed or agar matrix was unknown.

   Examples of drugs used in oral administration (the quantity of active ingredient for each 50 g wet body weight of turtle per day is indicated in parentheses) were ampicillin (sodium, 0.5 mg), chloramphenicol palmitate (oral suspension, 2.5 mg), quinacrine hydrochloride (0.35 mg), chloroquine phosphate (1.5 to 3 mg), minocyclin hydrochloride (0.2 to 0.4 mg), neomycin (0.75 mg), and ketaconazole (2 mg). The daily drug dose was divided into two equal portions, one given in the morning and the other in the afternoon. In intraesophageal intubation, the drug solution was delivered by means of a hypodermic syringe fitted with plastic tubing inserted into the esophagus of the turtle.
3. Parenteral injection of small loggerhead and Kemp's ridley turtles was accomplished by subcutaneous injection of the drug. Until 1980, the site of injection was the suprafemoral pouch area immediately above the hind femur on the ventral side of the torso. Thereafter, the dorsal side of the neck was favored because it was discovered that sodium diatrizoate, a commonly used excretory, urographic, iodinated contrast material, was absorbed more rapidly in the dorsal neck than in the suprafemoral pouch area in subcutaneous injection (McLellan and Leong, 1982). These findings implied a similar differential absorption of therapeutic drugs in

the two locations. Examples of drugs (quantity of active ingredient of drug for each 25 grams wet body weight of turtle per day is indicated within the parentheses) used in parenteral administration were ampicillin (sodium, 0.25 mg), chloramphenicol sodium succinate (0.63-1.25 mg), pennicillin G (500-2,500 units), gentamicin (0.06 mg), terramycin (0.6 mg), and amphotericin B. Administration of amphotericin B was started at 0.0125 mg per 100 g body weight per day, with weekly increments of 0.0125 mg per 100 g per day.

4. Topical application of certain drugs or chemicals to minor surface wounds or lesions was accomplished with sterile cotton swab. Examples were neosporin ointment (Burroughs Wellcome), fungizone lotion (Squibb), tincture of iodine, merthiolate (Lilly) and gentian violet. In our experience, gentian violet was ineffective against many external lesions, and after it leached into the seawater it appeared to be toxic to small hatchlings, especially when applied too often. Neosporin appeared to be effective against certain presumptive bacterial lesions. The effects of the other topical agents have not been determined.

Diseases, Maladies and Injuries

Sudden Hatchling Death Syndrome

Sudden hatchling death (SHD) syndrome involves death of hatchlings, usually overnight, without forewarning signs or symptoms. On rare occasions, lethargy in hatchlings up to three weeks old may be observed prior to death. This disease, which affects both loggerhead and Kemp's ridley hatchlings, appeared in the former about one week after they arrived at the Galveston Laboratory in September 1977. The disease was so devastating that within four weeks after the first hatchling died, about 40 percent of the entire captive population was lost.

Etiology — Our current hypothesis assumes that SHD syndrome is the result of microbial infection magnified by polluted culture seawater. Pollution could have occurred in the closed (non-flow-through), recycled seawater system due to the gradual build-up of soluble organics from excess food and turtle wastes. Such conditions probably favored multiplication of pathogenic microorganisms, and at the same time created undue stresses on the turtles, thereby lowering their resistance to infection. Evidence to support the above hypothesis came from laboratory analyses and tankside observations. Bacteria were isolated from blood taken from moribund and freshly dead Kemp's ridley and loggerhead hatchlings, and the incidence of SHD syndrome was found to decline sharply (from about four percent to about 0.3 percent or less per day) and almost immediately after the hatchlings were transferred from polluted seawater to clean seawater.

Bacteria isolated from hatchlings showing SHD syndrome were of many varieties. One of them, *Clostridium bifermentans*, was derived from blood cultures of one moribund and one freshly dead loggerhead. This same bacterium has been isolated from cases of gas gangrene in humans (Smith, Conant and Overman, 1964). Another isolate, *Vibrio alginolyticus*, which is a common marine organism frequently associated with diseases in marine animals, was also obtained from blood culture of the same freshly dead loggerhead. The presence of these two bacteria in moribund or freshly dead turtles has suggested their possible role in causing SHD syndrome. However, more experimental studies will be required to confirm their true pathogenicity.

Other bacteria isolated and identified from post-mortem cultures were *Achromobacter pinnatum, Ac. delmarvae, Aeromonas formicans, Aer. punctata, Aer. shigelloides, Citrobacter (Escherichia) freundii, C. intermedius, Escherichia aerogenes, Pseudomonas* sp. (a pathogen of the Atlantic croaker, *Micropogonias undulatus*), gamma *Streptococcus* sp. (not group A, B or D), *Proteus mirabilis* and *Vibrio algosus*. All of these except *Escherichia aerogenes, C. intermedius, Achromobacter pinnatum, Ac. delmarvae* and *Vibrio algosus* have been associated with infections in humans, terrestrial animals or aquatic animals (Smith *et al.*, 1964; Jawetz, Melnick and Adelberg, 1972; Buchanan and Gibbons, 1974). Moreover, *C. freundii* has been associated with a fetal infection, known as septicemic cutaneous ulceration disease (SCUD) in turtles, Kaplan, 1957; Campbell and Busack, 1979). However, the symptomatology described for SCUD bears little resemblance to SHD syndrome. Determination of pathogenicity of bacterial isolates in relation to SHD syndrome will require more study.

At one time during the 1977 epizootic in loggerhead hatchlings, poisoning from the following sources was considered a possible mortality factor due to: remnants of stale, uneaten fish flesh left in the raceways, and dense blooms of a variety of algae in the closed system raceways. Stomachs of dead loggerhead hatchlings were frequently packed with fish flesh and algae. However, experimental feeding of healthy hatchlings with stale fish flesh and algal masses collected from the raceways and with food-packed stomachs of dead turtles produced no ill effects.

Signs and Symptoms — Although there are usually no observable external signs and symptoms associated with SHD syndrome, careful observations in an epizootic may show a few very weak hatchlings up to three weeks of age that float passively on the water surface with their front flippers hanging loosely downward. In normal hatchlings, the front flippers are folded back over the carapace during rest. Lethargic animals usually die overnight. Slow-dying animals display no external abnormal signs, so the lethargic condition is considered part of the SHD syndrome.

Necropsy of hatchlings with SHD syndrome frequently reveals a feed-packed stomach and fecal impaction in the lower bowel. Paralytic ileus is indicated.

Occurrence — An epizootic of SHD syndrome occurred in September 1977 when newly arrived loggerheads were about one week old. The loggerheads were maintained in concrete raceways with recycled (non-flow-through) seawater. Within four weeks, more than 400 hatchlings (about 40 percent) had died. Peak mortality reached about four percent per day toward the end of the fourth week.

In 1978, Kemp's ridley hatchlings were introduced and reared in fiberglass tanks and basins with daily changes of seawater (non-flow-through). In January 1979, due to outbreaks of various diseases and biting injuries, the ridleys were transferred to individual buckets suspended in the tanks, and seawater was completely replaced at least three times a week. About two percent of the 3,081 ridleys died from SHD syndrome during the 10 months of rearing. In all subsequent annual batches of Kemp's ridleys reared singly in suspended buckets, mortality attributable to SHD syndrome was negligible, estimated at less than one percent for the 1979 year-class and virtually non-existent in year-classes 1980-1983.

A condition designated as "early hatchling mortality" in green sea turtle (*Chelonia mydas*) hatchlings is thought to be an early manifestation of the grey-patch disease (Haines, Rywlin and Rebel, 1974). This latter disease has been attributed to a herpes virus infection (Haines *et al.*, 1974; Rebel, Rywlin and Haines, 1975; Koment and Haines, 1977). The sudden death nature of "early hatchling mortality" appears to resemble that of SHD syndrome. However, we have not observed signs of grey-patch disease in ridley or loggerhead hatchlings. Therefore, we do not consider "early hatchling mortality" and SHD syndrome to be the same.

Remedy — There is no established treatment for SHD syndrome. The key to its prevention seems to be use of non-polluted culture seawater. Frequent exchange or replacement with fresh seawater by manual draining and refilling of tanks is required to ensure good water quality in the rearing tank. Experiments have been conducted toward developing flow-through and recycled water systems, but none of these has proved practical for rearing Kemp's ridleys in our situation.

Chlorination (5 ppm chlorine) of seawater in the reservoir tanks before transferring the seawater to the turtle holding tanks was tried in early 1978 for prophylactic purposes. The results were not encouraging. Incidence of SHD syndrome and many other kinds of diseases in the chlorinated seawater did not appear appreciably different from those in control (non-chlorinated) seawater. Therefore, chlorination is not considered an effective method of prophylaxis. These observations suggest that the causal organisms of many infectious diseases were introduced into the seawater after it was transferred to the raceways and to other rearing tanks from the reservoir tanks. Apparently, the pathogens multiplied under favorable conditions in the culture seawater after the residual chlorine disappeared.

Papillary Dermatitis

Papillary dermatitis (PD), formerly called papillary eruption (Leong, 1979), affects skin tissues. Lesions occur around the eyes and the anus and on the limbs and the plastron. Although hatchlings of both Kemp's ridley and loggerhead can be affected, the disease was more prevalent in the latter species than in the former when reared in our laboratory.

Etiology — PD is responsive to antimicrobial chemicals, and is therefore presumed to be a microbial infection. Bacteria isolated from eye and anal lesions have included *Aeromonas formicans, Vibrio alginolyticus, V. algosus* and *Pseudomonas* sp.

Rebel *et al.* (1975) mentioned the presence of papillar tissues in virus-caused grey-patch disease of green sea turtles. Electron microscopic work performed in our laboratory on eye lesions of PD in loggerhead hatchlings did not show the presence of viruses.

Signs and Symptoms — Small, papilla-shaped projections that develop around the eyes and anus and on the skin and the plastronic suture are off-white, yellowish-tan or light-tan in color. When occurring around the eye, multiple papillae usually protrude from underneath the upper and lower eyelids and from the rear corner of the eye-socket. In advanced cases, the papillae may fuse into a crust which may spread to cover the whole eye, blocking eyesight. At the anus, the area surrounding the anal aperture usually becomes pale and swollen and assumes the shape of a ring bearing rows of small papillae. In advanced cases, crusts will form in the affected area.

Localized, small papillae also occur singly on the limbs, protruding through gaps between adjacent scales on the surface of the flippers. These flipper papillae do not form crusts. Similar single papillae can develop on the ventral side of the turtle's body, projecting through sutures between plastronic scutes. Currently eye, anal, flipper and plastronic eruptions are collectively considered under the name of one disease, PD.

PD is frequently accompanied by progressive emaciation of the turtle. Since only one or the other condition alone also is found in some turtles, it is not known yet whether PD and emaciation are related. Emaciation is discussed in more detail as a separate malady later in this paper.

PD progresses slowly. It takes many days for minor eruptions around the eyes and cloaca to become serious, as manifested by crustiness. Papillae on the flippers and the plastronic sutures usually remain solitary and non-fusive.

Occurrences —PD was first observed in one-month-old loggerhead hatchlings in early October 1977 after they were transferred from non-flow-through raceways to flow-through concrete tanks at the Galveston Laboratory's East Lagoon facility on the northeast tip of Galveston Island. The disease spread relatively fast. Within two months, practically every one of the more than 600 juvenile loggerheads held at the East Lagoon facility had contracted the disease. During the same period, 120 similar loggerhead juveniles were maintained individually in the Galveston Laboratory in 4-liter glass vessels for experimental purposes. Despite daily replacement of the culture seawater, approximately 15 percent of them developed PD.

In 1978, when new crops of loggerhead and Kemp's ridley hatchlings were group-reared in closed raceways in which seawater was replaced daily, less than two percent of each species developed PD, although other diseases flared.

Remedy — The prognosis in PD is good when not complicated by emaciation. Although PD alone does not seem fatal, the blocking of eye-sight by necrotic tissues (crust) may affect the turtle's ability to find food, a point not yet proven. However, when PD is complicated with emaciation, the survival rate for affected young turtles is estimated as 20 percent or less, even with medications.

Formalin baths (50 to 100 ppm for seven days with daily replacement of medicated seawater) combined with daily subcutaneous injections of a one percent (w/v) sodium ampicillin solution for 10 to 21 days has proven to be an effective treatment for PD. The lesions usually clear up within four weeks after medication. For unknown reasons, neither formalin bath nor ampicillin injection alone seems as effective as when combined in treating PD.

Ampicillin for injection is prepared in either sterile distilled water or a sterile solution containing 10 percent (v/v) Multiple Vitamin Infusion Concentrate (U.S. Pharmaceutical) and 10 percent (w/v) dextrose. The latter preparation is intended primarily for an emaciation complication. The dosage for injection is 0.25 mg ampicillin, or 0.025 ml of the ampicillin solution per 25 g wet body weight per day, preferably divided into two equal doses, one given in early morning and the other in late afternoon. The whole daily dose may be administered in a single injection, although this may be less effective.

Ampicillin, if unavailable, may be substituted with the less effective chloramphenicol sodium succinate. The recommended dosage is 1.25 mg chloramphenicol per 25 g wet body weight per day. Inconclusive results were obtained with the following chemicals and antibiotics in clinical tests against PD in loggerheads: malachite green, methylene blue (may be toxic as a bath), gentian violet (may be toxic to very young hatchlings), penicillin G, oxytetracycline, minocycline, erythromycin, and furacin. The routes of delivery of these drugs included subcutaneous injection, medicated bath and topical swabs.

Emaciation

Emaciation is a wasting syndrome with various underlying causes in young Kemp's ridleys and loggerheads. Affected turtles are weakened and their health deteriorates progressively until death. From the first discernible signs of emaciation until death, the whole process may last up to two months or more. In general, it appears that the younger the turtle, the more susceptible it is to emaciation and the more difficult is its recovery. Circumstantial evidence has indicated that loggerhead hatchlings are more vulnerable to emaciation than ridley hatchlings.

Emaciation in animals is the net result of dehydration or depletion of body tissues or both. There are many possible causes. Examples are microbial infection, metabolic or catabolic dysfunctions, inappropriate diet and involuntary reduction in intake of food, water or both. The last cause can be dismissed as a factor contributing to emaciation of turtles at the Galveston Laboratory, because plentiful food and seawater were always available to the animals, but all the other causes have been considered as potential contributers to emaciation.

A bacterium, *Mycobacterium marinum*, was isolated from the lungs of two dead and severely emaciated loggerhead hatchlings, the carcasses of which were kept frozen for over one month at 0°C prior to necropsy. It was possible that emaciation in those turtles was a result of lung infection by the bacillus. In necropsy, small fecal impaction was frequently observed in the lower bowel of emaciated specimens indicative of constipation prior to death.

Reichenbach-Klinke and Elkan (1965) suggested that faulty nourishment combined with lack of exercise may produce constipation in captive turtles. Thus, faulty diet could have been a possible cause of constipation in loggerheads of the 1978 year-class, leading to a form of emaciation which gave the hatchlings a shrivelled but hardened or block-like appearance. These turtle hatchlings were fed a diet composed exclusively of commercial feed (Master Mix S. S. Turtle Feed 9349) which might have been unsuitable for them, because within five months 95 percent of the head started loggerheads became emaciated and many died. Loggerhead hatchlings of the 1977 year-class, which were fed raw fish flesh during their early stage of life, did not contract a similar form of emaciation. Neither Kemp's ridleys at the Galveston Laboratory nor olive ridleys (*L. olivacea*) (Lyle Kochinsky, Nova University, Dania,

Fla., personal communication), appeared to have a similar problem when fed with the same pelleted food.

Lack of exercise was an unlikely cause of constipation in the Galveston turtles. Fecal impaction of the bowel was observed in necropsy whether the hatchlings had been allowed to swim freely in large rearing tanks with ample opportunities to exercise or had been confined in individual buckets.

There have been reports of emaciation and its causes in other turtles and reptiles. An epizootic among 2,000 captive-reared green sea turtle hatchlings at Cayman Turtle Farm (1983), Ltd., Grand Cayman, British West Indies, resulted in typically flat, weak and emaciated hatchlings, and was caused by a coccidian parasite, *Caryospora* sp. (Rebel, Rywlin and Ulrich, 1974). Marcus (1977) reported that reptiles infected with intestinal amoebiasis exhibited non-specific signs of decreased activity, progressive weight loss and anorexia although they also exhibited diarrhea, vomiting and excretion of bloody stools. Although emaciation has not been mentioned, it is reasonable to expect that in prolonged amoebiasis, emaciation eventually would follow. No evidence of similar parasitic infections has been found in the Kemp's ridleys and loggerheads head started at the Galveston Laboratory.

Weight loss and emaciation in turtles at the Penrose Laboratory of the Zoological Society of Philadelphia have been attributed to inanition (Cowan 1968), which is physiological dysfunction due to insufficiency of nutritional factors necessary for health and well-being. Berklow (1977) classified nutritional deficiency as either primary or secondary. Primary deficiency is due to inadequate nutrient intake, and secondary deficiency is a result of failure to absorb or utilize nutrients, increased nutritional requirements or excessive excretion. Digestion and absorption may be disturbed by gastrointestinal disease, and utilization and storage of nutrients may be impaired due to endocrine dysfunction, inborn errors of metabolism, severe infection or degenerative disease. Experiments will be required to determine whether the turtles reared at the Galveston Laboratory suffered from primary or secondary deficiency or both.

Captive Kemp's ridley hatchlings suffered a fatal form of systemic mycosis with the fungus *Paecilomyses* isolated as a presumptive causative organism (see Yolk-sac Mycosis). At first glance, such affected hatchlings appear emaciated, but careful examination will show that they do not possess the typical lean-and-wrinkled-neck characteristic of the emaciation syndrome as defined in this section. Instead, the infected turtles usually exhibit taut cervical skin with good muscle tone. Therefore, mycosis is not considered a cause of emaciation.

Signs and Symptoms — Sick turtles gradually lose weight and have a sunken plastron and a wrinkled and lean-looking neck. In advanced cases, anorexia is common, the vertical plane of the body trunk becomes thin and looks flattened due to severe sinking of the plastron, and the turtle becomes very weak and lethargic. Quite often the pliable skin of the suprafemoral pouch between the base of the hind femur and the shell sags and fails to assume a taut, domed shape as in normal turtles. In some cases, the body shell may become softer and more pliable than normal. On other occasions, the whole torso may appear relatively hard, solid and shrivelled as in constipated loggerheads of the 1978 year-class, which were suspected of having been fed a faulty diet. X-radiography shows that in "soft-shelled" individuals, the ribs in the carapace are poorly developed.

Necropsy shows that emaciation could be associated with one or more kinds of internal disorder such as fecal impaction of bowel (most common), mycobacterial pneumonia, intestinal perforation and peritonitis. In fecal obstruction of the bowel, the lower colon is packed with hard feces, while the rectum is usually void.

Growth of hatchlings after recovery from emaciation is often stunted, the animals retaining a dwarfed physique and having a weak and unhealthy appearance. A few recovering turtles also maintain a rather soft and pliable shell.

Occurrence — Emaciation first appeared in early October 1977 in one-month-old loggerhead hatchlings maintained in outdoor, flow-through raceways. The condition was frequently concurrent with papillary dermatitis (PD) described earlier in this paper. Emaciation, either uncomplicated or complicated with PD, continued to spread when the loggerheads were transferred to an indoor, non-flow-through raceway in December 1977 in anticipation of colder weather. The seawater in the raceway was recycled through an oyster-shell filter bed. Emaciation soon reached epizootic scale, affecting more than 300 of about 600 hatchlings within two months. By April 1978, about 80 percent of the turtles had exhibited emaciation at one time or another, and many of them died. Meticulous clinical care and the development of new therapeutic methods helped some (about nine percent) emaciated turtles recover.

Kemp's ridleys and loggerheads of the 1978 year-class were mass-cultured in non-flow-through raceways. An estimated 10 to 15 percent of the ridleys became emaciated, often in association with PD, and died within the first nine months. The loggerheads did well in the first five months, but later 95 percent of them developed the hardened and "block" form of emaciation with no contemporary PD. Necropsy showed that most of the emaciated loggerheads had hard feces in the colon. Nevertheless, these data should not be taken to imply that Kemp's ridleys were less susceptible to emaciation than loggerheads until more conclusive data from controlled experiments are obtained, because the ridleys of the 1978 year-class were reared in solitude in individual buckets in the raceways starting from the eighth month, while the loggerheads continued to be kept under conditions of non-isolated, group rearing. The isolation culture of sea turtle hatchlings had been found to play an extremely important role in disease prevention, although

the reason is unknown. Emaciation occurred only sporadically in Kemp's ridley hatchlings of subsequent year-classes kept under isolation rearing.

Conditions resembling emaciation have been reported in other turtles and reptiles. At the Penrose Research Laboratory, among 1,249 cases of reptilian mortality including 92 turtles and tortoises, 60 percent were characterized by a wasted condition, depletion of fat depots and fragile tissue and skin (Cowan, 1968). In the spring of 1973, 2,000 captive green turtle hatchlings at the Cayman Turtle Farm were ill and described as typically flat, weak and emaciated (Rebel *et al.*, 1974).

Although no emaciated turtle hatchlings have been noted among those shipped to us, other workers have reported that on occasion newly acquired turtles may be received in a severely starved and dehydrated condition (Campbell and Busack, 1979). The age of these turtles was not specified. The emaciation syndrome encountered in the Galveston Laboratory was not shipment-related.

Remedy — Current prognosis in emaciation is grave because of difficulty in diagnosis and lack of fundamental understanding of the etiology. Despite treatment of symptoms and general clinical care given to sick turtles, the recovery rate has been less than 20 percent.

To a large extent, emaciation seems preventable by isolation-rearing. For example, in Kemp's ridley hatchlings of the 1978 year-class, an estimated 10 to 15 percent of the animals contracted fatal emaciation while being held in free-swimming groups in raceways. Since then, solitary rearing has been the standard, and incidence of emaciation has decreased correspondingly. In the 1980 year-class, the incidence of emaciation was less that two percent. For loggerheads, there have been no comparable data for both isolation and non-isolation rearing within raceways, but in 1977 loggerhead hatchlings that were isolated in individual containers under laboratory conditions were rarely afflicted with emaciation, while about 80 percent of those group-reared in raceways suffered from the syndrome.

In clinical care, emaciated turtles should be individually isolated as soon as possible. The culture seawater should be completely replaced every day. When only a few animals have to be cared for, and staff is sufficient, it may be wise to disinfect the container with sodium hypochlorite every time the used seawater is replaced. This disinfection procedure may not be practical, and therefore omitted, when a large number of sick turtles is involved. Resources permitting, non-corrosive and autoclavable containers may be used, so that they can be steam-sterilized.

It is preferable to feed sick hatchlings thin slices of frozen-and-thawed raw fish flesh in lieu of pelleted commercial feed. Freezing and thawing can destroy some potential pathogens, and freezing can preserve the nutrients in the fish flesh in storage. The daily ration should not be excessive: three percent of body weight or an amount which the sick turtles can totally consume in an eight- hour work day. Animals which do not eat may be fed a semisolid cereal diet by means of intraesophageal intubation. Occasional starving of anorexic animals for 24 hours does not appear to harm them. Either independently or in combination with intubation feeding, subcutaneous injection of life-sustaining doses of a sterile dextrose-multivitamin solution is also recommended. Intubation feeding, injection or both may be continued until the animals regain appetite.

In clinical tests, injections of antibiotics such as chloramphenicol, ampicillin, oxytetracycline and gentamicin did not produce significant therapeutic effects, nor did bath treatments with formalin, methylene blue, chloramphenicol, minocycline (either alone or in combination with erythromycin) or gentamicin. The recovery rate from emaciation was no better in medicated turtles than in non-medicated ones.

A number of cathartics including warm water, light mineral oil, milk of magnesia and Metamucil (psyllium hydrophilic mucilloid; Searle Laboratories) have been tested in attempts to correct constipation in emaciated turtles. These carthartics were administered either orally by intraesophageal intubation or as an enema as appropriate. Only milk of magnesia at 0.025 ml per 100 g body weight per day *per os* occasionally induced a slight level of defecation in two out of six juvenile Kemp's ridley patients. There are unconfirmed reports that castor oil appears to be effective in inducing defecation in some constipated Kemp's ridley hatchlings.

Focal Erosive Dermatitis

Focal erosive dermatitis (FED) is characterized by the progressive disintegration of cutaneous tissues and formation of shallow, erosive lesions which are sometimes covered with crusts of necrotic tissues. The disease may affect the skin or surface tissues of many body parts, such as the eyelids (blepharal FED), head (cranial FED), carapace (carapacial FED), flippers (flipper FED) and nose (nasal FED). An additional form which erodes the edge of a flipper is named flipper-edge focal erosive dermatitis (Flipper-edge FED).

Although the lesions of FED are sometimes rather unsightly and alarming, there has been no evidence that the disease by itself is fatal.

Etiology — FED is presumably caused by bacterial infection. Several bacteria have been isolated from lesions on the eyes and carapace of Kemp's ridleys, and these lesions can be cured by the use of antibacterial drugs.

Injury to the skin is perhaps a predisposing factor for bacterial invasion. Skin injuries may be caused by mutual

scratching or biting among hatchlings that are placed in close contact (group-rearing) with each other. Also, human handling of the turtles during routine maintenance or transhipment may contribute to skin injuries. The supposition of an injury-infection is supported by the observation that there was a rapid decline in incidence of FED when the group-rearing approach was replaced by solitary rearing.

The bacteria isolated from eye and carapace lesions have included *Aeromonas formicans, Vibrio anguillarum, V. alginolyticus* and *Citrobacter freundii.* One or more of these bacteria may be the causative agent(s) contingent upon further pathogenicity studies. Stickney, White and Perlmutter (1973) reported isolation of an *Aeromonas* sp. from superficial lesions in three and a half-month-old loggerhead hatchlings. In reference to this findings, Sinderman (1977) commented that *Aeromonas* spp. were common inhabitants of aquatic environments, and might be facultatively pathogenic to animals living under conditions of environmental stress.

An anaerobic bacterium, *Bacteroides* sp., has been considered as the causal organism of a skin disorder in one- or two-month-old loggerhead hatchlings (Witham, 1973a). The disease has been described to produce necrotic, spreading, nonwalled skin lesions causing most of the hatchlings to die within a week of the first appearance of the malady. It is dubious that this disease is the same as FED, since FED does not seem to be fatal by itself.

Signs and Symptoms — Except in carapacial FED, freshly formed lesions have not been observed. Relatively fresh lesions of carapacial FED have an ivory color due to exposure of underlying ground substance of the shell after the dark-colored epidermis erodes away. Older lesions are greyish-tan or yellowish-tan, usually shallow, localized erosions of the skin. In blepharal FED, it appears that the eyelids become puffy and discolored in a pre-erosion phase, but this observation remains to be confirmed.

Typically FED forms shallow lesions below the skin level due to the loss of surface tissues. The lesions are usually irregular in shape, spreading out in all directions and producing an uneven margin. They are variable in size, ranging in diameter from about 2 mm, when first noticeable on hatchlings in the raceway, to more than 1.5 cm. Often as neighboring lesions spread, they become merged, producing a large necrotic patch.

Besides the typical FED lesions on the skin surface of the flippers, there is a condition in which the entire thickness of part of the edge of a limb is eroded away, giving a worm-eaten appearance. Because the condition involves the invasion of deeper rather than just surface tissues, it may be a different form of disease. However, until further studies, it is included under FED for the purpose of this paper. The name flipper-edge FED is given to this abnormal form of FED to distinguish it from the typical, skin-surface type of flipper FED.

Usually there is little if any build-up of crust in cranial, carapacial and flipper FED lesions or in flipper-edge FED lesions. In blepharal and nasal FED, crusts may be present. In severe cases, an overabundance of crusts may cause either total or partial closure of the eyelids or blocking of the nostrils.

Occurrence — In early October 1977, approximately 600 four-week-old loggerhead hatchlings of the 1977 year-class were transferred from closed concrete raceways to flow-through concrete tanks. Within two weeks, many of the young turtles began to exhibit signs of cranial FED. Within the following two months, an estimated 80 percent of the population contracted cranial FED of either severe or limited extent.

During the summer of 1978, 3,081 newly emerged Kemp's ridley hatchlings were acquired and reared in close contact in closed-system, fiberglass raceways.

These turtles were extremely aggressive, chasing and biting each other vigorously. Within three months, practically every turtle was afflicted with either one or more forms of FED at one time or another.

Immediate isolation of sick hatchlings into individual vessels coupled with drug medication generated excellent therapeutic effects. However, when about 2,000 cured turtles were returned to the mass populations in the raceways, they were re-infected. Beginning in January 1979, the isolation-rearing method (see section Rearing of Turtles) was implemented. The incidence of focal erosive dermatitis rapidly fell. To this date, FED no longer constitutes a health threat to captive Kemp's ridleys reared in isolation from each other during their first year of life.

Remedy — Isolation of individual sick turtles and daily replacement of culture seawater coupled with subcutaneous injection of ampicillin (sodium) at 0.25 mg per 25 g wet body weight per day is effective treatment for FED, particularly the blepharal and flipper forms. A seven-day formalin bath (50 to 100 ppm) is also effective against the flipper-edge form of FED. Lesions are usually healed in about four weeks following onset of medication.

The best prophylaxis against FED is to raise the hatchlings by the isolation-rearing method as described in the section Rearing of Turtles.

Self-limiting or spontaneous healing of lesions frequently occurs in carapacial FED when the afflicted turtles are individually isolated and provided with clean seawater daily. The healing process may last up to two months or more. Administration of ampicillin does not seem to shorten the wound-healing time in carapacial FED, as it does in blepharal FED, or have harmful effects from ampicillin been observed. Since blepharal, flipper and carapacial FED often occur simultaneously in a single Kemp's ridley, both ampicillin and isolation treatments are given to such turtles having a mixture of different forms of FED.

Cranial and nasal FED do not respond to medication and isolation as well as do blepharal and carapacial FED. Cranial and nasal lesions can be very persistent. Some cases have failed to respond to clinical treatments for four months or more. Occasionally, a lesion may even expand while the turtle is under clinical care.

A condition that appears to resemble FED and that is designated as focal necrosis of skin has been reported in young green and loggerhead sea turtles (Witham, 1973b). However, unlike FED, focal necrosis of skin has been described as causing death of the affected animals unless treated with potassium permanganate (1 g per 220 liters in bath treatment). Therefore, FED and focal necrosis of skin are probably diseases of a different nature. In short-term observations, application of potassium permanganate bath does not cure FED in Kemp's ridleys.

Aggressive Biting

Aggressive biting is included in this paper because it happens extensively among hatchlings of Kemp's ridley and frequently causes serious physical damage in the bitten turtles. There is no evidence that aggressive biting contributed directly to the death of a turtle at the Galveston Laboratory, but apparently the inflicted wounds provide a convenient portal of entry for pathogenic microorganisms. Further, it may be reasoned that if a turtle with a missing eye or part of a flipper were released into the sea, chances of survival would be reduced, because such a handicapped turtle would be easy prey for larger marine animals. Therefore, a standard practice in the head start project has been not to release such injured sea turtles.

It has not been conclusively established that Kemp's ridleys older than one year do not bite each other, but evidence has indicated that they at least are not as aggressive as individuals one year or less in age.

Etiology — Aggressive biting apparently is an intrinsic behavior in young Kemp's ridleys. Why such aggressive behavior is so intense in captive Kemp's ridley hatchlings but not in loggerhead hatchlings under similar environmental conditions is unknown. What actually stimulates Kemp's ridley hatchlings and juveniles to bite one another is also not understood. Color and movement are two presumptive stimuli, but controlled experiments are needed to evaluate this hypothesis.

Signs and Symptoms — Almost every part of the body of a Kemp's ridley turtle that is accessible to the mouth of another Kemp's ridley is vulnerable to injury through biting. The most vulnerable sites are the flippers, the edge of the shell, the neck and the head. In serious cases, a large piece of body tissue or a portion of a limb may be torn off, leaving behind large fleshy wounds.

Occurrence — Aggressive biting began when captive Kemp's ridleys were about three weeks old. Among the 3,081 ridley hatchlings acquired in late July 1978, more that 800 (27 percent) showed signs of bite wounds by mid-August. Bite-wound incidence continued to mount and affected more than 80 percent of the turtles by January 1979. Afterwards, all the hatchlings were individually confined in plastic buckets in isolation-rearing and therefore were prevented from biting each other. Surprisingly, when solitarily confined ridleys were returned to free-contact and group-rearing raceways upon recovery from disease or injury, they showed a higher level of aggressive biting behavior than before they were isolated.

Minor chasing and biting were observed in hatchling loggerheads, but the turtles suffered no apparent injuries. Hatchlings of the green sea turtle seem even more docile. In summer 1978, no aggressive biting was observed by the senior author among approximately 100 young green sea turtles averaging 250 g each, held in an outdoor concrete tank at Miami Seaquarium, Miami, Florida.

Remedy — Individual isolation-rearing is the best protection against aggressive biting and wounding in Kemp's ridley, but it is labor-intensive, especially in a mass-culture situation such as that at the Galveston Laboratory. Unfortunately, no better rearing system has been developed to date for Kemp's ridleys.

Injured hatchlings are immediately isolated in individual vessels that receive daily changes of seawater. For wound treatment, a piece of sterile surgical sponge or a cotton swab is used to absorb the water from the injured area, followed by cleansing with hydrogen peroxide (three percent) on a cotton swab. When the wound is dry, it may be treated topically with a general antiseptic such as neosporin ointment or merthiolate, and the turtle is then returned to the holding vessel. In serious injuries, ampicillin (sodium) may be administered subcutaneously at a dose of 0.25 mg per 25 g body weight per day. Wounds usually heal in four to eight weeks. The healed surface will resume the normal dark color, but the bulk of the missing tissue is not replaced.

Focal Dermal Granulosis

Focal dermal granulosis (FDG) produces localized lesions in the form of discolored and often grainy patches in the skin of young sea turtles. The disease is not fatal, and the affected turtles are active and continue their normal growth.

Etiology — A bacterium, *Pseudomonas alcaligenes*, was isolated from the deeper tissues in focal dermal granulosis lesions which had been surface-sterilized with 70 percent alcohol and tincture of iodine. Further studies are needed to determine the pathogenicity of that organism.

Signs and Symptoms — Discolored, localized lesions that have a granular appearance can be found on the surface

of the shoulders and the axilla of the front flippers. Lesion color ranges from light grey to greyish-tan, often overlaid by a thin network of bright yellow substance.

The lesions are flat and slightly elevated. They are usually more or less oval-shaped in the neck, but irregularly shaped in other affected skin areas. When first noticed on hatchlings in the raceway FDG lesions are usually about 1 cm or more in length or diameter, depending on their shape. Such lesions continue to expand in time. An axillary lesion may spread to cover an irregular, area 2 cm or more in diameter.

Occurrence —An estimated 2 to 3 percent of loggerhead and Kemp's ridley hatchlings contracted FDG in 1977 and 1978 under group-rearing conditions. However, no deaths were attributed to the disease.

Witham (1973b) reported a fatal condition called focal necrosis of skin in tank-reared green and loggerhead turtles. Since FDG is non-fatal, we assume that it is a different disease from focal necrosis of skin.

Remedy — Static formalin bath (50 to 100 ppm) continued for five to seven days is effective. The medicated bath water is replaced completely on a daily basis. Occasionally, signs of healing appear after only three days of medication. Care should be taken not to over-extend the treatment period. Over-treatment will delay instead of promote healing. Potassium permanganate bath (5 ppm) was tried, but the results were inconclusive.

Occasionally, FDG is self-healing when the affected turtle is kept isolated in clean seawater. The FDG lesion sheds a scab and leaves behind a discolored scar on the skin. The healing and scab-shedding processes are promoted with formalin bath treatments.

Scolecobasidiosis

Scolecobasidiosis is an infection caused by a fungus belonging to the genus *Scolecobasidium*. At least two kinds of scolecobasidial infection have been observed: scolecobasidial pneumonia (SP), an infection of the lung, and scolecobasidial osteomyelitis (SO), an infection of the bone. An infected turtle may live a long time before it dies. In some cases of SP, progress of the disease may arrest spontaneously under the right environmental conditions, and the animal continues to live with only one functional lung and with abnormal swimming and floating patterns; i.e. tilted swimming and side-floating. Both SP and SO have been encountered only in young Kemp's ridleys and not in loggerhead hatchlings.

Etiology — The fungus *Scolecobasidium constrictum* has been observed repeatedly in and isolated from tumor-like or cyst-like spherical bodies in affected lungs and rear flippers of Kemp's ridleys. The same fungus has been observed or isolated in a limited number of cases of scoliosis and inflamed shoulder joints. Cultures of synovial fluid taken from inflamed shoulders were negative for bacterial infections.

Sometimes other fungi such as *Paecilomyces* sp., *Penicillium* sp. and *Cephalosporium* sp. are also recovered in cases of SP. Their role in such infection has not been determined. *Penicillium* and *Cephalosporium* are probably contaminants. *Paecilomyces* sp. is also often isolated from smaller tissue nodules as described under Internal Nodular Mycosis.

Signs and Symptoms — In the majority (estimated 97 percent) of SP cases, an infected turtle swims or rests on the seawater surface with its body tilted to one side. This side-floating syndrome is usually the first sign that the animal may have contracted SP. Another frequently observed gross sign is bulging of the dorsal front half of the carapace of the buoyant side of a tilted turtle into a minor hump. Side-floating and humping are usually not observed until the animals are four months old or older, when the disease is in a relatively advanced stage. Methods for early diagnosis are not known. It should be noted that side-floating alone is not specific for SP. Turtles having lung aplasia (described separately in this paper) also exhibit a similar sign. Jacobson *et al.* (1979) reported isolation of three fungi, *Sporotrichum* sp., *Cladosporium* sp. and *Paecilomyces* sp., from infected lungs in green turtles which exhibited tilted swimming behavior.

Necropsies of turtles that have died from SP generaly show consolidation of tissues of one of the lungs into a relatively large spherical cyst. This tumor measures as much as 2 cm or more in diameter and may be empty or filled with blood or a clear fluid. Tissue consolidation appears to occur more frequently at the frontal portion of the lung. The interior wall of an empty sphere may be dark-green, but if the sphere is filled with fluid, the wall is lined with coagulated blood. Also residing in the wall are fungal mycelia and spores from which the fungus *S. constrictum* is invariably isolated. Another fungus *Paecilomyces* sp. is also sometimes isolated.

Generally, only one of the lungs develops a large spherical body (2 cm or more in diameter). Smaller solid tissue spheres or nodules ranging from pin-head size to 1 cm in diameter may also be present in one or both lungs, in the liver and occasionally in the cardiac auricles. These smaller nodules cannot be distinguished from those caused by other fungal organisms such as *Paecilomyces* sp. Therefore, unless they are confirmed as scolecobasidial nodules through the actual isolation of *Scolecobasidium* they are categorized as Internal Nodular Mycosis for the purpose of this paper.

Images of infected lungs can be seen in X-radiographs, but the diagnosis is non-specific. Also, X-ray can reveal that a non-affected lung may expand over to the other side of the spinal column.

SO affects the bones of the hind flippers and perhaps the vertebrae and the shoulder joints. Tissues adjacent to infected bones in a flipper swell to form a tumor. X-ray shows that the phalanges, the metatarsals, the tarsals and the tibia may be eroded to a greater or lesser extent.

There are indications that SO can cause scoliosis of the vertebral column as well as swollen and stiffened shoulder joints. X-ray shows the formation of a curvature in the spine and sometimes there is erosion in some of the vertebrae. *S. constrictum* has been recovered by culturing tissues taken by biopsy adjacent to the affected vertebrae. In correspondence to curvature of the internal spinal column, the ridge of the carapace is also curved, thus affording an external means of detecting scoliosis. The specific relationship between scoliosis and scolecobasidiosis remains to be determined.

When a turtle experiences an inflamed shoulder joint, the affected front flipper shows stiffness and difficulty in swimming. On closer examination, the shoulder joint is swollen, and X-ray may show erosion of the head of the humerous at the glenoid fossa. *S. constrictum* sometimes can be recovered through culturing the affected tissues as in scoliosis.

Occurrence — With the exception of one unconfirmed case in a young loggerhead in 1981, all cases of scolecobasidiosis have been observed in Kemp's ridleys. SP was by far the most frequent of the two forms of scolecobasidiosis in Kemp's ridleys with 7, 18, 4, 23, 8 and 6 cases in the 1978 to 1983 year-classes, respectively. Since SP is confirmed only through isolation of the causal fungus or by actual observation of the characteristic tumefaction of the lung at necropsy, and since we could not perform detailed laboratory analysis on every turtle, there may have been cases of SP that escaped our detection.

There were three cases of rear-flipper SO and two cases of scoliosis in the 1979 year-class of Kemp's ridleys. One of the scoliotic cases was associated with arrested SP in a Kemp's ridley that has been kept in captivity for three years because of fungal pneumonia, but there was no sign that the infection had spread to the vertebrae. In the other case of scoliosis, X-ray showed lesions in a few vertebrae. There were at least two cases of inflammed shoulder joint diagnosed in the 1979 year-class of Kemp's ridleys.

Casual observations suggested a direct relationship between the incidence of SP and lower environmental temperatures, especially when there were frequent fluctuations between cold and warm temperatures during winter.

Remedy — In clinical trials, fungizone (Squibb; containing amphotericin B as the active ingredient) was injected subcutaneously into six young ridleys, averaging about 300 g in body weight and suffering from advanced SP. The starting dosage was 0.0125 mg amphotericin B per 100 g wet body weight per day, with weekly increments of 0.0125 mg per 100 g. Four turtles died after one to two months of medication indicating that the therapy was ineffective. Therefore, treatment was terminated.

Other forms of chemotherapy were also tried, but found to be ineffective. These methods included formalin bath, malachite green bath, and oral ketoconazole (dissolved in dimethyl sulfoxide). In general, evaluation of chemotherapy for SP was difficult because there was lack of specific internal monitoring and diagnostic methods. It is possible that some of the antifungal drugs are effective against scolecobasidiosis if applied at an early stage of infection. Therefore, research should be done to discover and develop early diagnostic and monitoring methods.

In 1978 and 1979, most ridley turtles that were afflicted with SP eventually died. Occasionally, the infection in some turtles seemed to be arrested spontaneously without medication. Upon discovery of turtles with signs of SP, these turtles were isolated quickly and were given a warm (26° to 28° C) clean seawater environment. In 1982, eight live Kemp's ridleys of the 1981 year-class were diagnosed as having presumptive SP. After receiving more than three months, non-medication, clinical care, six (75 percent) of the animals survived, and the SP infection in them appeared to have been arrested. This 75 percent recovery rate was an exception rather than the norm. In our experience, the rate of spontaneous recovery of SP infection does not exceed 20 percent. Nevertheless, in the absence of effective chemotherapy, the key to spontaneous recovery of SP-stricken Kemp's ridleys is immediate isolation and provision of a clean, stable and warm (26° to 28°C) seawater environment. It is not necessary to reduce the feeding level unless the animal becomes anorexic.

The isolation-rearing method was also effective against inflamed shoulder joints. After about three months solitary rearing in two turtles with SO, the swelling and stiffness at the shoulder joints subsided and the turtles were able to use the flippers freely again in swimming.

There is no effective treatment for scolecobasidial infection of flipper bones and scoliosis. Surgical removal of infected soft tisues in two cases of rear-flipper SO followed by daily oral administration of ketaconazole (4 mg in dimethyl sulfoxide per 100 g wet body weight per day) was ineffective. Both turtles died within one month. The two turtles with scoliosis also died.

At this point, the best strategy seems to be prevention. Based on our experience, it appears that avoidance of sudden changes of ambient temperature from warm to cold would reduce incidence of scolecobasidiosis.

White-suture Syndrome

White-suture (WS) syndrome involves the whitening and broadening into a narrow ribbon shape of the suture lines between scutes of the carapace. There are two kinds of WS syndrome: (1) dull white-suture (DWS) syndrome and (2) shiny white-suture (SWS) syndrome. These two kinds of WS syndrome not only are morphologically different but also respond differently to the same medication. It is most likely that their etiology, which remains to be determined, is also not the same. In this paper, they are grouped under the same heading for convenience.

Etiology — The etiology has not been determined for either form of WS syndrome. *Fusarium*-like fungal spores have been observed in the white ribbon on the suture line in the DWS syndrome. Confirmation of the pathogenicity of this fungus will require further studies.

Signs and Symptoms — In DWS syndrome, the carapace sutures widen into a narrow ribbon shape and assume a dull white or greyish-white color. The edges of the "ribbon" are smooth and non-undulate. Transformation and discoloration of the sutures are gradual, starting out with a few sutures and slowly spreading to the others. In severe cases, all sutures are affected. Microscopic examinations of ribbon materials reveal a mixture of debris, bacteria, protozoans and *Fusarium*-like fungal spores.

In SWS syndrome, the white ribbon over the transformed suture is shiny or glistening with a bluish tint and appears slimy. The edges of the ribbon are uneven and undulate. Microscopically, the ribbon material is composed of debris, bacteria and protozoans.

Occurrence — DWS syndrome occurred very commonly in young loggerheads of the 1977 year-class. In static seawater in raceways, more than 70 percent of the turtles contracted DWS syndrome. In loggerheads and Kemp's ridleys of the 1978 year-class, less than 10 percent of the young turtles contracted either DWS or SWS syndrome, and since then either syndrome was encountered only sporadically. The decrease in WS syndrome could have been due to the progressive modification of turtle rearing methods, resulting in a significant improvement of seawater quality in the culture tanks.

Remedy — DWS syndrome responds well to formalin bath (50-100 ppm) treatments carried out for three to seven days with daily replacement of medicated seawater. One week or more after termination of the bath treatment, the ribbon-like white material, which by then has turned grey, detaches from the affected sutures. The healed sutures on the carapace resume a normal appearance. Formalin bath is not effective against SWS syndrome.

From all indications, both DWS and SWS syndromes seem to be preventable through the provision of a sanitary seawater environment.

Yolk-sac Mycosis

This disease is called yolk-sac mycosis (YSM) because the causal fungus invades the yolk-sac inside the body cavity of neonate Kemp's ridleys. Most infected hatchlings die young, usually within the first month after hatching.

Etiology — A fungus, *Paecilomyces* sp., has been frequently observed in or isolated from infected yolk-sac tissues. This fungus is a presumptive causal organism for yolk-sac mycosis.

Signs and Symptoms — Hatchlings usually die very young with little external manifestation of disease. Therefore, it is very hard to detect infected live hatchlings in a mass-culture situation such as that at the Galveston Laboratory.

At necropsy, the infected yolk-sac is usually found to be hardened into a block with the internal yolk material turning into a friable mass. Vascular congestion is often prominent on the yolk sac surface. Microscopic examination of diseased yolk materials show the presence of abundant fungal hyphae and spores characteristic of *Paecilomyces*. The fungus which can be isolated from infected tissues will grow on Sabouraud dextrose agar supplemented with a three-salt solution at 26°C.

Occurrence —YSM was first observed in hatchlings of the 1980 year-class of Kemp's ridleys. Since then, the disease occurred in every year-class through 1983. There were 7, 59, 5, and 3 cases in the 1980 to 1983 year-classes, respectively. Younger hatchlings appeared to succumb more readily to the disease than older ones.

Remedy — There is no known therapy for YSM. Currently, the disease is only discovered at necropsy, too late to provide a remedy even if one were available. Methods are needed for early detection and diagnosis. Moreover, information is needed on the source and mode of infection to guide possible development of prophylaxis.

Internal Nodular Mycosis

Internal nodular mycosis (INM) refers to formation of nodules in an internal organ as a consequence of mycotic infection. The nodules are solid and relatively small in contrast to the larger, spherical, hollow cysts formed in the lungs in advanced stages of SP. It is possible that some of the nodules in INM are early lesions of SP, and some are caused by *Paecilomyces* infection. Grossly, INM nodules are indistinguishable with respect to etiological agent. The only way to distinguish them is detection of the specific fungus in laboratory analyses such as culturing the nodular tissue to isolate the microorganism or direct microscopic examinations of tissue specimens. Unfortunately, such diagnostic procedures are time-consuming and labor-intensive, especially when the nodules are numerous and

several organs are infected. To compound the problem, sometimes *Scolecobasidium constrictum, Paecilomyces* sp. and perhaps other fungi such as *Cephalosporium* sp. and *Penicillium* sp., which are thought to be contaminants, are cultured from the same nodule. Therefore, precise diagnosis is not easy when many turtles are infected and when resources are limited. In light of such difficulties, we do not attempt at this time to distinguish the different kinds of mycotic nodules, but group them as one disease category, INM.

INM appears to progress slowly in a hatchling host after initial infection. The net result of INM infection is usually death of the host.

Etiology — The fungi *S. constrictum* and *Paecilomyces* sp. have been frequently isolated from nodular tissue specimens. These two fungi are presumptive causal organisms. Other fungi such as *Cephalosporium* sp., *Pencillium* sp. and *Aspergillus* sp. are found occasionally. Pending further studies, we regard them as either secondary pathogens or contaminants.

Signs and Symptoms — Hatchlings afflicted with INM do not always display external manifestations. Those that do usually but not always show an atrophied body trunk, which resembles a solid hard block and is thickened at the horizontal plane (i.e., from carapace to plastron), so that the whole trunk appears bloated. The neck, however, is not affected as in emaciation syndrome; i.e., it remains relatively full with good muscle tone and its skin is taut, not wrinkled. An afflicted hatchling often, but not always, floats higher in the seawater than a normal one, and its activity ranges from normal to lethargic. Appetite for food may be reduced. Infected turtles usually continue to feed until they become very weak or approach death.

External signs are nonspecific for INM. Definitive diagnosis is dependent upon observing fungus-infested nodules in internal organs. Unfortunately, techniques for such observations have not yet been firmly established for live hatchlings. X-radiography coupled with *in vitro* culture and isolation of fungus from biopsied tissues provides a promising approach to diagnosis of this mycosis.

Many major visceral organs or tissues can be afflicted with the mycotic nodules. Nodular formation is most frequently (about 85 percent of the cases) encountered in the lungs. It is also found in the kidneys, liver, and mesentery, and occasionally in the alimentary system (stomach, intestine and esophagus), muscle, inner surface of the carapace and in the yolk-sac. In about 20 percent of the cases, more than one organ or tissue in the same turtle have nodules on them.

The nodules are solid, spherical objects that usually protrude on the surface of an afflicted organ. In a few cases, some nodules have been found embedded below the surface of an organ. The nodules are either white or creamy white and range in size from about 1 to 8 mm in diameter. Their solid core distinguishes these nodules from the hollow, often fluid-filled cysts in the advanced stages of SP, although *S. constrictum*, which is a presumptive causal organism of SP, is also one of the fungi isolated from the smaller, solid nodules.

Occurrence — Based on necropsy records, the annual occurrence of INM in Kemp's ridley hatchlings maintained in the Galveston Laboratory was 19, 8, 13, 138, 73 and 23 cases in year-classes 1978 to 1983, respectively.

Remedy — Clinical trials with prolonged, daily intraesophageal incubation of potassium iodide in hatchlings that exhibited outward signs of INM succeeded in reversing or reducing some of the abnormal signs in a few turtles. These turtles continued to live. In other similarly infected hatchlings, potassium iodide treatment was ineffective and the animals died. Nevertheless, potassium iodide treatment appears promising and more research should be done to explore its usefulness as an anti-INM agent in sea turtles.

Hypernecrotic Warts

Hypernecrotic warts (HW) are tumor-like or swollen lesions that occur on the skin, front flippers, carapace, plastron and head and that usually become heavily encrusted with continuous formation of necrotic tissues. The disease appears to be fatal, although sometimes an afflicted hatchling can live a relatively long time (e.g., two months or more) before it dies. Necropsies reveal that hypernecrotic warts are often accompanied by INM, but not necessarily vice versa. Whether death occurs as a direct result of hypernecrotic outgrowth, INM or both has not been determined.

Etiology — Two fungi, *Scoloecobasidium constrictum* and *Paecilomyces* sp., have been isolated from hypernecrotic lesions. They are the presumptive pathogens. Although *S. constrictum* has been cultured from flipper and carapace lesions and *Paecilomyces* sp. from cranial and skin nodules, the specific affinity of individual fungi to specific tissue types has not been established.

Signs and Symptoms — Basically there are two forms of HW lesions: a conical form and a round (non-conical) form. Conical lesions appear to be limited to occurrences on soft skin parts such as the neck and the suprafemoral pouch. They are cone-shaped projections with pointed ends distal from the skin. The nodule is about 3 to 5 mm high and about 2 to 4 mm in diameter at the base. The color of the nodule is grey or dark-grey, similar to the color of the skin. Necrotic tissues that appear on older lesions continue to form as laminated layers on the nodule.

A rounded HW is basically represented by elevated, localized swollen tissues. The lesion is relatively round or flat at the top, rather than cone-shaped. Such lesions may be found on a variety of external body parts.

Formation of the lesions differs according to the site of infection. On the front flipper, a lesion arises from either the elbow or the base of the lateral claw. In the latter cases, the tissues adjacent to the claw swell to form a localized and irregularly oval-shaped lesion visible from both the upper side and underside of the flipper. The lesion, when measured from either face of the flipper, usually grows to about 5 x 10 mm. At a yet undetermined time, necrotic tissues begin to appear on the swollen lesion, and they continue to grow and accumulate in laminated layers following the contour of the lesion.

On the head, a round hypernecrotic lesion begins as one or more small elevated hard nodules or bumps in the crown area above the brain. The nodule(s) continue to grow and usually, although not always, the skin of a nodule breaks open to expose an accumulation of necrotic tissues. These necrotic tissues continue to multiply gradually to form a necrotic mass outside the skull. Surgical excavation shows that the crust can reach the soft tissues underneath the skull.

A round HW on the carapace perhaps begins as a small vesicle or bleb. Later, this bleb breaks open and necrotic tissues begin to develop into a small necrotic nodule of approximately 3 to 4 mm in diameter above the carapace surface. In the limited number of cases of carapacial HW observed in Kemp's ridley hatchlings, all the lesions were located on the front margin of the carapace close to the neck or shoulder of the animal. Round hypernecrotic lesions have also been encountered in the plastron and the neck.

Hatchlings or juveniles afflicted with HW usually remain active and eat well. They may become lethargic shortly before they die.

Occurrence — There were 3, 6, 32 and 10 cases of HW in the 1978, 1979, 1981 and 1982 year-classes of Kemp's ridleys, respectively.

Remedy — There is no established drug therapy for HW. Experimentally, long-term oral administration with a saturated solution of potassium iodide (SSPI) plus daily topical application of three percent hydrogen peroxide has produced positive responses from warty outgrowths on the flippers and carapace. After more than four weeks of treatment the lesions begin to show signs of regression and one or two weeks later black pigmentation returns. Diarrhea can be a side-effect of SSPI treatment. When diarrhea occurs, oral SSPI should be discontinued for a few days then resumed when diarrhea stops.

The cranial form of HW responded well to sunlight treatment. After about two months of ineffective treatments with formalin and malachite-green baths inside the laboratory, the turtles were taken outdoors daily for a 30 to 60 minute exposure to sunlight. After about five days, the cranial lesions began to heal. While the turtles were outdoors, the water temperature in the holding vessels was carefully monitored to ensure that the turtles were not overheated. If the water temperature exceeded 28 °C, the turtles were moved to a shady place or returned to the laboratory. Sunlight therapy has not been used for the other forms of HW.

In formalin bath treatment, the nodule of the conical form may shed but is regenerated after the treatment is terminated.

Malabsorption of Yolk Sac

Malabsorption of yolk sac (MYS) refers to a condition in which a hatchling, after a reasonable period of posthatching time, fails to absorb either the entire or the bulk of the embryonic yolk sac, presumably due to physiological dysfunction. The length of posthatching period within which a Kemp's ridley neonate is expected to complete the yolk-sac absorption process is unknown. According to F. Wood [Cayman Turtle Farm (1983), Ltd., Grand Canyon, BWI, personal communication, January 1985], the yolk sac in hatchling green sea turtles probably has been absorbed by the time the hatchlings start to eat, which is about five to six days after hatching. Observations at necropsy suggest that in many Kemp's ridley hatchlings, by the seventh day after hatching, a large portion of the yolk sac has been absorbed. Therefore, if a week-old or older Kemp's ridley is found to bear a relatively large yolk sac, such as one that fills a large area of the abdominal cavity, it might be considered a case of malabsorption. [Editors' note: initiation of feeding of pelletized diets to hatchling Kemp's ridleys is now postponed for one to two weeks after emergence.]

Etiology — The cause for malabsorption of yolk sac in Kemp's ridleys is unknown. It is probably an organic dysfunction. G. Harwell, Houston Zoological Gardens, Houston, Tex., suggested that certain avian neonates would die from malabsorption of yolk sac if fed too soon. Malabsorption of yolk sac has also been observed in young alligators with undetermined cause (E. Jacobson, University of Florida, Gainesville, personal communication, January 1985). It is uncertain if results with birds and alligators could be applicable to sea turtles, but some biologists believe that sea turtle hatchlings will not eat until the yolk sac is absorbed (F.E. Wood, Cayman Turtle Farm, Grand Cayman, BWI, personal communication, January 1985).

Signs and Symptoms — There are no external signs or symptoms in Kemp's ridley hatchlings suffering from MYS. The only evidence comes from week-old or older hatchlings that die in captivity, and which are shown through necropsy to retain relatively large yolk sacs 15 mm or larger in diameter. In many instances, the unabsorbed yolk sac almost completely fills that portion of the abdominal space not occupied by other viscera. The unabsorbed yolk sac

is soft and creamy-yellow in color and its surface is frequently lined with congested blood vessels. The liver is usually pale and mottled, indicating anemia.

Occurrence — The occurrence of MYS in the head started Kemp's ridley hatchlings was 1, 4, 25 and 4 cases in the 1978, 1980, 1981 and 1983 year-classes, respectively.

Remedy — There is no known treatment or prophylactic method against MYS. If the hypothesis of too-early-feeding is proven as a cause of this anomally, then the obvious remedy is prevention by postponing initial feeding. The current standard practice at the Galveston Laboratory is no feeding of newly hatched Kemp's ridleys until they are one to two weeks old (Fontaine *et al.*, 1989).

Urolithiasis

Urolithiasis is the formation of calculi or crystals in the urinary system. The disease is fatal in Kemp's ridley hatchlings.

Etiology — The crystalline deposits found in the urinary systems of affected Kemp's ridley hatchlings have been identified by X-ray crystallography as struvite or ammonium magnesium-phosphate (E. Czerwinski, The University of Texas Medical Branch, Galveston, Tex., personal communication, 1980). The cause of such calculus formations has not been determined. It may be a consequence of an infectious disease, because urolithiasis is frequently accompanied by Internal Nodular Mycosis (INM) of the kidney, the lung, the liver, or a combination of these organs, as shown by necropsy. However, urolithiasis is not always present in all cases of such fungal infections. Delineation of the possible relationship between urolithiasis and INM will require more study.

Signs and Symptoms — Externally, a Kemp's ridley having severe urolithiasis displays a shriveled and stunted trunk, much like that in INM. The animal can be very weak and may refuse to eat shortly before death. At necropsy, crystalline calculi are present in the urinary bladder and ureters. The bladder may be so packed with crystals that it is distended up to five times or more its original size and becomes a solid block. The kidneys are probably also impregnated with crystals, because when they are sliced across with a scapel blade a sandy texture in the tissues is sensed.

Occurrence — Urolithiasis was first observed in Kemp's ridleys of the 1982 year-class in which about 43 cases were recorded. In the 1983 year-class, only two cases were confirmed.

Remedy — There is no known treatment or therapy for urolithiasis.

Duodenal Ulceration

Ulceration of the duodenum can occur suddenly in otherwise healthy-looking hatchlings with few warning signs. Ulcers can cause perforation of the duodenum and result in death of the animals.

Etiology — The cause of duodenal ulcers is not known. There has been evidence that it could be food-related. For instance, in a serious epizootic caused by duodenal ulceration in 1979 in Kemp's ridley hatchlings, necropsies showed that along with an ulcerated duodenum, the stomach was packed with undigested, pelleted feed. Most of the hatchlings (about 350) had contracted signs of duodenal ulceration. Either the turtles were being overfed or something was wrong with the pelleted feed which caused gastrointestinal paralysis. Various modified feeding regimens were tested including feeding a total daily ration of no more than about seven percent of body weight, reduced frequency of feeding from four meals per day to either one or two meals per day, and either partial or complete substitution of the pelleted feed with thawed fish flesh which had been frozen. If a turtle became sick or stopped eating, the ration was greatly reduced or withheld. Within a month, new incidence of duodenal ulceration dropped to practically zero. There appeared to be no difference among the three tested feeding regimens with respect to effectiveness in suppression of the disease.

After successful implementation of the modified feeding regimens, the manufacturer of the pelleted feed informed us that analyses of feed samples showed contamination by a fungal toxin, afflatoxin (James McVey, National Oceanic and Atmospheric Administration, Sea Grant Program Office, Washington, D.C., personal communication, 1980). It is possible, though not conclusive, that afflatoxin may have been responsible for the ulceration.

Signs and Symptoms — Live Kemp's ridley hatchlings that are afflicted with duodenal ulceration usually are much bloated in the body trunk. In severe cases, the intestine partially protrudes outside the body through a suture between plastronic scutes.

In dead hatchlings, the stomach is usually distended by packed pelleted feed, as shown by necropsy. The duodenum bears an ulcer, usually in the portion that is proximal to the pyrolic valve. In some cases (3 out of 13 necropsies in the 1979 year-class), duodenal ulcers have occurred concomitantly with ulcers in the large intestine. The intestine is frequently highly distended due to gas formation in the tract, probably the cause of bloating of the body.

Occurrence — A major outbreak of duodenal ulceration occurred in the 1979 year-class of Kemp's ridley in October 1979. Suddenly, about 350 hatchlings were discovered ill, and many died within one week. Both morbid and dead turtles showed signs and symptoms of duodenal ulceration. Morbidity and mortality continued to rise daily until

modified feeding regimens were adopted for the surviving hatchlings in the raceways. About 150 hatchlings died before the feeding changed. About 250 surviving hatchlings that were obviously ill with duodenal ulcration recovered after they were isolated from those remaining in the raceways and placed on either a fasting or a restrained diet.

Thirty-two cases of duodenal ulceration, frequently concomitant with ulceration, or tissue necrosis, or both in the stomach and other parts of the intestine, were also recorded at necropsy in Kemp's ridley hatchlings of the 1978 year-class. However, unlike the epizootic in the 1979 year-class during which cases of duodenal ulceration surged suddenly to more than 400 within a few weeks, the 32 cases of the 1978 year-class were spread out throughout the 11 months or so of rearing period. Bloating sometimes occurred in the 1978 year-class cases, but not nearly as frequently as in the 1979 year-class.

In addition, at necropsy, ulceration or tissue necrosis, or both have been observed at sites in the gastrointestinal tract without involving the duodenum. There were eight and two such cases in the 1979 and 1981 year-classes, respectively. Etiology of this pathological condition is unknown and its relation to duodenal ulceration is uncertain.

Remedy — Morbid turtles with bloating should be isolated and maintained in clean seawater without feeding. The key factor in successful treatment of the illness appears to be fasting, which probably provides an opportunity for the affected turtle to purge stale food from its gastrointestinal system.

Treatment of duodenal ulceration with Maalox (aluminum and magnesium hydroxides; Rorer, Inc., Fort Washington, Pa.) did not appear to be effective. Death continued among turtles under such treatment. Parenteral administration of kanamycin also did not help control the disease. Currently, prophylaxis for duodenal ulceration involves avoidance of overfeeding and proper storage of the pelleted feed to prevent growth of microorganisms which may release toxins into the food. In feed manufacture, precautionary steps should be taken to prevent potential contamination of the turtle feed with toxin-producing microogranisms.

Hemorrhagic Bacteriosis

Hemorrhagic bacteriosis is a bacterial infection in which there is significant bleeding from tissues and organs of the infected hatchling. The word hemorrhagic is used to distinguish this type of bacterial infection from those in which there is no primary, profuse bleeding involved, either externally or internally. Primary bleeding here refers to bleeding directly attributable to the infection.

Etiology — With use of sterile techniques, a bacterium, *Vibrio parahemolyticus*, was isolated from the blood of a few recently dead, 11-month-old Kemp's ridley juveniles of the 1982 year-class during an epizootic in May 1983. Septicemia was suspected. The outbreak could have been triggered by stresses caused by tagging with monel flipper tags. Secondary infection through tag wounds was also possible.

On another occasion, Gram-negative bacteria were observed in blood smears prepared from a five-month-old Kemp's ridley. The bacteria were not identified.

Signs and Symptoms — In hemorrhagic bacteriosis attributable to *V. parahemolyticus*, live Kemp's ridleys often vomit blood before death. Even after death, blood frequently flows from the mouth. At necropsy, the body cavity is typically filled with bloody fluid, and the lungs and other internal organs, such as the stomach, liver and kidneys, are either hemorrhagic or congestive and dark-purple in color. The liver often displays a mottling pattern in a purple cast. The lungs are usually not inflated. The deflated lungs probably serve to explain why freshly dead animals are frequently found submerged under water on the bottoms of their buckets.

Besides vomiting blood, live turtles exhibit few external signs or symptoms indicative of the infection. Occasionally, the plastron is more or less depressed (scaphoid) and bruise spots may be observed on it, but these signs have not been unequivocally correlated with morbidity. Similarly unconfirmed as a sign of this disease is a depressed appearance of the carapace on each side of the carapacial ridge. This condition is sometimes observed in postmortem examination.

It was almost impossible to identify infected turtles with hemorrhagic vibriosis through external gross examinations. Infected turtles usually looked healthy with perfectly good muscle tone. Attempts to recover bacteria from the blood of a few live Kemp's ridleys taken from the same groups in which death occurred in the epizootic in May 1983 were unsuccessful. The blood samples were sterile.

Occurrence — Hemorrhagic bacteriosis appears to be enzootic in sea turtle juveniles, as evidenced by occasional sporadic incidences. The disease assumes epizootic scale probably when the turtles are subjected to stress or when the environment becomes favorable for spreading of the disease.

On May 7, 1983, 13 Kemp's ridleys of the 1982 year-class suddenly died in the raceways. Another eight turtles died the next day. The turtles had recently been tagged with monel flipper tags. Postmortem examinations showed signs and symptoms of hemorrhagic bacteriosis, and a Gram-negative rod-shaped bacterium, later identified as *V. parahemolyticus*, was cultured from blood taken from freshly dead hatchlings. Chemotherapy with ampicillin (sodium) was applied, prior to positive identification of the bacterium, to more than 400 live turtles maintained in the same raceways in which deaths had occurred and presumed, therefore, to have been contaminated. By May 27, the

epizootic had tapered off following seven more deaths, for a total of 28 killed by the disease.

Remedy — Hemorrhagic bacteriosis, apparently an acute infection, is unpredictable. Since it displays limited outward signs until it is too late, attempts to identify infected live turtles for isolation and treatment have been unsuccessful. Such lack of diagnostic criteria to identify infected turtles rapidly is a serious handicap, and leads to emergencies. In an outbreak in which the turtles are fast-dying, as in the epizootic of May 1983, infected live turtles cannot be quickly identified for therapeutic treatments. An alternative is to medicate all survivors, whether actually infected or not. However, when antibiotic injection is the method to be used, and when there are hundreds of captive juveniles, it is difficult, labor-intensive and unrealistic if not impossible to complete treatment on all the turtles in a short time. Under this condition, those live turtles that are reared in the same sea water as those that die should be given the highest priority for medication.

The kind of drug or antibiotic to be used for treatment depends on the species of bacterium, the sensitivity of the bacterium to the drug and the tolerance of the juvenile turtles to the drug. In an emergency situation, those three factors cannot be determined immediately, so a drug must be selected on a best-guess approach. However, the situation should be closely monitored and drug susceptibility tests conducted on the bacterial isolates if possible. If the resulting information indicates resistance to the drug in use, then changes should be made. In the hemorrhagic vibriosis outbreak in May 1983, ampicillin (sodium) was used with success. The dosage was 0.5 mg per 25 g wet body weight per day, for the first day, and half of that amount for each of the subsequent six days. The total daily dosage was divided into two equal doses injected subcutaneously in the neck at about 8 a.m. and 3 p.m. The epizootic subsided by the end of the second week.

Mycobacterial Pneumonia

Mycobacterial pneumonia (MP) is an infection of the lungs by bacteria belonging to the genus *Mycobacterium.* It is a wasting disease and probably fatal.

Etiology — Acid-fast, rod-shaped bacteria were seen in impression smears and paraffin sections of lung lesions taken from a three-month-old loggerhead hatchling of the 1977 year-class and stored near 0°C for about one month following the turtle's death. Similar bacteria were cultured on synthetic media from the affected lung tissues of the same turtle. They were identified as *Mycobacterium marinum.*

Signs and Symptoms — Observations on the three-month-old morbid loggerhead hatchling showed stunted growth, emaciation of the body and weakened condition before it died. Postmortem examination revealed a 5-mm long, cylindrical, greyish-colored nodule in the left lung. *M. marinum* was isolated from tissues of the left lung.

Occurrence — Only one confirmed case of invasion of lungs by *M. marinum* was observed as described above. A second presumptive case was observed in an eight-month-old loggerhead of the same year-class. Postmortem examination of the latter turtle within 16 hours after death showed numerous greyish-white small nodules (1 mm or smaller in diameter) in the lungs. Unidentified acid-fast bacteria were cultured from the lung tissues. The animal intermittently exhibited a tilted-swimming behavior while still alive.

Mycobacterial infections in turtles involving other species of *Mycobacterium* have been reported in the literature. *M. chelonei (M. friedmannii)* has been isolated from extensive lesions in two turtles (Stanford and Beck, 1969). Brock *et al.* (1976) described six cases of tuberculosis attributable to *Mycobacterium avium* in captive green turtles. Reichenback-Klinke and Elkan (1965) discussed occurrence of tuberculosis caused by mycobacteria in reptiles and suggested that "the clinical picture is that of typical tuberculosis with pulmonary tubercles (in tortoises and turtles) and analogous lesions in skin, liver and spleen (in snakes and crocodiles)."

Remedy — No treatment has been established for MP in loggerhead turtles. Murphy (1975) reported that antibiotic treatment for MP has been ineffective, despite recommended use of streptomycin.

Swollen-eye

Swollen-eye (SE) is a chronic inflammation in the eye of sea turtle hatchlings. Usually only one eye is afflicted, and the disease can be fatal.

Etiology — The cause of SE can be mycotic infection. On one occasion, a fungus, tentatively identified as *Paecilomyces* sp., was cultured from necrotic tissues in the swollen eye of a Kemp's ridley. Whether all cases of SE involve mycotic invasion is not known.

Signs and Symptoms — The tissues surrounding the eye are swollen. In serious cases, the eyelids may be totally closed. Swimming and feeding activities of the hatchlings generally are not affected, except in the terminal stage when such activities become very weak.

In one case, at necropsy, necrotic tissues were present adjacent to an eye-gland behind the lower corner of the swollen eye of a Kemp's ridley. A fungus, *Paecilomyces* sp., was recovered from these tissues.

Occurrence — SE has occurred sporadically in captive populations of Kemp's ridley hatchlings. Incidence has been very low. There was one case each in the 1978, 1979, 1981 and 1982 year-classes.

A swollen eye disease has been reported in land turtles (Reichenbach-Klinke and Elkan, 1965). Both eyes were affected and the disease was attributed to vitamin deficiency. This disease probably is not the same as that in Kemp's ridleys, since in the latter, usually only one eye was affected. It seems reasonable that if the SE syndrome in Kemp's ridley were caused by vitamin deficiency, then both eyes instead of only one eye would have been affected most of the time, and that more turtles would have been affected since they were all fed with the same food.

Remedy — There is no known effective treatment despite various attempts at chemotherapy with a variety of general germicides and antibacterial, antifungal and antiviral drugs. Afflicted turtles may die after a relatively long period of bearing an inflamed eye. Spontaneous remission of swelling of the eye occurred in two five-month-old Kemp's ridleys after they had been held in isolation for about two months.

Intussusception

In a few Kemp's ridley hatchlings of the 1978 year-class, intussusception was observed at necropsy. One segment of the small intestine sloughed into an adjacent distal segment, resulting in a telescopic appearance in that part of the bowel.

Etiology — What caused intussusception and whether this anomaly contributed directly to the death of the hatchlings have not been determined.

Signs and Symptoms — In one hatchling, localized small patches with a charred appearance were present in several areas of an intussuscepted intestine. The significance of such blemishes and their possible relationship with intussusception is unknown.

In human pathology, intussusception in time may lead to infarction, as mesenteric blood supply becomes progressively compressed due to the entrapment of the mesentery in the fold (Robins and Angell, 1981).

Occurrence — Rare.

Remedy — Remedy for intussusception in human infants is through corrective surgery. This procedure is not practical for turtle hatchlings because intussusception in them is not detected until after death.

Curved-back (Lordosis)

In curved back, the carapace is curved with the rear end turning upward.

Etiology —The cause for curved-back is unknown. Death has not been reported in hatchlings with this anomaly.

Signs and Symptoms — The carapace is curved with the rear end turning upward.

Occurrences — Curved-back syndrome (lordosis) occurred in about 16 (0.1 percent) of the 1977 year-class of loggerhead hatchlings. The condition was observed in both neonates and hatchlings which had been reared for some time. On one occasion, a loggerhead began to develop a curved back when it was about 10 months old.

Remedy — Unknown.

Soft-shell

In soft-shell, the shell (especially that of the carapace) in a loggerhead or Kemp's ridley hatchlings may become relatively soft.

Etiology — Softening of the shell occasionally occurs after the turtle has recovered from certain kinds of illness such as emaciation syndrome. X-radiographs show that the ribs in the carapace of a soft-shelled turtle are underdeveloped. It is possible that soft-shell is the result of impaired calcium metabolism.

Signs and Symptoms — The shell of the turtle is soft to the touch. The turtle displays retarded growth. For example, a one-year-old turtle affected by soft-shell may be only about one-third the normal size of af turtle of that age.

Occurrence — Between 0.2 and 0.5 percent of each year-class of hatchlings contracted the soft-shell syndrome.

Remedy — Unknown.

Coelomic Edema

Etiology — A few Kemp's ridley hatchlings of the 1978 year-class that exhibited a tilted-swimming behavior were indicated by X-rays to contain fluid-like substances in one side of the pleural cavity. In collaboration with G. L. McLellan, The University of Texas Medical Branch, Galveston, we withdrew a clear fluid via the carapace, using thoranthetic techniques. As much as 7 ml of fluid were obtained from a single turtle. The fluid was sterile with no growth of bacteria when cultured on synthetic media. The cause of the syndrome is unknown.

Signs and Symptoms — Coelomic edema is a sign of illness rather than a disease in itself. Peritonitis and hepatitis have been observed at necropsy in hatchlings having the edemic condition.

Occurrence — Only three tilted-swimming ridleys of the 1978 year-class were examined for and found to have coelomic edema. The other tilted-swimmers were not examined.

Remedy —Unknown.

Lung Aplasia

Lung aplasia was observed in Kemp's ridley hatchlings of the 1978 year-class. Afflicted turtles had one of the lungs

missing. When alive, these turtles exhibited a frequent tilting of the body to one side during swimming.

Etioloy — The cause of lung aplasia is not known. It is probably congenital.

Signs and Symptoms — Side-floating behavior was not specific to lung aplasia. Other diseases (e.g., SP which damages one of the lungs) can also manifest a similar swimming pattern.

Occurrence — The turtles with lung aplasia ranged from two to seven months in age. The incidence was about 0.15 percent as determined from dead turtles.

Remedy — Unknown.

Congenital Flipper Malformation

Two conditions of congenital malformation of the front flippers of Kemp's ridleys were observed in the 1978 and 1979 year-classes. They are hypoplasia and multibranched-flipper.

Etiology — Congenital flipper malformation is a congenital abnormality.

Signs and Symptoms — In hypoplasia, one or both front flippers are not fully developed at hatching. The animal cannot resurface after it has submerged in the water in the raceway. To prevent suffocation, the turtle needs to be maintained in shallow water.

In multibranched-flipper, the forearm of a front flipper branches to form one or two additional arms. The animals otherwise look normal and survive well.

Occurrence— Less than 0.3 percent of the 1978 and 1979 year-classes of Kemp's ridleys had congenital flipper malformation.

Remedy — None.

Cross-beak

Etiology — Cross-beak is a congenital abnormality.

Signs and Symptoms — In cross-beak, the front part of the lower beak of the mouth is bent sideways. Afflicted hatchlings usually cannot eat and have to be fed via intraesophageal intubation to survive.

Occurrence — Available records show that as many as 0.2 percent of cross-beak occur in a given year-class of Kemp's ridleys. In some year-classes, such as 1978, 1980 and 1981, there was no incidence of cross-beak.

Remedy — None.

Congenital Blindness

Two Kemp's ridleys of the 1978 year-class were hatched without eyesight. One died. The survivor was donated in 1980 to Texas A&M University for use in research. Since the blind survivor was able to locate turtle feed in the holding tank, eat and grow, it indicated that Kemp's ridleys are able to find food via the sense of smell alone.

Etiology — Congenital.

Occurrence —Two Kemp's ridleys of the 1978 year-class were hatched without eyesight.

Remedy — None.

Intestinal Prolapse

Etiology —Unknown.

Signs and Symptoms —The lower part of the intestine protruded from the anus, and one of two turtles died. The other received corrective surgery from a local veterinarian but died later.

Occurrence — Intestinal prolapse occurred in two Kemp's ridley hatchlings of the 1981 year-class.

Remedy — Surgery could be a potentially useful corrective measure, although past attempts were unsuccessful.

Urinary Bladder Prolapse

Etiology — The urinary bladder of a Kemp's ridley hatchling of the 1983 year-class protruded from the anus, and the turtle died. Necropsy showed that the urinary system of the animal was seriously enlarged due to mycotic infection. The pressure from that swollen system had forced the urinary bladder to protrude from the anus. While the turtle was still alive, attempts to restore the protruded bladder to its original place by pushing it back into the body with a small lubricated, cotton swab were not successful. The bladder re-evaginated after a short period of time.

Signs and Symptoms — Protrusion of the urinary bladder and lethargy are the typical signs.

Occurrence — Less than 0.1 percent of the 1983 year-class contracted urinary bladder prolapse.

Remedy — Unknown.

Discussion and Recommendations

Out of necessity, we adopted a two-phase strategy to address the diseases, injuries and associated mortality problems of head starting Kemp's ridley and loggerhead sea turtles at the Galveston Laboratory. Many animals that died rapidly, especially during the early years of the rearing operation, were afflicted with a great variety of diseases of little known nature, or they suffered severe traumatic injuries caused by intraspecific biting. If these diseases and

injuries had continued unabated, catastrophic losses of turtles would have continued to occur, seriously hampering progress of the head start project.

The first phase of our strategy was aimed at stopping, as quickly as possible, on-going mortality and reversing any observed conditions of disease or injury even though the reversals might have been accomplished through treatment only of the symptoms. Due to the paucity of information on diseases and injuries of sea turtle hatchlings at that time, we often had to employ therapeutic methods, skills and knowledge that originated from other scientific disciplines or that were developed as a result of our own observations or short-term experiments. Prescriptions were frequently, if not always, based on educated guesses. Our objective was to save as many of the head started turtles as possible, disregarding means, so that the head start project could progress through its rearing, tagging and release stages. This first phase of our strategy involved clinical practices without much baseline information.

Phase two of our strategy, which was engaged based upon the availability of resources and only after most of the needs of phase one has been met, was intended to involve elaborate and in-depth studies designed to understand better the fundamental nature and causes of sea turtle diseases and injuries. The objective was to provide essential baseline information for improvement and development of techniques and methodologies for diagnosis, therapy and prophylaxis. Such information could lead to more confidence and surety in clinical practices and to a higher degree of predictability of health conditions and prognosis. The net result would be more and healthier sea turtle yearlings for release.

Initially, the objective of phase one was rapidly achieved through discovery and subsequent implementation of the isolation-rearing and use of clean seawater for culturing the turtles from hatchling to yearling stages. While the latter requirement of good hygiene and sanitation was an obvious one, the need for isolation rearing was not. These methods and innovations, coupled with appropriate medications on an as-needed basis, quickly brought under control many significant and wide-spread health problems which plagued the earlier year-classes. Examples of controllable health problems were sudden hatchling death syndrome, papillary dermatitis, focal erosive dermatitis and aggressive biting.

Isolation-rearing and seawater cleanliness became cardinal requirements for maintaining health of captive-reared Kemp's ridleys, and laid the cornerstone for subsequent successes in head starting this species. General statements concerning importance of culture water to rearing aquatic turtles (Pope, 1950) were published before 1977, the year when the Galveston Laboratory initiated loggerhead rearing, but there were few specifics described concerning the desirable level of cleanliness or water quality. It was indeed a surprise to us to find that the quality of the recycled seawater suitable for the culture of marine shrimp (*Penaues* spp.) in closed raceways was unsuitable for rearing loggerhead hatchlings of the 1977 year-class. Nearly 40 percent of the animals died from sudden hatchling death syndrome within about four weeks. Biodisc filter systems used to remove wastes from the recycled seawater had maintained a seawater quality sufficient for intensive shrimp culture in these raceways (Mock, Ross and Salser, 1977).

Despite the considerable progress and success in phase one of our strategy, certain earlier maladies such as emaciation syndrome remain little understood, incurable and unpredictable. In addition, other forms of disease and injuries emerged, and some of them had the potential of killing large numbers of turtles. Examples were the various forms of scolecobasidiosis, internal nodular mycosis, malabsorption of yolk sac and urolithiasis. Some of the new maladies (e.g., duodenal ulceration in October 1979 and hemorrhagic bacteriosis in May 1982), suddenly erupted into serious epizootics, creating emergencies of potentialy alarming proportions. Under such circumstances, we devoted our entire efforts to addressing these new problems, trying to find immediate answers to prevent potential catastrophes. Thus, we remained for the most part engaged in phase one and inevitably had to interrupt all phase two work, either on-going or scheduled, and to postpone or forego parts of the mission-oriented and fundamental pathological studies.

Despite unforeseen difficulties, we have been able to lay much groundwork for future pursuits of phase two work. Some of our accomplishments included identifying and categorizing various major forms of disorders afflicting captive sea turtles, isolating and identifying many presumptive pathogens (e.g., *Scolecobasidium constrictum* and *Paecilomyces* sp. in mycoses, and *Vibrio parahemolyticus* in hemorrhagic bacteriosis), providing X-radiography as a potential tool for disease diagnosis in the laboratory, and obtaining evidence that potassium iodide is a potentially effective drug against sea turtle mycoses.

Pathology information is the backbone for research and development of techniques and knowledge essential for the practice of good medicine on any living system, whether it be man, other animals (including sea turtles) or plants. Correct approaches to diagnosis, therapy and prophylaxis and the development of techniques and methodologies for such require fundamental understanding of the nature and cause of disease, injury or death. Such basic information can be acquired through pathological observations and studies. Once the basic knowledge and skills are established, clinical and laboratory examinations and testing can be evolved from these basics and employed to obtain data in specific patients to effect correct medical judgements and decisions.

Because of practicality, it was inevitable that many minor illnesses in head started Kemp's ridleys would have to be handled medically on a "best-guess" basis without going through extensive and costly pathology research. However, for diseases which potentially can cause serious debilitation or death in a significant portion of a captive population and which may lead to catastrophic losses, reliance on best-guesses alone is risky. The spread of these diseases could result in loss of the entire captive population. Such a price could be high for a seriously endangered species such as Kemp's ridley, where each surviving female could provide a substantial contribution to the conservation and augmentation of the declining wild population. It is fortuitous that we were able to resolve all major disease or injury problems that arose during the head start project up to the 1983 year-class, but there were no quarantees that such luck would persist.

For pragmatic reasons, we recommend that more pathological studies on Kemp's ridleys be conducted. These studies, should focus on certain fatal diseases which presently are incurable and unpreventable. Examples are emaciation syndrome, scolecobasidiosis, internal nodular mycosis, yolk-sac mycosis, urolithiasis, hemorrhagic bacteriosis and malabsorption of yolk sac. Research should be directed toward determining causes of these illnesses (e.g., through pathogenicity experiments), sources of the problems, how the diseases are transmitted and spread, the nature and biology of the etiological agents, histopathology (both basic and clinical), hematology (both basic and clinical hematology for diagnosis), X-radiography and other similar techniques for specific diagnosis and monitoring of internal ailments, and *in vitro* responses of pathogens and host turtles to potential therapeutic agents and techniques.

A good understanding of the microflora and chemistry of the culture seawater is also of paramount importance. Baseline profiles of microflora and chemical constituents in the culture seawater should be determined and the potential role of these entities in disease development should be delineated. With such information on hand, environmentally-oriented prophylactic measures, which in the long run are perhaps the least expensive in disease control, can be developed.

Aggressive biting can be contained through isolation-rearing, but other methods might be developed to accomplish the same end. Among other things, isolation-rearing is costly in labor and materials and many turtles outgrow their buckets during the typical head start period of 9 to 11 months. One obvious alternative is to provide larger containers, but they would take up more space in a given raceway or tank and reduce the numbers of turtles reared per raceway or tank. Along with adding more raceways or tanks to accommodate greater numbers of turtles, other needs such as more space, seawater, electric power, labor and supplies will arise. In light of the costs of isolation rearing, studies are needed to determine the underlying mechanism of the aggressive behavior in hopes of developing procedures for alleviating it.

Finally, since the methods by which the sea turtles are maintained during head starting have great impact on their diseases and traumatic injuries, pathologists should be involved in the design of culture systems and modes of operation. What may appeal to the culturist as useful or practical may turn out to be unacceptable from a turtle health point of view, as was demonstrated in our early experiences with both loggerheads and Kemp's ridleys reared in groups. Effective compromises can be worked out through better understanding of pathology in relation to rearing methods. We encourage more studies to provide relevant information needed to optimize the culture and operation systems in relation to health maintenance and disease control while assuring their cost-effectiveness.

Despite the continuing need for improvement, the culture and health care procedures that have evolved during the rearing of 11 year-classes of Kemp's ridley sea turtles have been successful (Caillouet, 1984; Fontaine, Leong and Harris, 1984; Fontaine *et al.*, 1989). Each year additional knowledge is gained and methods are improved. In all, as of October 31, 1988, about 14,060 Kemp's ridleys of the 1978-1988 year-classes had been successfully reared out of 16,538 live hatchlings received, representing 85 percent survival during head starting (Fontaine *et al.*, 1989). Of these, 13,572 had been tagged and released into the Gulf of Mexico (this does not include the 1988 year-class). The remaining normal and healthy turtles were transfered to other locations for extended head starting and captive propagation, and a few that were abnormal, sick or injured were transferred to other laboratorys for research or humanely disposed of.

In conclusion, sea turtle pathology research has barely started. Since 1978, there have been good successes in containing diseases and injuries in head started sea turtles at the Galveston Laboratory, but some difficult disease problems remain to be solved. Carefully planned and selected research can shed light on some of these difficult problems which if left unexplored have the potential of developing into uncontrollable epizootics. Research should include in-depth studies on basic and applied pathology of the host turtle, the etiological agents and the culturing environment as well as their inter-relationships. Such information will provide the prerequisite data for development of sound and practical health care methodologies, within the constraints of established guidelines and regulations controlling the possession, handling and care of endangered sea turtles.

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Carapacial Scute Variation in Kemp's Ridley Sea Turtle (*Lepidochelys kempi*) Hatchlings and Juveniles

Roderic B. Mast and John L. Carr *

The carapacial scutes of 5,919 specimens of hatchling and juvenile Kemp's ridley sea turtles (Lepidochelys kempi), *representing five different incubation-handling categories, were examined.*

Scutes were examined with regard to variation within carapacial scute series and variation in carapacial scute pattern. The vertebral and marginal series were the most variable, the costal series showed less variability, and the nuchal scute was extremely stable. The most common scute pattern, observed in 44.7 percent of the specimens, was 13 pairs of marginals, 5 pairs of costals, 5 vertebrals and a single nuchal.

Comparisons among the five incubation-handling categories indicated that the least handled eggs produced turtles with lowest levels of variability in scute series and patterns, while the most roughly handled eggs produced hatchlings with highest levels of variability in scute series and patterns.

Comparisons between dead (unhatched embryos or hatchlings found dead in the nest) and live hatchlings suggested that selection may act to remove the extremes of carapacial scutation phenotypes from the population. Though there was evidence suggesting that dead turtles had more variable scute series than live turtles from the same incubation-handling categories, this evidence was not uniform among the categories.

Transplantation, translocation and artificial incubation of sea turtle eggs should be re-examined with greater scrutiny concerning their possible effects on viability of turtle populations. When the mechanisms causing scute abnormalities are better understood, scute patterns may be useful external indicators of normal or abnormal hatchlings as related to their future viability.

The large scales that cover the shell in nearly all turtles are called scutes. Deraniyagala (1939) referred to the number and arrangement of these scutes as scutation. There has been a great deal of stability in scutation of the carapace during chelonian evolution (Zangerl and Johnson, 1957). Despite this phylogenetic stability, individual variations in scutation have been observed for nearly all species of turtles that possess scutes. Previous workers have examined this variation in numerous studies and have suggested various genetic and environmental factors as causative agents.

While investigating scutation in the loggerhead sea turtle (*Caretta caretta*), Gadow (1899) noted that adults appear to have far less variation than do hatchlings of the same species. He proposed the idea of "orthogenetic variation," theorizing that young turtles that possess more than the normal complement of scutes undergo fusion of scutes during ontogeny such that the adult stage exhibits the normal reduced scute pattern. Newman (1906) opposed this view, and suggested that supernumerary scutes were an atavistic reappearance of scutes that had been lost during phylogeny. Brongersma (1968) questioned the validity of Gadow's (1899) study, pointing out that Gadow's specimens did not consist solely of loggerheads, but rather of a mixture of loggerhead and olive ridley (*Lepidochelys olivacea*) specimens, thus explaining the disparity in scute number between hatchling and adult turtles. Atavism (Newman, 1906) is also an unlikely explanation for the multiscutate condition, as additional scutes appear to arise by subdivision of those typically present (Coker, 1905a, b and c, 1910; Pritchard, 1969b; Hill, 1971), and because of the aforementioned phylogenetic stability in numbers of carapacial scutes.

Other authors have suggested that abnormalities of scutation arise from accidents or disturbances during ontogenetic development (Parker, 1901; Wandolleck, 1904; Hildebrand, 1930; Zangerl, 1969). Pressure within the nest as a result of crowding has been cited as a possible source of scute abnormalities (Coker, 1910). Hildebrand (1938) suggested that scute anomalies in diamondback terrapins (*Malaclemys terrapin*) resulted from changes in available oxygen supply during incubation. Abnormal scutation and other shell deformities were induced by Lynn and Ullrich (1950) in hatchling painted turtles (*Chrysemys picta picta*) and snapping turtles (*Chelydra serpentina*) through partial dessication of the eggs at certain stages of development. Temperature variation during incubation may also account for scute abnormalities. Scutellation patterns of garter snakes have been influenced by lowering the ambient temperature during gestation (Fox, 1948; Fox, Gordon and Fox, 1961). The work of Yntema (1976), Bull and Vogt (1979), Yntema and Mrosovsky (1980), and others concerning temperature-dependent sex determination indicates that morphogenetic effects can occur in turtles as a result of varied incubation temperature. Also, handling of eggs

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at certain stages of development has been cited as a source of increased scute variation in olive ridleys (Hill, 1971), and has been shown to induce mortality in embryos (Limpus, Baker and Miller, 1979). Thus, there is evidence to suggest that several different environmental factors may influence scute pattern variation during incubation.

There also exists a possibility that there is sexual dimorphism in scute counts as suggested by Hill (1971). As most studies of adult turtles are based predominantly on observations of nesting females, perhaps our concept of a "normal" scute pattern is biased by lack of data from adult males. Given the strong influence of incubation temperature on sex in sea turtles, and the example cited above of temperature-induced scute pattern variations in garter snakes, perhaps incubation temperature could be influencing sex and scute pattern in a parallel manner. However, Frazier (1984) examined a series of olive ridleys from Mexico and concluded that there were no significant differences between the sexes in any of the meristic characters he compared, including carapacial scutes.

The typical chelonian carapacial scutation consists of a median longitudinal series of unpaired elements (the vertebral scutes), flanked on each side by a series of bilaterally paired scutes (the costals), which are bordered exteriorly by another series of bilaterally paired scutes (the marginals). Situated anteriorly between the first pair of marginals is a single nuchal. Thus, midline elements consist of a nuchal scute anteriorly, followed posteriorly by a series of vertebral scutes. The paired marginal scutes border the periphery of the carapace except where the nuchal separates them anteriorly. The costal scutes occupy the region lateral to the vertebrals and medial to the marginals on each side. Some workers consider the posterior-most pair of carapacial scutes (the supracaudals) apart from the marginals (e.g., Frazier, 1984; Pritchard and Trebbau, 1984), but for the purposes of this study we have considered these scutes as part of the marginal series.

Among the sea turtles, the most deviance from the scute pattern common to most individuals of a species as well as the greatest variability in pattern are found in the genus *Lepidochelys*. The olive ridley possesses such a high frequency of scute pattern anomalies that it is considered by Pritchard (1969b) to be "unique among turtles in having a truly polymorphic carapace" (i.e., essentially having no "normal" pattern). Though it does not possess carapace polymorphism to the degree of its congener, Kemp's ridley has nevertheless been shown to exhibit some carapacial scute variation (Chávez, Contreras and Hernández, 1967, 1968; Pritchard, 1969b). The modal carapacial scutation for Kemp's ridley consists of 13 pairs of marginal scutes, five pairs of costal scutes and five vertebral scutes, with a single nuchal (Figure 1).

The intent of our study was to describe and document scute anomalies in Kemp's ridley from two perspectives:

1. meristic variation with each series of scutes (left marginals, left costals, vertebrals, right costals and right marginals), and
2. variation among individual turtles from the modal scutation pattern (Figure 1).

Further, we attempted to relate variation in Kemp's ridley scutation to the various types of natural and artificial conditions under which our study animals were incubated and handled and also to the ontogenetic stages represented in our study animals.

Continued research into the causes of scute pattern variation in turtles is necessary to elucidate possible relationships of such variation to viability. An improved understanding of these relationships could greatly assist management and conservation of endangered and threatened species of turtles. Zangerl (1969) has commented that "the morphogenetic controls that determine the bone and shield patterns of the turtle shell are unquestionably complex." It is hoped that the present study will enhance the knowledge of these complex processes.

Materials and Methods

The carapacial scutes of 5,919 specimens of Kemp's ridley hatchlings and juveniles were examined. The study animals were grouped both by ontogenetic stage and conditions under which they were incubated and handled (Table 1). During the 1981 nesting season at the Kemp's ridley rookery near Rancho Nuevo, Tamaulipas, Mexico, 4,114 live hatchlings were examined and later released. Another 298 hatchlings and embryos, either dead in the egg, dead in the nest, or alive but severely deformed or underdeveloped and unable to rupture the egg, were examined at Rancho Nuevo during the same nesting season. Those that were unable to rupture the egg were included as dead hatchlings because they would have died naturally had they not been used in our study. Dead hatchlings and embryos were considered a younger ontogenetic stage than live hatchlings. The remaining 1,507 were juveniles examined at the National Marine Fisheries Service (NMFS) Southeast Fisheries Center (SEFC) Galveston Laboratory during head starting of the 1980 year-class. The specimens examined at Rancho Nuevo came from nests that had been handled or incubated, or both, in four different ways:

1. The largest group of hatchlings came from 37 nests incubated in corrals at Rancho Nuevo. This category will be referred to hereafter as the corral nest category. These eggs were dug by hand from their natural nests on the beach, then transported in bags to the corrals where they were reburied in holes carefully fashioned to

closely resemble the depth and shape of natural nests. The corrals were located high on the dune to lessen the risk of inundation during spring tides and were fenced to protect the eggs from large predators such as coyotes. Due to the large number of turtles nesting during *arribadas*, eggs replanted in this fashion often remained *in situ* for up to seven hours before replantation. These nests were sometimes subjected to bouncing and heat during transportation from their natural nests to the corrals, and were at times left out of the substrate for several hours prior to replantation. We authors consider the eggs replanted to the corral in this manner to have received the roughest or least careful handling of any of the incubation-handling groups.

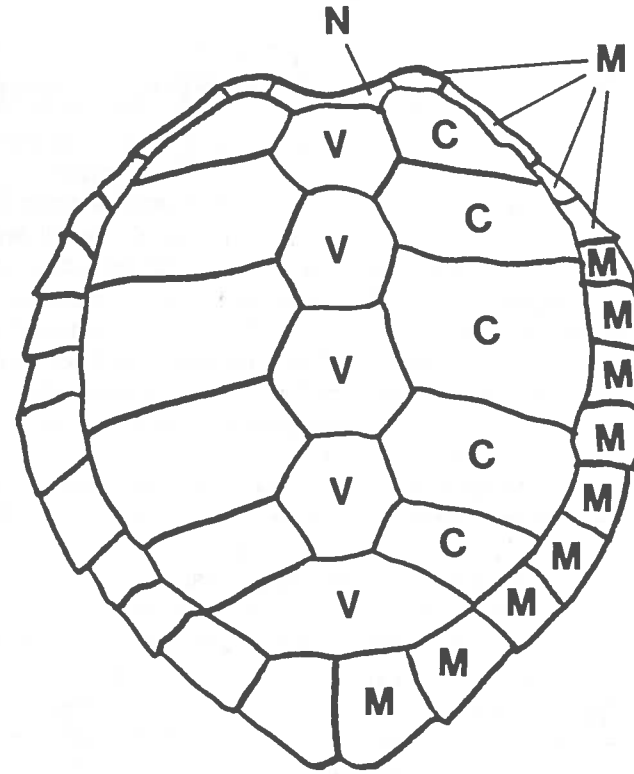

Figure 1. Modal carapacial scute arrangement for Kemp's ridley sea turtle including 13 pairs of marginals (M), 5 pairs of costals (C), 5 vertebrals (V) and 1 nuchal (N).

2. The second largest group of hatchlings came from 11 nests replanted using the special handling techniques of the international effort to establish a new nesting colony on Padre Island, Tex., through head starting. Padre Island boxes will be the category used in this paper to refer to these nests. Padre Island eggs were collected in clean plastic bags as they dropped from the cloacas of ovipositing females, thus avoiding contact with Rancho Nuevo sand. They were immediately transported to a shaded area where they were placed by hand into polystyrene foam boxes filled with sand collected from Padre Island. These boxes containing Padre Island sand and the eggs were placed on elevated shelves in a concrete block building at the Rancho Nuevo turtle camp where they were carefully monitored to prevent their dessication or infestation of any kind. The intended destination of these 11 nests was the Padre Island National Seashore, where the eggs were to be incubated by the National Park Service to provide hatchlings for the Kemp's Ridley Head start Research Project at the NMFS SEFC Galveston Laboratory. Due to numerous delays, these eggs hatched at Rancho Nuevo before they could be flown to the National Seashore. The hatchlings used in our study were released offshore of Rancho Nuevo. The eggs that produced this group of 894 hatchlings were exposed to virtually no rough handling and were expeditiously transplanted.
3. Seven nests were incubated in Rancho Nuevo sand in polystyrene foam boxes in the same concrete block building, concurrently and under the same conditions as the 11 originally destined for Padre Island. However, these Rancho Nuevo nests were transplanted as much as 24 hours after oviposition. This group will be referred to as the Rancho Nuevo boxes category. In all but one of the Rancho Nuevo nests, special handling techniques were used to avoid changing the orientation of the eggs as they were removed from the natural nest. These eggs produced 549 hatchlings used in our study.
4. The 151 hatchlings that represented a sample of five natural nests at Rancho Nuevo were discovered as they were entering the sea. We categorized this group as natural nests. The exact number of hatchlings from each nest therefore was unknown. One of the five nests was severely infested with ants and contained many dead hatchlings that might otherwise have emerged alive. This may have biased that portion of the sample of natural nests represented by dead hatchlings; i.e., some of the hatchlings that died due to attack by ants may have had scutation characteristics nearer those of the live hatchlings than those that died from other causes. Though there were fewer hatchlings from natural nests than in any of the other three categories from eggs incubated at Rancho Nuevo, we included the data for naturally incubated nests due to the paucity of such information in the literature for Kemp's ridley and because of its value in comparative studies.
5. In addition to the four categories of hatchlings examined at Rancho Nuevo, 1,507 living juvenile Kemp's ridleys of the 1980 year-class were examined in April 1981 at the NMFS SEFC's Galveston Laboratory. They were categorized as Galveston head starts. These juveniles were presumably handled and incubated in the same

manner as described in item 2 above for the Padre Island sample incubated at Rancho Nuevo, except that the boxed eggs from which the 1980 year-class hatchlings were produced were transported from Mexico to the Padre Island National Seashore where they were incubated, and where the hatchlings were imprinted before being transferred to Galveston.

Temperature regime, including mean temperature and temperature range, differed between the corrals and the concrete block building at the Rancho Nuevo turtle camp. Levels of humidity and their fluctuation also doubtlessly varied between these two environments, as the nests incubated in polystyrene foam boxes were sheltered from precipitation, receiving only occasional and intentional sprinklings to prevent dessication of the eggs. Because of these humidity and temperature differences, as well as differences in internal nest conditions brought about by incubation in boxes, the environmental conditions acting on the eggs and embryos incubated for various periods in the concrete block house (i.e., Padre Island boxes, Rancho Nuevo boxes and Galveston head starts) were substantially different from those for the beach-incubated nests (i.e., corral nests and natural nests).

For each turtle, the number of carapacial scutes in each series was recorded from left to right, including left marginals, left costals, vertebrals, right costals and right marginals (e.g., 13-5-5-5-13). Also recorded for each turtle was whether or not it had the normal single nuchal scute. Each five-element array constituted a scute pattern or scutation. Frequencies of each pattern variation were also recorded by nest. Variation in frequencies within each scute series (left marginals, left costals, vertebrals, right costals and right marginals) as well as nuchals, was examined separately from that of scute pattern. This approach to analysis of scute variations did not recognize abnormal seam placement unless it also entailed a change in the number of scutes in a particular series. For instance, a specimen may have had the usual five vertebrals, but with the seams positioned in such a way as to clearly indicate a non-normal arrangement. In our analysis, such abnormality would not be recognized. In this sense our data are conservative with regard to levels of variability, because a specimen such as that described above was recorded as normal with regard to vertebrals.

Statistical procedures generally follow the recommendations and procedures of Sokal and Rohlf (1981). Because of the disparity in magnitude between marginal counts and costal or vertebral counts, direct comparisons among coefficients of variation for these different series are misleading. While the significance of each unit deviation from the mode is no different for marginals than for costals or vertebrals, the coefficients of variation for marginal counts are smaller as a result of the larger denominator (i.e., 13 instead of 5). Therefore, the standard deviation is the best indicator of relative variation among scute series in a given incubation-handling category. In comparing different incubation-handling categories with regard to a given scute series, the coefficient of variation was a valuable indicator. The magnitude of the standard deviation for a given scute series within an incubation-handling category was an indicator of relative variability in that scute series because of the discrete nature of the data. Paired comparison t-tests were used to test for asymmetry in counts of costals and marginals. G-tests of independence were used to test the goodness of fit of cell frequencies to expectations in examining the frequencies of individuals exhibiting the modal scute pattern in the various incubation-handling categories and ontogenetic stages.

Results

Variation in the Nuchal Scute Series

Nuchal scute variation from the normal single nuchal was confined to a small number of turtles in which this scute had either split to form a double nuchal or was fused with adjacent scutes from the marginal or vertebral series. The double nuchal was the more common of these two departures from the norm. However, such variations in the nuchal were rare, because 99.5 percent of the 5,919 turtles possessed a single nuchal scute.

Variation in the Vertebral Scute Series

The number of scutes in the vertebral series ranged from 3 to 9 with a mode of five (Table 2). The standard deviation and coefficient of variation were higher for the vertebral series than for any other scute series. The magnitude of variation in vertebral counts, as indicated by standard deviations and coefficients of variation, ranked highest in the corral category, followed by the Galveston head starts, Padre Island boxes, Rancho Nuevo boxes and natural nests (Table 3).

Ranges in vertebral scute counts in live turtles show similar rankings with the widest range for corral nests, followed by the Galveston head starts, Padre Island boxes, Rancho Nuevo boxes and natural nests (Table 4). A similar ranking by range is mirrored in the dead turtles except that no dead Galveston head start turtles were examined.

The proportion of turtles possessing the modal count of five vertebrals is another criterion useful in comparing incubation-handling categories. For live turtles, Galveston head starts exhibited the smallest proportion (62.4 percent) with five vertebrals followed by corral nests (67.4 percent), Padre Island boxes (85.9 percent), Rancho Nuevo boxes (90.7 percent) and natural nests (97.5 percent). In all categories, except Galveston head starts which had no dead turtles, the frequency of the modal vertebral count was greater for live turtles than for dead.

Table 1. Number of live and dead specimens of Kemp's ridley sea turtles in each incubation-handling category.

Ontogenetic stage and incubation-handling category[a]	Number of specimens Live	Dead	Total
Hatchlings			
Corral nests (37)	2,677	141	2,818
Padre Island boxes (11)	874	20	894
Rancho Nuevo boxes (7)	483	66	549
Natural nests (5)	80	71	151
Juveniles			
Galveston head starts (unknown)	1,507	0	1,507
Total	5,621	298	5,919

[a]Number of nests is shown in parentheses.

Table 2. Summary statistics for carapacial scute counts by scute series for 5,919 Kemp's ridley hatchlings and juveniles.

Scute series	Range	Minimum	Maximum	Mode	Mean	Standard deviation	Coefficient of variation (%)
Left marginals	7	9	16	13	13.27	0.512	3.86
Left costals	5	3	8	5	5.13	0.381	7.44
Vertebrals	6	3	9	5	5.35	0.628	11.75
Right costals	5	3	8	5	5.10	0.336	6.59
Right marginals	7	9	16	13	13.28	0.532	4.01

Table 3. Summary statistics for carapacial scute counts of Kemp's ridley hatchlings and juveniles, by incubation-handling categories and scute series.

Incubation-handling category and scute series	Range	Minimum	Maximum	Mode	Mean	Standard deviation	Coefficient of variation (%)
Corral nests (n=2,818)							
Left marginals	7	9	16	13	13.26	0.532	4.01
Left costals	5	3	8	5	5.16	0.426	8.27
Vertebrals	6	3	9	5	5.41	0.682	12.61
Right costals	4	4	8	5	5.13	0.383	7.46
Right marginals	7	9	16	13	13.28	0.554	4.17
Padre Island boxes (n=894)							
Left marginals	5	10	15	13	13.23	0.473	3.58
Left costals	3	4	7	5	5.10	0.317	6.22
Vertebrals	3	5	8	5	5.16	0.416	8.07
Right costals	1	5	6	5	5.08	0.265	5.23
Right marginals	5	10	15	13	13.27	0.482	3.63
Rancho Nuevo boxes (n=549)							
Left marginals	2	12	14	13	13.17	0.393	2.98
Left costals	1	5	6	5	5.05	0.227	4.50
Vertebrals	3	4	7	5	5.09	0.320	6.29
Right costals	3	3	6	5	5.04	0.219	4.34
Right marginals	3	11	14	13	13.12	0.530	4.04
Natural nests (n=151)							
Left marginals	1	13	14	13	13.17	0.393	2.98
Left costals	1	5	6	5	5.05	0.225	4.45
Vertebrals	1	5	6	5	5.07	0.261	5.14
Right costals	1	5	6	5	5.04	0.196	3.89
Right marginals	2	13	15	13	13.25	0.450	3.40
Galveston head starts (n=1,507)							
Left marginals	5	11	16	13	13.37	0.532	3.98
Left costals	3	4	7	5	5.12	0.379	7.39
Vertebrals	5	4	9	5	5.46	0.680	12.45
Right costals	3	4	7	5	5.09	0.320	6.29
Right marginals	4	12	16	13	13.35	0.513	3.84

Table 4. Frequency distribution of vertebral scute counts for dead and live Kemp's ridley hatchlings and juveniles, by incubation-handling category.

Number of vertebral scutes	Incubation-handling category: Corral nests frequency	%	Padre Island boxes frequency	%	Rancho Nuevo boxes frequency	%	Natural nests frequency	%	Galveston head starts frequency	%	Total frequency	%
Dead Turtles												
3	1	0.7	0		0		0		0		1	0.3
4	4	2.8	0		1	1.5	0		0		5	1.7
5	65	46.1	13	65.0	59	89.4	62	87.3	0		199	66.8
6	47	33.3	5	25.0	4	6.1	9	12.7	0		65	21.8
7	20	14.2	2	10.0	2	3.0	0		0		24	8.1
8	3	2.1	0		0		0		0		3	1.0
9	1	0.7	0		0		0		0		1	0.3
Subtotal	141		20		66		71		0		298	
Live Turtles												
4	17	0.6	0		1	0.2	0		5	0.3	23	0.4
5	1,804	67.4	751	85.9	438	90.7	78	97.5	941	62.4	4,012	71.4
6	669	25.0	114	13.0	43	18.9	2	2.5	440	29.2	1,268	22.6
7	157	5.9	6	0.7	1	0.2	0		105	7.0	269	4.8
8	27	1.0	3	0.3	0		0		15	1.0	45	0.8
9	3	0.1	0		0		0		1	0.1	4	0.1
Subtotal	2,677		874		483		80		1,507		5,621	
Combined												
3	1	0.0	0		0		0		0		1	0.0
4	21	0.7	0		2	0.4	0		5	0.3	28	0.5
5	1,869	66.3	764	85.5	497	90.5	140	92.7	941	62.4	4,211	71.1
6	716	25.4	119	13.3	47	8.6	11	7.3	440	29.2	1,333	22.5
7	177	6.3	8	0.9	3	0.5	0		105	7.0	293	5.0
8	30	1.1	3	0.3	0		0		15	1.0	48	0.8
9	4	0.1	0		0		0		1	0.1	5	0.1
Total	**2,818**		**894**		**549**		**151**		**1,507**		**5,919**	

Table 5. Frequency distribution of left costal scute counts for live and dead Kemp's ridley hatchlings and juveniles, by incubation-handling category.

Number of left costal scutes	Incubation-handling category: Corral nests frequency	%	Padre Island boxes frequency	%	Rancho Nuevo boxes frequency	%	Natural nests frequency	%	Galveston head starts frequency	%	Total frequency	%
Dead												
3	1	0.7	0		0		0		0		1	0.3
4	8	5.7	1	5.0	0		0		0		9	3.0
5	97	68.8	17	85.0	61	92.4	63	88.7	0		238	79.9
6	30	21.3	2	10.0	5	7.6	8	11.3	0		45	15.1
7	4	2.8	0		0		0		0		4	1.3
8	1	0.7	0		0		0		0		1	0.3
Subtotal	141		20		66		71		0		298	
Live												
4	25	0.9	0		0		0		15	1.0	40	0.7
5	2,238	83.6	794	90.8	458	94.8	80	100.0	1,301	86.3	4,871	86.7
6	392	14.6	75	8.6	25	5.2	0		180	11.9	672	12.0
7	20	0.7	5	0.6	0		0		11	0.7	36	0.6
8	2	0.0	0		0		0		0		2	0.0
Subtotal	2,677		874		483		80		1,507		5,621	
Combined												
3	1	0.0	0		0		0		0		1	0.0
4	33	1.2	1	0.1	0		0		15	1.0	49	0.8
5	2,335	82.9	811	90.7	519	94.5	143	94.7	1,301	86.3	5,109	86.3
6	422	15.0	77	8.6	30	5.5	8	5.3	180	11.9	717	12.1
7	24	0.9	5	0.6	0		0		11	0.7	40	0.7
8	3	0.1	0		0		0		0		3	0.1
Total	**2,818**		**894**		**549**		**151**		**1,507**		**5,919**	

Table 6. Frequency distribution of right costal scute counts for dead and live Kemp's ridley hatchlings and juveniles, by incubation-handling category.

Number of right costal scutes	Incubation-handling category: Corral nests frequency	%	Padre Island boxes frequency	%	Rancho Nuevo boxes frequency	%	Natural nests frequency	%	Galveston head starts frequency	%	Total frequency	%
Dead												
3	0		0		1	1.5	0		0		1	0.3
4	7	5.0	0		0		0		0		7	2.3
5	105	74.5	18	90.0	60	90.9	65	91.5	0		248	83.2
6	26	18.4	2	10.0	5	7.6	6	8.5	0		39	13.1
7	3	2.1	0		0		0		0		3	1.0
Subtotal	141		20		66		71		0		298	
Live												
4	19	0.7	0		0		0		15	1.0	34	0.6
5	2,307	86.2	808	92.4	465	96.3	80	100.0	1,351	89.6	5,011	89.1
6	337	12.6	66	7.6	18	3.7	0		138	9.2	559	9.9
7	13	0.5	0		0		0		3	0.2	16	0.3
8	1	0.0	0		0		0		0		1	0.0
Subtotal	2,677		874		483		80		1,507		5,621	
Combined												
3	0		0		1	0.2	0		0		1	0.0
4	26	0.9	0		0		0		15	1.0	41	0.7
5	2,412	85.6	826	92.4	525	95.6	145	96.0	1,351	89.6	5,259	88.8
6	363	12.9	68	7.6	23	4.2	6	4.0	138	9.2	598	10.1
7	16	0.6	0		0		0		3	0.2	19	0.3
8	1	0.0	0		0		0		0		1	0.0
Total	**2,818**		**894**		**549**		**151**		**1,507**		**5,919**	

Table 7. Frequency distribution of left marginal scute counts for dead and live Kemp's ridley hatchlings and juveniles, by incubation-handling category.

Number of left marginal scutes	Incubation-handling category: Corral nests frequency	%	Padre Island boxes frequency	%	Rancho Nuevo boxes frequency	%	Natural nests frequency	%	Galveston head starts frequency	%	Total frequency	%
Dead												
9	2	1.4	0		0		0		0		2	0.7
10	0		1	5.0	0		0		0		1	0.3
11	2	1.4	1	5.0	0		0		0		3	1.0
12	5	3.5	1	5.0	3	4.5	0		0		9	3.0
13	86	61.0	13	65.0	55	83.3	63	88.7	0		217	72.8
14	37	26.2	3	15.0	8	12.1	8	11.3	0		56	18.8
15	8	5.7	1	5.0	0		0		0		9	3.0
16	1	0.7	0		0		0		0		1	0.3
Subtotal	141		20		66		71		0		298	
Live												
11	0		0		0		0		1	0.1	1	0.0
12	29	1.1	3	0.3	1	0.2	0		4	0.3	37	0.7
13	1,988	74.3	669	76.5	394	81.6	60	75.0	975	64.7	4,086	72.7
14	606	22.6	195	22.3	88	18.2	20	25.0	498	33.0	1,407	25.0
15	52	1.9	7	0.8	0		0		28	1.9	87	1.5
16	2	0.0	0		0		0		1	0.1	3	0.1
Subtotal	2,677		874		483		80		1,507		5,621	
Combined												
9	2	0.1	0		0		0		1	0.1	2	0.0
10	0		1	0.1	0		0		4	0.3	1	0.0
11	2	0.1	1	0.1	0		0		975	64.7	4	0.1
12	34	1.2	4	0.4	4	0.7	0		498	33.0	46	0.8
13	2,074	73.6	682	76.3	449	81.8	123	81.5	28	1.9	4,303	72.7
14	643	22.8	198	22.1	96	17.5	28	18.5	1	0.1	1,463	24.7
15	60	2.1	8	0.9	0		0		0		96	1.6
16	3	0.1	0		0		0		0		4	0.1
Total	**2,818**		**894**		**549**		**151**		**1,507**		**5,919**	

Table 8. Frequency distribution of right marginal scute counts for dead and live Kemp's ridley hatchlings and juveniles, by incubation-handling category.

Number of right marginal scutes	Incubation-handling category: Corral nests frequency	%	Padre Island boxes frequency	%	Rancho Nuevo boxes frequency	%	Natural nests frequency	%	Galveston head starts frequency	%	Total frequency	%
Dead												
9	2	1.4	0		0		0		0		2	0.7
10	1	0.7	1	5.0	0		0		0		2	0.7
11	0		0		1	1.5	0		0		1	0.3
12	6	4.3	0		1	1.5	0		0		7	2.3
13	89	63.1	17	85.0	57	86.4	58	81.7	0		221	74.2
14	39	27.7	2	10.0	7	10.6	13	18.3	0		61	20.5
15	4	2.8	0		0		0		0		4	1.3
Subtotal	141		20		66		71		0		298	
Live												
9	1	0.0	0		0		0		0		1	0.0
10	0		0		0		0		0		0	
11	1	0.0	0		0		0		0		1	0.0
12	25	0.9	3	0.3	44	9.1	0		8	0.5	80	1.4
13	1,923	71.8	628	71.9	333	68.9	56	70.0	972	64.5	3,912	69.6
14	658	24.6	237	27.1	106	21.9	23	28.8	515	34.2	1,539	27.4
15	67	2.5	6	0.7	0		1	1.2	9	0.6	83	1.5
16	2	0.1	0		0		0		3	0.2	5	0.1
Subtotal	2,677		874		483		80		1,507		5,621	
Combined												
9	3	0.1	0		0		0		0		3	0.1
10	1	0.0	1	0.1	0		0		0		2	0.0
11	1	0.0	0		1	0.2	0		0		2	0.0
12	31	1.1	3	0.3	45	8.2	0		8	0.5	87	1.5
13	2,012	71.4	645	72.1	390	71.0	114	75.5	972	64.5	4,133	69.8
14	697	24.7	239	26.7	113	20.6	36	23.8	515	34.2	1,600	27.0
15	71	2.5	6	0.7	0		1	0.7	9	0.6	87	1.5
16	2	0.1	0		0		0		3	0.2	5	0.1
Total	**2,818**		**894**		**549**		**151**		**1,507**		**5,919**	

Table 9. Mean values of the differences between paired left and right counts for costal and marginal scute series of Kemp's ridley hatchlings and juveniles, by incubation-handling category.

Scute series and incubation-handling category	n	Mean	Standard error	P[a]
Marginal Scutes				
Dead[b]	298	0.017	0.038	0.656
Live	5,621	-0.015	0.007	0.039*
Corral nests	2,677	-0.030	0.011	0.007*
Padre Island boxes	874	-0.046	0.018	0.012*
Rancho Nuevo boxes	483	0.052	0.024	0.035*
Natural nests	80	-0.063	0.060	0.300
Galveston head starts	1,507	0.011	0.012	0.349
Total	**5,919**	**-0.013**	**0.007**	**0.062**
Costal Scutes				
Dead[b]	298	0.030	0.031	0.335
Live	5,621	0.027	0.005	< 0.001*
Corral nests	2,677	0.025	0.008	0.002*
Padre Island boxes	874	0.022	0.009	0.013*
Rancho Nuevo boxes	483	0.014	0.010	0.162
Natural nests	80	0.000	0.000	1.000
Galveston head starts	1,507	0.038	0.010	< 0.001*
Total	**5,919**	**0.027**	**0.005**	**< 0.001***

[a]Probability that the observed mean difference between paired left and right scute counts was significantly different from zero; i.e., that there was significant departure from bilateral symmetry in a matched pairs t-test. *Indicates significance at alpha ≤ 0.05.
[b]Not subdivided by incubation-handling category because of small sample size.

Table 10. Summary statistics for carapacial scute counts of dead and live Kemp's ridley hatchlings from 37 corral nests.

Scute series	Range	Minimum	Maximum	Standard Mode	Mean	Coefficient of deviation	variation (%)
Dead (n=141)							
Left marginals	7	9	16	13	13.28	0.895	6.74
Left costals	5	3	8	5	5.22	0.656	12.56
Vertebrals	6	3	9	5	5.67	0.908	16.02
Right costals	3	4	7	5	5.18	0.538	10.40
Right marginals	6	9	15	13	13.21	0.826	6.25
Live (n=2,677)							
Left marginals	4	12	16	13	13.26	0.506	3.82
Left costals	4	4	8	5	5.15	0.411	7.97
Vertebrals	5	4	9	5	5.40	0.666	12.34
Right costals	4	4	8	5	5.13	0.373	7.27
Right marginals	7	9	16	13	13.29	0.536	4.04

Table 11. Summary statistics for carapacial scute counts of dead and live Kemp's ridley hatchlings from 11 Padre Island boxes.

Scute series	Range	Minimum	Maximum	Mode	Mean	Standard deviation	Coefficient of variation (%)
Dead (n=20)							
Left marginals	5	10	15	13	12.95	1.050	8.11
Left costals	2	4	6	5	5.05	0.394	7.80
Vertebrals	2	5	7	5	5.45	0.686	12.59
Right costals	1	5	6	5	5.10	0.308	6.04
Right marginals	4	10	14	13	12.95	0.759	5.86
Live (n=874)							
Left marginals	3	12	15	13	13.24	0.451	3.41
Left costals	2	5	7	5	5.10	0.315	6.18
Vertebrals	3	5	8	5	5.15	0.406	7.88
Right costals	1	5	6	5	5.08	0.264	5.21
Right marginals	3	12	15	13	13.28	0.472	3.56

Table 12. Summary statistics for carapacial scute counts of dead and live Kemp's ridley hatchlings from seven Rancho Nuevo boxes.

Scute series	Range	Minimum	Maximum	Mode	Mean	Standard deviation	Coefficient of variation (%)
Dead (n=66)							
Left marginals	2	12	14	13	13.08	0.404	3.09
Left costals	1	5	6	5	5.08	0.267	5.25
Vertebrals	3	4	7	5	5.11	0.434	8.50
Right costals	3	3	6	5	5.05	0.369	7.32
Right marginals	3	11	14	13	13.06	0.425	3.26
Live (n = 483)							
Left marginals	2	12	14	13	13.18	0.390	2.96
Left costals	1	5	6	5	5.05	0.222	4.39
Vertebrals	3	4	7	5	5.09	0.302	5.93
Right costals	1	5	6	5	5.04	0.190	3.76
Right marginals	2	12	14	13	13.13	0.543	4.13

Table 13. Summary statistics for carapacial scute counts of dead and live Kemp's ridley hatchlings from five natural nests.

Scute series	Range	Minimum	Maximum	Mode	Mean	Standard deviation	Coefficient of variation (%)
Dead (n=71)							
Left marginals	1	13	14	13	13.11	0.318	2.43
Left costals	1	5	6	5	5.11	0.318	6.23
Vertebrals	1	5	6	5	5.13	0.335	6.54
Right costals	1	5	6	5	5.08	0.280	5.51
Right marginals	1	13	14	13	13.18	0.390	2.95
Live (n=80)							
Left marginals	1	13	14	13	13.25	0.436	3.29
Left costals	0	5	5	5	5.00	0.000	0.00
Vertebrals	1	5	6	5	5.03	0.157	3.13
Right costals	0	5	5	5	5.00	0.000	0.00
Right marginals	2	13	15	13	13.31	0.493	3.70

Table 14. Frequencies of the modal scute number for Kemp's ridley sea turtles.

Group	13 left marginals frequency	13 left marginals %	5 left costals frequency	5 left costals %	5 vertebrals frequency	5 vertebrals %	5 right costals frequency	5 right costals %	13 right marginals frequency	13 right marginals %
Hatchlings[a]										
Corral nests (n=2,677)	1,988	74.3	2,238	83.6	1,804	67.4	2,307	86.2	1,923	71.8
Padre Island boxes (n=874)	669	76.5	794	90.8	751	85.9	808	92.4	628	71.9
Rancho Nuevo boxes (n=483)	394	81.6	458	94.8	438	90.7	465	96.3	333	68.9
Natural nests (n=80)	60	75.0	80	100.0	78	97.5	80	100.0	56	70.0
Juveniles[a]										
Galveston head starts (n=1,507)	975	64.7	1,301	86.3	941	62.4	1,351	89.6	972	64.5
Subadults[b] (n=96)			95	99.0			96	100.0		
Adult Females[c] (n=154)	89	57.8	151	98.1	135	87.7	148	96.1	123	79.9

[a]This study; live turtles only.
[b]From Carr and Caldwell (1956).
[c]From Chávez *et al.* (1967, 1968).

Clearly, the most interesting observation regarding variation in vertebral scute count was its apparent relation to incubation-handling technique. Various aspects of the data suggested greatest departure from normal vertebral counts in the corral nests and Galveston head starts, least in naturally incubated turtles, and intermediate in the Padre Island and Rancho Nuevo boxes. This same trend recurs in other scute series, as well as in overall scute pattern.

Variation in the Costal Scute Series

Patterns of variation in left and right costal scute series were very similar (Tables 2 and 3), reflecting their bilateral symmetry. Among the 5,919 specimens, left and right costals exhibited the same range (5), minimum (3), maximum (8) and mode (5). The two costal series exhibited the least variation in count among the carapacial scute series (with the exception of the nuchal), as indicated by the low ranges and standard deviations (Tables 2 and 3). The means and modes for each costal series were closer to one another in all incubation-handling categories than the means and modes of any other scute series, further depicting the stability of costal scute counts as compared to counts in the other scute series.

Variability in scute counts within both costal series was greatest in the corral nest category, followed by the Galveston head starts, Padre Island boxes, Rancho Nuevo boxes and natural nests as shown by the standard deviations and ranges (similar in Padre Island and Rancho Nuevo boxes, Table 3). There was greater variation among dead turtles than among live turtles (Tables 5 and 6). The proportion of turtles exhibiting the modal count of five costals, whether left or right, was lower for dead turtles than for live ones in all incubation-handling categories. This suggested greater stability in costal scute count in live turtles than in those that died as hatchlings or embryos.

Variation in the Marginal Scute Series

Bilateral symmetry between counts of left and right marginals was evidenced by their identical ranges (7), minima (9), maxima (16) and modes (13) among the 5,919 turtles (Table 2). The greatest range in marginal scute counts occurred in the corral category, followed in descending order by Galveston head starts, Padre Island boxes, Rancho Nuevo boxes and natural nests. Mean scute numbers and standard deviations indicated that marginal scutes were the most variable scute series in Padre Island box, Rancho Nuevo box and natural nest categories, and were exceeded in variability only by the vertebral series in the corral nest and Galveston head start categories (Table 3).

As was the case with vertebrals and costals, the corral nest and Galveston head start categories exhibited the greatest variation in counts of marginals as contrasted with natural nests which exhibited the least. However, the differences in variability of marginal counts among the incubation-handling categories were slight, suggesting more stability in marginal scute counts among the five incubation-handling categories than for the other scute series.

Dead versus live comparisons for marginal count variability were not as clearly differentiated as were the cases for the costal and vertebral series. Marginal scute counts showed generally greater variability in dead than in live turtles, but the percentages of turtles exhibiting the modal count of 13 marginals (left or right) followed a different rank order among incubation-handling categories (Tables 7 and 8) than for other scute series (Tables 4-6).

Tests of Symmetry in Paired Counts of Scute Series

A series of t-tests was performed on mean differences between left and right counts of costals and marginals for all 5,919 turtles, and for various subgroupings (Table 9). Tested was the null hypothesis of bilateral symmetry in left and right counts. The difference was obtained for each specimen by subtracting the right scute count from the left scute count, for marginal and costal series separately.

For marginals, the mean difference for the entire sample of 5,919 turtles was not significantly different from zero, suggesting bilateral symmetry in scute counts, though certain groupings exhibited significant asymmetry (Table 9). For example, marginal counts were significantly asymmetric in live turtles, but the dead specimens showed no significant asymmetry. The live turtles from corral nests, Padre Island boxes and Rancho Nuevo boxes had significantly asymmetric marginal counts, even though Galveston head starts and turtles from natural nests did not.

In contrast, left and right costals for the entire sample of 5,919 turtles were significantly asymmetric (Table 9). Yet, only the live turtles exhibited significant asymmetry in costal counts, while the dead turtles did not. Substantial differences in sample size between the live and dead subgroupings may have contributed to the difference in costal scute results for these two subgroupings. The dead subgroup was the smaller of the two, so its t-test of the mean difference between counts of left and right costal scutes was more conservative than that for the live subgroup.

For costals and marginals, the natural nest and Rancho Nuevo box categories did not have significant mean differences between left and right counts, whereas corral nest, Padre Island box and Galveston head start categories exhibited significantly asymmetric counts. In those incubation-handling categories exhibiting costal count asymmetry, the greater number of scutes occurred in the left series (Table 9). Among the incubation-handling categories displaying asymmetrical marginal counts, corral nest and Padre Island box categories had a greater number of scutes in the right series, while the Rancho Nuevo category had the greater number in the left series. It is tempting to suggest, based on the corral nest and Padre Island box categories, that there is a relationship between the increase in right

marginals and left costals. This may reflect some developmental mechanism that balances combined costal and marginal scute counts on left and right sides of the carapace such that overall symmetry in left and right counts is maintained. However, this balance was not evident in the Rancho Nuevo box category.

Variation in Scute Series by Incubation-Handling Category

Corral Nests – Several of the preceeding analyses indicated that hatchlings from corral nests exhibited a higher degree of variability than those from any of the other incubation-handling category. Corral nest hatchlings had the greatest ranges, standard deviations (with one exception: left marginals for Galveston head starts), and coefficients of variation for scute counts in each of the scute series (Table 3). However, corral nests represented the largest incubation-handling category (2,818 turtles), or 48 percent of all turtles examined. Also, greater variability in dead than in live turtles from corral nests for all scute series (Tables 4 and 10) contributed to the overall variability in the corral nest category. Within the corral nest category, the most variable scute series was the vertebral, followed by the marginal, then the costal.

Galveston Head Starts – Juvenile turtles from the Galveston head start category were second to the corral nest category in degree of variability within scute series. Based on ranges, standard deviations and coefficients of variation for each scute series (Table 3), Galveston head starts had slightly lower scute variability than hatchlings in the corral nest category, though consistently higher variability than Rancho Nuevo box, Padre Island box and natural nest categories. Galveston turtles, like hatchlings from corral nests, showed greatest variation in the vertebral series, followed by the marginal then the costal series.

The reader is cautioned about drawing broad conclusions based on our observations of the 1980 year-class of Galveston head start juveniles as compared to hatchlings of the 1981 year-class. We only witnessed the incubation-handling techniques used in 1981, and not those used for the 1980 year-class of Kemp's ridleys head started at the Galveston Laboratory. We had no data to compare environmental conditions between the two years, thus raising the possibility that the observed differences between the Galveston head starts from the 1980 year-class and the other incubation-handling categories from the 1981 year-class might be due to differences in environmental variables other than incubation-handling techniques. Also, we had no dead subgroup to compare to the live subgroup from the Galveston head start category, thus there was no opportunity to investigate changes during ontogeny within this category. Finally, we had no way of determining whether incubation-handling was consistent from year to year for those nests destined to provide hatchlings for head starting.

Padre Island Boxes – Hatchlings from the Padre Island boxes were consistently intermediate in scute series variability between the two extremes represented by the highly variable corral nest and Galveston head start categories and the slightly variable Rancho Nuevo box and natural nest categories. This is shown by ranges, standard deviations and coefficients of variation for the scute series (Table 3). Costals were the least variable of the scute series for both live and dead hatchlings in the Padre Island box category, with marginals showing greatest variability in the dead subgroup, and vertebrals showed greatest variability in the live subgroup.

The mean marginal scute counts of dead hatchlings in the Padre Island box category were lower than those for live turtles in that category (Table 11). This tendency toward lower counts of marginals in dead Padre Island hatchlings (Table 11) was unique among all live-dead contrasts, scute series and incubation-handling categories (Tables 4-8 and 10-13). However, only 20 dead specimens in the Padre Island box category were examined.

Rancho Nuevo Boxes – In general, both live and dead turtles in the Rancho Nuevo box category exhibited the least amounts of variability in scute counts (Table 12) as judged by ranges, standard deviations and coefficients of variation in scute counts for all incubation-handling categories except the natural nests. The dead turtles showed greatest variability in the vertebral series, while live turtles show greatest variability within the marginal series. Costals were the most stable series for both live and dead hatchlings in the Rancho Nuevo box category.

Natural Nests – The least overall variation in scute counts was observed in the natural nest category (Table 13), no doubt due in part to the small sample size for this category. Indeed, in nearly all scute series, the turtles from natural nests showed the lowest variation of all among the incubation-handling categories. The greatest variation for natural nest turtles was in the marginal series, followed by the vertebral and costal series (which exhibited 100 percent modal counts in the live subsample).

Departures from Modal Scute Counts

Table 14 provides for comparisons among scute series and incubation-handling categories of our study, as well as within sub-adult (Carr and Caldwell, 1956) and adult female Kemp's ridleys (Chávez *et al.*, 1967, 1968) from other studies. Only live turtles were used in this comparison because the other studies were based on live specimens.

Costals showed less departure from the mode than vertebrals or marginals, the latter of which had the lowest percentage of turtles with the modal count. An exception to this was that the corral nest and Galveston head start categories exhibited a high percentage of turtles with modal counts for costals, and percentages for modal counts of

vertebrals similar to those for marginals. In general, corral nest and Galveston head start categories exhibited greater departures from modal counts for all scute series than did the other categories.

Adult female Kemp's ridleys (Chávez *et al.*, 1967, 1968) also exhibited higher proportions of modal scute counts for costals and vertebrals than for marginals. The percentages of adult females exhibiting modal counts for vertebrals and costals fell within the range of comparable percentages for the Rancho Nuevo box, Padre Island box and natural nest categories. In the adult females, the proportion with modal counts for left marginals was considerably lower than that for the right marginals. It was also the lowest of the percentages for any group of turtles in Table 14. On the other hand, the proportion with modal counts for the right marginal series was higher in the adult female than for any of the categories in our study. Only costal scute counts were available for subadult Kemp's ridleys (Carr and Caldwell, 1956), and the proportions of turtles with modal counts were on the high end of the range, similar to those of the Rancho Nuevo box and natural nest categories of our study.

Variation in Scutation

Among the 5,919 turtles examined in our study, 264 different scute patterns or scutations were recorded: 77 patterns among the dead turtles (n = 298) and 233 patterns among the live turtles (n = 5,621). Included among the 77 scute patterns found in the dead specimens were 31 patterns that did not occur in live turtles. The modal scute pattern (13-5-5-5-13) was observed in 2,646 (44.7 percent) turtles. The next most common patterns were: 13-5-5-5-14 (in 444 turtles or 7.5 percent), 13-5-6-5-13 (in 438 turtles or 7.4 percent), 14-5-5-5-14 (in 384 turtles or 6.5 percent) and 14-5-5-5-13 (in 373 turtles or 6.3 percent). It is interesting that the most common of the aberrant scute patterns involved additional marginal or vertebral scutes. A scute count lower than the mode was a much rarer occurrence than one higher than the mode for any scute series. In cases in which there were above-modal vertebral and costal scute counts, the additional scutes most often appeared at the posterior end of the scute series as a split fifth costal or fifth vertebral scute, or as a supernumerary scute between the fourth and fifth vertebrals. Extra marginal scutes, on the other hand, nearly always appeared at the anterior end of the series as a split second, third or fourth marginal scute.

The mean number of different scute patterns per nest (i.e., per clutch) within each incubation-handling category provided another measure of relative variability in scutation. The mean number of scute patterns per clutch was highest in the corral nest category (20.8 patterns), followed by the Padre Island box (11.2 patterns) and Rancho Nuevo box (9.1 patterns) categories. The small amount of information available for natural nests suggested even fewer variants per nest (approximately 4.5 patterns). We were unable to make such calculations for the Galveston head starts, because we had no data on how many clutches were represented in our sample.

Departures from Modal Scute Patterns

The proportion of turtles exhibiting the modal scute pattern (13-5-5-5-13) was not significantly different in live and dead subgroupings in the 5,919 specimens in our study (Table 15). In that regard, the only significant difference occurred for the corral nests in which more of the live turtles (41.7 percent) exhibited the modal scute pattern than did the dead turtles (26.2 percent), as shown in Table 15 and Figure 2. The greatest percentage of individuals showing the modal scute pattern was in the Rancho Nuevo box category, followed closely by natural nests, with the Padre Island box category being about 10 percent less. Live turtles from corral nest and Galveston head start categories had nearly the same proportions (about 42 percent) of individuals with modal scute patterns.

Discussion

While most earlier researchers examined carapacial scute variation in Kemp's ridley only with regard to individual scute series, we expanded our examinations to include variation in frequencies of scute patterns as a whole. Comparisons among the five different incubation-handling categories of our study, each of which was exposed to different environmental conditions during ontogeny, provided tests of the working hypothesis that scute variability might be related to environmental circumstances during ontogeny. To determine if there were differences in scute variation within a given incubation-handling category during development, we examined different ontogenetic stages represented by dead (younger hatchlings and embryos) and live specimens (later stage). One might expect increased variability to be evidenced in the dead turtles relative to the live ones if selection were acting to remove extreme phenotypes from the population. Evidence in support of this hypothesis would indicate that scute variation may be related to the survivability of the individual. This could act through underlying problems of viability associated with some scute pattern variants (Zangerl, 1969; Hill, 1971).

We have no reason to believe that scute pattern itself is a selective factor. Pritchard (1969a) commented that the hydrodynamics of a turtle's shell would be little affected by the arrangement or quantity of scute seams and the overall appearance of a turtle's shell is little affected by scute variation. Therefore, it seems more likely that an abnormal scute pattern is an external phenotypic expression of some underlying physiological or morphological problem which may affect the viability of the turtle. The senior author has noted, on several occasions, that extreme deformity and albinism

Table 15. G-tests of the null hypothesis of independence between scute pattern and incubation-handling category for Kemp's ridley hatchlings and juveniles.

Pairwise contrasts between incubation-handling categories	G[a]
Dead vs. Live[b]	
Corral nests	13.9956*
Padre Island boxes	0.5418
Rancho Nuevo boxes	1.6555
Natural nests	0.0424
Combined (total)	0.1838
Live only	
Corral nests vs. Padre Island boxes	11.4840*
Corral nests vs. Rancho Nuevo boxes	55.3000*
Corral nests vs. Natural nests	7.7996*
Corral nests vs. Galveston head starts	0.1186
Padre Island boxes vs. Rancho Nuevo boxes	17.3342*
Padre Island boxes vs. Natural nests	2.4970
Padre Island boxes vs. Galveston head starts	8.0904*
Rancho Nuevo boxes vs. Natural nests	0.1830
Rancho Nuevo boxes vs. Galveston head starts	46.4818*
Natural nests vs. Galveston head starts	7.1012*

[a]* indicates significance at alpha ≤ 0.05, leading to rejection of the null hypothesis; i.e., concluding that the two groups being compared are significantly different.
[b]There were no dead turtles in the Galveston head start category, so no tests were possible with that category.

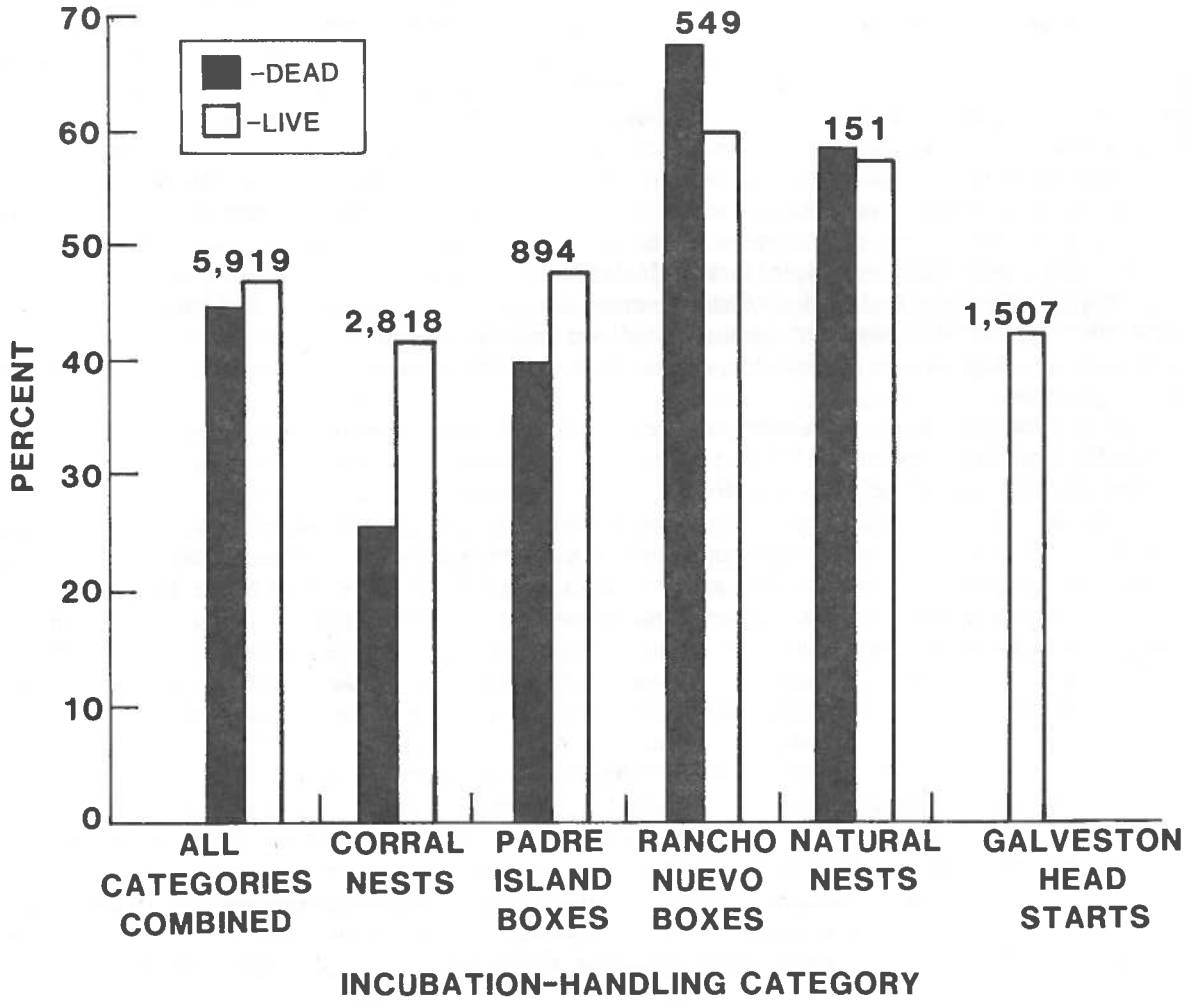

Figure 2. Proportions of live and dead Kemp's ridley hatchlings and juveniles that exhibited the modal scute pattern (13-5-5-5-13), by incubation-handling category (sample size is shown above the vertical bars for each category).

in dead hatchling sea turtles is nearly always accompanied by aberrant scute pattern, yet the abnormal scute pattern itself was certainly not the cause of death. Certain abnormal scute patterns were never observed in live turtles, but only in dead specimens. There were 31 of these "lethal scute patterns" observed in this study.

A high degree of carapacial scute variation was encountered in the young Kemp's ridleys in our study, despite various statements in the literature regarding the great stability of scutation in Kemp's ridley as compared to olive ridley (Pritchard and Márquez, 1973; Frazier, 1984). Though the most common carapacial scute pattern we observed in Kemp's ridley was 13-5-5-5-13, it occured in only 44 percent of the 5,919 turtles we examined, thus it constituted less than half of our relatively large sample.

Differences in amounts of carapacial scute variation among the five incubation-handling groups we examined were notable. Based on our qualitative judgements in ranking the five incubation-handling categories, the most carefully handled and undisturbed eggs (Padre Island boxes and natural nests) produced turtles with less carapacial scute variability, and the most roughly handled eggs (Corral nests) produced turtles with higher levels of scute variation. Even if the 1980 year-class represented by the Galveston head starts is ignored, the trend from higher variability in carapacial scutes of turtles from roughly handled eggs to lower variability in turtles from carefully handled eggs or unhandled eggs appears in nearly all analyses of the data. For the Galveston head starts we possessed the least complete information regarding actual incubation conditions and no dead subgroup for this sample. Indeed, large and significant differences in amount of variability were present among the groups of turtles derived from eggs incubated or handled in different ways. These results suggest that environmental circumstances during incubation affect scute variability of the resultant hatchlings.

Several environmental factors have been implicated as agents causing scute pattern variation (see review by Ewert, 1979), all of them acting during the embryonic phase of the life cycle. Handling is merely one of these factors (Hill, 1971), so we have considered both incubation and handling together rather than handling alone. Incubation temperatures and humidity regimes varied greatly among our five incubation-handling categories, with the widest differences in this regard being between the concrete block house and the natural beach. There was no great disparity in carapacial scute variability within the 1981 year-class hatchlings derived from the two incubation-handling categories incubated in the concrete block house (*viz.* Rancho Nuevo and Padre Island). Both of these categories were considered to be carefully handled eggs. The greatest disparity in carapace scute variation occurred between the two groups of eggs incubated on the Rancho Nuevo beach, with roughly handled eggs represented by corral nests producing turtles with the greatest amount of scute variation and untouched eggs represented by natural nests which produced turtles with far less scute variability. Though there were numerous factors, like temperature and humidity, that may have affected embryonic development of the turtles from our five categories, we had no quantitative measurements of these potentially significant factors. Instead our conclusions are based on qualitative judgements of the environmental differences and obvious distinctiveness among the five incubation-handling categories. While no cause and effect relationship has been demonstrated, we believe that the differences in the degrees of scute variability among the categories are attributable, at least in part, to the ways in which the eggs were treated or not treated after oviposition.

Comparisons of carapacial scute variability between dead and live individuals were made among the four incubation-handling categories examined in Mexico. On the whole, dead turtles exhibited somewhat more variation than live turtles, and correspondingly lower relative frequencies (percentages) in the modal scute class (for a given series) than live turtles. This is particularly notable in the corral nest category, as this was the only category with a large sample of dead individuals. Our results suggest that dead animals (the youngest ontogenetic stage in our study) had more variability in carapacial scutes than live animals, indicating that selection was acting to remove extreme phenotypes from the younger age classes. Nevertheless, these results are no more than suggestive. Comparisons between categories of Kemp's ridley hatchlings in our study and categories represented by juveniles (Carr and Caldwell, 1956) and adult females (Chávez *et al.*, 1967 and 1968) revealed no marked differences. Confirmation that selection acts on the extremes of carapacial scutation phenotypes in Kemp's ridleys awaits further study.

Interest in possible significance of carapacial scute variation as an index of the effects of differences in incubation-handling techniques may increase now that we have demonstrated considerable variation in carapacial scute counts among turtles obtained from eggs incubated and handled in a variety of ways. The process in which phenotypic variation occurs as a consequence of physical environmental factors acting on sensitive portions of a developing organism was referred to by Smith-Gill (1983) as phenotypic modulation. Scutes or scales are phenotypic variables that are easily quantified and which have been presumed to reflect, at least in underlying genetic variation (Fox, 1975). Several studies of squamate reptiles have examined the evolutionary significance of scale count variation at different ontogenetic stages (see review by Simbotwe, 1981). However, the carapacial scutes of turtles do not seem to have

received such attention, possibly due to the relatively low frequencies of individual variations, and to the phylogenetic stability of the overall scute pattern (Zangerl and Johnson, 1957; Zangerl, 1969). The large extent to which phenotypic modulation appears to determine the degree of variability in carapacial scutes of turtles brings into question the role that heritability plays in the observed variation. It seems likely that the extent of phenotypic modulation present is itself a heritable feature. Nevertheless, each generation may be subject anew to selection on the variety of carapacial scute phenotypes produced by phenotypic modulation. As noted by Smith-Gill (1983), this variation may not necessarily be adaptive, or it may be non-adaptive. Hill (1971) found that adult olive ridleys (*L. olivacea*) in Surinam were less variable in scutation than hatchlings, and he implied that increased variation was not desirable. A study of green turtles (*Chelonia mydas*) by Le Toquin, Gamel and Trotignon (1980) also implied that the scutes of adult sea turtles were less variable than those of hatchlings. These previous studies support the hypothesis that selection acts against extremes in carapacial scutation phenotypes.

Conclusions

Implications of our findings to the conservation of endangered sea turtles such as Kemp's ridley are numerous. We have presented evidence confirming that the manner in which eggs of Kemp's ridley are handled after oviposition has a marked effect on carapacial scute variability. Further, it is apparent that increased variability is undesirable, with more extreme variants being less viable and selectively removed from the population over the course of ontogenetic development. Therefore, transplantation, translocation and artificial incubation of sea turtle eggs should be evaluated with concern for their possible effects on viability of hatchlings.

When the mechanisms of scute abnormality are better understood, scute patterns may become useful external indicators of phenotypic or genotypic deficiencies related to future viability. Many selective pressures are removed by artificial incubation but are replaced by others, so any external indicator of phenotypic or genotypic deficiency would be a useful tool in determining the long-term effects and suitability of artifical incubation and various other techniques involving the incubation and handling of eggs. For example, culling of abnormal individuals based on the presence of certain known, lethal scute patterns might be an effective means of maintaining healthy stocks.

Developmental plasticity is the process whereby environmental input alters the phenotype of an organism (Smith-Gill, 1983). Environmentally determined sex in turtles is a well documented example of this sort of alteration (Bull, 1980, 1983). The possible consequences of artificially altering sea turtle sex ratios through control of conditions during incubation of eggs have been widely publicized (Mrosovsky and Yntema, 1980; Yntema and Mrosovsky 1980, 1982; Morreale *et al.*, 1982; Mrosovsky, 1982). Smith-Gill (1983) reviewed the concept of critical period during development with regard to phenotypic plasticity. It holds that organs are most susceptible to environmental influences during periods when they are most actively differentiating. The critical period during which temperature influences gonadal differentiation in turtles is the middle third of incubation (Bull and Vogt, 1981; Yntema and Mrosovsky, 1982). Similarly, the carapacial scute pattern must also have a critical period for differentiation (Ewert, 1979). Research to determine when this critical period occurs could aid conservationists in making wise choices about when to move eggs, if at all, and would doubtless help in determining linkages between aberrant scute patterns and other organ system abnormalities which are more directly related to long-term viability.

Acknowledgements

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Morphometry of Captive-Reared Kemp's Ridley Sea Turtle

André M. Landry, Jr. *

*Morphometry and growth were characterized for head started Kemp's ridley sea turtles (*Lepidochelys kempi*) from the 1984 year-class. Straight-line carapace and plastron length and width measurements were taken biweekly from 100 hatchlings in nine clutches during late August 1984 through early May 1985. Growth rate and anatomical growth pattern were described through analysis of morphometric data. Carapace and plastron dimensions were analyzed by clutch, feeding rate, raceway location and hydrological parameters. Regression equations were developed for carapace and plastron length-width relationships.*

An international recovery program designed to save the endangered Kemp's ridley (*Lepidochelys kempi*) from extinction has incorporated, among other things, a head start project in which hatchlings are reared in captivity at National Marine Fisheries Service's Galveston Laboratory for 10 to 11 months. Head starting provides care, maintenance and husbandry of Kemp's ridleys to increase their survival and optimize growth during their first year. Projects such as this provide opportunities for conducting research on growth of captive species such as the Kemp's ridley.

Growth studies of captive-reared Kemp's ridleys conducted by Caldwell (1962), Márquez (1972), Pritchard and Márquez (1973), Klima and McVey (1982), McVey and Wibbels (1984), Caillouet and Koi (1985), Fontaine *et al.* (1985) and Caillouet *et al.* (1986) have defined growth in terms of body weight. The same is generally true for growth studies of captive-reared species other than Kemp's ridleys (Uchida, 1967; Stickney, White and Perlmutter, 1973; LeBrun, 1975; Witham and Futch, 1977; Wood and Wood, 1981; Frazer and Schwartz, 1982; Hirth, 1982; Nuitja and Uchida, 1982; and Rajagopalan, 1984).

Studies defining growth of captive-reared Kemp's ridleys in terms of carapace and/or plastron measurements are few and incomplete. Data on morphometric growth of head started ridleys mainly include regression formulas defining the relationship of carapace length and width (Caillouet *et al.*, 1986) and growth in carapace length following release from captivity (McVey and Wibbels, 1984). No studies have systematically examined morphometric growth of captive-reared ridleys or the relationship of growth rate to constitutent variables of a head start project such as clutch, feeding rate, rearing location and hydrological factors.

The study reported herein was designed to:

1. characterize morphometry and growth of the 1984 head start year-class of Kemp's ridley sea turtles;
2. determine the effects of clutch, feeding rate, raceway location and hydrological effects on growth rate; and
3. develop regression statistics describing carapace and plastron length/width relationships.

Materials and Methods

Morphometry and growth measurements were taken on 100 head started Kemp's ridleys from August 30, 1984, (41 to 46 days after hatching) through May 13, 1985, (297 to 302 days old and 8 days prior to release in the Gulf of Mexico). Measurements were taken biweekly during this period to produce 19 data sets. Four straight line measurements – carapace length, carapace width, plastron length and plastron width – were the basis for all morphometry and growth characterizations. Measurement protocol followed that outlined in Bacon *et al.* (1983) whereby: carapace length (minimum) – precentral scute to notch in postcentral scute; carapace width – distance across the widest part of the carapace, perpendicular to the longitudinal axis of the body; plastron length – anteriormost gular scute to posterior edge of anal scute; and plastron width – distance across the widest part of the plastron, perpendicular to the longitudinal axis of the body. All measurements were taken with vernier calipers to the nearest 0.1 mm.

The 100 turtles used in this experiment were comprised of 10 turtles chosen at random from each of nine clutches dispersed over four 3,140-liter rearing raceways (Figure 1). Three raceways – 2, 3 and 4 – were located in rearing

* *Texas A&M University at Galveston*

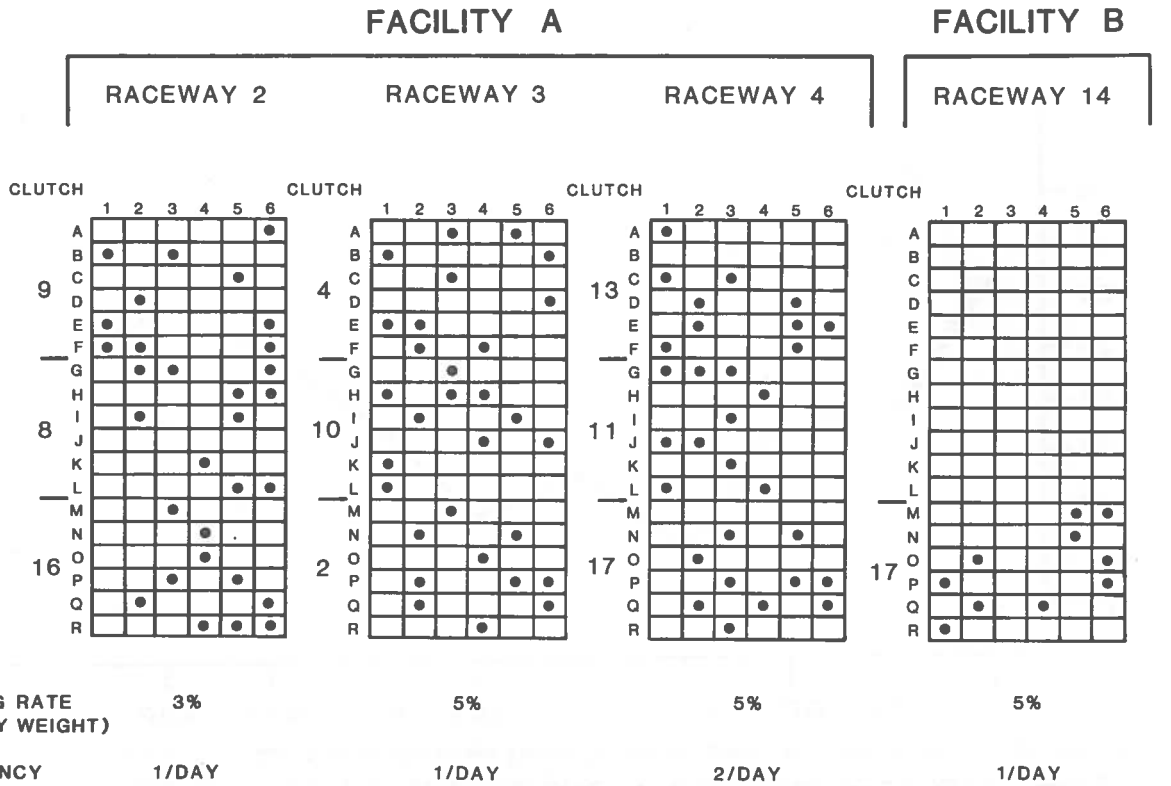

Figure 1. Allocation of nine clutches of Kemp's ridley sea turtle hatchings of the 1984 year-class across four raceways and three feeding regimes.

Facility A and each contained three unique clutches with 10 turtles apiece. The fourth raceway, 14, was located in rearing Facility B and contained only one clutch, 17, whose constitutents (20 turtles) were partitioned between this raceway and raceway 4. Survival among experimental turtles during the study was 96 percent.

Experimental turtles were fed a dry, high-protein pelleted diet. The ration (manufactured by Central Soya and Subsidiaries) used for six previous year-classes (1978-1983) was initially fed the experimental turtles but did not float as required for surface feeding hatchlings. This ration was subsequently doubled in order to obtain enough floating pellets for adequate feeding through November 10. Thereafter, a floating, modified trout chow manufactured by Purina was fed to turtles. The quantity of pelleted food given to each raceway/clutch combination each day was based on a percentage of the monthly geometric mean weight per turtle in a clutch. Three feeding regimes were provided turtles through February 1985. These regimes included: 1) raceway 2 turtles – 3 percent of body weight fed once daily; 2) raceway 3 and 14 turtles – 5 percent of body weight fed once daily; 3) raceway 4 turtles – 5 percent of body weight fed twice daily (Figure 1). All turtles were fed a uniform rate (2.2 percent of body weight) twice daily after February.

Seawater in raceways housing experimental turtles was pumped from the Gulf of Mexico and stored temporarily in reservoirs heated only during the winter. Raceway water temperature varied as did air temperature of Facilities A and B, which were ventilated by exhaust fans during summer and heated by forced-air heaters in winter. Water temperature and salinity were monitored daily in each raceway with a mercury laboratory thermometer and refractometer, respectively. Seawater in raceways was replaced completely three times a week, and raceways scrubbed once weekly to remove unconsumed food, algae and excrement.

Morphometry and growth were assessed across four experimental variables which included: 1) clutch – 9 experimental clutches; 2) feeding rate – 3 feeding rates (through February); 3) location – 4 raceways (3 in Facility A and 1 in Facility B); and 4) hydrological components – water temperature and salinity.

Carapace and plastron length-width measurements were logarithmically transformed and subjected to analysis of variance to detect differences in morphometry and growth across clutch and feeding regime. A Bartlett's test of homogeneity of variances was conducted to test equality of sample variances (Sokal and Rohlf, 1981). Regression analysis was used to determine length-width relationships for carapace and plastron measurements across clutch. Functional length-width relationships described by regression equations were compared by tests for homogeneity of slopes (Sokal and Rohlf, 1981).

Results

Raceway water temperatures exhibited a seasonal pattern (Figure 2). Average monthly levels peaked between 26° and 27°C in August, declined to fluctuating lows near 21° and 22°C during November through January, and gradually

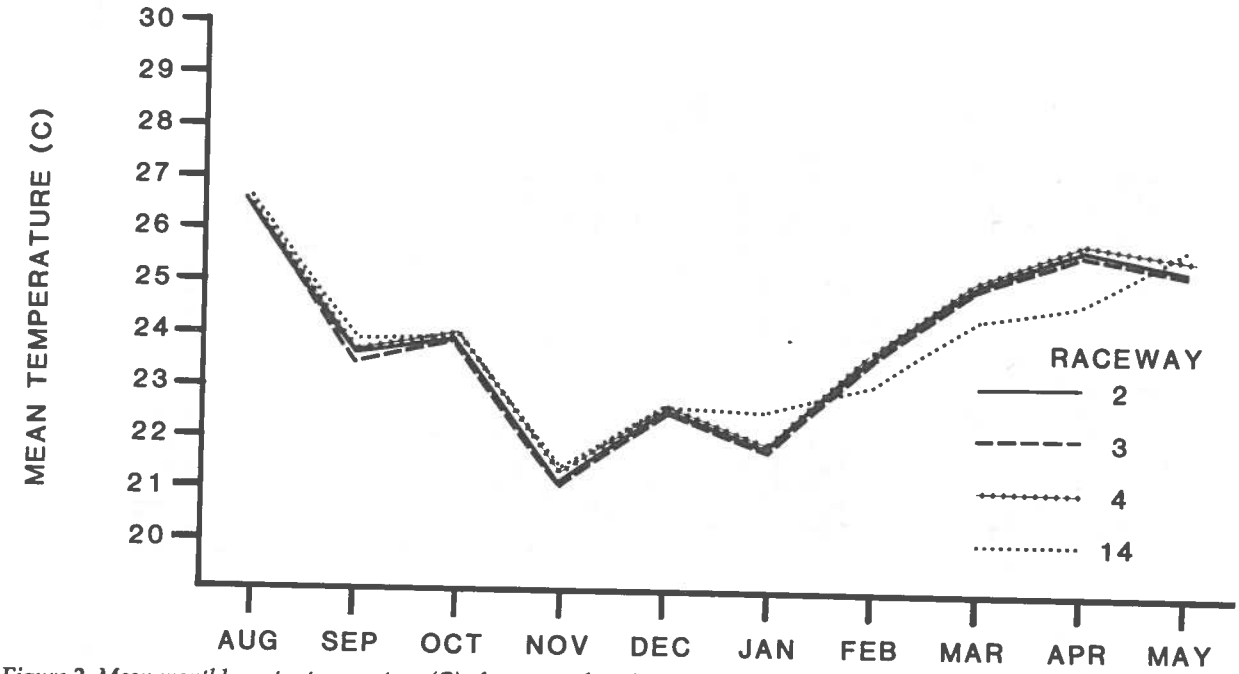

Figure 2. Mean monthly water temperature (C) of raceways housing Kemp's ridleys used in morphometric growth studies.

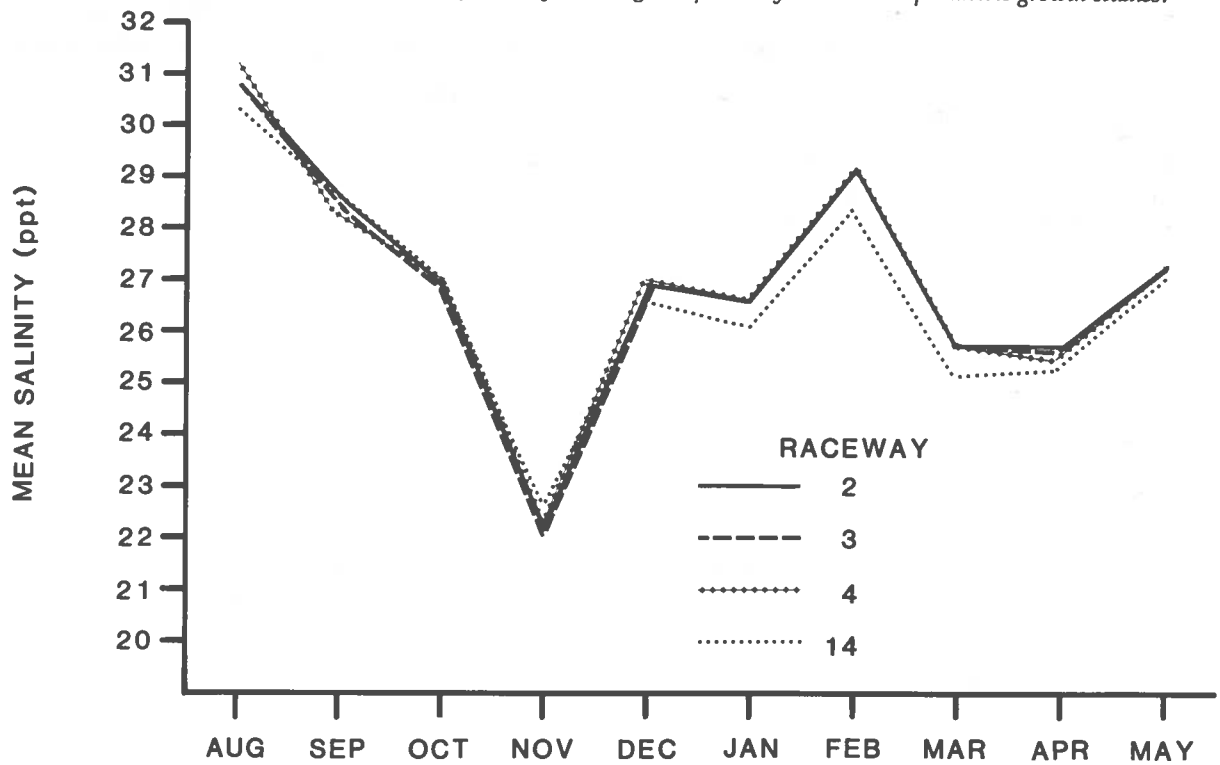

Figure 3. Mean monthly salinity (‰) of raceways housing Kemp's ridleys used in morphometric growth studies.

returned to near 26°C in April and May. Temperatures across all raceways paralleled one another through December. Thereafter, temperatures in raceway 14 (the only raceway in Facility B) typically differed from those of raceways in Facility A by 1.0°C.

Salinity exhibited a precipitous decline from mean values of 30‰ in August to a low of 22‰ by November (Figure 3). Thereafter, salinities rose gradually to fluctuate between 26 and 29‰. As with water temperature, salinity trends across raceways were nearly identical through December, after which time those in raceway 14 were 0.5 to 1.0‰ lower than those of other raceways.

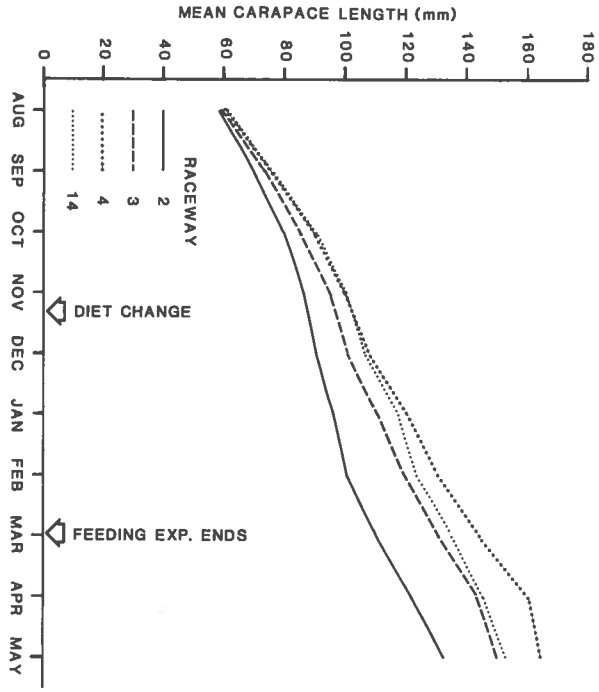

Figure 4. Monthly mean carapace length (mm) values from all turtles (regardless of clutch) in raceways 2, 3, 4 and 14. Arrows denote the change from sinking to floating chow and initiation of a uniform feeding rate.

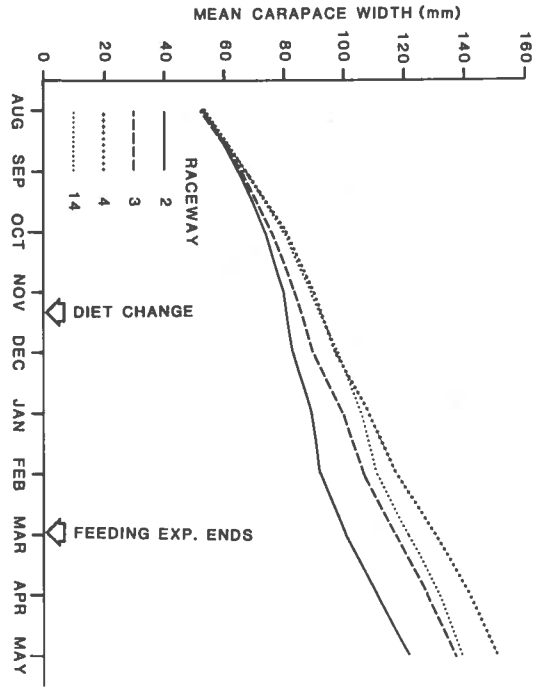

Figure 5. Monthly mean carapace width (mm) values from all turtles (regardless of clutch) in raceways 2, 3, 4 and 14. See Figure 4 for meaning of arrows.

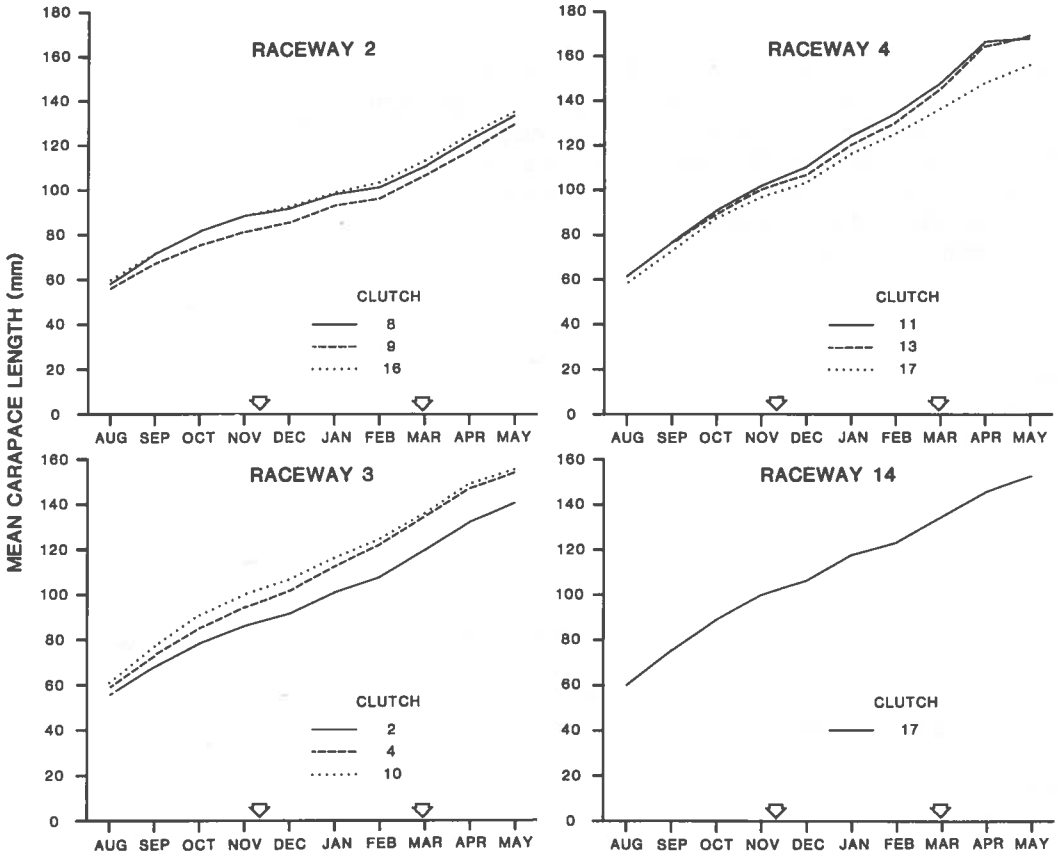

Figure 6. Monthly mean carapace length (mm) values for individual clutches in raceways 2, 3, 4 and 14. See Figure 4 for meaning of arrows.

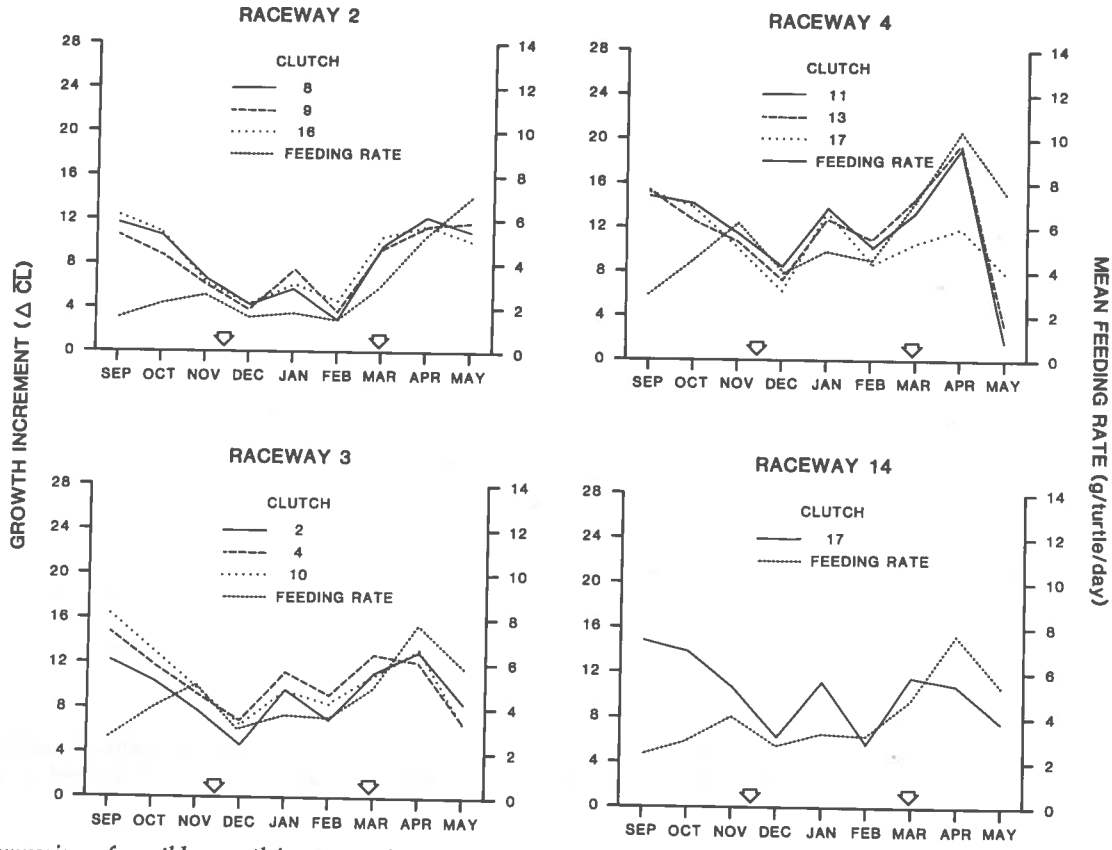

Figure 7. Comparison of monthly growth increments in carapace length and mean feeding rate for turtles in individual clutches across raceways 2, 3, 4 and 14. See Figure 4 for meaning of arrows.

Morphometry and Growth

Carapace length and width growth patterns were similar (Figures 4 and 5). Growth in carapace length was most rapid and relatively comparable among raceways/feeding regime during August through October (Figure 4). This growth slowed appreciably through December as raceway water temperature and salinity (Figures 2 and 3) exhibited strong fluctuations and the pelleted diet was changed from a sinking to floating chow. This period also marked the beginning of a 6-month span in which carapace length for turtles given the highest feeding rate (raceway 4 – 5 percent body weight fed twice daily) diverged more and more from those fed the lowest rate (raceway 2 – 3 percent body weight fed once daily). Clutches in raceway 4 consistently produced significantly greater carapace length statistics ($P \leq 0.05$) during every measurement set in this period (Figure 6).

Despite differences in growth rate, carapace length statistics among all raceways exhibited noticeable increases from February through May (Figures 4 and 6). This upswing in growth coincided with sizeable increases in water temperature (Figure 2) and the initiation of a uniform feeding rate (2.2 percent body weight fed twice daily) for all turtles in late February. Monthly growth rate increases were most consistent among clutches in raceway 2, which prior to March were fed at the lowest feeding regime (Figures 4 and 6). Raceways initially fed higher feeding rates exhibited a modest decline in growth rate after April (Figure 4).

February to May carapace length measurements revealed a pattern (Figures 4 and 6) of increasing convergence in growth of turtles in raceways (3 and 14) fed the intermediate feeding rate (5 percent body weight once daily). This pattern of converging growth rate differed sharply from that exhibited by these raceways during October through January (Figure 4).

Overall mean increase in carapace length during the study ranged from 8.2 mm per month in raceway 2 to 10.0 mm per month in raceways 3 and 14 to a high of 12.0 mm per month in raceway 4. Turtles fed the highest rate exhibited a 42.8 percent greater increase in carapace length when compared to those fed 3 percent once a day. Growth increment for carapace length fluctuated across raceways, feeding regimes and months (Figure 7). All raceways exhibited a general pattern of declining monthly growth increments from September through December, a noticeable growth spurt in January followed by a similar slowing in February and upswings through April. Raceway 2 turtles were the only clutches not to exhibit sizeable declines in growth increments during May.

Comparison of monthly carapace length increments with monthly feeding totals (mean number of grams fed to each turtle per day) revealed intriguing patterns (Figure 7). Monthly length increments across all raceways during

Table 1. Growth in carapace length (CL) and width (CW) across raceways and feeding regimes.

Raceway	Initial CL (mm)	Final CL (mm)	CL Gain (%)	Initial CW (mm)	Final CW (mm)	CW Gain (%)
All Months						
2	58.5	133.0	127.4	52.9	121.0	128.7
3	58.9	150.8	156.0	52.6	136.7	159.9
4	60.8	164.3	170.2	54.3	150.2	176.6
14	60.7	153.0	152.1	54.5	138.8	154.7
August to Late February						
2	58.5	100.6	72.0	52.9	91.8	73.5
3	58.9	119.1	102.2	52.6	105.5	100.6
4	60.8	130.4	114.5	54.3	116.9	115.3
14	60.7	123.2	103.0	54.5	109.9	101.7
Late February to Mid-May						
2	100.6	133.0	32.2	91.8	121.0	31.8
3	119.1	150.8	26.6	105.5	136.7	29.6
4	130.4	164.3	26.0	116.9	150.2	28.5
14	123.2	153.0	24.2	109.9	138.5	26.0

September through November declined despite increasing volumes of food fed turtles. This three-month decline in growth increment also coincided with sharp temperature and salinity reductions (Figures 2 and 3). After November, fluctuations in monthly growth increments generally followed those for feeding levels (Figure 7). This trend was particularly true for the latter part of the study (February-April) when temperature and salinity levels rose significantly and diet volume increased dramatically. Likewise, declines in the amount of food fed raceways 3, 4 and 14 during May produced noticeable reductions in growth increment among constitutent clutches.

Growth in carapace length across raceways/feeding regimes exhibited different trends across time and change in feeding rate (Table 1). Over the entire study period, raceway 4 clutches exhibited an average gain in carapace length of 170.2 percent as compared to 127.4, 156.0 and 152.1 percent, respectively, for raceways 2, 3 and 14. Partitioning carapace length data into two groups based on the late August to late February period of different feeding regimes and the late February to mid May period of uniform feeding rate yields different growth patterns. Carapace length growth patterns during the August to February feeding experiment parallel those outlined above for the entire study. However, these growth trends were reversed during late February to mid May when all clutches were fed the same rate (2.2 percent of body weight fed twice daily). Average percent gain in carapace length over this 74-day period was significantly greatest ($P \leq 0.05$) in raceway 2 clutches (32.2 percent) and lowest in raceway 14 clutches (24.2 percent). Raceways 3 (26.6 percent) and 4 (26 percent) also yielded significantly smaller gains when compared to that of raceway 2. These trends coincided with diverging patterns in the amount of food fed to raceway 2 clutches and those in the other three raceways (Figure 7).

Monthly growth patterns and feeding rate relationships recorded for carapace width (Figures 5 and 8, Table 1) generally paralled those exhibited by carapace length (Figures 4 and 6, Table 1). Mean carapace width was significantly greater ($P \leq 0.05$) for raceway 4 turtles than that of other raceways. Within raceway comparisons detected no statistical difference in carapace width among constitutent clutches, except in raceway 3 where clutch 2 turtles exhibited significantly ($P \leq 0.05$) slower growth (Figure 8).

Regression of carapace length on carapace width for all clutch/raceway combinations produced fitted lines whose slopes were nearly identical (Figure 9). High coefficients of determination (r^2 typically > 0.99) indicated excellent fits of regression lines.

Plastron length and width statistics displayed the same trends evident for carapace measurements (Figures 10-13, Table 2). These trends indicated that plastron growth was largest among raceway 4 clutches, intermediate and converging to similarity among raceway 3 and 14 clutches, and significantly smallest among raceway 2 cohorts. Within raceway comparisons of plastron length and width measurements across clutches detected no divergence from those presented for carapace statistics (Figures 6, 8, 12 and 13).

Regression analyses for plastron length and width yielded strong correlations between the two parameters and fitted lines whose slopes were very similar across all clutches/feeding regimes (Figure 14).

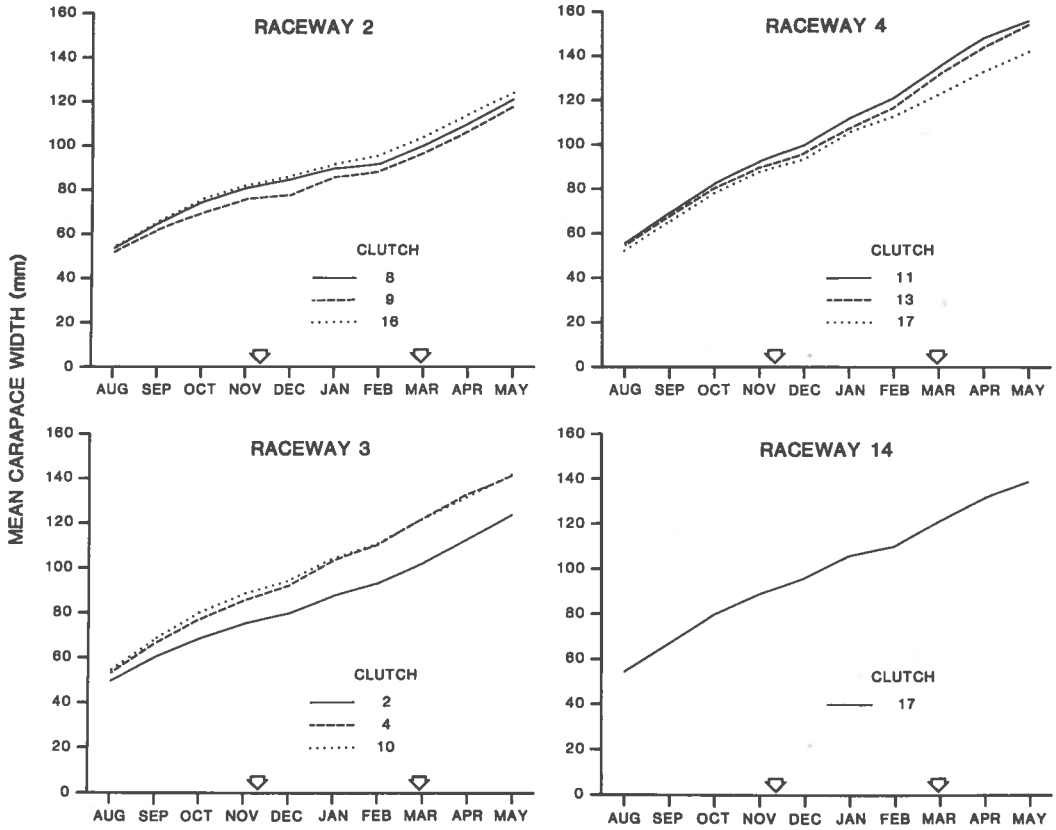

Figure 8. Monthly mean carapace width (mm) values for individual clutches in raceways 2, 3, 4 and 14. See Figure 4 for meaning of arrows.

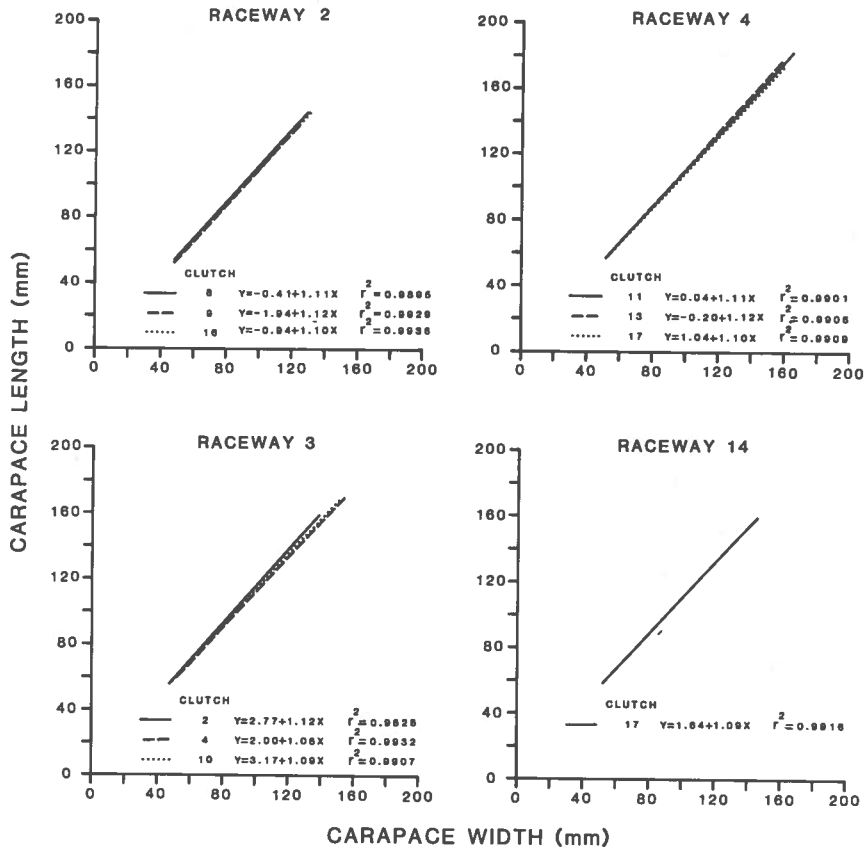

Figure 9. Rectilinear regressions of carapace length (Y) on carapace width (X) for individual clutches across raceways 2, 3, 4 and 14.

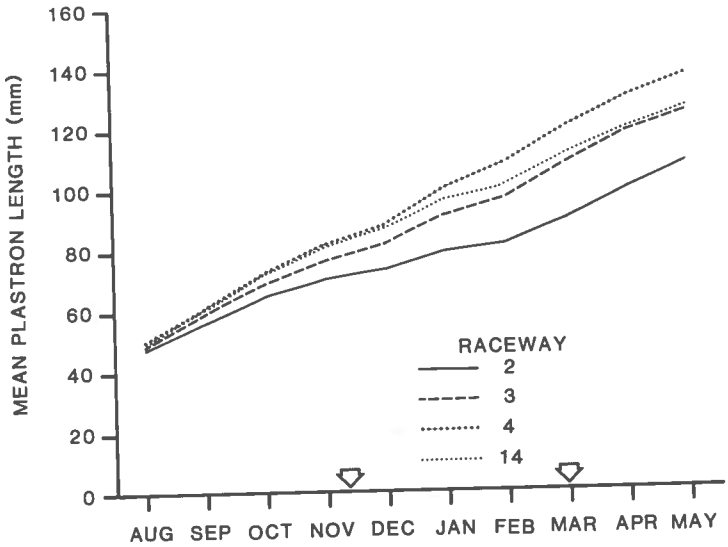

Figure 10. Monthly mean plastron length (mm) values for individual clutches in raceways 2, 3, 4 and 14. See Figure 4 for meaning of arrows.

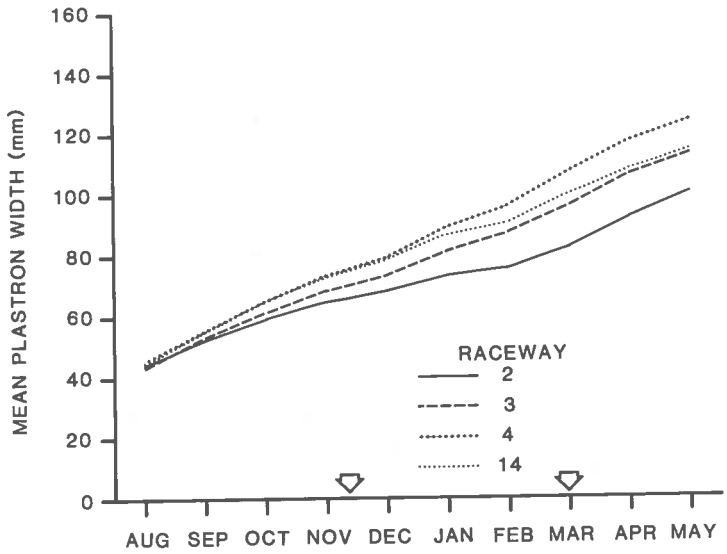

Figure 11. Monthly mean plastron width (mm) values for individual clutches in raceways 2, 3, 4 and 14. See Figure 4 for meaning of arrows.

Table 2. Growth in plastron length (PL) and width (PW) across raceways and feeding regimes.

Raceway	Initial PL (mm)	Final PL (mm)	PL Gain (%)	Initial PW (mm)	Final PW (mm)	PW Gain (%)
2	47.5	108.4	128.2	44.3	100.8	127.5
3	52.6	124.9	137.5	43.5	113.5	160.9
4	49.3	137.2	178.3	45.0	124.9	177.6
14	54.5	126.0	131.2	45.0	114.9	154.8
August to late February						
2	47.5	82.0	72.6	44.3	75.5	70.7
3	52.6	97.4	85.2	43.5	57.4	100.9
4	49.3	108.7	120.5	45.0	96.7	114.9
14	54.5	101.1	85.5	45.1	90.9	101.6
Late February to mid-May						
2	82.0	108.4	32.2	75.6	100.8	33.3
3	97.4	124.9	28.2	87.4	113.5	29.9
4	108.7	137.2	26.2	96.7	124.9	29.2
14	101.1	126.0	24.6	90.9	114.9	26.4

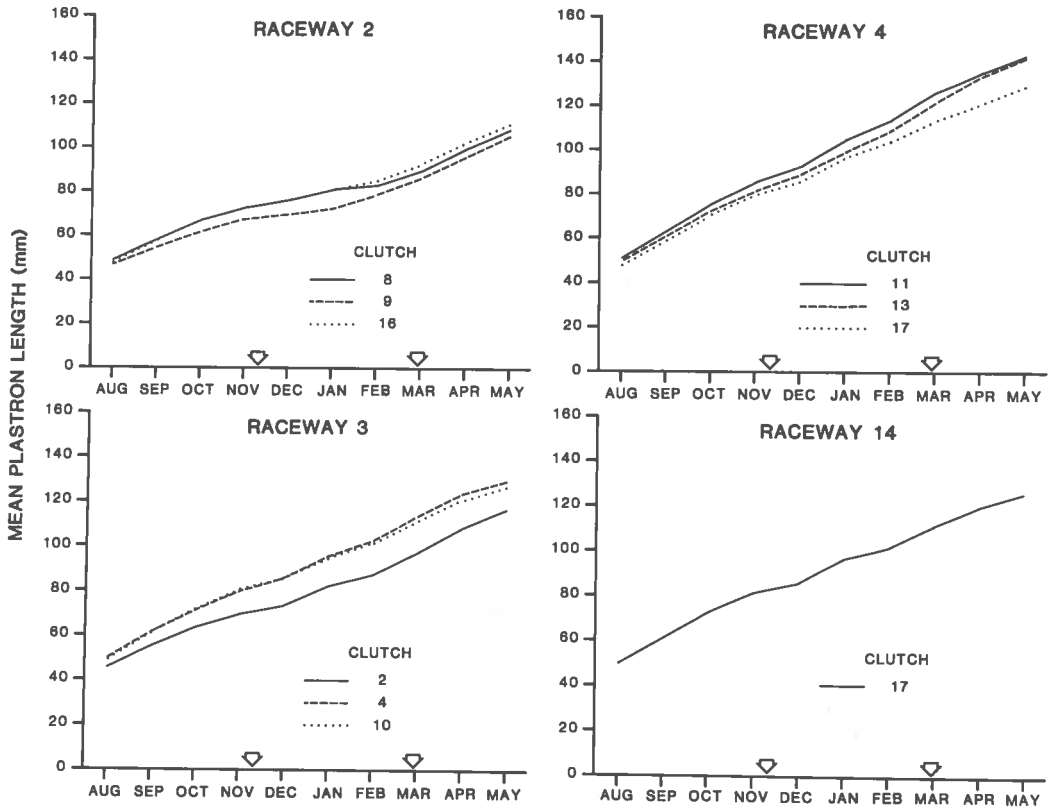

Figure 12. Monthly mean plastron length (mm) values for individual clutches in raceways 2, 3, 4 and 14. See Figure 4 for meaning of arrows.

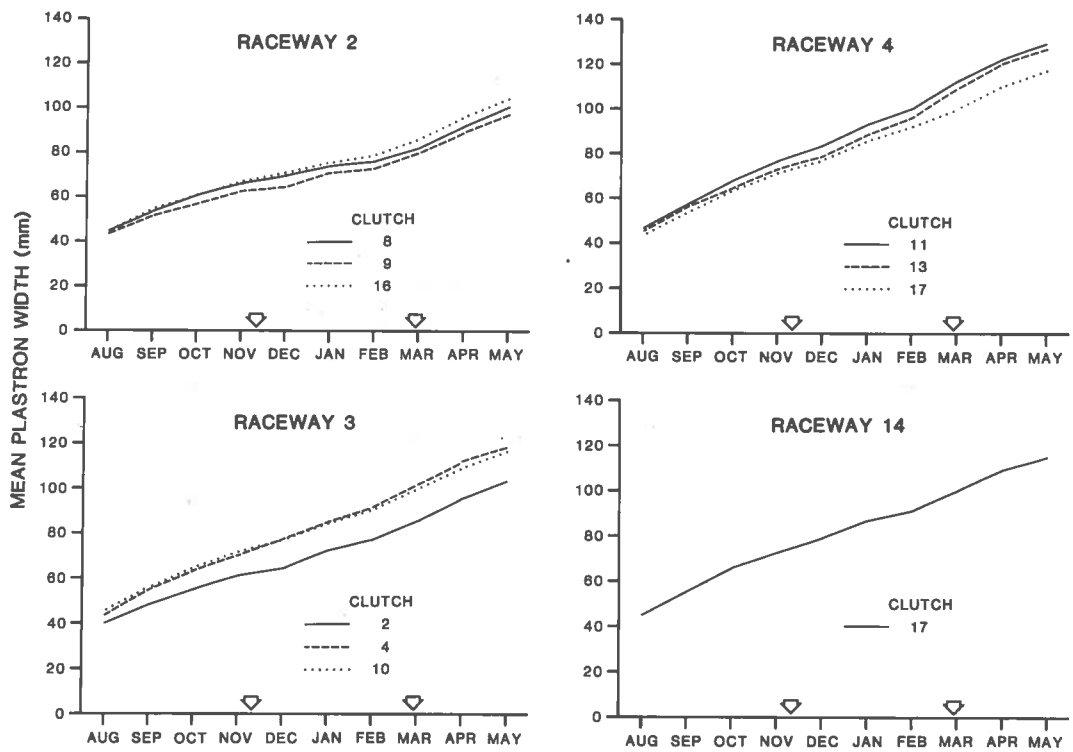

Figure 13. Monthly mean plastron width (mm) values for individual clutches in raceways 2, 3, 4 and 14. See Figure 4 for meaning of arrows.

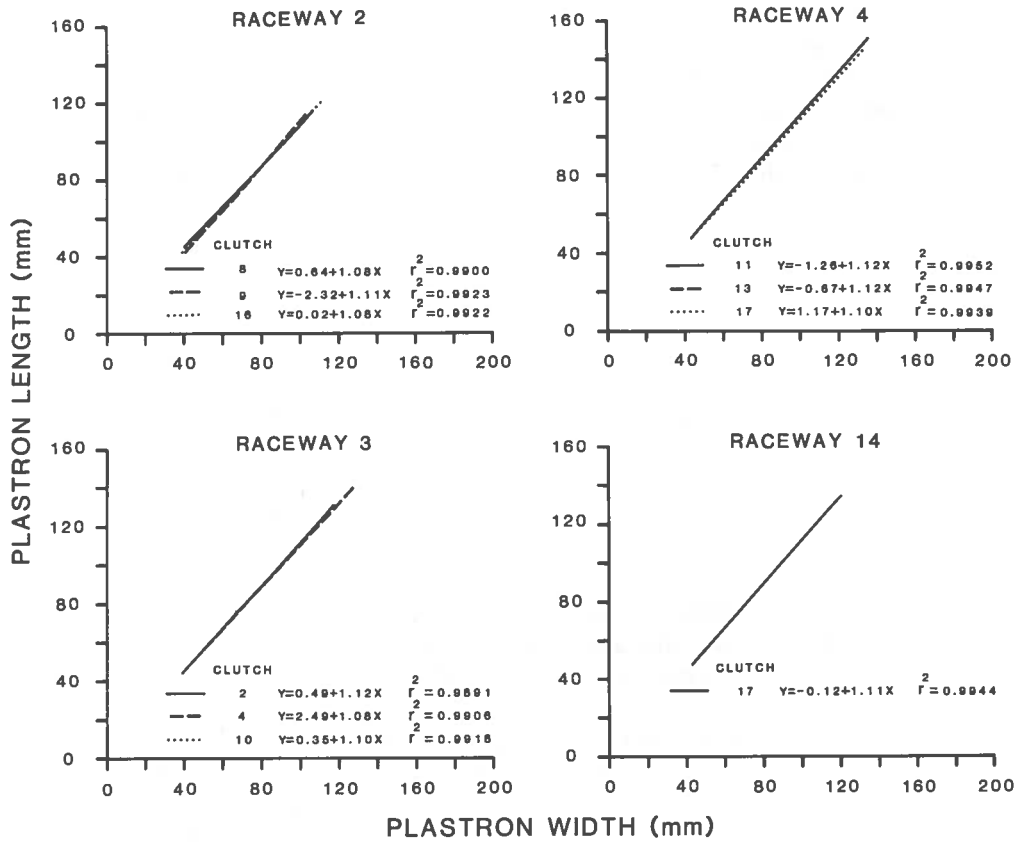

Figure 14. Rectilinear regressions of plastron length (Y) on plastron width (X) for individual clutches across raceways 2, 3, 4 and 14.

Discussion

Considerable similarity existed between the growth patterns and growth rate curves recorded for all carapace and plastron parameters. This consistency in growth, regardless of morphological parameter, justifies the selection of only one meristic character upon which to discuss results of this study. Carapace length will be the primary meristic discussed herein since turtle researchers tend to use this variable more frequently than other growth variables involving length and/or width.

Feeding regime, clutch and microenvironmental effects all appeared to influence growth of the head started, 1984 year–class of Kemp's ridleys. Greatest impact on growth resulted from feeding regime. Feeding experiments during August through late February clearly proved that growth rate was dependent upon feeding rate and frequency. Turtles fed 5 percent of body weight twice daily experienced a 30.2 percent greater carapace length than cohorts fed 3 percent once daily during the six-month experiment. Similarly, turtles fed at the same rate (5 percent) but at different frequencies exhibited average carapace lengths that differed by 12.3 percent.

Comparison of growth patterns for turtles fed the same feeding regime but housed in different locations appeared to indicate feeding regime exerted greater influence on growth than did location. Overall percent gain in carapace length for raceway 3 and 14 turtles (housed in Facilities A and B, respectively) was 156.0 and 152.1 percent, respectively. More importantly, carapace length gain for these two raceways during the feeding experiments was almost identical (102.2 percent raceway 3; 103.0 percent raceway 14).

The effect feeding regime had on growth also became more apparent during the 74 days that all raceways were fed the same feeding regime (2.2 percent of body weight twice daily). Average monthly increment in carapace length growth was 10.8, 10.6, 11.3 and 9.9 mm for raceways 2, 3, 4 and 14, respectively. The similarity among these values appears indicative of fairly uniform growth across turtles fed the same rate.

Growth curves revealed a pattern of relatively gradual increase in carapace length across months for all raceways. These smooth growth curves tended to mask the sharp fluctuations in monthly growth rate within respective raceway/clutch combinations. Monthly growth rate dipped noticeably across all raceways during September through December. These declines in growth increment occurred despite increased feeding rates through November. It is unlikely that mandated feeding rates during this period of rapid growth among relatively small-sized turtles may have resulted in food not being eaten. Instead, growth rate reductions were probably the result of lower, fluctuating

water temperatures through November. This trend in slower growth among captive-reared Kemp's ridleys also has been reported by Caillouet and Koi (1985). These workers found turtles in year classes 1978-1983 exhibited slowed growth near the middle of the head starting period and attributed this trend to temperature reductions during winter. However, monthly fluctuations in raceway temperature and growth rates during this four-month period were generally opposite one another and, as such, cast doubt on temperature acting alone to produce reduced growth increments.

Sizeable increases in monthly growth increment across raceways after January were due to a combination of increased water temperatures and amount of food fed turtles. This was particularly true through April. Thereafter, raceway temperature dipped slightly, amount of food fed dropped drastically in raceways 3, 4 and 14, and growth increments among constitutent turtles plummeted. Raceway 2 turtles failed to exhibit the same sizeable reductions in growth rate observed across the other raceways. These turtles continued to receive an increased feeding rate which buffered the impact of reduced water temperatures and kept growth increments near those recorded in April.

Little difference could be detected in growth among clutches. Detection of clutch variation was, in part, masked by an experimental design incorporating different feeding rates. Other workers (Caillouet and Koi, 1985; Caillouet *et al.*, 1986) have reported considerable variation in growth (as weight) among individual turtles, clutches and year classes. However, their studies were based on uniform feeding rates whereby growth responses of different clutches to the same treatment could be characterized. Only one clutch (2 in raceway 3) exhibited significantly different growth rates during the present study's within raceway/feeding regime comparisons. This clutch was among the oldest group of hatchlings and one of the first to be hatched. Nevertheless, this clutch exhibited the smallest initial carapace length measurements recorded among the nine clutches. NMFS' head start personnel have found that clutches hatching earliest frequently exhibit poorest survival and growth (Clark T. Fontaine, NMFS, personal communication).

Similarity of growth among clutches also was evident from regression analysis. Within raceway comparisons of regression formulas for carapace length and width yielded nearly identical slopes across clutches. Slope values for clutch 17 turtles exposed to different feeding regimes also were nearly identical. Regression analysis also confirmed Carr's (1967) contention that the carapace of Kemp's ridleys is almost as wide as it is long, even at an early age.

In summary, growth of captive-reared ridleys can be manipulated by feeding regime and environmental conditions. Higher feeding rate and feeding frequencies produced faster growth over the six-month feeding experiment. Rate of growth during these months was influenced by fluctuations in environmental parameters, particularly water temperature and, secondarily, salinity. Similar growth patterns exist for other captive-reared turtles. Growth rates of captive loggerheads (*Caretta caretta*) are dependent upon the amount and quality (percent protein) of food provided (Stickney *et al.*, 1973; Nuitja and Uchida, 1982). Furthermore, it has been found that captive green turtles (*Chelonia mydas*) achieve optimal growth at or above 25°C (Stickney, 1979). Findings of these latter studies also were pertinent to raceway 2 turtles in the present study. These turtles exhibited the highest percent gain in carapace length among cohorts in other raceways when they were changed to the higher feeding regime (2.2 percent twice daily as opposed to 3 percent once daily) in late February. This higher feeding rate and the increased water temperature during March to May enabled raceway 2 turtles to exhibit the second highest overall gain in carapace length (32.4 mm as opposed to 33.9 mm in raceway 4) recorded among raceways.

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A Report on Attempts to Breed Kemp's Ridley Sea Turtle, *Lepidochelys kempi*, in Captivity

Steven R. Rabalais, David W. Owens and Peter Thomas *

*Four (two male and two female) adult Kemp's ridley sea turtles (*Lepidochelys kempi*) were kept under controlled laboratory conditions for one year at The University of Texas Marine Science Institute. During this time, the animal serum androgen (testosterone) and estrogen (estradiol) levels and breeding behavior were monitored. A significant increase in serum estradiol was noted in one female, simultaneous to the males' attempts at breeding with this individual. An increase in serum testosterone levels of the males prior to the increase in female serum estradiol levels was noted. The significance of these changes relative to the breeding biology of this species was discussed. The breeding biology of this species coincides with published accounts of turtles breeding in the wild. A video record of the apparent unsuccessful breeding activity was presented.*

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Attempts at Breeding Kemp's Ridley Sea Turtles at Miami Seaquarium

Timothy B. Bentley*

A breeding program for the highly endangered Kemp's ridley sea turtle (Lepidochelys kempi) *was initiated to investigate its breeding behavior and to induce its successful reproduction in captivity. One adult male, three adult females and four subadults maintained at Miami Seaquarium were observed from February to August 1984. Breeding behavior was exhibited by the adult male, but no successful mating occurred. Two adult females were held with two-four males during 1985, but again no nesting was observed although eggs were found in the seawater.*

Kemp's ridley (*Lepidochelys kempi*) is the most endangered of all the sea turtles. In response to the decline in the Kemp's ridley population, Mexico's Instituto Nacional de la Pesca, the U.S. Fish and Wildlife Service, the National Park Service and National Marine Fisheries Service have undertaken a head start project to collect Kemp's ridley eggs from wild turtles, hatch them, then rear the turtles in captivity. Most of the hatchlings have been imprinted to Padre Island, Tex., then reared in captivity for a year or less before being tagged and released as yearlings into the Gulf of Mexico in hopes that they will have a better chance of survival than would hatchlings (Klima and McVey, 1982). Others have been transferred to various oceanaria and retained in captivity for an extended number of years (currently up to 10 more years), creating a pool of individuals that could eventually be used as a breeding stock.

Information on the reproductive behavior of Kemp's ridley is limited, although it is known that courtship and mating occur at the surface of the water just off the nesting beach (Ernst and Barbour, 1972). For the most part, nesting by this species is limited to one stretch of beach bordering the Gulf of Mexico in Tamaulipas, Mexico, where nesting occurs generally in the daytime with the turtles emerging singly or in groups known as *arribadas*. Unlike the other sea turtles, *Lepidochelys* spp. generally nest annually with variable intervals between each nesting in a given year (Ehrhart, 1982). Little is known of Kemp's ridley breeding activity including courtship behavior, duration of mating, etc. As a result of the reduced population of Kemp's ridleys and the limited knowledge of its breeding behavior, a project was undertaken to concentrate a number of captive adult ridleys at one location and systematically observe them during spring and summer to document their breeding and nesting behavior.

Materials and Methods

Four adults, one male and two females, maintained at Miami Seaquarium, on Virginia Key, Miami, Fla., and a third adult female on loan from Sea Turtle, Inc. of South Padre Island, Tex., were used in this study during 1984 and 1985. To facilitate identification of the four adult turtles, each was given a letter name and was tagged with a flipper tag. The wild-caught adult male was named S (NMFS tag NNK006), the captive-reared, adult female from Texas LF (tag no. 52), and the two wild-caught, adult females P (NMFS tag NNK004) and SB (NMFS tag no. NNK005). LF had been raised in captivity since hatching and consequently was known to be 12 years old at the time. The exact ages of the wild-caught, older turtles are uncertain. When they were received at the Seaquarium about 11 years earlier they already had reached adult size and, consequently, were presumed to be sexually mature.

The facility used at Miami Seaquarium consisted of a circular channel approximately 7 to 12 meters wide and 0.2-1.2 meters deep, encircling a small island about 45 meters in diameter. An elevated wooden walkway skirted the circumference of the channel allowing easy viewing of the turtles throughout the entire channel. Seawater was pumped from adjacent Biscayne Bay into the channel and drained via an overflow standpipe back into the bay. Both the island surrounded by the channel and the outer bank of the channel were heavily covered with mangrove trees and other tropical vegetation, so the channel remained well shaded throughout much of the day. At one side of the channel an artificial nesting beach was constructed by sloping the outer bank up onto a sand beach that extended 10 to 15 meters from the water's edge. The beach was approximately 15 meters wide, 1 to 1.5 meters thick, and was surrounded by a wooden wall on all sides except that facing the water.

Before observations began and during the initial period (February 20 to March 19, 1984) after LF was introduced, the turtles were free to roam the entire channel together with a number of large mature green turtles (*Chelonia mydas*)

and hawksbills (*Eretmochelys imbricata*). After this initial period, two pens were constructed in the channel by running wire mesh fences across the channel. The downstream pen holding the male was about 7 x 7 meters, while the upstream pen holding the three females was about 11 x 9 meters and had an open side leading to the nesting beach. A gate that could be opened from the walkway connected the two pens.

The turtles were under observation during the day several times a week for periods of one to three hours at a time. Specific behavior patterns for each turtle were recorded and additional written notes were made. Still photographs were taken using a 35 mm camera, and a videotape was made of some of the behaviors. The timing of the observation periods during the day was varied to allow a more complete description of the animals' behaviors.

The male was introduced into the pen containing females at various times from March through May 1984 by opening the gate between the pens. The behavior of the animals was followed closely to observe any breeding activity. If either the male or all of the females were disinterested in breeding, the male was returned to his pen and the experiment repeated at a later date. When no matings occurred among these four turtles, two additional male Kemp's ridleys from a stock of head started individuals of the 1978 year-class were introduced to the three adult females in hopes that a larger number of individuals might stimulate reproduction. Initially, these two additional males were kept in the pen with the older male and introduced one at a time to the females. Later, all three males were placed with all three females. Early in 1985, female SB died. The remaining two adult females (LF and P) and male S as well as several head started males were segregated and then introduced during 1985 as in 1984.

Results

The behaviors shown by the Kemp's ridleys while they were together with other species in the channel involved very little intraspecific or interspecific interaction. On two occasions in early March 1984, male S was observed following either female SB or LF and placing a flipper over her back or driving her before him. Both times the female swam off, and the interactions were over in several minutes. Interspecific interaction was also limited, primarily consisting of female LF biting the green and hawksbill turtles and subsequently being bitten herself. She was bitten by a large green turtle and sustained an injury to her head and jaw that required her isolation until the middle of June.

The other females (P and SB) that had been residents in the channel for years appeared to have established territories or selected favored habitats. SB was consistently found resting on the bottom of the north side of the channel, and P on the south side. Male S appeared to be more active and less attached to one site since he constantly travelled around the entire tank. Sedentary habits of the females as compared to the increased movement shown by the male may indicate a sex-specific behavior, but the small number of animals involved prevent firm conclusions being drawn.

The turtles were segregated by sex and held in the smaller pens from early March 1984 on, during which time they were observed for any behavior indicating readiness for mating. None of the turtles showed any behavior indicating a desire to be together, and in fact they stayed at opposite ends of their pens possibly because they were attracted to the high activity level of the green turtles outside the pens.

When the male did show interest in the females by swimming along the edge of their pen, he was transferred to their pen where he would approach one of the females and swim behind her. He would drive her before him and attempt to mount her. After trying unsuccessfully to mount her several times and to grip her with his foreflippers, he would turn his attention toward the other female where upon the second female would begin to avoid him. Occasionally he was successful in mounting a female and hooking his front claws over her carapace, but this lasted no more than one to two minutes before she would dive or turn away. The male often bit the hind flippers of the females, at times becoming very aggressive, and this occasionally induced the females to bite each other. Generally, after 10 to 30 minutes the male apparently lost interest, or the females became more determined in their resistance, either by swimming away rapidly or by biting at him. If his breeding behavior did not resume, the male was removed from the female pen and returned to his own. This pattern of behavior continued during each introduction of the male into the female pen during April and May.

By the end of May 1984, the interest male S showed in the females had declined so much that he no longer actively pursued them, although occasionally he placed his head under the rear margin of their carapaces. The two young males from the head started 1978 year-class were placed in the male pen with S in the hopes that their presence would induce a competitive drive in S or that they might mate with the females themselves. The gate between the male and female pens was left open, but none of the males showed any interest in the females.

Head started males were removed near the end of June 1984, and female LF was reintroduced into the male pen. The three females and male S were held together, but they remained very passive, resting on the bottom and showing no interaction. On June 28, tracks on the beach indicated that one turtle had crawled across the nesting beach and back to the water. One of two adult crocodiles (*Crocodylus acutus*) kept in the channel also had crawled onto the beach and followed the same track as the turtle part of the way. The following morning only female LF was present in the pen,

so apparently she had been the turtle making the crawl whether as a false nesting crawl, an exploratory crawl, or to escape the crocodile that had not previously been seen in the pen area was not determined.

Three females, male S and the two head started males were held together in the rebuilt pen in July 1984. All the turtles remained passive and did not interact during the two weeks they were together. Females LF and P were held together in the female pen and on July 30 a turtle crawled from this pen onto the nesting beach. No nest was dug, so the crawl apparently was exploratory. No further significant behavior was observed so observations were concluded in early August, and the pens were removed from the channel.

Seawater temperature in the channel was monitored throughout the period of observations, and despite the relatively large volume of seawater and a significant turnover from the bay, the temperature could change several degrees in only one or two days. The temperature was as low as 18°C in February and rose during March and April to 23-24°C. During May, June and July the temperature varied between 27°C and 30 °C. Most intraspecific interaction and the breeding behavior shown by male S occurred while the water temperature was 20-24°C, although it continued even after the water had warmed to 29°C.

During 1985, when male S was held with the females, no significant breeding behavior occurred, so the two 7-year-old head started males were introduced into the pen with the older turtles, again in hopes of stimulating reproduction. No mating was observed, but on June 6 a crawl track was observed on the nesting beach, and several eggs were found in the water of the female pen. Seawater temperature was 30°C at the time.

Between June 6 and 13, 1985, approximately 35 eggs were found in the water, and although most of these eggs were found in the female pen, some of them were in the channel outside the wall of the pen. Approximately 15 clean, intact eggs were buried in two spots on the nesting beach, and those eggs that were torn or appeared to have been in the water for an extended period were frozen for later identification. Only the two ridley females LF and P were in the pen, but numerous adult female green and hawksbill turtles were present outside the pens. A sample of 22 eggs averaged 40.1 mm in diameter (range 36-44 mm), a size range appropriate for Kemp's ridley or hawksbill, though too small for green turtle (Groombridge, 1982). The crawl made by a ridley and the presence of the majority of the eggs in the Kemp's ridley pen indicated that eggs probably were laid by a ridley, but it remains possible, due to presence of eggs and female green and hawksbill turtles outside the ridley pen, that the eggs were laid either by green or hawksbill turtles and were carried into the ridley pen by the water.

None of the eggs buried on the nesting beach had hatched as of August 16, 1985, suggesting that they had been in the water too long before burial or that they were infertile. The two females LF and P were X-rayed on August 9 in an attempt to determine their reproductive status. A male was also X-rayed for comparison. No developed eggs were visible in either female although LF contained what appeared to be follicles 4 to 10 mm in diameter.

Discussion

Although no nesting and probably no successful breeding occurred during the period of observation, progress was made in the attempt to establish a captive breeding project for captive ridley turtles at Miami Seaquarium. Much information on the turtles' behavior was gathered, initial ideas on induction of breeding were tried and refined, and the habitat requirements were investigated.

The Seaquarium's channel habitat appeared to be a very suitable location for this project to be continued. Seawater quality, salinity, temperature, shade level and bottom topography all seemed appropriate for maintaining sea turtles in good health. Since little is known of the environmental requirements for breeding in ridleys, it can only be assumed that if the animals appear healthy and well adapted to their confines, the habitat is fulfilling their needs. The nesting beach has been used by numerous loggerhead and green turtles for nesting in past years, and it seems likely that this beach could fill the requirements for the ridleys too, since it has been reported that there is little difference in the major aspects of nesting among the various sea turtle species (Hendrickson, 1982). The beach used by Kemp's ridleys in Tamaulipas, Mexico is a broad, white sand beach with no particular distinguishing features (Pritchard and Márquez, 1973), and therefore is similar to the nesting beach at the Seaquarium.

One characteristic that may be of some concern regarding nesting behavior of Kemp's ridleys in captivity as contrasted with that shown in Mexico is the distance travelled from the sea to the nesting site. In one study, most turtles crawled more than 40 meters and up to 60 meters before nesting (Pritchard and Márquez, 1973). Since the Seaquarium beach was only about 15 meters long, it is possible that its limited area could have deterred the turtles from nesting. However, the wild turtles are probably looking for sufficient elevation above the water and a clear spot free of rocks or vegetation, and since all of the Seaquarium beach fills these requirements, it seems unlikely that the small size of the beach would inhibit nesting.

A second characteristic of the Seaquarium habitat that may have deterred nesting was the passage of people on the boardwalk during the daytime when the Kemp's ridley turtles would be expected to nest. The turtles generally appeared undisturbed by people, but the presence of people may have been sufficient to keep the turtles from nesting. Unfortunately, the commercial nature of the Seaquarium precluded closing this area to visitors.

Acknowledgements

I thank the Miami Seaquarium and its conscientious employees who assisted in the project. Mrs. Ila Loetscher and others of Sea Turtle, Inc. were most supportive of the project, providing both a Kemp's ridley turtle and funding for the project. I appreciate the invaluable efforts of Mr. Suresh Ramanathan and Mr. Pedro Gonzalez who assisted in the project in 1984 and 1985, respectively. Direction and advice were provided by Mr. Fred Berry of the NMFS Southeast Fisheries Center, Miami, Fla. and Dr. David Owens of Texas A&M University, College Station, Tex. Funding for the 1984 portion of the project came from the NMFS under Contract No. NA-84-CEA-00148.

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Captive Rearing and Breeding Kemp's Ridley Sea Turtle at Cayman Turtle Farm (1983) Ltd.

James R. Wood and Fern E. Wood*

*Cayman Turtle Farm (1983) Ltd. received 96 yearling Kemp's ridley sea turtles (*Lepidochelys kempi*) of the 1979 year-class in July 1980 from Mexico. Fed on rations ranging from 35 percent to 45 percent protein, the turtles increased in weight from 0.98 kilograms to 23.6 kilograms in 62 months. In May 1984 at least three of the 5-year-old females became sexually mature, and two of them nested. Three hatchlings were produced, but survived only three to four days. This was the earliest documented age of nesting in Kemp's ridleys.*

In July 1980, Cayman Turtle Farm (1983) Ltd. received 96 yearling and 67 hatchling Kemp's ridley sea turtles (*Lepidochelys kempi*) from Mexico (Wood, 1982). The yearlings had been raised by the U.S. National Marine Fisheries Service Galveston Laboratory at Galveston, Tex. These had been returned to the Mexican government and thence, along with the 67 hatchlings from Rancho Nuevo, were transferred to Grand Cayman, B.W.I. All turtles were obtained through a cooperative Kemp's ridley program between the Cayman Islands and Mexico with the long term objective of establishment of a captive breeding herd of Kemp's ridley. Observations and data collected during the first five years of this project are discussed below.

Growth and Nutrition

During the first three months following receipt of the turtles, all were fed *ad libidum* with Biodiet, a semi-moist ration produced by Bioproducts, Inc., Warrenton, Ore., containing 38 percent protein. Use of the semi-moist pellet reduces the incidence of gut compaction associated with drier rations. For the next three months, the turtles received a hatchling food manufactured by Central Soya, Fort Wayne, Ind., containing 45 percent protein. When Central Soya ceased manufacturing this diet, the turtles were fed a 45 percent protein hatchling ration prepared by Ralston Purina, St. Louis, Mo. The hatchlings remained on the Purina ration until September 1982 when they began receiving a modified Purina Trout Chow containing 42 percent protein.

At 20 months of age (February 1981) the older ridleys began receiving Purina turtle chow containing 35 percent protein. During the next six months, their growth rate declined. Therefore, beginning in August 1981, the larger turtles were split into two groups, one receiving the Purina Chow containing 35 percent protein and the other fed the Purina Chow containing 45 percent protein.

Figure 1 illustrates the results of this experiment. Rate of growth for the five-month period was three times greater in turtles receiving the 45 percent protein ration than in those receiving the 35 percent protein ration. Following termination of this experiment, all the turtles were maintained on the Purina ration containing 45 percent protein until the modified Purina trout chow became available in September 1982. Turtles remained on the modified trout chow until transferred in May 1984 to the breeding pond. At this time, it became impractical to feed them modified trout chow, since the ridleys were mixed with green turtles (*Chelonia mydas*) in the breeding pond. In July 1985 the breeding pond was modified so that the ridleys could be confined in a separate area, and they were again fed trout chow.

Growth of the ridleys received as yearlings is shown by Figure 2. Growth was probably adversely affected by the use of the Purina 45 percent protein ration. Green turtle hatchlings fed the Purina 45 percent protein ration certainly have a slower rate of gain and higher mortality than when fed the Purina Trout Chow. Growth was also adversely affected between May 1984 and July 1985 when the ridleys were fed the 35 percent protein ration but improved following feeding of the Purina Trout Chow.

Mortality and Disease

Of the 96 yearlings received in 1980, 33 (34.4 percent) remained alive after five years at Cayman Turtle Farm (1983) Ltd. As shown by Figure 3, 54 percent of the mortality occurred in these turtles during their first year at the farm. In general, mortality appeared to result from secondary infections of lesions caused by biting. By the end of their second year at the farm, when the turtles were three years old, their aggressive behavior had virtually disappeared. During

* *Cayman Turtle Farm (1983) Ltd.*

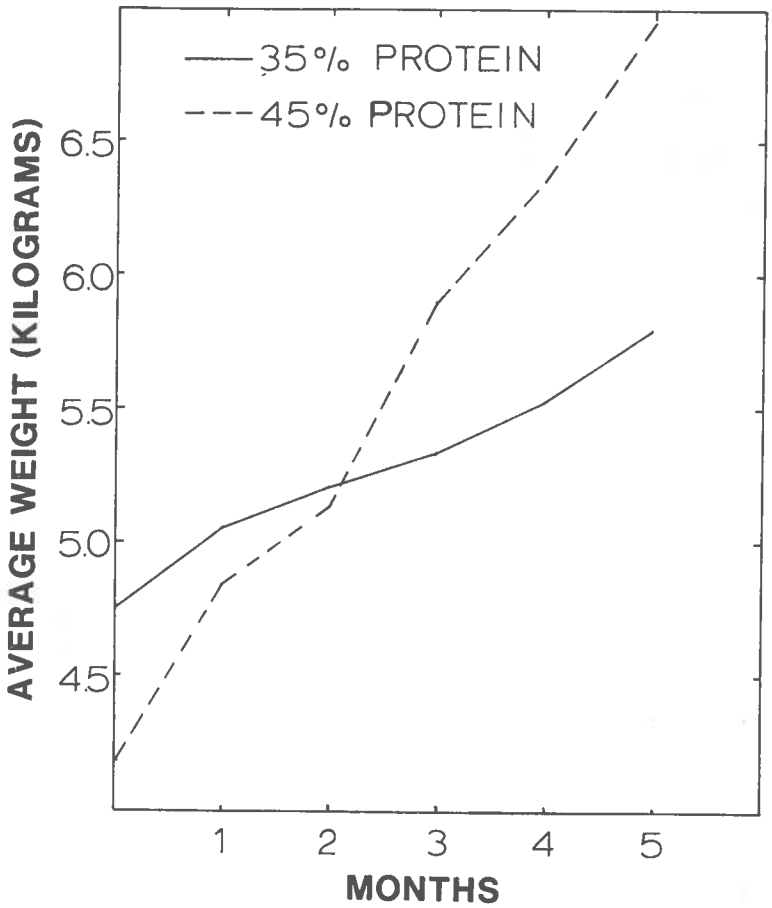

Figure 1. Rate of growth of Kemp's ridley sea turtles fed ration containing 35 percent and 45 percent protein.

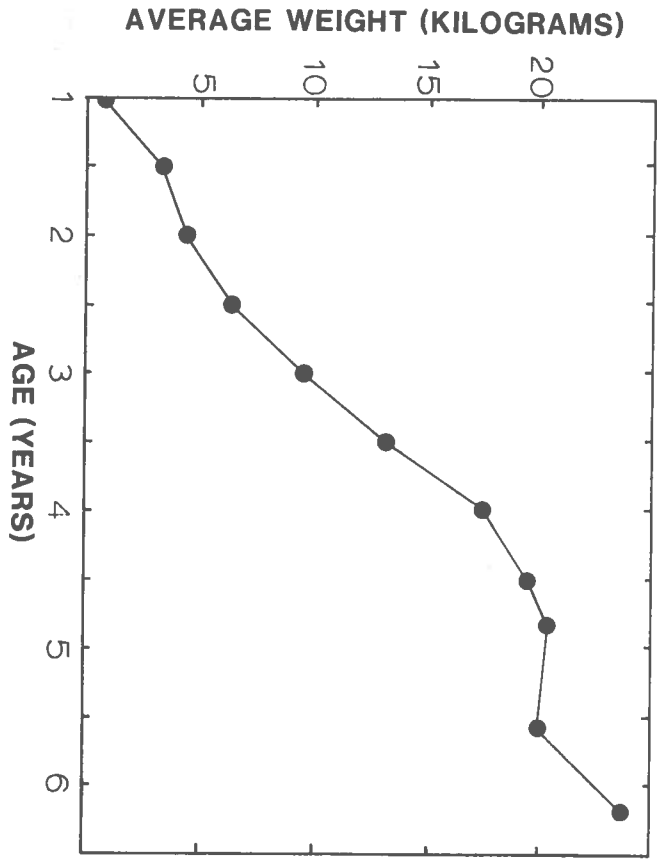

Figure 2. Growth of Kemp's ridley sea turtles reared at Cayman Turtle Farm (1983) Ltd.

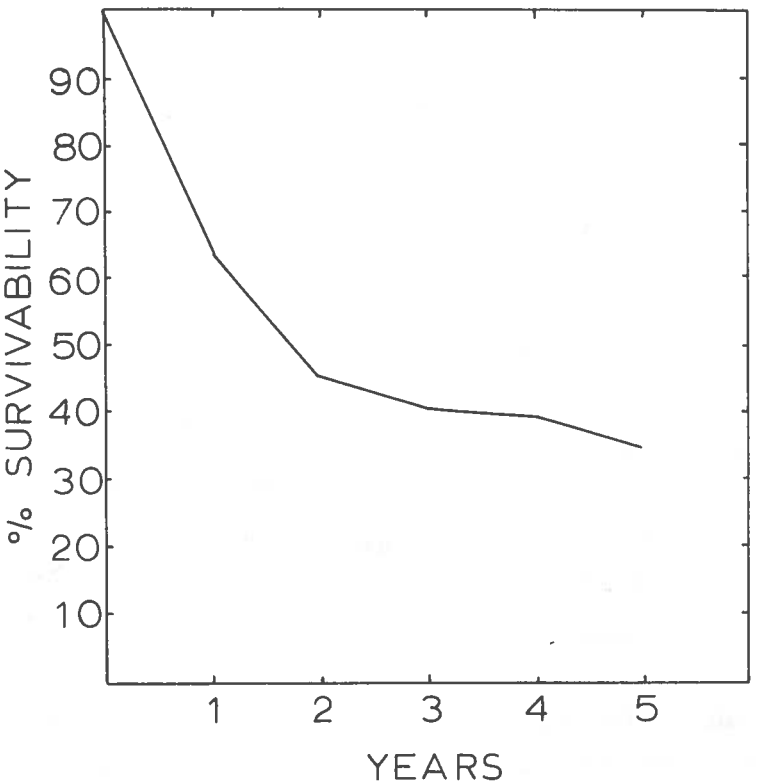

Figure 3. Survivability of Kemp's ridley sea turtles received as yearlings.

the next three years, ten of the ridleys died and one escaped. One mortality occurred following surgical removal of a large abcess from the ventral surface of a front flipper. Cause of death was not determined for other mortalities.

Reproduction

As previously reported (Wood and Wood, 1984), in May 1984, eggs were observed in one of the fiberglass tanks housing a portion of the Kemps ridleys. All 43 ridleys, consisting of 39 five-year-old and four-year-old animals, were transferred to the breeding pond. During transfer, eggs were found in the cloaca of one female (tag 1336). This female weighed 24.5 kg with a curved carapace length of 53.3 cm. On 20 May another female (tag 1359) laid 62 eggs at 0010 hour. That female weighed 20.0 kg and had a curved carapce length of 48.3 cm. Female (tag 1336) laid seven eggs while crawling on the artificial beach on June 9 at 2325 hours.

Kemp's ridley mating behavior had been observed in the fiberglass tanks during April 1984 by some of the farm's staff. The seven eggs laid by the first female (tag 1336) did not develop. However, several of the eggs laid by the second female (tag 1359) began development, and after 62 days three hatchlings were produced. Of the 59 eggs that did not hatch, 32 were undeveloped, 20 suffered early embryonic death and seven died during late embryonic stages. The three hatchlings produced had hard yolk which they were unable to absorb, and they died after three to four days.

The female with tag 1359 spent seven hours on the beach two days after nesting and spent four hours on the beach during the night of June 19, but did not nest again. The female with tag 1336 crawled 12 more times in June after having laid the seven eggs on June 9, spending approximately 5.5 hours in total on the beach. Eight other females spent five hours or more on the beach. One of these, tag 1321, was found dead on the beach after spending several hours during the day on the beach. She had dug a shallow body pit but no egg chamber. Necropsy revealed that her ovaries contained a number of partially developed eggs. Another female with tag 1340 crawled several times in July, digging at least one egg chamber, but she did not nest. This turtle had a very large abcess on her right front flipper. She was taken from the breeding pond on July 22, and the abcess was removed by two University of Florida veterinarians. Although the turtle appeared in good health following surgery, she was found dead the following morning. Examination showed that one oviduct contained seven shelled eggs, and the ovaries contained a number of well-developed follicles. During the 1984 season, five males also crawled on the beach. Three of these males dug nests as if preparing to lay.

Much of the time spent on the beach by both females and males was spent resting or sleeping, usually covered at least partially with sand. This behavior is different than that observed for our captive colony of green turtles. For some of the females, the length of time spent on the beach may have reflected some difficulty they had in laying their first

clutch of eggs. Another possibility is that the animals were attempting to rid themselves of parasites. Earlier in the year, an overnight pump failure resulted in the death of all the fish in the breeding pond. Normally these fish clean the turtles of external parasites. During the 1984 season all the turtles in the breeding pond had extensive infection of the fish leech. The greens would get in very shallow water and allow Ruddy Turnstones to pick off the leeches, but this behavior was not observed for the ridleys.

Nine copulatory mountings lasting five minutes or more were recorded among the Kemp's ridleys between April 19 and June 15, 1985. The combined duration of these observed mountings was 427 minutes, with the longest single mounting lasting 180 minutes. Beach crawls were limited to four known females and one male. One female (tag 1339) remained motionless on the beach for 260 minutes, but all other crawls were less than 12 minutes. No nest digging was observed in 1985.

Eleven mating behavior interactions between ridleys and green sea turtles were observed. These consisted of four instances in which a ridley male attempted to mount a female green, one attempted mounting of a male ridley by a male green, one attempted mounting of a female ridley by a male green, two instances of a female ridley chasing a female green, one instance of a female green chasing a female ridley, a male ridley biting a hybrid male, and a green female biting a ridley.

Since the initial nesting in 1984 (and the presentation of this paper in October 1985) the Kemp's ridleys at Cayman Turtle Farm have successfully reproduced and produced viable hatchlings in 1986, 1987 and 1988 (Wood and Wood, 1988). Some of the hatchlings from the 1987 and 1988 year-classes were transferred to the Galveston Laboratory for head starting as part of a Memorandum of Understanding between the Cayman Islands and the United States governments signed in early 1985.

Other Behavioral Observations

Kemp's ridley sea turtles have frequently been observed burying themselves in the sandy bottom of the breeding pond. They placed the two front flippers together above the head and pushed them back through the sand. With only a few strokes a turtle can be almost completely covered and almost invisible. This could be a type of feeding behavior with the objective of uncovering food items in the sand. However, the turtles did not appear to move their heads or to look for food. Since seawater surrounding the Cayman Islands is much clearer than that found in the normal ridley habitat, this burrowing behavior might be a means of protection from ultraviolet radiation. However, these animals were also occasionally seen buried at night. This behavior perhaps is more likely a method of hiding in an environment that normally offers few natural features under which to hide.

Literature Cited

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Questions and Answers

Nat Frazer: Peter, in the general subphylum of the vertebrates as a whole, what we see as we move from fish to amphibians to reptiles to mammals is a reduction in the number of skull bones. Given that, could you not turn your proliferation of scutation pattern around and say that the proliferate scutation pattern is primitive and that what we get as we move from Lepidochelys *to* Caretta *to* Eretmochelys *to* Chelonia *is a reduction in the number of scutes?*

Pritchard: I agree that there is that tendency throughout vertebrate evolution of elimination of bony elements, particularly in the skull. But, looking not at vertebrates as a whole, but turtles as a whole, it is true that some of the earliest turtles like *Proganochelys* from the Triassic had a few extra scutes and a few extra bones. But, by the time turtles really became established at all, certainly by the Cretaceous, the standard turtle patterns were incredibly fixed. The five vertebrals and four pairs of costals pattern is fixed across both suborders and every family and with an amazing degree of fixity for hundreds of millions of years. And only a few turtles today diverge from that. And they are not ones that seem to be primitive in other respects.

René Márquez Millan: Do you suspect why the ridley is nearly absent in the Caribbean Sea?

Pritchard: The ridley is indeed nearly absent in the Caribbean. I had that on my notes to talk about if time had allowed. I will steal a few seconds here. It is found around Trinidad and Isla Margarita in the bottom right hand corner of the Caribbean but does not reach much farther. That corner of the Caribbean is characterized by being influenced by Orinoco estuary. The Orinoco estuary is an enormous thing. If you fly over it in a light aircraft it takes about an hour to get from one side to the other of that river mouth. So that influences the environment tremendously. Basically you have estuarine conditions there and in the Guianas, with high productivity and good feeding for ridleys. Caribbean waters, on the other hand, partake more of the nature of mid-Pacific waters – relatively blue, clear, corraline waters, low productivity, not really ridley habitat. Ridleys have had ample opportunity to get into the Caribbean. They live on both sides of it in the Gulf of Mexico and the South Atlantic, and geologically speaking they could have come in before Panama closed from the Pacific. But, I believe that the strays that may from time to time get there simply do not find it appropriate habitat, and are unable to make a living or to reproduce there for that reason. There was one record of a ridley nesting on the Caribbean coast of Columbia reported to Reinhart Kaufmann some years ago, and I believe that you, René, received that record. This was published as a *Lepidochelys kempi*. I believe that it was more likely to be an *L. olivacea* in that the same tag number was used on a L. *olivacea in* Suriname and that the dimensions of the animal were more closely similar to that of the known animal from Suriname than the animal from Rancho Nuevo that corresponded to that tag number.

Robert King: How do you explain the discrepancy in your asymptotic (kilogram) limitation in your equation as opposed to what is actually nesting on the beach down in Rancho Nuevo?

Caillouet: Well, I think the turtles grow more rapidly in captivity, and as a result they may mature earlier, and therefore grow slower thereafter. That is just a speculation, but that was my interpretation.

Jill Clarridge: It is interesting about the Vibrio *diseases of the turtles. They have shown that in the blue crabs, 95 percent of the stressed crabs have* Vibrio *spp. in their hemolymph, and in the unstressed or healthy crabs still 75 percent of them have a hemolymph that has* Vibrio *spp. in it. I wonder if you have any baseline data for healthy crabs – whether they have* Vibrio spp.

Lewis: I am aware of Rita Colwell's work that you are referring to. But, I am not aware of there being any baseline data on that. However, I think if you compare the two, the turtles have a fairly advanced immunologic system that neither blue crabs nor other decapod crustaceans possess. And so it may be that that is just part of the normal existence of a crab and is sort of abnormal existence of a turtle.

Clarridge: And also there are some Vibrio *spp. that have this very virulent toxin which could account for that very quick demise that you noticed.*

Lewis: Exactly. You are right. In fact, *Vibrio parahemolyticus* not only has a very potent toxin, but it is one of the organisms that has the fastest replication time of any bacteria. A replication of about eight minutes.

Clarridge: That is right. Some of the others, vulnificus *and* damsella, *also have these very strong toxins.*

Witham: As a comment, this mating behavior can sometimes get pretty violent. A few years ago there was a case in Ocean World in Fort Lauderdale, where a male loggerhead got so aggressive that he simply bit the female's head, crushed it and killed her.

Caillouet: It has been our experience, with some of the yearling Kemp's ridley turtles and perhaps some of the older ones that are introduced either in groups with one another or with loggerheads, that they will pester one another. They will injure one another. But also, when they are put in with loggerheads they will irritate the loggerheads until the loggerheads kill them. Do

you think that putting even large ridleys in with other species is sort of jeopardizing them?

Bentley: In general, no. I think they get used to being with other turtles, at least it would appear to be the case in the Seaquarium. "Little Fox" seems to be particularly pugnacious despite being bitten that severely. When she was put back in with the other turtles she did not seem to have learned her lesson, and she continued to chase the other turtles. The other three adults did not seem to have very much trouble with the other greens or hawksbills, and they did not seem to fight with each other or aggress against each other. The head started animals were held rather closely in captivity for a number of years, and I think they had some trouble with aggression when they were very little, maybe one or two years old, but they seem to have outgrown that for the most part. They can be held, all seven of them, within that one tank, 7 meters by 7 meters, and there seems to be relatively little interaction. They will just stack one next to the other.

Forcucci: Do you have any explanation why those ridleys nested at night?

Wood: No, I do not have any idea. I was actually thinking that, although ridleys normally nest during the day, it was not that uncommon for them occasionally to nest at night, but it apparently is so. I really do not know. All of our greens, of course, only nest at night, and we did have them up crawling. There is actually less interference during the day than there is at night, because at night all the greens are up, and we have our watch people collecting eggs as they are laid, walking around with flashlights and so forth – that sort of thing. So I really could not say. I would have thought it would have been quieter and everything during the day.

Caillouet:Would it be fair to ask you whether or not you are exploring this matter of sex-reversal as it might relate to fertility rates in greens and maybe later in Kemp's ridleys?

Wood: As far as having genotypic sex determination?

Caillouet: Yes, with temperature causing sex reversal.

Wood: We are looking into it. From what we can learn, the technique for doing that, the antigen technique, seems to be rather complex, and also there seems to be some question as to the validity of the test, and so our debate is whether it is worthwhile getting involved in the hassle of trying to do that. If someone else had a setup to do it, we would surely like to get involved in it, and I think there is such a fellow somewhere in Tennessee. We would like maybe to try to work with him, provide samples, and get someone else who knows how to do it to do it. That sounds like a better way to do it.

Carr: How closely related are the individuals which you have in captivity?

Wood: I do not have a clue. The 96 we have came from Galveston.

Carr: You do not know if they are from the same clutches or not?

Wood: I do not know about it.

Carr: Could it be inbreeding depression?

Wood: The question of whether the 96 animals that we have are all from the same clutch, or from ten different clutches, or whatever, I just do not know.

Caillouet: The record keeping at that time was not very good. My guess is that it was probably a number of clutches, but I do not know the clutch histories of those particular ones. We did not really start keeping track of clutches until I became involved in the project in October 1981.

Carr: Do you have any idea why it is that the behavior exhibited by the ridley seems to be rather aberrant in comparison to the greens you have in captivity?

Wood: How is that?

Carr: Like the nesting at night and the males coming out.

Wood: Well, we have had males coming out before and dig nest holes. Male greens have come out in Suriname and dug nest holes before. That in itself is not all that aberrant. Why they spend so much time sitting up on the beach, I do not know, other than the hypothesis we put forth that it was their reaction to a parasite problem. We have not seemed to have quite that much problem other than that one female this year came out and sat there for hours. But other than that, I do not know what they are doing.

Marydele Donnelly: I would like to ask you two questions about density at which these animals are kept. Number one, when you first got the hatchlings and the yearlings, had they not already found that there were aggression problems in captivity, and that they should be kept more separated than perhaps you had them at the farm?

Wood: It was obvious that there were aggression problems. I mean people knew there were aggression problems. From our point of view, trying to do this particular project at Cayman Turtle Farm was simply to see if it were possible to raise them in a different way. Galveston does a good job on the way they do it, but it is very labor-intensive. We were trying to see whether it would be possible to do it on a larger scale with less labor. That is basically why we did it. Later on, we did have very high densities of turtles in a tank. You know, we would have ten of these turtles in a single fiberglass tank. After having them two years, their aggressive behavior was completely gone. They did not bite each other at all.

Donnelly: *After how may years?*

Wood: They were a year old when we got them. By the time they reached three years of age they were totally non-aggressive toward each other.

Donnelly: *It just seems as though it was high mortality considering how precious these animals are. Secondly, now that you have them in the large pond with the greens and hawksbill-green mix, is there any life-threatening aggression between the different species, or between ridleys?*

Wood: No. As I thought I had pointed out, we now have them in a separate pond. They are in the big pond, but they are completely separated. That is how we can feed them the high protein diet now.

Donnelly: *Alright. It is my understanding also that you had better fertility results with greens once you reduced their diet somewhat. You had some greens that were considered fat, and they were breeding better afterwards. Do you think perhaps that the fact that your ridleys have bred, as opposed to the ones that were in the other facilities, is related to the diet regimen that they are on?*

Wood: Well, there are a lot of differences. I do not really know. Our turtles have grown relatively slowly, and we have not particularly taken pains not to try to get them fat, or feed them too fast. But, other than that, I do not really know.

Donnelly: *Alright. Thank you.*

Witham: I have just a bit of information. A number of years ago when I raised a pair of green turtles in captivity, it was a year after mating before she laid any eggs. It just may be a point of interest.

Pritchard: *A point you did not really bring up, Jim, is that I think these ridleys are showing reproductive maturity at a smaller size than they are known to breed in the wild. Is that true?*

Wood: Yes, as far as I know, they were very small for mature animals.

Pritchard: *Do you notice this with your captive-raised breeding green turtles, that they start laying eggs at a smaller size than in the wild?*

Wood: Well, we had a couple that have, but generally I would say that our captive turtles are bigger than wild turtles. Our greens are bigger than wild turtles, and probably reflect this more in the sense of being heavier, maybe fatter, than wild greens. We do almost all of our stuff on the basis of weight rather that length so, I would say basically our greens are probably bigger than the average wild turtle when they come up, whereas the ridleys were smaller.

Pritchard: *Now the ridleys showed a spurt in growth at the end of your curve, corresponding to a new diet, am I correct?*

Wood: Yes, we did go back to the higher protein diet.

Pritchard: *I see. That corresponded to the time when these turtles that you would have considered subadult also started producing some eggs. Is that correct?*

Wood: Well, no. It has been only the last two months or so that we have had them on the high protein diet. What happened is that, once they were in the pond receiving the 35 percent protein diet, their condition seemed to go down. By May of this year (1985), we picked up a few animals that were weak and so forth. We had to pull them out and treat them, because they were losing fitness, and we could not seem to correct it by feeding more of the 35 percent ration. Also, we deliberately got them where we could isolate them and get them on the higher protein ration, and they made a really good recovery. The only thing I will have to consider now is where I want to only occasionally, you know, like two days a week or something like that, feed the high protein ration, so that they do not get too fat.

Panel Discussion

Panel Members

Edward Klima, Director, National Marine Fisheries Service, Galveston Laboratory, Galveston, Tex., Panel Convener

Chuck Oravetz, Chief, Protected Species Branch, National Marine Fisheries Service, St. Petersburg, Fla.

Jack Woody, National Sea Turtle Coordinator, U.S. Fish and Wildlife Service, Albuquerque, N.M.

Peter Pritchard, Florida Audubon Society; Sea Turtle Recovery Team.

Carole Allen, Chairman, Help Endangered Animals – Ridley Turtles, Houston, Tex.

Milford Fletcher, Chief of Natural Resources Management, Southwest Region, National Park Service, Santa Fe, N.M.

René Márquez Millan, Jefe del Programa Nacional de Investigación de Tortugas Marinas, Instituto Nacional de la Pesca, Mexico.

Ralph Rayburn, Executive Director, Texas Shrimp Association.

Opening Remarks

Klima – I would like to focus this discussion, if at all possible, on one major subject, and that is the fact that the Kemp's ridley population is not increasing and may, in fact, be decreasing. I am talking about the nesting population where we do have some information. And I ask some questions: What is basically known to date? What do we need to know for management of this species, and what should we do about it, given the fact that the population has been stable, or more or less stable for the last 10 years at a very low level? We all seem to take that as an accepted fact. I would like to ask René to give us some comments on what we know and what we need to know about this population to start this discussion.

Discussion

Márquez – I think we know very little, but we have some information, especially from the land-based part of the life cycle of this species. We know roughly the size of the nesting population. We know some parts of the life cycle and feeding behavior. We have some information on adult migrations. We know that some part of the female population, after the end of the nesting season, goes to the north and some to the south in the Gulf of Mexico, split more or less in 50:50 proportion. We do not have adult recoveries outside of the Gulf of Mexico. We suppose that all the adult population is inside the Gulf of Mexico.

We know that juveniles go out through the northern Gulf of Mexico, through the Strait of Florida, along all of the U.S. east coast to Europe, and some of them appear especially during winter in European waters. We have some records from the north coast of France. We have another report from Morocco that you heard about yesterday. That is conclusive information, because these reports came from animals that were tagged, and we know how long it took them to go from the point of release to recapture. We do not know if this represents the final travels of these animals. We hope that all those animals, or at least a good part of this population, are able to come back to the Gulf of Mexico and contribute to the nesting population.

A point that is very important and one that we do not know about—there was speculation yesterday about this—is the proportion of males to females necessary to have a healthy population and good fertility. At least until now at Rancho Nuevo, the eggs have had good fertility. We have more than 90 percent, maybe more than 95 percent at least, fertility in the natural population. That means that the health of the population is more or less good. Because the fertility has not dropped yet, that means that the population can sustain itself for some years more.

But the population will not sustain itself if we do not make any progress against the decline in nesters and if we do not make progress in stopping problems like oil pollution and shrimp trawling. The problem of shrimp trawling is very important in the U.S. and in Mexico. We do not know how many turtles are caught per year in the Gulf of Mexico. We suppose, for the Mexican fleet of shrimp trawlers, that they are catching at least 500 per year. This is only statistical information. It is not exact, because fishermen do not always report when they catch the turtles. I do not know if this is the case in the U.S. Maybe they do, maybe they do not. But in Mexico, they clearly do not report, because it is against the law to catch turtles, and the fishermen want to have some meat to bring to their families when the trip is finished. We very often saw flippers in the holds of the vessels. Usually we would see flippers and meat, but some of them would also have eggs in plastic bags. When we saw only these things we did not know which species was caught, because the officials in the ports cannot distinguish between species from only the meat and flippers. Sometimes they report a tag when the animal has a tag. Usually they make the reports through the underground, because they do not want to be prosecuted for poaching. Maybe we do not have information on all the animals that had tags.

Another thing that we do not know exactly or even approximately is the age of maturity. It is easy enough to speculate about the age of maturity after the nesting of two females at Grand Cayman. If we develop a growth curve from the captive animals and we apply this curve to the wild population, we will be able to more or less approximately estimate the age of maturity in natural conditions. We have the size at maturity and the weight at maturity for females in wild or natural conditions. And we have these same figures for females in captivity. I have the measurements for about 10 males, all of them mature. And we know that the males reach maturity at slightly smaller size than the females. We could make more speculations about the life cycle, but I think it will be necessary to have additional scientific investigations at the nesting beach and in captivity so we will have some more data from captivity that are possible to apply to the wild population.

It is necessary to know more about how we should manage the sea turtles. We now have the refuge at Rancho Nuevo, so at least we will be able to save the nesting beach from construction and tourism. It is the most important nesting beach for this species. But we have information that this animal nests elsewhere under natural conditions in small groups. For example, at Tecolutla we have historical information from Archie Carr, from Caldwell and from the fisheries inspector there that every year more or less 20 or 25 ridleys come in small groups during the season. We have some other locations of nesting, but they are not many. They are just solitary nestings, as in Islaguada in Campeche. Maybe this is the easternmost point of nesting now. And in Veracruz, there are some locations of nesting. We flew over that area some years ago and saw turtle tracks of this species at several points during May and June.

Klima – René is addressing the major problem, which is that we do not really know whether we have problems of recruitment into the nesting population, or whether the nesting population is declining faster than is normal, or if it is a combination of both. René raised a number of questions here. One is the unknown catch rates in Mexican waters by fishermen. It is estimated at about 500. We also do not have that kind of information for the U.S. except through the stranding network that Bob Whistler and Barbara Schroeder are working on, which gives us an inclination of what is happening, plus a tagging program that was conducted off of Georgia.

Chuck, would you want to address ways of trying to get valuable information on what the catch rates of turtles are? Of ways to do that?

Oravetz – Very simply, I think it would be nice if we knew exactly what all the sources of mortality and incidental take were. I think we have some information, certainly, that shrimp trawlers do take ridley turtles and account for some level of mortality. I think that we know they are taken by sports fishermen, hook-and-line, from piers and boats, etc., and somewhat in gill nets. Ed mentioned that we have some stranding data, too, that give us some indications, but I think that it is often difficult to make sound management decisions based on indications.

I do think there are certain ways and steps that we can take to gather additional information. One of the things we talked about earlier this week is to try to institute some permitting system, primarily with the shrimp fishery which we think is a major taker of the species, and to legally permit certain sections of this industry to take and report on their incidental take of ridley sea turtles. We think this will provide additional information on what the takes may be and where and when they are being taken. I think it will also stimulate some additional conservation measures by the shrimp fishery. We have had some preliminary discussion of instituting such permit systems through associations like the Texas Shrimp Association and have indications that they are willing to do this. So over the next several months we will be helping them develop applications and conservation plans that may allow this permit system to be introduced, which will help our information base.

Klima – Ralph, would you comment on how receptive that would be based on your knowledge of the shrimp industry?

Rayburn – I have not really discussed with the Board of Directors whether or not they are oriented in this direction to take on the permit type of thing. Basically, it has been an information discussion among Chuck, me and others about the possibility of doing this. I would think, though, that they would be responsive as they have been in other areas to providing the necessary information. Basically, we have, in the past, conducted surveys through the Association to determine the level of catches of sea turtles. I guess the question would be, if we did get involved in this program, what would be the response from the environmental community as far as the credibility of any information we would get? Is it worth the hassle? If it does show that the catch rates are a lot lower than what is projected now by the environmental community, would that hold any weight? Or is it basically an exercise in futility? If it shows high catch rates, I am sure that will be used by the community, but if it shows low catch rates, will it have any credibility among you all? That would be my question, whether it is worth the hassle or not?

Klima – Peter, would you like to comment on that?

Pritchard – Your remarks suggested there is a certain level of antagonism, I guess, between the shrimping community and the environmental community that I do not feel is that bad. We agreed several years ago to try the whole TED thing on a voluntary basis, so there was a lot of good faith, a lot of trust in that. We have not abandoned good faith and trust. I mean, we are disappointed at the rate at which TEDs have been implemented, and we are looking for ways

that will work to get TEDs implemented more. But, we are not looking for ways of nailing the industry to the wall or causing it any more grief or inconvenience than is absolutely necessary to save the Kemp's ridley. And, if the means that are necessary to prevent the vessels capturing ridleys can be provided without any expense to the industry, if outside funds can be found to buy TEDs and this sort of thing, we would be delighted. In other words, we do not regard you as the enemy. We regard you as a partner in this effort. So, we would not automatically disbelieve data that came from the shrimpers. I mean, if it looked as if the data were very different from data that came from other sources, then we would wonder why the discrepancy occurred. You do bring up a good point. If the data revealed that an awful lot of ridleys were being caught, you would probably have some comments within the industry about not revealing this. Or some people might say "look, we are going to give people the rope to hang us if we reveal this data." And that would be a dilemma. So, I see the worry that inspires you to make these points, but I do not think that you need feel that we are looking to make trouble. We would rather simply find ways of letting everyone continue to do his thing, but keep the Kemp's ridley population vigorous. I have been a little general, I am afraid, but that is how I feel.

Rayburn – Well, I appreciate that and certainly that is one of our reasons to stay involved, because I think that has been the attitude. I could not really sense from this meeting whether that attitude had varied much or not. But, certainly it would be my intent to get the type of information needed. For instance, René was pointing out earlier that much of the impact may be outside where most of my membership fishes. It may be closer inshore; there has been a rapid increase in the inshore fisheries for shrimp over the last four or five years. If we could find that there are critical areas where at certain periods of time we do have a large incidental take of ridleys, I think that would help us as we try to solve this problem.

Klima – Carole, would you like to comment on that.

Allen – Yes, I would. This must be the conservation block right here. I appreciate knowing your feelings representing the shrimp industry, and I see that it is very important that HEART and conservation groups such as ourselves know exactly what you are doing and how hard you are working to solve this problem. Because people contact us and we have interviews, there are questions asked, and we should have total information so that we are not blaming anyone prematurely. We can say the shrimp industry knows the problem and you are working on it and these steps have been taken. Maybe this is a pivotal point. Going on from here there will need to be more emphasis. But I think, as far as HEART is concerned and what we are doing, it is very important that we be in touch with you and have good communication with you, which we have not been or had before. So this is a good step.

Pritchard – Ralph, in our discussions of the best way to solve this joint problem, I would ask you to give open consideration to this issue of mandatory TED at a certain point in the relatively near future. I believe that the objections to it are a psychological rod-and-reel. The device now is inexpensive. Without webbing, it is a couple of hundred dollars; with webbing, it is, what – $300, $400? The daily costs of running a shrimp boat are high. Even if the shrimp industry is in economic distress at the moment, which it is, I do not believe that such cost would be the make or break of the industry or even of the individual vessel, especially since the statistics show that one can anticipate on average about a 7 percent improvement in shrimp catch. And you would have the data, I think, to calculate how long it would take for that 7 percent increase in shrimp catch to pay for a $200 TED frame. I do not think it would be very long. I think what we are mainly doing is asking a rather conservative sector of the community to do things slightly differently, but not drastically differently. And I think if they got these things, within a week or two they would regard them as standard equipment. They would have gotten over that psychological hurdle, and would regard shrimping as something you do with a TED, as standard practice, with no more worry, no more complaints and probably, once the thing was amortized over a month or two, more profits.

Rayburn – Well, I do not think we want to get into a debate over TED. Let me explain one thing that I think might be helpful to your understanding. There are different numbers of trawls used by the industry. The bay boats that you see on your way to this facility are generally pulling one main net and a try-net during this time of year; one main net that can range up to 95 feet measured from the tip end of one door around the headline to the tip end of the other door, plus a try-net. Normally, that is a day fishery, so if they tear up their nets they will just come back home. If you look out in the Gulf and you see the larger vessels – there are some smaller nearshore vessels – those further out are pulling four nets. They also have a complete set of spare nets onboard their vessels, because the potential for hang-ups is fairly enormous when you consider all the oil exploration activities being done in the Gulf. They cannot afford, at 20 gallons of fuel an hour, to run six or eight hours back home to get a new set of nets, and possibly lose a crew, then go back. So, they carry spare nets. So, you are not talking about buying one TED. You are talking about buying at least eight TEDs. Not only for the four nets they are pulling now but also a try-net. Let us say five nets, and an extra five nets; so you are talking about ten TEDs onboard the vessel. So, you are not talking about $300 - $400. You are talking about $4,000. You are also talking about additional costs because, while it was said these things might last two years, most of the trawls that are used in the fleet do not last more than six months. The reason is the wear and tear, but more importantly the potential for hang-ups wiping out the entire net. The TED is going to create even more

vulnerability within the trawl. So it is not a simple economics of $200. Also we might look into the 7 percent increase in catch. Unless it has been changed, as I understand it, that is the difference in catching a small number of shrimp in one net compared to the other. I mean, you are talking about seven shrimp on one side and five shrimp on the other. That 7 percent is a very soft number, am I not correct on that, Chuck? The 7 percent is something that is being used. Yes, we put it out as a 7 percent increase in catch, and it sounds good, but if you look at what that is based on it is not anything that I, with any sense of comfort, could sell to our people – the idea that you could pay for these TEDs because you are getting a 7 percent increase in take. It is not true. It is not true, as I understand it, unless there is new information on that.

Klima – The information I have is, of course, that the TED's main advantage is that it eliminates a large portion of the by-catch. This is very, very enticing to Louisiana fishermen where they catch 20 pounds of finfish per one pound of shrimp. This is with the fish excluding option on the TED. As a result of that reduction in the finfish catch, it also reduces your towing drag, which then reduces your fuel consumption, which is an important aspect. And I would tend to agree, Ralph, that the increase in shrimp catch is not a hard number, but that the decrease in the finfish catch and the resulting gain that you obtain from the fuel economy is something that we need to look into. We need to have shrimpers aware of these problems. And I think in fact Chuck is starting to address many of these things at this point in time. Would you capsulize some of the things that you are doing with the industry, Chuck, in this area?

Oravetz – Let me first touch on the magnitude of the problem, if you will. Someone handed me a note that I think is a good question and maybe an example to try to use to say how we could solve it in one way and maybe not the other. Someone asked how was this same problem solved in the tuna fishery. Those of you that follow that fishery would know that several years ago the tuna fishery had a major problem with the incidental catch of porpoises. And there were regulations imposed that required, basically I think, some gear changes, some sort of a panel that was used in those tuna purse seines, as well as some additional procedures that were employed to release the porpoises from the seine. That problem was solved with those procedures and with the technology, and it was solved with a hundred tuna boats. TED is again the solution to the incidental catch problem in the shrimp fishery, but instead of a hundred owner-operators, you have 6,000 big offshore vessels and another 30 or 40 thousand inshore boats. Let me go one step further. Ralph (Rayburn) is the focal point of much of the discussion about why the shrimp industry does this or that. I think he is due a lot of credit for being a leader in the shrimp industry to try to work out a compromise and a solution. What you need to realize is that he may have a problem making commitments on behalf of an industry – he represents only 400 vessels out of a 40,000-boat fleet. So, you need to be aware that when you ask for a commitment from the man, he will give you the commitment to the extent he can. I got off on a little side-track there. But anyway, we are continuing to do it. There is a solution. I think the basic problem is the magnitude of it. It is not as visible and as critical and as potentially diverse as the tuna problem, but it is just the sheer magnitude of it that we are fumbling around with.

Márquez – I have a question. I do not know if it will be necessary to use TEDs all around Mexico and the U.S. I think, at least in Mexico, we have two critical areas. These are the Campeche Bay near to the coast and in front of Rancho Nuevo. I think it is very important to use TEDs there during the time when the ridleys are there. Also, it is not necessary to use them all year around. For example, at Rancho Nuevo it is very important to use TEDs from March until August or September. We know, from recoveries showing the area of dispersion of the adults, which are the dates, the more important times, to protect the area. Maybe that will reduce the cost for the operation.

Ross Witham – This is just directed to Ralph. We have been talking about the absolute cost of the TED unit. What is the cost of the TED unit in relationship to the net that it goes into? If the nets last only six months and the TEDs last two years, what is the relationship of those costs?

Rayburn – I was trying to figure that up. I think the rig is about $1,500. That is with the doors on, as I recall. So the webbing probably is around $800 per net. Now, the reason I say six months life on a net is not so much that the net wears out. There is a lot of abrasion, of course, as it drags across the bottom. But it is lost or just destroyed in one way or another. So, if you would lose a net, even though you would have the two-year life on the TED, because the TED would be a part of the net I would assume that it would be lost with the net. So, you are talking about, on a per-net basis, a fairly considerable increase in the overall cost of that net when you include a TED in it. Those are rough figures, Ross.

Witham – I think that is something we need to look at. When you lose a net, do you lose the boards? Do you lose everything? Or do you just lose the net?

Rayburn – Yes, well, of course it depends on the size, the type hang, etc. In the majority of the cases, the net is ripped up beyond repair, and in some of the more severe cases, the whole cable will snap and you lose the entire system, the doors as well as the trawl itself. In the more frequent cases there is a tear-up of the net that can be done in dragging through some heavy mud lumps or something like that–just weighting it down so much–or actually hitting an obstruction of some kind– a pipeline, debris that is thrown over by an oil service vessel, a cap off and stuff like that.

Sally Murphy – While we are talking about the cost of things – this is something that Ralph and I have discussed before – there is a cost that seems to be forgotten in all of this, the cost of cleaning up the carcasses on resort beaches up and down the coast. I do not think anybody has figured what it costs the municipalities along the coast to get crews out there each day to pick up carcasses and move them and bury them or take them to the dump or whatever. Another unknown cost, and it is sort of a philosophical one, is the cost of one adult female Kemp's. Can you put a price tag on that animal?

Also, we started a discussion on a topic that Chuck brought up about permitting shrimpers to catch Kemp's ridleys in order to get information on them. I think we have two goals that are in opposition to each other. You have the goal to gain information on Kemp's ridleys and you have the goal to save Kemp's ridleys. If you want to get TEDs on boats, you are not going to get information on turtles because they are not going to catch any. If you are going to try to get information on turtles, you are not going to get TEDs on boats. This is something we discussed in our Section 6 project we drew up. As long as the boats are not going to use TEDs, we ought to try to get the information from them. But to me the principal goal should be to get TEDs on the boats.

Klima – Going to a little more biological problem, yesterday Larry Ogren brought up some information on tag returns along the Atlantic coast that I found very interesting. To capture this very quickly, as I understand it, Kemp's ridleys are moving along the Atlantic coast northward during the summer months, and during the winter or fall months they migrate south. Also, Larry said that if they get caught in a cold spell in the Cape Cod area or in Europe they are lost to the population. But, by and large, the data indicate that there is a migration northward in the spring and summer and a southward migration in the fall, which would indicate that these turtles could contribute to the overall population. René also said that he believed that only adult turtles were in the Gulf of Mexico and subadults are in the Atlantic. I wonder if anyone would like to comment on whether these turtles in the Atlantic are still felt to be lost or do they contribute to the population.

Pritchard – I think Richard Byles made a good point when he said that the Chesapeake Bay ridleys that he handles on a regular basis simply have the appearance of vigorous, well-fed, healthy animals. I think the occurrence of juvenile ridleys on the Atlantic side of the United States is sufficiently abundant, or at least historically has been sufficiently abundant, and even today is sufficiently high in terms of how many ridleys there are in the overall population, that it is hard to believe that these are all waifs. I believe that the ones that show up in France and Ireland and so on, historically have been waifs. Whether the head started one that ended up in Morocco would have survived – is it still at large or was it caught?

Klima – It was released, was it not?

Fontaine – It was a live turtle and was released.

Caillouet – It was just as large as the ones that nested at Cayman Farm.

Pritchard – Really? It would be very interesting to know if several of them ended up in Morocco, reached sexual maturity and started to breed if they happened to find each other. It brings up the issue of whether there is the possibility of natural seeding of new breeding grounds for Kemp's ridley. The species is a lot older than any given beach or any given nesting grounds. And, for sea turtles as a whole, we tend to think that what is true today has been true forever, barring human exploitation and so on. But the fact is, beaches shift, islands come and go, or beaches may not so much physically move but simply become unsuitable for nesting. And yet we are talking about species with 50 or 100 million year histories. So there must be some potential for ridleys to form new nesting grounds, and we do not know whether we are watching the natural decline of the Rancho Nuevo nesting ground, or whether it is entirely a result of human caused predation on eggs and turtles that has caused it to drop to one percent of what it was only 40 years ago. In 1947, by all agreed-upon estimates, that film shows 40,000 turtles in one day. And even if we assume that was all the nesting that took place that year, that is 40,000 nesting animals. Now we have perhaps 400 nesting animals, or one percent of that.

Klima – In the whole season?

Pritchard – Yes, in the whole season.

Woody – One hundred and seventeen was the largest *arribada* this year (1985) for comparison.

Pritchard – Well, I think when the turtles get very rare the *arribadas* break down. And it could have been there was more integrity of *arribadas* when there were tens of thousands of turtles. And even from the conservative viewpoint, let us just say that with all the breeders that came out that day in 1947 it might not have been. We have lost 99 percent of them, and that would make you very pessimistic about the future of Kemp's ridley. And yet, there is still mystery in my mind as to how we lost that many, that fast.

I have some black and white photos in my files, taken I think by Antonio Montoya in 1968, showing what I think was the last big *arribada* at Rancho Nuevo. These are rather grainy black and white photos, but they show thousands of Kemp's ridleys on the nesting beach. It is a picture as impressive as the density you see at the surviving *arribadas*

or *Lepidochelys olivacea*. And this was about three years after the Mexican effort started to protect that beach. And this was not just token protection. This was marines; this was fisheries inspectors; this was corrals with hatcheries; 25 to 50 thousand hatchlings released per year. And since that year, the species has been very well protected at the nesting beach end, and there has not been significant directed take anywhere as far as I can tell. And yet it has collapsed. I do not know why. This is one of the biggest mysteries I think as to why it has got down to this low a number. And I think we need to keep our eyes open for any possibility of new nesting grounds forming somewhere completed remote from Rancho Nuevo, but I do not know where they are.

Klima – I think your comments are very interesting. The only correlation that we can look at from 1947 to the present is that man, in the United States at least, is certainly using the coastal areas much more than we have in the past. Pesticides increased dramatically. Our utilization of bays and estuaries is phenomenal, and with the information that we are gaining – from Larry Ogren, head start, from strandings – we find an enormous amount of Kemp's in the shallow areas. Richard's Chesapeake Bay work and the stuff that we find at Bridge City, Tex., show that they are caught by a host of means by man. Hook-and-line, gill nets, shrimp trawls, whatever, and most of them appear in the bays. We see an awful lot of this. I am not trying to jump to conclusions, but certainly it is a species that is very vulnerable to man because of its close proximity and contact, at least during the summer months. And I do not think that there is any black and white correlation, but there is certainly suspicion.

Ogren – I think you had a question, Ed, about the presence or absence of adult ridleys in the Atlantic.

Klima – Yes.

Ogren – They are there. Given that the capture data we get is some fraction of the total population, we had one adult size – going by René's and Pritchard's size class minimum size of a female at Rancho Nuevo at 59 cm– at Cape Canaveral, and Lew Ehrhart had one from the Ski Lagoon. We both had about four others that were just shy of that figure. I think Molly Lutcavage had one dead adult she found. There are adults in the Atlantic.

Pritchard – These are interesting data. And I was aware that you got these specimens just a few centimeters short of maturity on the Atlantic side of Florida. Now, if an animal meets the minimum size at Rancho Nuevo, should we call it adult or not? Some animals may mature at 61 cm, some at 66 cm, some at 69 cm, which seems to be the pattern for sea turtles. The range of adult size reflects more the different sizes at which maturity is reached than it does progressive growth after maturity is reached. I would be convinced if I heard of a big adult outside the Gulf. If I hear of marginal adults outside the Gulf, the question remains as to whether or not that animal had yet reached maturity even though it had reached minimum mature size.

Ogren – I think two of them are in the 60-cm class, so they are well into the mature category.

Pritchard – Alright, 65 cm is around modal length for adults.

Klima– Milford, we have not talked about Padre Island and what your plans are when we get some turtles moving up on that beach, and how you are going to deal with that problem of people and turtles, and what kind of impact that might have, not only on the seashore, but what kind of impact people would have on turtles as they are crawling up the beach.

Fletcher – Well, the obvious answer, of course, is to close Padre Island National Seashore to all visitation, say the months of April, May, June, July and August, for a couple of months of nesting activities and a couple of months of incubation and then a month leeway. Unfortunately, I do not think we are going to be able to do that, unilaterally, right off the bat.

We do have two of three questions that we need to answer first. We have the incubation questions and the temperature regime. So far, the preliminary data that we are seeing lead us to believe that we are producing a preponderance of male turtles because of the temperatures at which the eggs are being incubated. We are going to, this coming season, either put each styrofoam box in a separate incubator or put together a large, walk-in type incubator so that we can mitigate these oscillations that come from ambient temperature swings during the day. The problem with that is, if – and there are a whole bunch of ifs – sex is determined during that second trimester, and if sex is temperature-related, we have to get those eggs at Padre and in the incubators before the sex is determined, and lots of times we do not. The sex of those turtles is determined before they ever cross the border. They sit around in Mexico long enough so that when we get them it is too late for us to really do anything of influence as far as the sex goes. So, that is one thing we have to do. We have to get those turtle eggs into Padre so that we can work on this temperature regime. The second thing is that if Bob King's data, which he presented yesterday, about the beach profiles at Padre are correct, the temperature at 45 cm never reached more that 29.5 C during the season. If that is so, then we need to start looking for another chunk of beach. So this coming summer, we will set up another five sets of temperature measurements up and down the 60 miles of Padre Island to look at some more sets of beach profiles. [Editors' note – mean nest depth for Kemp's ridley is 30 cm, not 45 cm.]

Someone else has suggested that our imprinting site may not be the best. We imprint these turtles right out behind

the ranger station where we get the sand and so on. The question has been "Is that where you want them to come back?" The answer is "Lord, no!" We would rather have them come back 40 miles down the beach. So, probably next year, when we do the imprinting, we will hatch the turtles out at the ranger station at the hatching facilities, put them in a helicopter, fly them 40 miles down the beach to a suitable site – a beach that we have predetermined will be satisfactory – imprint them there, let them run down the beach into the surf, pick them up, put them back in the helicopter and fly them to Galveston. Those kinds of things are all within the realm of possibility.

As far as what we are going to do when all these turtles come back – we have three or four things that we are going to do immediately. First, we are going to create and present to the public a brochure on sea turtles, in addition to the interpretive efforts that are already ongoing at Padre Island. This is what a sea turtle looks like; this is what a crawl looks like; this is why they are important; here is who you let know when you see one. We are going to try to raise public awareness on that beach and see if we can get more and more people looking for crawls and turtles and that sort of thing and reporting them. The second thing that we are going to do is we are going to put together a visitor use survey this coming year, and we are going to sample the visitors at Padre Island. We are going to sample them on a whole bunch of stuff. Where are you from? What is your average income? We are trying to get a demographic profile of who uses Padre Island. Along with this visitor use survey instrument, we are going to ask a number of questions about ridley turtles. Do you know what a turtle is? Do you like turtles? Would you be willing to see the beach closed one day a week for turtles? How about one week a month for turtles? How about one month a year for turtles? How about six months a year for turtles? Let us get the public involved with this and first raise public awareness about turtles, and secondly we are going to have to have public opinion behind us before we are going to be able to go in and really actively manage what is going on at Padre. As long as the Texans think it is their God-given right to drive their four-wheel drives up and down the beach, we are going to have problems with sea turtles nesting. There is just no way around it. If we start getting turtles, say 100 nesting, or 200 nesting, I firmly believe that through organizations like Carole Allen's HEART and the Corpus Christi Audubon Society and the "Fund for Aged Ox Cart Drivers" and those sorts of things, I firmly believe that we are going to be able to put enough people on that beach – volunteers – to really be able to protect sea turtle nests and sea turtles. Now when I saw that film the other night again, and I looked out there and saw 40,000 turtles crawling up that beach, I thought "My God! That is going to be really difficult." I suspect if we ever get those kinds of returns it will be a moot point. I do not think that is going to be that big of a problem. The idea, though, of closing Padre Island is just about the same kind of inflammatory talk as shutting down the fish industry. You are talking about the sports fisheries organizations of America, the four-wheel drivers, the sports fishermen, the recreation types. That is like playing with matches in a room full of gasoline. We just would really rather not talk about closing the National Seashore for several months of the year until we have exhausted a number of other kinds of alternatives.

So we are going to start an increased level of surveillance. We are going to run more patrols down the beach, along with our program to remove hazardous wastes from the beach. We have an ongoing program to remove barrels and other kinds of hazardous wastes. Some Superfund monies have been plowed into that. Along with that program, we will increase our surveillance: we will have a least one good observation trip a week for sea turtles up and down that 60-mile island. And that is a 14-hour trip if you are in a big hurry to do it in one day. So those are the things that we are going to do. We are going to increase the visitor understanding by a brochure that will be handed out to everyone that comes onto the beach. Fortunately, at Padre we have a captive situation. They all enter the beach in one place, and they all leave the beach in one place.

Second thing. We are going to straighten out our hatching facilities. We are going to increase that sort of activity. And let us not kid ourselves. We have already decided that if we are turning out a preponderance of males, then we want to raise the temperature. So, we have already decided, in a tacit agreement here, if we are going to raise the temperature of the incubation of couple of degrees and hold it between 30° and 32° C, then we have tacitly decided that what we are going to try and do is produce a 50:50 split of males and females. Nobody has written it down, but that is what it means. So we have already agreed that we are going to try to raise that. And we are going to increase our beach patrols.

Questions and Answers

Charles Caillouet: *About the ridley that nested on Padre Island this year – you collected the eggs, incubated them and sent them up to Galveston for head starting. Is this going to be sort of a standard operating procedure for all ridleys that nest on Padre, or is there some number after which the nests will be left* in situ.

Fletcher: I wish I had an answer to that. The reason that particular nest was dug up was that it was right square in the middle of a four-wheel drive track. And so we knew that the next four-wheel drive vehicle down the beach would crush that nest. We had no option. Certainly, the idea is to leave those nests *in situ* and hatch turtles at Padre. Right now, we are going to dig up every nest that comes along because of the predation problems that occur with eggs. We feel those nests that are natural nests on Padre – and I know it sounds arrogant – are too important to be left to chance. We know that turtle's eggs came from a female that found the beach and went up there and laid her eggs. Those are very, very important eggs. And so, for the foreseeable future, suppose that – I imagine there is a breaking point – we got say 25 or 30 turtles, we would probably pick up 10 nests and probably put corrals around the nests and put some kind of surveillance on them to see if we could keep the crabs and coyotes and other sorts of two and four legged critters from bothering them. That of course is our intent, to eventually have that nesting situation as an *in situ* site. Is that evasive enough?

Larry Ogren: *I hate to compound the problem with how to anticipate the females that might nest in the future, but I understand you are going to the trouble to define a different temperature regime, and you will do that. I was wondering if you had also considered checking offshore to see if the current regime is favorable for the dispersal of the hatchlings out to the pelagic zone?*

Fletcher: So far – Bob Whistler, correct me if I am wrong – we have not done any work with the currents. That will have to be looked at.

Klima: I am glad you asked the question.

Fletcher: There is something though. Bob Whistler tells me that this coming year he and his crews will be mapping seagrass beds in both the Laguna Madre and the ocean side of Padre Island. So at least we will have some better idea about seagrass habitat areas.

Klima: One of the fruitful things of this conference is that Jack Woody and I were able to talk to Tony Amos about currents, and René has been interested in obtaining currents off Rancho Nuevo for several years. We have a very tentative, soft agreement at this time that The University of Texas' R/V LONGHORN may be able to go into Mexico to look at currents, releasing drift bottles and placing some long-term current meters offshore of Rancho Nuevo, providing we have a permit from Mexico, we get a free contribution fromThe University of Texas and providing a few other things. At the same time, we may be able to do some current work off of Padre Island, because this ties in with some other work that the Galveston Laboratory is doing. We may be able to have a current regime monitored from Aransas all the way down to Rancho Nuevo. We hope that this will work out this year.

Sally Murphy: *In light of the statement that was proferred yesterday by Rod Mast and John Carr, why do you not take a more conservative look at moving nests and move only those that are in absolute jeopardy, and if they are in a perfectly good site and can be protected by other means, then not moving them might just be a better strategy?*

Fletcher: Yes, well certainly that is a thought. Right now, though, what we are seeing is, if the rest of the beach is similar to the parts of the beach that we have measured, the maximum temperature of that beach at 45 cm is 29.5°C. So right now, if everything is like we said it is, we would turn out males, entirely males, out of those nests anyway, if the rest of the beach is similar to what we have looked at. I hope it is not.

Earl Possardt: *Milford, if the beach temperature profiles that you look at this next summer all turn out to be similar to the ones you already looked at, and you do not have a temperature that can theoretically turn out females, is the Park Service prepared to give up their ridley program down there? Has that been thought about?*

Fletcher: Unequivocably, no! We are into this thing, and where else are you going to put them? I mean, if you are going to put them in the U.S., and if the rest of the temperatures parallel what we have now, we are not ready to give up. We are looking at a biological population. Therefore, I assume we are looking at a somewhat normal distribution, which means that through the middle of the bell-shaped curve of normal distribution, we are going to get the majority of the population that will probably have a 50:50 sex determination at around 30°, 31°, 32°C. But there are, no doubt, those on both ends of the curve. And what we may end up doing, as someone suggested here yesterday, is selecting for another population with different kinds of genetic characteristics, different kinds of sex determination temperatures and perhaps a differently skewed sort of male:female relationship in the population. We are a long way from giving up on this. We are just starting to figure out what the questions are.

Woody: I think we need much further discussion on that question, Fletch. We recognize that is the Parks Service's position, I assume. But, we need a lot of discussion on that. I do not agree with you.

Fletcher: Are you intimating that the Fish and Wildlife Service is going to push the Park Service out of this?

Woody: We are not going to push you out of anything. But if Padre is not suitable, and we are not able to establish what we would hope is a natural population, I think we would have to seriously question the artificial extent we go to and the resources we use to try to keep going with a very artificial situation, thinking of where our resources could be put elsewhere where they are so badly needed. That is not to say that Rancho Nuevo must not go on. It is the key, and we must initiate all management practices possible to maintain the greatest number of turtles throughout the Gulf of Mexico, whether it is in Mexican or United States waters.

A question came up before on whether you catch a lot of ridleys or whether you are catching a few ridleys. As far as we are concerned, we are dealing with an endangered species. There are not a lot of ridleys to catch. One ridley, from our standpoint, under the Endangered Species Act, is one ridley too many. I deal with many, many, many species. The turtle is one with which I deal. Most of the species that I deal with that are listed as endangered have more individuals in the reproducing population than we have in that of the Kemp's ridley. I will not tolerate the loss of a pair of bald eagles. And we are not going to tolerate, if we can help it in any way, the loss of a single endangered species if there is a way to prevent it. Now, I want to make that very clear. Also, and I do not want to steal René's thunder, tag returns based on René's work show that between 40 to 45 percent of the adult tag returns come out of United States' waters and, for all practical purposes, 100 percent are coming out of the Gulf of Mexico. The other 50-odd percent are coming out of Mexican waters.

David Bowman: Perhaps Fletch or Jack can help me. If I recall correctly, the temperature data that have been obtained for Padre Island have been obtained prior to and up to the time that the hatchlings hatch at Padre Island in the Styrofoam boxes. And they are only collected in the area of the egg house or relatively near there. Is that correct?

Fletcher: What temperature data are you talking about? In the Styrofoam boxes, or the beach profiles?

Bowman: The beach profiles.

Fletcher: The beach profile temperatures, all right.

Bowman: Am I correct?

Fletcher: Yes. There have been people wandering around poking thermometers in the sand all over the place. But for all practical purposes, the real research that has been done – the temperature at three depths, every two hours, seven days a week for three months – has only been conducted behind the ranger station out at what we call our imprinting beach.

Bowman: All right, so Jack is saying that if the turtles are only going to nest from April to July near the Turtle House, then he is opposed to continuing the project at Padre Island. What I would suggest is that we are far from having enough data to make any kind of a decision about the future of the head start and the imprinting project on Padre Island. And I am not sure that we can say that the turtles can only nest, that Kemp's ridleys can only nest successfully, from April to July.

Fletcher: Yes, you could be entirely correct, in that there is speculation that down at Rancho Nuevo the early nests that are laid when the beach is cold may produce a preponderance of males. Later in the summer when the beach warms up there may be a preponderance of females produced. What we may end up with is a population that nests in July or later in the year.

Márquez: I would like to make a recommendation. At Rancho Nuevo, the nests are not more than 35 cm deep. That means, perhaps 1°C more than your profile. And that is very important in this situation. So, you must examine the temperature around 35 cm for the nest.

Ross Witham: I hate to throw an extra variable in here, but I think there is an overemphasis on incubation temperature alone. Here is a paper that I just got this morning that says, for a different genus of turtle, that the hydric environment influences the sex ratio. So the moisture content that you have got in there, at certain temperatures that are supposed to produce specific sex ratios, will influence the sex ratios or the apparent sex ratios of those turtles.

Klima: It shows you that we are still learning, and we are learning very quickly. The program has been going on for eight years and we just recently have the information that we are producing a preponderance of males, and we are taking action on this. Jack may want to comment, not only on this, but also on what our plans are for next year on the beach and the number of eggs and so forth.

Woody: I agree with Ross. I think certainly there is a relationship between the moisture and the temperature. They go hand in hand. Regarding plans for next year, we recognize there are two problems as far as this sex thing goes. We have got a problem with Padre Island and the way we handle it. We also have probably a bigger problem at Rancho Nuevo. The reason I say that is that at Rancho Nuevo we generally have those eggs in our crew's possession during that second trimester critical period. Padre Island gets the majority of their eggs after it has already been determined what their gender is going to be. And of course at Rancho Nuevo, we do not have facilities to manipulate temperature very much. We are going to do what we can. I think we can do something along these lines. We have other options.

It is a logistical nightmare, getting eggs gathered at a certain time or getting them out on a number of flights or by boat or however we are going to do it. I do not know if that is feasible. Because of Galveston's acquiring a new turtle house, we will request of Mexico an additional 1,000 eggs as we have in some past years for a total of 3,000. Now what Mexico will do is they will give us the 2,000 and will put a stipulation on the permit that will not allow us to take this additional 1,000 until there are probably 60,000 eggs in the corral at Rancho Nuevo. And I think this is a correct decision on the part of Mexico. So, we will have, theoretically, authority to take an extra 1,000 this coming year, but that will not occur until we, as I say, have a minimum of 60,000. Now, I am using 60,000. That has been a figure in the past. Mexico could increase that number. They could decrease that number. But, from past experience, I would say it is probably in that neighborhood.

Klima: Thank you Jack. I would like to just make a comment here. Our data from the head starting, I am firmly convinced, indicate that this program is beyond the experimental stage. When we started the program, we were very careful to identify this as an experimental program, that being that we do not know whether head starting was really going to work and increase the total number of nesters. The indications to date show that obviously we can culture the turtles fairly well. When they are released into the wild, they are found in areas that we expect them to be found. They are growing very well. We do not have information on their survival rates because the tags drop off. However, we do find that we have turtles that are out for three and four years. They have grown very well, and this leads to a conclusion, without proof, that this program is working and that in the near future these turtles are going to nest someplace. That is a hope. But it also is based on some speculation of data. If they only nest at Padre Island or if they nest at Rancho Nuevo or both, any of those combinations are successful. If that does occur, then we have a new management tool available. And, however we use that tool we need to use it judiciously, because one of the key questions which we are trying to address is, "Is there a lack of recruitment into the nesting population?" And that is trying to solve that portion of the problem. I know Jack has some comments here.

Woody: All I wanted to say is, I feel this is still experimental. To me, in all due respect to you, Ed and Ross, it is still an experimental program. We will not have reached that point until, as you said there at the end, you have got identifiable animals coming up at Padre or Rancho Nuevo or some other area. I think one of my concerns here is – I think it is going to work, and I think those animals are going to show up on the beach – that it is a very expensive proposition. Extremely expensive. It can also be expensive in numbers of animals lost. This has not occurred here, but it could be, and I guess I am a little bit afraid of selling this as the thing to do where it could be adopted in areas either in or out of the United States and not handled properly because the resources are not there to support it. It is an experimental technique, as far as I am concerned, all the way.

Klima: I agree with you. We need to have care with this type of an operation. I am just saying that the data indicate that it is going to be successful. It is a long time in getting to the final product. The final product is, of course, the number of turtles on the beach which we can identify as head started. This is going to be virtually impossible to prove if they go back to Rancho Nuevo because we will not be able to identify them because they will not have tags, at least those from the first portion of the program. If they go up on Padre Island, and if we get say four or five next year without tags, we would assume from that type of data that those are head started turtles, because historically only one or two Kemp's ever nest in any year on Padre. So, again it is questionable because of the tag problem that we have.

Murphy: I think that Peter will verify that the recovery team agreed that it would be experimental, and considered experimental, not only until a tagged head started female came up and nested, but as George Balazs said – and he is not here now – in his comments on the review copy of our recovery plan, we should say it is experimental until head started turtles that nest exceed that of the natural population. In other words, if you are trying to get recruitment into the natural population, head starting can only be considered a success if head started turtles exceed that of what you get from your natural population. Is that not what we said, Peter?

Pritchard: Yes. And there was an exchange about that in the Marine Turtle Newsletter, along those same lines – the criteria for evaluating head starting. The softest criterion might be if a head started turtle is recaptured and it is bigger than when you released it, therefore it has settled down. But the most conservative criterion would be that the head started turtles are appearing on the nesting beaches in greater numbers or greater proportions than the wild turtles. And even more conservative than that would be that the head starting was the most cost-effective way. You invested probably $100 or $200 in each head started turtle. Could you have achieved the same results by a different form of management for less money? So these are some pretty tough criteria at the right hand side of the spectrum. I have one or two theoretical musings about ridleys that do bear on the Padre Island situation. One thing is to contemplate why this turtle nests so early in the season. They are coming out in April and in May in the northern hemisphere when the water is still cold. And I think you might postulate that, evolutionarily, they have been pushed into that nesting season because, in the northern hemisphere sea turtles cannot nest in the winter, very early spring or late fall. It is simply too cold for eggs to hatch. When there were lots of turtles of all species occupying most of the available beaches, the green turtles, loggerheads and possibly the leatherbacks commandeered the mid-summer slot. If you have ever seen a leatherback nesting on a ridley beach and seen five or six ridley nests thrown all over the place by the leatherback

diggings its body pit, you can see who wins out in that particular competition. The ridley is the one that has to avoid the times or places where the big turtles are nesting. It seems to have done that by coming in just about as early as it can. So the eggs laid, say in April, will be out by June. And when the big turtles are peaking around July or early August the little ridleys are already out. This then constrains them to nest in certain places. You would not really want to nest in April in Virginia or the Carolinas. It would just be too cold. So it has pushed them into this semi-tropical nesting zone, and the possible scenario is that the Padre Island nesters are male-producing, that this is where the males are made, or at least some of them. They are balanced by females that might be made in Campeche and in southern Veracruz, by the stragglers there that may approximately balance in numbers the northern Padre Island nesters. The ones at Rancho Nuevo are producing males early in the season and females later in the season.

So, we are not looking at a series of discrete populations. We are looking at one big population forming a sort of bell-shaped distribution curve with Padre Island on one side, Campeche or southern Veracruz on the other or Tabasco on the other, and with Rancho Nuevo at the peak. Then, this suggests that Padre Island is a male-producing area which has certain implications. It does not mean you abandon the effort on Padre Island. There are important administrative reasons for keeping Padre Island efforts going, and there is nothing wrong with producing males. Males are important too. But, it could well be that we might want to adjust the temperatures in the egg house for the artificially incubated eggs that are brought to Padre Island so they produce all females. And then this will be partly balanced by an increasing number of nests on Padre Island that were producing a disproportionate number of males. You can get very philosophical and come up with some interesting theories about this whole sex determination thing, and I cannot really get into them here. But it may well be that you have got this latitudinal spread, one population, male-producing at the colder end and female-producing at the warmer end. Selection working on individuals tends to keep the overall population sex ratio about 50:50, because as soon as you get a serious deviation from 50:50, then a female that puts her eggs in a place calculated to produce the minority sex will tend to be selected for. And this will be an automatic feedback position or a negative feedback position where you will zero in on 50:50. But that might not be what you want to do as a manager. Evolution works on individuals, managers work on populations. And for management for rapid recovery of populations, you may want to go 60, 70 or 80 percent female and get a more rapid recovery, a greater production of eggs and so on. And you can do that by manipulations that may be unnatural and yet calculated to achieve the desired result.

Klima: Let me change the subject just briefly here. Public awareness is an important part of this whole program. Carole, how do you see improving the public awareness for the Kemp's ridley program?

Allen: Well, first of all, I have really absorbed a lot up here. The center of the table has fallen silent as well as the end. We have a gentleman here from the **Houston Chronicle**, and I am very curious as to what I am going to see in the paper tomorrow about the future and what is going on. But I want to point out, and I am sure that he sees it this way, that this is an extremely healthy exchange of ideas, that there is so much yet to do. This is not what I was going to answer, so I am clear off the subject. We put a lot of money into it, and we put a lot of time into it, and here we see running through this entire group, from the philosophy that Sally touched on to the very deep scientific problems that we have, this basic thread of desire to save an endangered species. I think that is where we are all coming from and I could not encourage all of you more. Even though you fight and scrap and have to really work things out, and it is hard work. I like Peter's optimism about what could be happening here. The work at Padre Island needs to continue.

We need to keep doing what we are doing in public awareness. I see one big value that we have. Let me tell you all, as I said in my comments the other day, people are extremely interested in turtles. They are extremely concerned about the fact that we are losing a lot of endangered species. We are in a tax squeeze, but I believe the majority of us feel that we want to hang in there with the tax money for projects like this. So, if HEART can do anything let us know. Now we are small, but I like to feel that we can do a few things. We kind of put energy where it will pay off the most. We primarily are concerned with keeping head starting going, because we feel until all these questions are answered that the best thing we can do is to keep raising these little turtles and putting them out into the population. We have many other areas that we want to go into.

René has been very quiet, but I see a tremendous possibility of the American population reaching out to those in Mexico who have for so long worked so hard. I do not know how many of you there are, but we would like to do more for you to continue what you have been doing, because long before we got into this, you were down there wondering what was going to happen to these turtles. So we appreciate that. Many, many people do, and we want to put a lot more energy into that part of it. We have got some plans that we have already worked out.

I would like to suggest, in the public brochure that you (NPS) are going to do, that you print them by the millions, because one group that we have to reach is all the college kids that come down, and they are going to hit the beach there at the Easter season. So we are not only going to be giving brochures in Texas, but we are going to be sending them to every college campus in the United States. It is very popular and yes, we have got to face it, the kids are coming. They have got to know about the turtle program.

We also want to organize. We are always looking for people, and I can guarantee executive salaries of twice what

I get, which is zero. But we need people in the Corpus Christi area. We see developments coming. We see the turtles coming in to nest. We see a Navy base coming, and we need people down there that will do some work for us. That will back up all you scientists, so you can spend your time working out all these very deep problems, and we can keep the heat off of you while you have the time to do it. So it is our privilege to do what we are doing and we encourage you.

Robert Whistler: I certainly support Carole 100 percent, and I think this is an important ingredient. In fact, one of the major ingredients in the program is the public awareness. I would like to suggest that perhaps a consideration in the Padre Island situation is that we have just gotten an indication of what is going on. I would suggest that perhaps we need a lot more study in so far as beach profiles are concerned, in different areas of the beach, and perhaps skewed somewhat in so far as time is concerned, so that we get duplication, substantiation of data. I think this is very important, because I think we just have an indication. We do not have the full understanding. So, I think really we still have a lot of questions to answer before we can really say that that is the case.

Barbara Schroeder: *I would like to make a recommendation. This is something René touched on the other day in the earlier meeting. There is so much we do not know about temperatures. We could sit and discuss it for a long time – how to manipulate temperatures in the egg houses or possibly down in the corrals of Rancho Nuevo. We know that, at least at one time, the Rancho Nuevo beach itself worked to produce hatchlings that came back and nested. And I know that there was at least a little bit of work done last year to protect nests, to use Chuck's favorite work,* in situ, *on the beach. And I think that maybe a little more effort should be directed toward leaving a greater proportion of those nests – that are put into the corrals now – on the beach at Rancho Nuevo. We have good ways of keeping the predators out, at least on the east coast. I know there are some different problems down in Mexico, but I think we should look into keeping some more of those nests in the natural situation on the beach. We know it worked before, and we do not know all of the changes that we might be introducing when we move nests. We know some of them and there are probably a host of others that complicate what happens to hatchlings after they leave an artificial nest, even if it is in the ground in another location.*

Márquez: We have another speculation. Maybe if we move some eggs, or the majority of those eggs, if we put all those nests in corrals, we are duplicating the situation of *arribadas*, the more natural condition of that population. When we put the eggs in the nests in the corrals, we increase, a little bit, the temperature inside the corrals as compared to the solitary nest. We do not know exactly. We are working with a wild population, and we do not know exactly what will be happening when those animals reach maturity. We do not know exactly how many males and females we are releasing now from Rancho Nuevo. But I do not understand exactly the question, but if we left more nests *in situ* we know that the waves or storms and those sorts of problems would erode many parts of the beach where the nests are laid by the females. So we need to move the nests, otherwise we will lose many nests if we do not move them to a protected area.

Schroeder: *Well, I am not saying move all the nests, but certainly there must be a portion of nests that are laid high on the beach. I mean you did say that last year or this past nesting season you did cover some nests and leave them on the beach. Is that correct? I am just saying that maybe we should try to do that with more nests. I do not know how many nests you did that with, but if it was say ten, maybe we should try leaving 25 or 30 nests that are laid high up on the beach, to let them incubate naturally and to let the hatchlings go down the beach naturally.*

Márquez: Yes, that is a good point, But, we will need more people working there. For example, we need one student for every four *in situ* nests. Because otherwise they will lose the nest to predation. They must keep watching the nests, because of coyotes. It we left the solitary nests, far away from the camp, it is a very high possibility that we would lose the eggs to coyotes. I think we will be able to protect the nests in other ways to avoid coyotes or some other types of predation, but that would increase the cost of the project.

Marydele Donnelly: *I have heard a lot of very informative and interesting things in the last few days. I think that one thing we cannot lose sight of is the fact that this year in 1985 for the first time in apparently 10 years, there has been a decline in the nesting female population. Jack has already said that the loss of any adult female is very important, and he does not like to ever see it happen. But we are losing adult females in addition to smaller animals. Now, René and Chuck have both touched on the fact that there has been a loss of Kemp's ridleys to shrimping boats. And I think that we are going to have to look very seriously at some sort of time table, whether it is voluntary or mandatory, about doing something concerning this problem. For how many years can we see a decline of, what is it, 20 percent this year?*

Woody: We are down approximately 200 nests out of, what René, 620 some odd? We have 600 something nests this year. If we follow the normal trend with the state of stability that we have seen over the last seven years, we should have had approximately 200 more. The data are still rough. We do not have the final polished figures yet.

Donnelly: *I know that there is certainly no easy solution to this. I think it is something that we should be looking at very hard, and the fact is that the nesting beach temperature profiles and everything else are not going to do us any good if you are not getting females in to nest.*

Henry Hildebrand: Well, I want to say that I agree 100 percent with René Márquez. There is nothing natural about

that beach at Rancho Nuevo. They have opened a road into it. The first time I went in there I had to go by horseback. I debated whether I should publish the discovery of that nesting site or not. You have all sorts of predators, both two-legged and four-legged predators, there. You have the natural conditions in which the waves come in , so you have to move the nests. There is no other way to protect them. And the Mexican government is 100 percent right there.

Nat Frazer: I see two disturbing trends in today's discussion. On the one hand, it appears that we are making decisions based on "biological information" that we do not really have. That is, in terms of temperature and incubation, we do not know what the pivotal temperature for Kemp's ridley is. In terms of imprinting, we do not know that that is occurring, but we assume it is, and I agree it probably is. But we are making decisions based on this information which really is not information. On the other hand, I see a trend in which we are not making the best use of the biological information that we do have. For instance, I did not see anyone in the audience or on the panel react to René's suggestion that, in terms of TEDs, we might consider looking at those areas in which we know ridleys occur and making them TED zones. No one even reacted to that. But we are willing to talk about putting a TED on every shrimp boat in the Gulf, which is probably very unrealistic. In terms of not making the best use of biological information that we do have, I detect sort of a "blind man looking at the elephant" kind of phenomenon, and I would suggest to you that if we say things often enough in sea turtle work they become true. I will begin saying that until you take the biological information that each of us has and put it together in a model, you will not be able to predict the ramifications of what we do know, piece by piece. It is only when you put it all together that you can assess how fuzzy our information is. That is, how important is it to be exactly right about age at maturity? Or can we afford a little bit of slop in the data? Only by putting this information together with other information in a model will you be able to assess where we need to fine-tune our information and where we can afford to have our information rather fuzzy.

Fletcher: I would like to address that for just a moment. Certainly you are correct about the utilization of the best data. But there is a saying that you "never can not not do nothing," and by not making decisions, we make decisions. If we are going to drag eggs up here from Mexico, and we are going to hatch them, they are going to be at a temperature. So, what we do is make an hypothesis and then we test it. And then we have change and we have to keep adjusting this as we go. For example, do we know that we are producing a preponderance of males at Padre? That is what the data say. But the data came from dead turtles. Are they representative of the population? No! They are dead! The others are alive. So, how can one say? If there were indeed truths that were hidden in the books, then we should be trying to find them. But there are not truths that we know of. So we just move a little bit here, and when we realize that we are going in the wrong direction, we fall back and we move a little bit there, and it does look like blind men examining an elephant. But I submit to you, that in some ways that is precisely what science is. It is try this, if it does not work, try to figure out why, then go try something else.

Klima: Thank you very much. I think we have had a very informative discussion. I would like to thank the panel members very much for their time and their very thoughtful comments, and I would like to thank the audience as well. I think this has been a fruitful meeting. I think we have had exchange of information here. I think Nat's comments were very appropriate, and I would like to thank everybody for attending this meeting.

Appendix

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