NOAA Technical Memorandum

NMFS-SEFC-117

SYNOPSIS OF DATA ON THE IMPACT OF HABITAT ALTERATION ON SEA TURTLES AROUND THE SOUTHEASTERN UNITED STATES

Linda Coston-Clements and Donald E. Hoss

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U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Center
Beaufort Laboratory
Beaufort, North Carolina 28516

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ABSTRACT

A brief description is given of the life histories of five species of marine turtles and the habitats they utilize. The impact of man's activities on these habitats is discussed with respect to their potential for harmful effects on turtles. Recommendations are made for additional research.

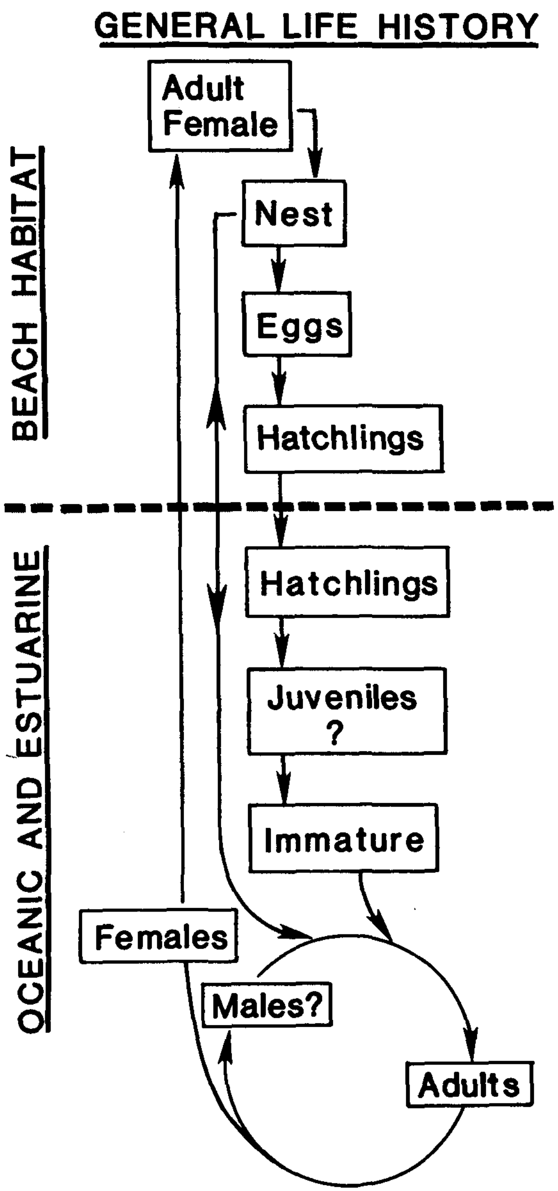
INTRODUCTION

Increasing industrial development, population growth, and recreational activities in marine and estuarine waters are encroaching on the natural habitats of sea turtles. Many areas once used by these animals have been lost or severely altered by man's activities. Construction and maintenance of navigation channels, dredge and fill for land development, sea bed mining, and siting and operations of industrial plants are just a few of the activities that contribute to the loss or degradation of habitat. Man's activities may impact on all stages of sea turtle life history (Fig. 1). Although it is obvious that these activities are changing and destroying habitat, there is at present no comprehensive listing of the types of activities that are most damaging to the various species. There is, however, a need for this information in order to develop plans for quantifying and assessing the impacts of specific alterations (e.g., oil spills) and for developing recovery plans for these animals.

The Endangered Species Act of 1973 requires the National Oceanic and Atmospheric Administration (NOAA) to conserve and protect endangered species. The Southeast Fisheries Center (SEFC) is responsible for conducting research to provide information to NOAA that is necessary for management of endangered and threatened species in the Western Atlantic and Gulf of Mexico.

Our objectives were to develop a comprehensive list of human activities that are known or suspected to impact on sea turtles and to prepare a bibliography of pertinent literature. This report deals specifically with human activities and habitat alterations that may affect five species of sea turtles in the southeastern United States (Table 1). Literature on related species and from other areas is cited.

Figure 1. EXAMPLES OF POTENTIAL IMPACTS OF HABITAT ALTERATIONS ON SEA TURTLES



ACTIVITY	IMPACT
Development, Domestic and Industrial Dredging & Mining Jetties	Loss or Modification of Nesting Habitat
Power Plants	Temperature Changes
Industrial and Domestic Discharge	Increased Pollutants
Trawling	Incidental Catch Destroy Bottom Habitat, Reef Habitat
Discharge & Spills	Increased Pollutant Levels
Mining & Dredging	Destroy Bottom Habitat
Energy Development	Pollutant Discharge Temperature Change
Recreational Activities	Damage Reef Habitat

Table 1. List of species considered in this report.

Scientific Name	Common Name
Caretta caretta	Loggerhead
Chelonia mydas	Green turtle
Dermochelys coriacea	Leatherback
Eretmochelys imbricata	Hawksbill
Lepidochelys kempi	Kemp's ridley (Atlantic)

In order to identify detrimental habitat alterations, it is necessary to know the habitat requirements of the species in question. Unfortunately, our knowledge of the habitat requirements for sea turtles is known only in a general way. For example, we only have a fragmentary picture of the biology of sea turtles in the marine environment, where they spend most of their lives, while we have detailed information on the very brief but critical period they spend on the beach (Owens 1980). Use of a wide range of habitats exposes turtles to man's activities during some portion of their life. In this report we give a brief life history of sea turtles and consider two major divisions of turtle habitat: 1) beach, and 2) oceanic and estuarine. Various modifications are briefly described and referenced under each division.

LIFE HISTORY

The life histories of all species of sea turtles are similar. They spend nearly all of their life in the water, either in large bays and sounds, in ocean waters relatively close to land, or in the vast reaches of the seas far from land. They mate in the water and the females come ashore on a sandy beach, usually at night, dig a hole in the sand above the waterline, deposit the eggs in the nest, cover them with sand, and return to sea.

Nesting

The nesting phase of turtle life history is generally considered to include the time spent close to the beach between nestings, as well as the time spent on the beach constructing nests and depositing eggs. General nesting requirements for all species are the same: sandy undisturbed beaches, readily accessible from the surf, and adjacent ocean areas where the turtles can rest between nestings.

The loggerhead, *Caretta caretta*, the most northward-breeding of the sea turtles found in waters of the southeastern United States, seems to prefer a wide-sloping beach (Caldwell 1959). Major nesting beaches are found on Cape Romain, S.C., the Cumberland Island area, Ga., Merritt Island, Fla., and Hutchinson Island, Fla. (Carr et al. 1979). Carr and Carr (1977) report that 90 percent of the loggerheads in Florida nest along a coastal strip from Volusia County to Broward County. The Florida east coast nesting colony is apparently second in size only to that of Masira Island, Oman (Carr et al. 1982). On the other hand, loggerhead nesting is sparse in the Gulf of Mexico (Carr et al. 1982). Loggerheads nest at night from May to August, usually every second or third year (Richardson et al. 1978).

The green turtle, Chelonia mydas, seems to prefer a beach with a steep slope, a platform above high tide, and light-weight medium-coarse sand (Rebel 1974; A. Carr, pers. comm. cited in Woodard 1980a). Nesting in the U.S., restricted to small populations on Florida's east coast (Carr et al. 1979), occurs at night from June through August at intervals of 2, 3, or 4 years. As many as seven clutches, 9 to 13 days apart, may be laid in one season (Carr and Ogren 1960).

The leatherback, Dermochelys coriacea, is dependent on steep wide beaches free from obstructions and with an open approach from the sea. They nest at night in the northern hemisphere from March to July, probably every other year (Baker 1981). Nesting, rare in the United States, is restricted to the east and west coasts of Florida. Pritchard and Stubbs (1982) speculate that a few leatherbacks nest annually on each of many Caribbean islands, but that the western Atlantic probably has a few large leatherback populations that tend to concentrate their nesting in major rookeries. Baker (1981) estimates that 50-70 leatherbacks nest on St. Croix, U.S. Virgin Islands, and that probably fewer than 25 nest each year in the continental United States. Up to six to seven clutches are laid about 10 days apart.

The hawksbill, Eretmochelys imbricata, is less of a colonial nester than other species. Small numbers nest at night on a vast number of tropical beaches, generally close to potential or actual feeding habitat (Carr 1972a as cited in Fuller 1981; Pritchard and Stubbs 1982). Length of the season varies with climatic conditions, but throughout the Caribbean it lasts from about May to August. Carr and Stancyk (1975) suggest that Tortuguero hawksbills nest every three years and lay at least two clutches.

The Atlantic ridley, Lepidochelys kempi, the only species to nest primarily in daylight (Pritchard and Marquez 1973; Fritts and Hoffman 1982), nests almost exclusively in the Gulf of Mexico along a single small stretch of beach in the Mexican state of Tamaulipas (Pritchard and Marquez 1973). It seems to prefer sections of beach backed up by extensive swamps or large bodies of open water. A well-defined dune area seems necessary for eggs to hatch successfully, probably because the dunes give the turtle a landmark for digging the nest above mean high tide. Nesting occurs between mid-April and mid-July (Carr et al. 1979), when there are strong or moderate north winds (Pritchard and Marquez 1973). Females lay 2 to 3 clutches and may nest every year (Zwinenberg 1977).

Sand particle size has an influence on nesting success (Mortimer 1979, 1981a; Schwartz 1982). If the sand is too fine, gas diffusion necessary for the eggs to hatch is inhibited and respiratory gas exchange and embryonic development is affected. If the sand is too coarse, the nests cave in. Mortimer (1981a) found a positive correlation between hatching success and depth of nest for green turtles, probably because higher moisture levels occur at greater depths. Studies have shown that eggs absorb moisture from the sand. Elevated levels of salinity in nests may induce desiccation through osmotic stress (Mortimer 1981a).

Incubation duration, sex ratio, and hatchling emergence from the nest are influenced by temperature (Mrosovsky 1980, 1982). In natural conditions it is estimated that a 1°C decrease in temperature adds about 8.5 days to the incubation period. Incubation periods vary by species and conditions but range from about 45-70 days. In green turtles Morreale et al. (1982) found that lower nesting temperature (<28°C) produced nearly all males while in warm thermostable nests (>29.5°C) nearly all the eggs developed into females.

Thermal inhibition of nest activity (at >28°C) is a major factor limiting the emergence of hatchlings (Bustard 1967; Mrosovsky 1968), and digging is resumed only when lower nocturnal temperatures return. Nocturnal emergence can enhance survival by protecting hatchlings from high surface temperatures on tropical beaches and from visually-oriented predators (Caldwell 1959; Bustard 1967). After struggling to the surface, hatchlings crawl over widely different beach surfaces in nearly all types of weather, toward a sea they have never seen (Carr and Ogren 1960; Ehrenfeld and Carr 1967; Mrosovsky 1967 as cited in Kingsmill and Mrosovsky 1982). They use visual cues and react positively to the brightest horizon. Since there is nearly always a brightness differential between the dark landward horizon and the more open seaward horizon, they head toward the ocean.

Developmental Stages

After hatchlings enter the ocean, the habitat they occupy varies with time and developmental stage. Initially, hatchlings entering the ocean appear to have a frantic offshore swimming motion to take them into their juvenile habitat (Carr 1982). Kraemer and Bennett (1981) found that post hatching yolk can support "frenzied" swimming activity of loggerhead hatchlings during the first few days after emergence. Frick's experiments (1976) reinforce assumptions that the swim frenzy and yolk store are suitable for a period of long range travel toward an open-ocean "lost-yearz" habitat. Witham (1980) believes this data strongly suggest that the initial post-hatching period, "the lost year", is a period of oceanic existence when turtles opportunistically use ocean currents and food resources to disperse and survive. There is increasing evidence that at least some species spend their time in sargassum rafts (Caldwell 1968; Fletemeyer 1978b; Carr and Meylan 1980a; Carr 1982; Pritchard and Stubbs 1982).

Following the "lost year" phase, the young turtles appear in areas suitable for completing their development to adults. Important development areas in the southeastern U.S. include lagoons in Florida (Ehrhart 1980), bays behind the Georgia Sea Islands and Pamlico Sound, N.C. (Carr et al. 1979), and Chesapeake Bay (Lutcavage 1981). In these areas juvenile sea turtles find abundant food and protection from larger predators. Unfortunately, they also find dangers engendered by intense human activity. Pritchard and Stubbs (1982) found that hawksbill juveniles, after drifting with sargassum rafts, would settle on a suitable reef. Hawksbills of all ages and sizes inhabit the diverse reef areas of Puerto Rico and adjacent islands (Carr 1980). A few hawksbills and green turtles, ranging upward from dinner-plate size, are found throughout the Virgin Islands area where coral reefs and seagrass beds are widespread (Carr et al. 1982). Young loggerhead turtles are known to enter estuaries (Ernst and Barbour 1972). Heavy mortality of sub-adults in shrimp trawls suggests that they are especially abundant in sounds and bays in Georgia and South Carolina (Hillestad et al. 1977; Ulrich 1978). Loggerheads up to 50 cm long are found in estuaries and coastal Georgia waters from April to October. Shrimpers off Georgia also catch non-nesting ridleys, greens, and an occasional leatherback (3-5 km offshore only). About 88% of all Georgia strandings, mostly loggerheads, are classified as juveniles or sub-adults (Richardson et al. 1978). Immature ridleys and loggerheads above dinner-plate size, found in Chesapeake Bay from May to October (Lutcavage 1981; R. Byles pers. comm.), are susceptible to drowning in the hedges of pound nets. Ehrhart (1980) found immature green and loggerhead turtles in the lagoonal systems surrounding Kennedy Space Center where there appeared to be a colony of approximately 140 young green turtles, of all ages except the "lost year" and adults, living on the grass flats. There is evidence that both species bury in the mud to overwinter (Felger et al. 1976; Carr et al. 1980; Ehrhart 1980; Ogren and McVea 1982), but recent trawling in channels north of Cape Canaveral has failed to find buried turtles (Richardson and Hillestad 1979; L. Ogren pers. comm.). The area off Mobile Point Peninsula, Ala., where juvenile ridleys have been captured by trawlers, may be a developmental area for this species (Carr et al. 1982). Small green turtles have been found in the lower Laguna Madre in southwest Texas, and a few juvenile leatherbacks have been found feeding on jellyfish in the western Gulf of Mexico. Loggerheads frequent the entire continental shelf off both Texas and Louisiana and are fairly common around oil platforms, rock reefs and shipwrecks (Carr et al. 1982).

Foraging and Resting

Sea turtles range from being very specialized feeders to being fairly omnivorous. Young green turtles feed mainly on small marine invertebrates (Carr 1965 as cited in Rebel 1974; Bustard 1976) before becoming herbivorous adults and feeding primarily on seagrasses and marine algae (Rebel 1974; Mortimer 1976; Carr 1977; Bjorndal 1980; Thayer et al. 1982), although a few small invertebrates are still eaten. It is the only species to subsist mainly on plants. Green turtles can be found around shoals, lagoons, and bays where marine grasses and algae are plentiful. Once a suitable feeding ground is found, they show a strong tendency to become resident, and are likely to display homing behavior once residency is established (Carr and Caldwell 1956; Schmidt 1916 and Burnett-Herkes 1974 as cited in Ehrhart 1980).

Food habits of hawksbills are not well known, but available data suggest invertebrates such as sponges and barnacles are important in the diet (Carr 1952; Carr et al. 1966; Carr and Stancyk 1975). Perhaps as Hendrickson (1980) suggests, their strategy for survival is that of a scrounging omnivore tied to a coral reef habitat.

Loggerheads are primarily carnivorous (Carr 1952) and may forage widely for molluscs and crustaceans, such as crabs, conchs, and clams (Carr 1977; Hendrickson 1980; Mortimer 1982b). Some may take up regular seasonal feeding stations on a suitable patch of rock or coral bottom; others may enter bays, lagoons and estuaries (Ernst and Barbour 1972). They generally spend more time in the open ocean and less time near grass flats than green turtles.

The limited data available for the Atlantic ridley indicate that it feeds on crabs and other invertebrates associated with the bottom (Dobie et al. 1961; Ernst and Barbour 1972; Zwinenberg 1977). There appears to be two main forage areas, one off Campeche and the other off western Louisiana (Pritchard and Marquez 1973; Carr 1980; Hildebrand 1982).

Leatherback turtles appear to be more specialized feeders. The diet of these open sea inhabitants consists almost entirely of jellyfish and tunicates (Rose 1950; Brongersma 1969, 1972; Bustard 1976; Baker 1981; Fletemeyer 1980c; Hendrickson 1980). Often they may not differentiate between jellyfish and floating plastic, for nearly 50 percent of leatherback stomachs examined contained plastic or cellophane (Mrosovsky 1981). This foreign material may cause an intestinal obstruction or decreased absorption from the gut.

Resting and feeding habitats may or may not be the same. Green turtles have been reported to frequently sleep among rocks and coral crags on the sea bottom (Carr and Ogren 1960; Carr 1967; Travis 1967), and the hawksbill is considered a reef inhabitant throughout its range (Carr and Stancyk 1975). Loggerheads have been reported resting on reef-like structures associated with oil platforms (Hastings et al. 1976) and power plants (Witham 1982).

Migration and Movements

"Migrations of sea turtles begin at the hatchling stage and continue throughout life. Their travels range in scope from daily commuting between feeding and sleeping places to periodic reproductive journeys that take them across a thousand miles of ocean or more" (Carr 1982). Migrations range from the relatively short movements of hawksbills (Pritchard and Stubbs 1982) to the over 2000 km journeys of leatherbacks (Pritchard 1971, 1976b; Baker 1981). Environmental cues that may influence the ability of turtles to find the way to some nesting beaches year after year are poorly understood (Owens et al. 1982), but they may include specific beach odors and water current direction (Bennett and Kleerekoper 1978). Mortimer (1981b) suggests the green turtles in Costa Rica are guided by river effluents.

Movements of females during the nesting season are similar for most species. Green turtles at Ascension Island that had successfully nested followed different travel patterns than those that had been prevented from nesting (Mortimer 1981a). The latter stayed close to the beach and traveled back and forth in nearshore waters, while successful nesters moved to a depth of 12-16 m then travelled parallel to the shoreline. Meylan (1982a), who found similar patterns for green turtles at the Tortuguero colony, also found that travel offshore was restricted to about 4.8 km from land. Hopkins and Murphy (1981) found that loggerhead turtles nesting in South Carolina tended to move parallel to the coast and to use shoals and areas of high relief intensively. They were inactive at night and tended to move in either long straight lines or randomly during daylight. Williams-Walls et al. (1983) thought that offshore reefs at Hutchinson Island, Florida might be attractive to females during intervals between nestings and thereby influence selection of nesting sites. There also appear to be areas where females take refuge from courting males (Booth and Peters 1972). Dizon and Balazs (1982), using radio telemetry, tracked Hawaiian green turtles and found that males and females remained close to the basking and nesting islands where they were tagged. They believed that the nesting beach and its environs are imprinted on both males and females and that the green turtle, once imprinted, is unlikely to switch its breeding habitat.

Movements of turtles at times other than during nesting seem to be influenced by a variety of factors, such as age, availability of food, and water temperature. The green turtle appears to be the most regular long distant migrant. Nearly always their nesting beaches and forage grounds are spatially separated (Meylan 1982b). Although tagged loggerheads have traveled long distances (Carr et al. 1979; Timko and Kolz 1982), they seem to be wanderers influenced more by prey distribution than by migratory instincts (Carr et al. 1978). Bell and Richardson (1978) speculate that after breeding, loggerheads follow a path from Georgia to the Cape Hatteras area and ultimately to warm mid-Atlantic water, perhaps the Sargasso Sea. Young ridleys have been observed as far north as New England (Lazell 1980). In Virginia, peak abundance of ridleys in June and October (Lutcavage 1981) implies a movement north in spring and a movement south in fall. Movements may be influenced by water temperature or prey distribution (Lutcavage 1981). Adults appear restricted to the Gulf of Mexico (Woodard 1980c). Leatherbacks, the most pelagic species, move between northerly feeding ranges and tropical nesting sites and overwintering areas (Lazell 1979). Records from the central Atlantic states indicate that many remain close to shore during migrations and are seasonally common (Lee and Palmer 1981; Hoffman and Fritts 1982). They appear to travel northward in the western Atlantic with the spring season, perhaps influenced by the Gulf Stream, and return south through the bays and sounds of New England (Lazell 1980). Rhodin and Schoelkopf (1982), who support Lazell's (1980) theory that postnesting leatherbacks can make at least a short migration northward, suggest that they are also capable of making very long, swift migrations. They do not know if females reach boreal waters only in non-nesting years. Little is known about movements of hawksbills. Once an adequate feeding area is located, they appear to be relatively sedentary, since feeding grounds such as coral reefs are typically close to nesting beaches. Tag returns have shown that some may be long-distance migrants (Pritchard and Stubbs 1982).

IMPACT OF HUMAN ACTIVITIES

Human-related activities such as urban and industrial development, petroleum exploitation, mineral sands mining, dredging, and commercial fishing appear to pose the greatest threats to turtle habitat (Shabica 1982). These activities may affect the well-being and survival of sea turtles in a variety of ways, from the direct physical destruction of nests to the more subtle effects of chemical pollutants on longevity and reproductive capacity. Because turtles come in close contact with man during their nesting cycle, they have been studied more thoroughly during this phase than they have during other periods of their life in the ocean. For convenience, we may divide the known information of man's activities on turtle populations into two major categories: the impact on nesting success, and the impact on oceanic survival.

Nesting Success

For turtles to nest successfully, they must breed successfully. Yet during breeding, turtles are quite susceptible to capture or injury by man. Although some turtles from the Tortuguero colony have been observed to copulate 100 miles from known nesting sites (A. Meylan pers. comm.), most turtles probably mate in water just off the nesting beaches (Hirth 1971; Bustard 1973b; Ernst and Barbour 1972; Rebel 1974; Dizon and Balazs 1982), where they are most likely to be disturbed by man's activities.

Copulating pairs, which have been observed floating on the surface for hours, are vulnerable to capture by trawls, drop nets, and harpoons. Some Culebra Island fishermen use decoys to attract male turtles, which become entangled in nets when they attempt to copulate with the decoy (Carr 1977). Nicaraguan fishermen set traps to catch copulating pairs (A. Meylan pers. comm.). A substantial group of loggerheads that may moblize and breed in the Florida Keys before moving to the mainland to nest causes problems for spiny lobster fishermen, who claim they damage their traps (Higman and Davis 1978).

Destruction or modification of beaches where turtles nest probably has the greatest impact on the ability of turtle populations to sustain their numbers. Increased light from industrial or domestic development may cause a reduction in the number of females coming ashore to nest (Worth and Smith 1976), and it may cause newly-hatched turtles to become disoriented and move away from the water (McFarlane 1963; Philibosian 1976; Baker 1981) to die of desiccation or predation. Increased recreational use may destroy nests and eggs; deep tire tracks may prevent hatchlings from reaching the surf (Hosier et al. 1981). Construction may deter or prevent females from coming ashore, as it did on Hutchinson Island, where a cofferdam offshore was a barrier to turtles swimming along the shoreline (Williams-Walls et al. 1983). Clearing vegetation from the beach may reduce shade and increase nest temperatures, whereas large buildings may lower nest temperatures by increasing the time an area is shaded. Since temperature is an important factor in hatching success and sex determination, even small changes could cause increased mortality, delays in hatching, or sex ratio imbalance.

In the intervals between depositing clutches of eggs, females remain close to shore, where they are particularly vulnerable to being killed or injured by accidents or being caught by fishermen seeking them for food. Shrimp trawlers, which usually operate close to shore, may catch large numbers incidentally. Recreational fishermen or boaters may accidentally injure turtles with propellers. The potential impact from these and ecological disasters, such as oil spills, on the survival of a colony is greatly increased since it is the reproductive contingent that is affected (Meylan 1982a).

Oil spills have received considerable attention in recent years because of their high visibility, yet their effects remain largely unknown. If they occur during the nesting season, the resulting cleanup operations could have harmful effects by 1) frightening gravid females from an area, 2) destroying nests, and 3) creating physical obstructions that would prevent hatchlings from reaching the ocean. Eggs, embryos, and hatchlings are more vulnerable than adults since volatile and water-soluble contaminants can be absorbed into the egg (see Ackerman and Prange 1972; Prange and Ackerman 1974; Bustard and Greenham 1968). There is considerable time for eggs to be affected, since incubation time is about two months (Frazier 1971, 1980). Fritts and McGehee (1982) found that fresh crude oil will cause significant mortality in incubating embryos, but that weathered oil might not. Any factors which would impair gas exchange in natural nests, and hence increase incubation time, would prolong the exposure of eggs to predators and the uncertanities of weather, disturb the synchrony of hatching, and increase egg mortality (Ackerman 1980).

Beach habitat is critical to turtle survival, for without it turtles could not reproduce. Yet it is extremely sensitive, directly or indirectly, to a wide range of human activities, including military exercises carried out on remote beaches. The following is an annotated list of human activities that may be harmful to nesting turtles:

Coastal Zone Development

Alteration of beach topography by

Artificial barriers - seawalls, riprap and jetties

- Impede turtle access to the nesting beach (Mann 1977; Witham 1982)
- Alter suitability of nesting beach by changing sand supply (Hopkins and Richardson 1981)

Traffic - vehicular, beach cleaning, pedestrian, horse, cattle

- Compression damage to nests (Mann 1977; Rainey 1978; Witham 1982; A. Carr pers. comm; P. Pritchard pers. comm.)
- Beach cleaning, including oil spill cleanup that may destroy nests (Mann 1977; Fletemeyer 1979a, Bureau of Land Management 1981) or cause compaction lowering hatching success (Ackerman 1980, 1981; Fletemeyer 1979a, 1982)

- Physical obstacles, such as tire tracks and sand piles that slow the rate of sea-approach for hatchling turtles and increase their susceptibility to stress and predation (Mann 1977; Hosier et al. 1981; Witham 1982)

Beach nourishment

- Dredge spoil may affect hatching success if deposited over nests (Mann 1977; Ackerman 1980; Witham 1982; Hopkins and Richardson 1981) or provide unsuitable nesting medium (Mann 1977; Fletemeyer 1979b, 1980a, 1981; Mortimer 1981a; Ehrhart and Raymond 1982; Witham 1982)
- Mechanical earth moving may damage nests by compression or excavation (see Traffic), increase chance of storm washover, or expose buried sediments unsuitable for nesting (Rainey 1978)

Sand mining

- May leave unsuitable nesting beach (Baker 1981; Mortimer 1981a; Sella 1982; A. Carr pers. comm.), or increase chance of storm washover (Rainey 1978)

Dredging

- Reduces sand supply that replenishes beaches (P. Pritchard pers. comm.)

Artificial illumination

- May discourage adults from nesting (Worth and Smith 1976; Mann 1978; Rainey 1978; Mortimer 1982a; Witham 1982) or disorient hatchlings (McFarlane 1963; Ehrenfeld 1968; Philibosian 1976; Mann 1977, 1978; Mrosovsky 1978; Rainey 1978; Towle 1978; Fletemeyer 1979a; Van Rhijn 1979; Frazier 1980)

Human activities and noise

- May deter nesting (Williams-Walls et al. 1983) or affect hatchling emergence (Balazs and Ross 1974 as cited in Rainey 1978)

Litter

- Solid debris may obstruct, entrap, or injure nesting females (Rainey 1978)
- May block progress of hatchlings from nest to water (K. Bjorndal, pers. comm.)
- Food may increase predation by attracting scavengers (Rebel 1974; Stancyk 1982)

Temperature alterations, such as shading of nesting beach by buildings or tar on beach

- May influence incubation time (Bustard and Greenham 1968; Fowler 1979; Mrosovsky 1980; Yntema and Mrosovsky 1980), sex determination in embryos (Yntema and Mrosovsky 1979; Limpus and Miller 1980; Mrosovsky 1980; Mrosovsky and Yntema 1980; Miller and Limpus 1981; Morreale et al. 1982; Mrosovsky 1982; Yntema and Mrosovsky 1982), or may influence hatchling emergence from nest (Mrosovsky 1968)

Exotic vegetation

- May increase shading of nesting beach, or form dense root mats that prevent nest excavation (Hopkins and Richardson 1981)

Pollution - including energy development, industrial discharges, and runoff from agribusiness (see Frazier 1980 for review on pollutants)

Oil spills and subsequent tar balls (Keller and Adams 1983)

- Act as deterrent to nesting (Bureau of Land Management 1981), affect hatching success (Fritts and McGehee 1982), irritate eyes and respiratory system of hatchlings (Bureau of Land Managment 1981), or interfere with olfactory imprinting (Manton et al. 1972 as cited in Rainey 1978)

Pesticides

- Have been detected, but minimum levels that will have adverse effects are unknown (Hillestad et al. 1974; Clark and Krynitsky 1980; Fletemeyer 1980a, 1980b; Hall 1980)

Heavy metals

- Have been detected, but effects unknown (Hillestad et al. 1974; Hall 1980; Stoneburner et al. 1980)

PCB's

- Have been detected, but effects unknown (Thompson et al. 1974; Hall 1980)

Thermal effluents

- May affect cues important in nest site selection (Lenarz and Stoneburner 1980; Stoneburner and Richardson 1981)

Military Activities

Ordnance impact and detonation

- May destroy or damage nests (Rainey 1978; Pritchard and Stubbs 1982) and pressure waves might reduce hatching success or trigger nest cave-ins (Rainey 1978)

Lights, either fixed or flares

- May discourage adults from nesting or disorient hatchlings (Rainey 1978; Pritchard and Stubbs 1982; see artificial illumination)

Troops and equipment

- May damage nests (Pritchard and Stubbs 1982)

Noise

- Possibly affect emergence of hatchlings (Balazs and Ross 1974 as cited in Rainey 1978)

Oceanic Survival

Throughout their life in the sea, turtles are subject to a host of human activities that threaten their survival. At some period in their life, however, they may be more susceptible than others. Young turtles may be more sensitive to lower levels of toxic pollutants than older turtles. Females may be more vulnerable to capture during the nesting season, when more of their time is spent close to shore. Human activities that are detrimental to turtle survival may be classified broadly into three categories: 1) those that destroy or damage habitat, 2) those that debilitate or weaken turtles physically, and 3) those that injure or kill turtles directly.

Any activity that reduces or contaminates the food supply or destroys resting places will reduce the ability of turtles to survive. For example, damage to sea grasses by dredging, thermal effluents, and chemical pollutants (Thorhaug 1981) will affect green turtles, which depend on grasses for food. Reef habitat destroyed by pollution (Johannes 1975), siltation (Rogers 1977), or mechanical damage (marine construction, dredging, ordnance) (Rainey 1978) constitutes not only a loss of foraging areas, but also a loss of resting places for adult and immature hawksbills and loggerheads. Many filter feeding detrital organisms that concentrate pollutants are important prey items for turtles in neritic habitats. The effect of these pollutants on the turtles is currently unknown. Large areas of hypoxia in the northwest Gulf of Mexico (Boesch 1983) associated with areas of "dead" bottom might influence the feeding of ridley and loggerhead turtles (B. Gallaway pers. comm.). At present, it is not known if these areas are natural and just previously undocumented, or are a result of the increased flow of nutrients from the Mississippi River discharge.

Possible effects of exploratory gas and oil drilling on sea turtles are largely speculative at present. Spoil disposal and oil development on live bottom areas may disrupt turtle feeding by smothering benthic organisms with sediments and drilling muds. Oil contamination may cause irritation or permanent damage to a turtle's eyes and respiratory system, resulting in abnormal behavior (Bureau of Land Management 1981). Loggerheads in the Gulf of Mexico are attracted to reef-like structures formed by drilling platforms for resting and feeding (Hastings et al. 1976; Rabalais and Rabalais 1980; B. Gallaway pers. comm.). This could be a positive facet of habitat alteration unless turtles remaining in these areas were exposed to pollutants or increased predation. Dredging, otter trawls, ordnance impact, and boat propellers can damage coral reefs and seagrass beds directly by altering bottom topography and indirectly by increasing sediment and changing patterns of water flow. Rogers (1977) documents responses of corals to sediments, and Thorhaug (1981) and Zieman (1982) consider the responses of seagrasses. Altering physical features close to nesting beaches could alter nesting distribution of turtles.

A wide number of activities contribute directly to the death or injury of turtles. Garbage discharge from ships may attract turtles and cause them to ingest plastic and other foreign material accidentally, or to become entangled with refuse. Green turtles near Ascension Island have been found with turnip tops in their stomachs (A. Carr pers. comm.), and young turtles have been found with styrofoam pellets in their guts (A. Meylan pers. comm.). Turtles have been observed trying to swim with sheet plastic wrapped around their shells (Morris 1980a). Activities associated with fishing cause much damage. All species are susceptible to injury by power boats (Fletemeyer 1979b), and those attracted to refuse from seafood packing plants are particularly vulnerable (Shoop and Ruckdeschel 1982). Incidental catches of turtles in various fishing gear, particularly in shrimp trawls, have received much attention (see Shrimp Management Plan, Fuller 1981; Recovery Plan for Marine Turtles, Hopkins and Richardson 1981; Roithmayr 1981; and Crouse 1982). Immature loggerheads and ridleys in bays and sounds are particularly susceptible to shrimp trawls, pound nets or other nets in nearshore areas. Loggerheads are attracted to fish culled from shrimp trawlers and to refuse from seafood packing plants (Shoop and Ruckdeschel 1982), making them more vulnerable to trawls. Leatherbacks, the most pelagic species, may become entangled in long lines and drift gill nets (Balazs 1982a, 1982b). Increased strandings in South Carolina during the nesting season correspond to the gill net fishery for sturgeon (S. Hopkins pers. comm.). Power plants ranging from Florida to New Jersey have reported turtles, mostly immature loggerheads, that have been collected on cooling water intake screens. The average annual incidental catch for one power plant in Florida was 134 from 1977-1979 (Wilcox 1980 as cited in Roithmayr 1981). The offshore intake structure of Florida Power and Light Company's St. Lucie Plant may appear as a reef or a suitable resting area, from which some attracted turtles may be subsequently drawn into the cooling system. Also, turtles may follow prey into the canals (Witham 1982). Over a 12-month period a power plant on the Cape Fear River, N.C., collected three loggerheads and a green turtle from an upstream intake (W. Hogarth pers. comm.). Lighted permanent structures at sea (OTEC, oil rigs), which may attract young sea turtles (Witham 1982), may also attract pelagic fish that will prey on the turtles. Hatchling turtles have been observed aggregating near a lighted vessel anchored off a major nesting beach (Rainey 1978).

Pollutants from industrial and residental development are perhaps the most pervasive and subtle threats to the oceanic survival of all species. The effects are difficult to detect and evaluate and may not show up until the turtles have been exposed for many years. Chemicals, including oil, may mask olfactory cues or interfere with their perception (Kleerekoper and Bennett 1976; Frazier 1980), and may cause chronic and insidious problems in the ability of turtles to reproduce and maintain their numbers. In the Sargasso Sea, young turtles may be exposed to a high level of pollutants (A. Carr pers. comm.) as a result of the entire community being exposed to long-term heavy contamination (Morris et al. 1976). It has been estimated that tankers introduce 86,000 metric tons of tar into the western north Atlantic and that 75% of that tonnage is in the Sargasso Sea (Lineaweaver 1979). It is difficult to interpret the significance of measured levels of trace metals since little is known about their baseline levels and physiological effects. Lead found at elevated levels in some green turtles (Witkowski and Frazier 1982) is considered to be the only important trace metal to be at elevated levels in the Sargasso Sea (H. Windom pers. comm.). Frazier (1980) questions whether the decline of Kemp's ridley, a species characteristically found in waters where organic content and turbidity are high and prawns are abundant, is related to high levels of pollutants in discharges from the Mississippi River. Thermal pollution, as heated effluents from power plants or desalination plants, may affect turtles indirectly by being detrimental to their food supply or more directly by causing hatchlings to become disoriented and reduce their swimming speed (O'Hara 1980). In addition to high temperatures, effluents from desalination plants may have higher salinities and may contain heavy metals, particularly copper. Some biological effects are given by Chesher (1975). The following is an annotated list of the important activities that may impact oceanic habitat:

Pollutant Discharges

Oil spills - including major spills (e.g., IXTOC-I), "deliberate" spills e.g., bilging operations (Travers and Luney 1976), refinery spills, and spills from exploratory drilling (Keller and Adams 1983)

- o Interference with olfactory perception (Kleerekoper and Bennett 1976; Bennett and Kleerekoper 1978; Witham 1978)
- o Ingestion (Witham 1978; A. Meylan pers. comm.)
- o Fouling of body with possibility of interference with respiratory functions (Fletemeyer 1980a; Frazier 1980; Bureau of Land Management 1981)
- o Direct mortality (Hall 1980; Hooper 1981 Shabica 1982)
- o Effects on seagrass habitat (Diaz-Piferrer 1962; Nadeau and Berquist 1977; Lopez 1978; Zieman et al. 1981; Zieman 1982;), reef habitat (Johannes 1975) Sargasso Sea habitat (Morris et al. 1976; Wade et al. 1976)

Pesticides from agricultural and urban runoff and spills

- Levels have been measured in tissues but effects have not been evaluated (Thompson et al. 1974; Hall 1980)

Heavy metals from power plants, desalination plants, other industrial effluents and urban runoff

- Levels have been measured in tissues but effects have not been evaluated (Hillestad et al. 1974; Hall 1980; Stoneburner et al. 1980; Witkowski and Frazier 1982)

Radionuclides from power plant or industrial effluents

- Levels have been measured in tissues but effects have not been evaluated (Hillestad et al. 1974)
- Laboratory experiments on uptake of radionuclides by Thalassia, which is eaten by green turtles (Parker 1962, 1966)

PCB's

- Levels have been measured in tissues but effects have not been evaluated (Thompson et al. 1974; Hall 1980)

Domestic discharges, including sewage

- Effects on seagrass habitat (Zieman 1982)
- Effects on reef habitat (Johannes 1975)

Energy Development, including OTEC

Power plant intake canals

- Entrainment and/or impingement (Fletemeyer 1979b, 1980a, 1981; Roithmayr 1981; Witham 1982; W. Hogarth, pers. comm.)

Thermal effluent

- Influence on hatchling swimming speed (O'Hara 1980)
- Possible attraction to thermal plume in cooler water (reference to work done by M. Stinson from M. Lutcavage pers. comm.)
- Degradation of seagrass habitat (Zieman 1970; Thayer et al. 1975; Zieman and Wood 1975; Thorhaug 1981; Zieman 1982)
- Degradation of reef habitat (Johannes 1975)

Lighted offshore structures

- By attracting young turtles may make them more susceptible to predation (Rainey 1978)

Dredging and mining, including oil drilling

Alteration of nearshore bottom topography

- o May affect internesting behavior (Hopkins and Murphy 1981; Williams-Walls et al. 1983)

Channel dredging

- o Resting and/or hibernating turtles may be vulnerable (Richardson and Hillestad 1979; Carr et al. 1980; Raymond 1980; Rudloe 1981)

Disposal of spoil or drilling muds on live bottom areas

- o May smother benthic organisms (Bureau of Land Management 1981)
- o May destroy reef communities utilized by turtles (Johannes 1975; Rogers 1977)
- o May affect seagrass ecosystems used by turtles (Odum 1963; Taylor and Saloman 1968; Thayer et al. 1975; Thorhaug 1981; Zieman 1982)

Fishing Activities (see incidental catch overview in Recovery Plan for Marine Turtles (Hopkins and Richardson 1981)

General (Hildebrand 1980; Roithmayr 1981; Crouse 1982)

Trawls

- o Incidental catch (Cox and Mauermann 1976; Hillestad et al. 1977, 1978, 1982; Ogren et al. 1977; Carr et al. 1978; Ulrich 1978; Rabalais and Rabalais 1980; Coleman 1981; Fuller 1981)
- o Attraction to culling by trawlers and disposal from seafood processing plants makes turtles more vulnerable to being caught (Shoop and Ruckdeschel 1982)
- o Bottom and reef destruction (Thayer et al. 1975)

Incidential catch by set nets (Talbert et al. 1980) longlines (Balazs 1982a, 1982b), pound nets (Lutcavage 1981; R. Byles pers. comm.), and gill nets (L. Ehrhart pers. comm.)

"Bleach fishing" and "dynamite fishing" in Caribbean (A. Carr pers. comm.)

Recreational fisheries

- o Rod and reel fishermen (Hildebrand 1980; Roithmayr 1981)
- o Spearfishing on reefs (Carr and Stanyck 1975)
- o Reef habitat destruction from anchoring, collection of shells and corals, and leaving litter (Johannes 1975; Hopkins and Richardson 1981)

Miscellaneous

Litter and garbage dumping by ships

- o Ingestion of styrofoam pellets and fouling by plastic etc. (Carpenter and Smith 1972; Morris 1980; Mrosovsky 1981; Van Dolah et al. 1980; Horsman 1982; A. Carr pers. comm.)

Increased runoff from overgrazing by cattle or from poor land management

- o May cause subsequent degenerative changes in reef system and hawksbill habitat (Carr 1977)

Military activities

- o Disturbance and destruction of reef habitat (Carr 1978)

RECOMMENDATIONS

Major gaps in the knowledge of life histories and habitat requirements of all species of sea turtles are major impediments to the development of programs for turtle protection and management. In our literature survey and in our conversations with investigators we found continual reference to a lack of knowledge on habitat utilization (except for beach habitat) and a need for additional research in this area. We agree with Carr et al. (1978) that additional information on habitat requirements is urgently needed, especially for developmental and internesting habitats.

Much of the results from sea turtle research and surveys is not published in journals, but is published in not readily available reports or resides in file cabinets of investigators. We suggest a central listing, preferably computerized, of: 1) available unpublished information and where it may be obtained, and 2) names and addresses of people involved in research and their area of interest. Access to this type of information would aid people involved in making recommendations, such as those in environmental impact statements, that could affect the future of all turtle populations.

Despite increased interest in recent years in the well being of sea turtles, the amount of "new" information being generated is low. Many of the reports are repetitious and tend to paraphrase the same source material. We feel that research, particularly long-term research with adequate funding, is needed in the following areas:

1. Development of fishing gear, such as the Turtle Excluder Device (TED), that will mitigate or prevent turtle capture, and funding for education in the use of the new equipment.

2. The impact of fisheries other than the shrimp fishery (e.g., the roller trawl fishery) on turtles and turtle habitat.

3. Research on practical techniques, such as the use of audible or ultrasonic noise, to divert turtles from danger areas.

4. The long-term effects of chemicals, such as synthetic organics, on reproduction, survival, and other phases of turtle life history.

5. Continuing studies on the dispersal mechanisms of hatchlings, effects of currents on their transport and the developmental habitat subsequently occupied.

6. Methods of externally sexing young turtles

7. The size and sex structure of turtles in specific inshore areas.

8. Tolerance levels during embryonic development to petrochemicals, bilge effluents, and chemicals used in cleanup of oil spills.

9. The effects of an oil spill on breeding and nesting success.

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