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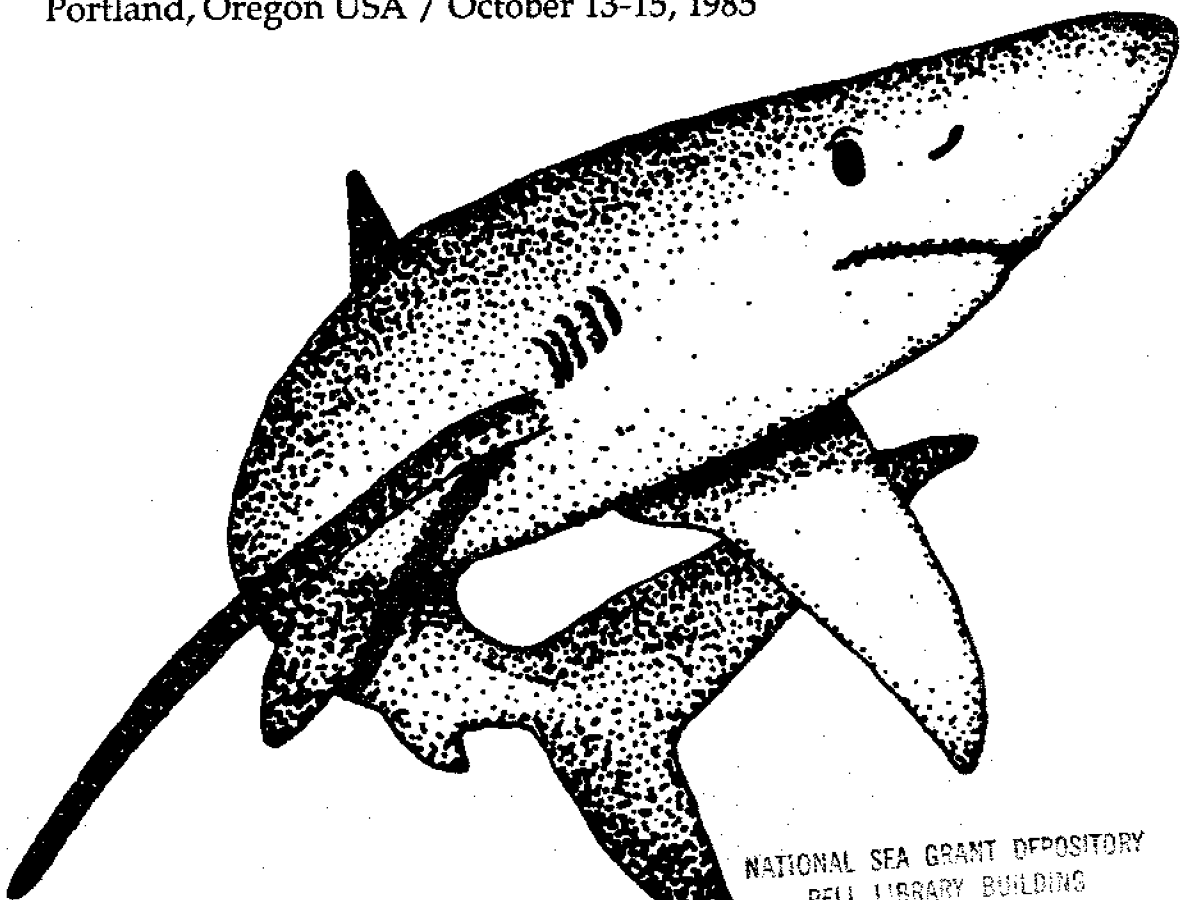
SHARKS
An Inquiry into Biology, Behavior, Fisheries, and Use

Proceedings of the Conference
Portland, Oregon USA / October 13-15, 1985



EM 8330 / March 1987

OREGON STATE UNIVERSITY
EXTENSION SERVICE

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Edited by Sid Cook
Scientist, Argus-Mariner Consulting Scientists

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Sharks: An Inquiry into Biology, Behavior, Fisheries, and Use

Howard F. Horton, Leader
Extension/Sea Grant Program
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Corvallis, Oregon 97331

We are delighted that so many of you have come from near and far to share our quest for up-to-date information of the biology, behavior, fisheries, and use of sharks. I have already met participants from Australia; Kotzebue, Alaska; Lincoln, Nebraska; Hawaii; Florida; Texas; and Maryland, to name a few of the more distant places.

I especially want to welcome our distinguished panel of speakers who represent the finest minds available on their respective topics in the United States. We value your contributions and appreciate your willingness to share your expertise with us. We hope your stay here will be rewarded with new knowledge, new friendships, and continued enthusiasm for the study of sharks.

A conference like this doesn't just happen. It takes lots of planning and working on details. I want to acknowledge our organizing committee chaired by Bob Jacobson, Marine Agent in Newport, Oregon, and including Sid Cook, Marine Biologist with Argus-Mariner Consulting Biologists who master-minded the program of speakers; Tom Gentle, Communications Specialist with our Extension/Sea Grant Program in Corvallis who handled all of the fliers, programs, and news releases; and Bob Schoning, Senior Policy Advisor, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, who kept a burr under our collective tails and insisted that we leave nothing to chance.

We received outstanding staff support from Ginny Goblirsch who recorded registration details, Sandy Enschede who administered travel and financial details, Mary Gosla who assembled the displays, and others of our staff who contributed in many ways.

This conference is sponsored by the Pacific Association of Sea Grant Colleges including the University of Alaska Sea Grant College Program, the University of Hawaii Sea Grant College Program, the Oregon State University Sea Grant College Program, the University of Washington Sea Grant College Program, and the University of Southern California Sea Grant College Program. Additional sponsors are the West Coast Fisheries Development Foundation and Argus-Mariner Consulting Scientists.

I am optimistic that this collection of speakers and talent will result in an outstanding conference. We are glad you are here, we look forward to your contributions and comments, and we hope you leave us feeling your time has been wisely invested.

Why Are We Talking About Sharks?

Robert W. Schoning
Senior Policy Advisor
Northwest and Alaska Fisheries Center
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Who cares about sharks? Many people all over the world do and for a great variety of reasons. So do all of you fine people in this room. I will highlight a few of the reasons and the 24 speakers following me will give you more detail. Sharks are found all over the world and are increasing in importance and use. We are talking about them during these two days because it has been several years since there was a significant national conference on such a broad range of shark related subjects as this one.

Much is being discovered about sharks and we felt it would be very worthwhile to have many of the nation's recognized authorities on sharks meeting together and report on some of their latest findings and provide material for a published proceedings for use by scientists, commercial and recreational fishermen, marine water sport enthusiasts, fish processors, and consumers.

In all fairness, you are not going to learn all there is to know about sharks in these two days, notwithstanding the array of experts we have assembled, but you will be exposed to much extremely interesting information and be afforded the opportunity to talk with these recognized authorities on matters of particular interest to you. Have you looked at the program in detail? We have 24 different individuals talking about their specialties. They include by profession: six professors of biology, ichthyology, or zoology, six marine biologists, five marine extension agents, one each of clinical phychotherapist, assistant editor, fisheries marketing specialist, marine business specialist, seafood consumer specialist, fish processor, research manager, sport fishing tackle shop operator, charter boat fisherman, and a chef.

Ever since the movie "Jaws," there has been greater public interest in sharks and potential shark attacks on swimmers. We have six speakers covering various aspects of shark-man relationships, including a newspaper man (how the media covers such incidents). You will learn that verified shark attacks are not nearly as common as many people think, but it is important that we discuss them to learn more about their frequency, severity, and actions we can or should take to minimize danger and injury. Sharks are not the ferocious man-seeking, man-eating monsters too often portrayed in the media.

Most of the people in this country are spending more time in pursuit of leisure activities including fishing, swimming, and surfing. Depending on the part of the country in which we live, we may encounter sharks in any or all three of these activities. We will learn about diving with them and fishing for them. We have people who have devoted significant parts of their lives to doing those things and learning much from their experiences. They will share their knowledge with us and I am sure you will find it most interesting and particularly useful if you participate in similar activities.

The present annual world commercial catch of fish is about 76 million metric tons. There is an increasing demand for more marine protein for human food. Present annual world landings of sharks, rays, and ratfishes is about 600,000 metric tons or 0.8% of the total. In some parts of the world these species are fished heavily and are overfished. In other areas they are underutilized for various reasons.

Little is known about their abundance or distribution, or how to catch them, prepare them, find a market for them, and sell them at profit. Those aspects do not in any way detract from the nutritional benefits of many species of shark meat. More people should know how tasty shark can be. Those who were at the cocktail party last night were fortunate in being able to try mako, angel, sixgill, and dogfish sharks prepared in various ways. I assume they found them to be as delicious as I did. I am convinced one of the reasons a lot more people don't eat shark is that they don't know how good it tastes and how good it is for them. If more people would ask their butchers or restauranteurs for it they would be able to enjoy it more often. I am reminded of an ad for Kaiser aluminum foil, a sponsor of the Bonanza show that used to be on TV years ago. That's back when Michael Landon as Little Joe Cartwright was little. The ad went something like this. "Ask your dealer for Kaiser aluminum foil. If he says he doesn't have it, tell him to get it. He'll get it." I believe the same approach will work with some merchants who logically could sell various species of sharks. Tell 'm to get it. I know of nothing merchants like better than customers, unless it's the money customers leave with them in exchange for their merchandise. One way to have customers keep coming back is to satisfy them while they are there. More should try it with shark.

We have several experts on various phases of handling, processing, marketing, and preparing sharks for consumption in restaurants and the home. There have been some very interesting related developments in recent years and sharks are being caught, marketed, consumed, and enjoyed much more than previously. They want to tell us about them for our collective information and use.

In many of the commercial fisheries for various species around the country, the fishermen have become more skilled and numerous than the resource could stand. With larger boats and more sophisticated electronic equipment, and innovations in the fishing gear itself, the fishermen have become more effective. Seasons have been shortened and limitations put on the number of fishermen or boats permitted to operate in given fisheries. Depending on the species and areas there are seasons as short as 10 minutes for herring, three or four 1- 2-day seasons for halibut, or a situation in which about 160 boats are licensed to fish for a surf clam catch that could be taken by only two boats. Such restrictions in some fisheries coupled with high mortage payments force fishermen to look for other species to harvest. Some have gone to sharks and I am convinced more will become involved. We have four speakers talking about specific shark fisheries that have developed in relatively recent times, one on yet untapped deep sea stocks, and another speaker on gear and methods of commercial shark fishing. There are some stories of success and failure but they are worth hearing to better understand existing potential for some of these species as well as others. There is no substitute for having someone who has been personally involved discuss such subjects.

In addition to the food benefits from eating shark, other parts of the animal have a variety of uses. They include fins for Oriental dishes, teeth as curios, and skin as extremely durable leather for expensive shoes and cowboy chaps. Materials from cartilage and flesh are used in clotting of human blood and as a skin for burn victims. A speaker will discuss the great variety of uses and markets involving shark products.

There are tens of millions of recreational fishermen in this country. Many of them fish marine waters. In several areas of the country, there are important shark stocks and associated recreational fisheries and tournaments, particularly on the Atlantic Coast and in the Gulf of Mexico. We have three speakers who are highly experienced and recognized authorities in recreational shark fishing. They will impress you with the magnitude of the participation, the geographical scope of activities, and the extent of the catches. You will hear about the growing importance of the tournaments and even about one in Panama City, Florida, where the catches are sold by the tournament management to provide prizes for the participants. Last year 28,000 pounds of shark was sold from this tournament. Anglers enjoyed the fishing experience, the entire catch was utilized for the benefit of those who caught it and was made available to commercial processors, and the communities profited from the influx of fishermen. That's a win-win situation.

There are many good reasons for sport fishing for sharks. They are fun to catch and put up a great fight, particularly on light tackle. They provide fishing when other species are not readily available or bag limits of quotas on them have been reached. And a growing number of fishermen are finding out just how delicious eating many species of shark are. As a matter of fact, I understand that in some tournaments in the Gulf of Mexico, the biologists have to really hustle around when makos are landed to get the biological measurements before the fish are cut up and taken away for consumption.

As a fringe benefit of recreational fishing for shark, many of the fishermen tag and release them as part of a nationwide cooperative tagging program with the National Marine Fisheries Service and California Department of Fish and Game. In the past 23 years over 60,000 sharks of 47 species have been tagged and 1,900 have been recovered. Over 2,500 individual anglers have participated and they have tagged around half the fish. The longest distance traveled was 3,600 miles and the longest time at liberty was 19.5 years. Much has been learned about many aspects of the life history of the individual species at a minimal cost. The National Marine Fisheries Service leader of these highly successful programs will discuss results.

There is interest in developing recreational fishing for sharks to help charter boat operators with potential customers when the salmon season is closed or bottomfish fishing is slow. Depending on environmental conditions, time of the year, and availability of sharks, this could provide a very needed and welcome assist to an otherwise poor season. Knowledgeable and experienced people here can explain to interested individuals what is involved and assist them as appropriate with information, ideas, and suggestions for starting or expanding shark fisheries in their areas.

Most anglers on the Pacific coast curse their luck when they catch a shark, usually a dogfish, while fishing for salmon. At some times and places they are the constant scourge of the salmon fishermen who used fresh and frozen herring for bait. In recent years, particularly off Oregon when salmon fishing has been sharply curtailed because of reduced abundance, many anglers are more successful catching dogfish than salmon. They would be more apt to be pleased with the dogfish and take it home and prepare it for eating than curse it and throw it back if they knew how to care for it properly from the time it was captured until it was eaten. One of our speakers will discuss those simple but critical procedures.

Orders of magnitude more sharks are captured in commercial fishing as an incidental species and discarded than are ever deliberately sought and retained for market because the demand for sharks and the supporting market structure have not been developed adequately. However, there is an increasing demand in markets and restaurants for various species of shark. We have many speakers who will cover developing fisheries for selected species in specific areas, and other who will talk about various aspects of the marketplace and preparing product for it.

I have only briefly referenced science. There are six presentations on shark biology. What role do sharks play in the ocean and the circle of life there, unrelated to man, and how do we affect them? What are some of the things we have done to learn more about these much misunderstood and maligned creatures? We are learning what sharks do, why they do it, and in some cases, how they are able to accomplish it. We can better understand them and maybe in the process help ourselves with the knowledge gained directly or indirectly by use of some of their body components or tissues to combat our health problems. This information can be of interest to fellow scientists as well as to a much broader audience.

In some respects it is much easier to study animals in captivity, assuming the captivity itself does not significantly alter the factors you wish to measure. It is relatively difficult to retain sharks in aquaria for prolonged periods. More work is needed and is underway on this. The Mid-Atlantic

Fishery Management Council, under the Magnuson Fishery Conservation and Management Act, is becoming involved in a $50,000 study on shark age and growth. Such biologial information is essential to development of a sound management plan. Ever since implementation of the Act in 1977, management plans have been the means by which the various marine fisheries resources between 3 and 200 miles from our coast have been managed. Other information on abundance and distribution is needed and is being gathered gradually.

In summary, we are talking about sharks because they are becoming increasingly important to humans in many ways. They are found worldwide. Although relatively little is known about the abundance and distribution of many shark populations around the world, it is generally believed that most are in good condition and not fully utilized by man.

When properly cared for after capture, they can be a very nutritious, delicious, low cholesterol food. They provide countless anglers with much enjoyment and food in the process. They afford commercial fishermen a livelihood and opportunities to supplement their income from catches of other species of fish. Scientists are learning much about shark life history, distribution, behavior, and their role in the ecosystem. Parts of the animal are used for food, pharmaceuticals, leather, and curios.

We hope that the conference will encourage the more effective use of sharks by those who are now catching them, encourage others to catch more within sound conservation standards, and still others to try eating them and learn what they have been missing. We want surfers, swimmers, and divers to know the facts about sharks, their infrequent attacks, the dangers involved, and what should be done in the event of an attack. Scientists will continue to learn more about these facinating creatures for human benefit. We hope the public, composed of its many special interest components, will participate more productively and satisfactorily in understanding, using, and enjoying sharks of the world. Yes, we are talking about sharks for many reasons. Now you will hear why in greater detail from a very impressive array of recognized authorities.

Shark Biology

The Position of Sharks in Marine Biological Communities
An Overview

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Abstract: Sharks are one of the most successful and enduring of vertebrate groups, having first appeared during the Devonian period of the Paleozoic Era. Fossil records indicate that even the earliest sharks had evolved as predators, a role which they have superbly retained in the 350 million years since. Because of their physiological, anatomical and behavioral efficiency as predators and their reproductive adaptations, sharks have flourished while other competing predators, such as the ichthyosaur, have vanished. Despite their long evolutionary history and success, sharks constitute a small group. At present there are about 350 species, compared to over 19,000 species of bony fishes. Sharks are, however, one of the most abundant large predators on earth. Yet, we know surprisingly little about this group of animals. Current knowledge of the role of sharks as predators and summit (top) predators is reviewed with comments on biology, reproduction and factors that limit our ability to observe and study sharks.

Sharks are one of the most successful and enduring of vertebrate groups. The earliest sharks first known appear as fossils in the rocks of the Devonian period, which started about 400 million years ago. These early sharks had already evolved as pelagic predators. Sharks have maintained the role of pelagic predators since Devonian times, competing against numerous groups of similarly adapted marine predators, such as ichthyosaurs, plesiosaurs, and toothed whales, through epochs that brought about the extinction or decline of their competitors. At present sharks are the dominant predators in the sea.

The evolutionary success of sharks can be attributed to their efficiency as predators and to their reproductive adaptations. Sharks have evolved exquisitely sensitive organs which allow them to detect injured or sick prey at long distances. Sharks can locate such prey easily, thus reducing the amount of energy used in pursuing and overtaking prey because injured or sick animals require less energy to overcome than healthy ones. Sharks have evolved as large, fast, aggressive predators with extremely powerful jaws and very sharp teeth. Their teeth are periodically replaced, so that they are always sharp. Armed with formidable jaws and dentition, sharks have a wide range of prey available; they can attack prey that is too large to swallow, rending a large fish into pieces that can be swallowed, or at least carving a large chunk of flesh out of very large prey. Furthermore, most sharks are opportunistic feeders which will take whatever prey is abundant or easily available. Thus, by avoiding dependence on a given prey species, sharks have survived the varied climatic changes that brought the extinction of many species along with their specialized predators.

The reproductive success of sharks is due to adaptations which reduce their losses to predation and enhance the survival of their offspring. The most significant of these adaptations are internal fertilization and the production of small numbers of large young, which hatch or are born as active, fully developed, miniature sharks or "pups." Sharks are either oviparous or viviparous. Oviparous, or egg laying species, carry their eggs only during the earliest developmental stages; after egg laying, the embryo continues to develop inside an egg case which affords some degree of protection. Viviparous species carry their embryos throughout complete development. Because adult sharks have relatively few predators, their losses to predation are reduced. In both oviparous and viviparous species, the pups hatch or are born at a relatively large size, which reduces the number of potential predators while increasing the number of potential prey, thus increasing their chances of survival.

In spite of their long evolutionary history and success, sharks constitute a small group. At present there are about 350 described species of living sharks (Compagno 1984), compared to about 19,000 bony fishes (Nelson 1976). New species of sharks are described every year (Fig. 1). The sharks being described are not just minute deep water species which have eluded notice. We are still describing new species of large sharks. By large I mean exceeding 3 m (9.7 feet) and 100 kg (221 pounds). For example, megamouth, a large deep-water shark exceeding 4.5 m (14.5 feet), was first described in 1983. The longfin mako, which exceeds 4 m (12.9 feet), was described in 1966. Three species over 3 m (9.7 feet) were described in the fifties, and two species were described in the forties. When we look at the number of valid species of sharks described per year (Fig. 2), we notice that there were two periods of great taxonomic activity, one around 1840 and one around 1910. When we start applying twentieth century methods, such as blood serum analysis, to the study of sharks, it is likely that we will see another period when numerous new species are described.

Although there is a relatively small number of shark species, sharks are one of the most abundant large vertebrates on earth. But despite this abundance, sharks are one the least known groups of animals. In most cases, we simply know that a given species exists and have a few assorted facts about its biology. Information on population dynamics, stocks, and effects of sharks upon other stocks of fishes is simply lacking. Data on migrations is limited to a few species. Data on aging and longevity is scant and requires validation. Data on reproductive potential is available for few species. Behavioral data is available for very few species. Several factors contribute to our ignorance of these great fishes. First, sharks are the object of few organized fisheries, thus shark research has lacked the impetus of commercial concern. Even when curious fishermen encounter large or unfamiliar sharks in their catches, they are often unwilling or unable to bring them back because sharks have little commercial value. Second, the state of our underwater capabilities precludes prolonged observations of free-ranging sharks. Third, most species of sharks do not adapt to captivity in present day-facilities and usually they die shortly after confinement, offering few opportunities for observation.

With a few exceptions, sharks are predators or summit predators. The exceptions are the basking shark, the whale shark, and the recently described (1983) megamouth shark. These species are filter feeding planktivores, although the whale shark is also a predator because it feeds on small schooling fishes such as sardines. These species occupy a much lower trophic level than most sharks, and thus they benefit from an abundant food supply which can be obtained with little expenditure of energy. This allows them to attain very large size, exceeeding 450 cm (14.5 feet), and freedom from predation. These three species are distributed as to avoid competition; the whale shark inhabits tropical surface waters, the basking shark inhabits temperate surface waters, and the megamouth inhabits deep waters.

Most other sharks can be classed as predators. Many dogfishes (Squalidae) and many catsharks (Scyliorhinidae) are tiny or small sharks, usually less than 60 cm (1.9 feet), which prey primarily on squid and other mollusks. Three families, the horn sharks (Heterodontidae), the carpet sharks (Orectolobidae), the smoothhounds (Triakidae), and one or two of the hammerheads (Sphyrinidae) are usually small sharks less than 120 cm (3.9 feet) which feed on crustaceans (primarily decapods) and small fishes. Most other sharks are piscivorous predators; these are medium to large fishes, with most species measuring less than 200 cm (6.5 feet).

A few sharks are truly summit predators at the very top of the food chain. These are the white shark, the makos, the tiger shark, the dusky shark, the bull shark, and the great hammerhead. These are all large sharks, exeeding 300 cm (9.7 feet), which feed on predators high in the food chain, such as mammals, billfishes, tunas, and other sharks. In many cases, juvenile top predators occupy a lower trophic level than the adult. For example, young white sharks are piscivorous, while adult specimens prey on marine mammals, especially pinnipeds (Tricas and McCosker 1984).

There is no evidence that the numbers of sharks are controlled by their food supply (Wyatt 1976). It is likely that the numbers of sharks are limited by their low reproductive rate and by the availability of nursery areas. Many species of sharks have annual or biannual reproductive cycles, while some may have even longer cycles (Clark and von Schmidt 1965). Furthermore, the litters produced by most sharks are small, ranging from two to about a dozen. Springer (1967) suggested that the availability of nursery areas comparatively free of large sharks may be the population regulating factor; and that the only important predators of sharks are other larger sharks, although sharks have been reported from the stomach contents of porpoises and sperm whales, and small sharks are occasionally eaten by bony fishes. Van der Elst (1979) provided evidence for the control of small sharks by larger sharks. He analyzed twenty-one years of catch returns of the sports fishery to detect trends in the catches off Natal. Along the Natal coast, large sharks are subject to two types of fishing mortality: sports fishing and gill netting. Gill nets are used to protect beaches and some 12% of the coastline has these anti-shark devices installed. The removal of large sharks from the area resulted in a proliferation of juvenile sharks and small species.

Thus, it is likely that freedom of predation by larger sharks causes gravid females to travel to discrete nursery areas to deliver their pups. These areas are usually in shallow water, or at least in shallower waters than the areas inhabited by the adults. Because large sharks are not usually found in shallow water, the pups are relatively free from predation in those areas. Each species has a geographically descrete nursery, separated in time or space from those of other sharks, often in high productivity areas where the pups find abundant food. For example, Florida Bay, with its large areas of very shallow banks interspersed with channels of depths ranging up to 3-5 m (10-15 feet), is one of the important nursery areas for the lemon shark (Negaprion brevirostris) (Springer 1950). Further north, the brackish lagoons of the central east coast of Florida provide the nurseries for the bull shark (Carcharhinus leucas) (Snelsen et al 1984). The shallow coastal marshes and the waters around the many islands off Georgia and the Carolinas are the nurseries for numerous species: the smooth dogfish (Mustelus canis), dusky shark (Carcharhinus obscurus), finetooth shark (C. isodon), scalloped hammerhead (Sphyrna lewini), black tip shark (C. limbatus), Sandbar shark (C. plumbeus), blacknose shark (C. acronotus), and the Atlantic sharpnose shark (Rhizoprionodon terraenovae). All these species share the same nursery area with some degree of temporal partitioning. The dusky delivers its much larger pups in April. The smooth dogfish gives birth in April and May. The fine tooth shark and the scalloped hammerhead give birth in late May and early June. The sandbar, blacktip, and the sharpnose sharks all give birth in June. There is probably some spatial partitioning occurring within the nursery as well, but this remains to be studied.

The young remain in the nursery areas for a few weeks or months, growing fairly rapidly during their first months. The onset of winter usually forces them out of the nurseries into deeper waters or southward, often forming large schools composed of sharks of the same species and uniform size.

Males generally do not enter the nursery areas, thus they avoid competition with females or preying on their young. Males often form migratory schools of individuals of uniform size. Presumably, the males become active every year.

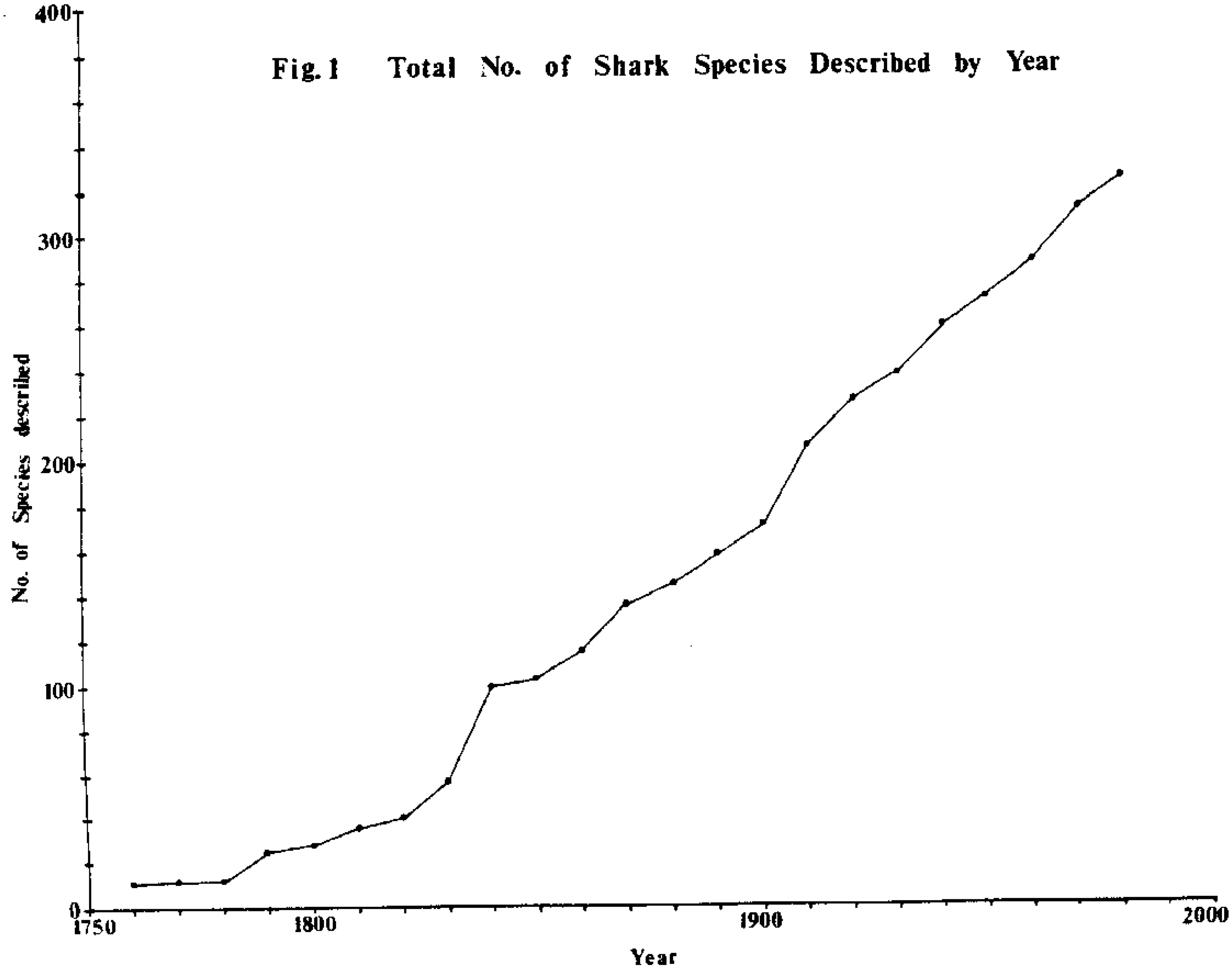
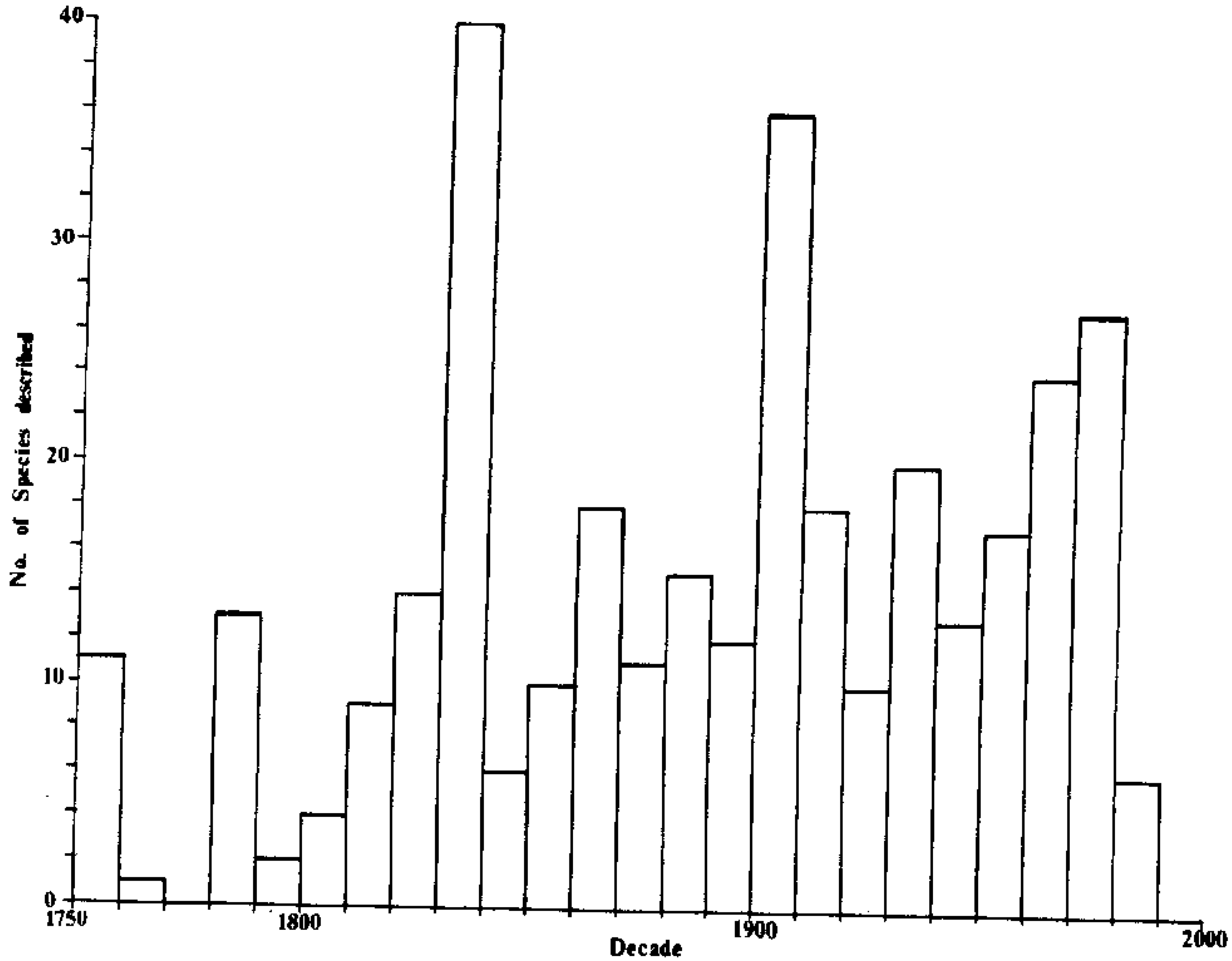


Fig. 1 Total No. of Shark Species Described by Year

Fig.2 Number of Shark Species Described by Decade



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Estimating Age and Growth in Sharks[1]

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Abstract: Growth curves for elasmobranchs have generally been derived from age estimates based upon opaque and translucent bands in calcified hard parts. The various methods used to estimate and to verify ages in elasmobranchs are reviewed. Verification techniques include size frequency analysis, growth model parameters, centrum edge dimensions and histological characteristics, laboratory growth studies, tag recapture results from the field, and tetracycline marking in both labaoratory and field studies. Two relatively new techniques are also presented. One is radiometric dating, which makes important assumptions about cartilage growth and calcification processes. The other is the use of electron microprobe analyses for calcium and phosphorous across sections of vertebral centra, which help verify the periodicity with which bands are deposited by quantifying the calcium phosphate fractions at the centrum edge. It is proposed that future elasmobranch age and growth studies will benefit from research which stresses the physiological aspects of calcium dynamics and the role that endocrine systems may play in calcium regulation.

Introduction

Because of increasing interest in elasmobranch fisheries, information on their life histories is important. This is especially true since many studies feel that elasmobranch populations are susceptible to over-fishing (Holden 1974).

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[1] Excerpts taken from G. M. Cailliet, R. L. Radtke and B. A. Welden. 1986. Elasmobranch Age Determination and Verification: A Review. Indo-Pacific Fishes Conference, Japanese Icthyological Society Chondrichthyan Symposium, Tokyo, Japan. In Press. This research was sponsored in part by National Oceanic and Atmospheric Administration, National Sea Grant College Program, Department of Commerce, under Project Numbers R/F-57, R/NP-1-11C, and R/F-84 to G.M. Cailliet through the California Sea Grant College Program, and under a cooperative grant to R.L. Radtke, through the University of Hawaii Sea Grant Program.

Information on growth of elasmobranchs has been derived from counts of opaque and translucent bands in their spines and vertebral centra, because elasmobranchs lack the hard parts (i.e. scales, otoliths, or bones) used in age and growth studies of bony fishes. Size mode analyses are difficult to apply to these generally large and mobile organisms; only in those species which are very abundant and for which a sampling program exists would this approach work, and even in these cases, the ages of the larger size classes can only be poorly defined.

Few elasmobranch growth studies have evaluated the temporal periodicity of the band deposition in the spines and vertebral centra, a process essential for a clear understanding of the growth processes that these bands represent (Beamish and McFarlane 1983). Several studies have noted that the amount and pattern of calcification varied considerably among species, thus stressing the importance of evaluating the temporal periodicity of growth zone deposition.

This paper: 1) summarizes the techniques which have been used in age determination of elasmobranchs; 2) reviews the approaches used to verify these age determinations, including new information from electron microprobe analyses and results from radiometric dating techniques; and 3) suggests other directions that researchers studying the age and growth of elasmobranchs might fruitfully take in the future to elucidate these processes.

Age Determination Studies

Several methods of age determination have been developed and applied to elasmobranchs and these were reviewed by Cailliet et al. (1983). Here, I update and summarize the previous review.

Length frequency analysis has been one of the most commonly used determination techniques, despite the obvious problems associated with biased or incomplete sampling. When length frequency analysis is coupled with tag-return analysis, the results are often more easily interpretable. In most studies of this kind, size changes in the tag-returned sharks matched the growth patterns indicated by size-frequency modes; however, individuals varied considerably. The use of size frequency analysis and tag-return data is limited because random sampling is virtually impossible and elasmobranchs appear to grow slowly, especially the older ones, resulting in the loss or obscurity of the larger size and age classes.

Analysis of tooth replacement rates provides only a general estimate of growth rate. Because tooth replacement rates vary considerably among individuals, this technique can only provide very rough estimates of age. Similarly, the use of secondary sex characters provides only crude categories such as young, immature and adult, and no true estimate of age is possible.

The growth of embryos in-utero has been measured in several studies but extrapolating from these rates to the young, immature and adult stages is dangerous and can be misleading. Indeed, growth rates vary a great deal among growth stanzas in the development of any species.

The enumeration of growth zones in fin spines has provided a great deal of information on those species of elasmobranchs which possess such spines, notably the spiny dogfish. Unfortunately, most elasmobranchs do not have fin spines, thus limiting the applicability of this technique.

It was long ago noted that concentric growth zones occur in vertebral centra of most elasmobranchs and that these had potential as age indicators. Numerous authors have developed techniques for cleaning the vertebrae and enhancing the growth zones. In addition, several sectioning techniques have been used to provide additional information on growth zones that would not have been obvious by viewing whole centra (Cailliet et al 1983).

Age Verification Studies

Many authors have assumed that the growth zones in elasmobranch vertebral centra were deposited annually, but few actually tested this assumption. Verification procedures can be categorized as: 1) statistical evaluations of growth; 2) "direct" measurements of growth; 3) marking of anatomical features relative to growth; and 4) chemical methods of analyzing growth. The techniques used in each of these four categories to verify age determinations of elasmobranch fishes are reviewed.

Statistical Evaluation of Growth

Growth Model Parameters. One way to qualitatively evaluate the ages estimated from counts of growth bands is to compare growth model parameters with known size information, such as length at birth and maximum observed length. This approach only provides rough comparative values because growth models may not fit a given set of size and age estimate data, and information on length at birth and maximum observed length may not be good estimates of mean values. These procedures are not a true test of annual periodicity of band formation.

Back-calculation. Growth curves can be developed from estimates of size at previous ages derived from measurements of the zones on a calcified structure. They then can be compared with growth curves derived from counts of zones in many different individuals. However, back-calculation does not verify temporal zone formation patterns. Thus, it can provide only a check on the von Bertalanffy growth equation derived from observed age estimates. However, it serves a useful purpose by providing information on sizes of missing age classes.

Direct Measurements of Growth

Size Frequency Analysis. When there are large, representative samples of a species' population, size frequency analysis can provide a comparative standard for the growth curves derived from vertebral bands. The means of the modes in a size frequency histogram can be compared to the mean sizes predicted by growth curves generated from vertebral band counts. The agreement is usually better for the smaller, younger size classes as they often predictably inhabit assessible sampling areas, and there is less variation in size at age in younger individuals than in older ones. Major problems with this technique include mode identification and the likelihood of emigration and immigration.

Many studies using size frequency analysis have found close agreement, especially in the smaller age classes, between size modes and mean sizes at age from band counts.

Centrum Edge Characteristics. The width and density (translucency or opacity) of the centrum edge, when compared to month or season, can also be used to verify age estimates. This approach usually involves categorizing the centrum edge as translucent or opaque or in grades of band width and comparing individuals among seasons or times of the year.

Seasonal periodicity was apparent, with opaque bands being deposited during the summer months and translucent bands in the winter, in all but two studies for those species in which centrum edge characteristics were evaluated. In two other studies, results were either unclear or indicated no seasonal periodicity in centrum edge formation using histology (Natanson 1984, on angel sharks). However, it is difficult to delineate the centrum edge without sectioning or even more objective techniques such as histology and microanalysis. These are necessary to establish solid criteria for seasonal growth patterns.

Laboratory Growth Studies. Elasmobranchs maintained under laboratory conditions can be used to produce growth information, but it is difficult to mimic natural conditions and adapt the sharks to act naturally in captive conditions. Thus, growth rates may be unnatural. They may grow faster in the laboratory, with unlimited food and low energy expenditures. Growth estimates can be further exaggerated when growth is monitored over short time periods in the laboratory. Few laboratory maintenance studies have applied their data to age and growth models.

Field Growth Studies. Tag-recapture studies provide directly comparable growth information. However, it is difficult to collect sufficient numbers of animals, make accurate measurements, tag fishes without harming them or inhibiting their natural growth rates, and finally, recapture them after a sufficient period of time has elapsed during which growth can be measured. This information is valuable, especially for larger, older fish because they tend to grow more slowly, and changes in their sizes, if measured accurately at recapture, are useful in evaluating the growth curves based upon vertebral bands. Tag-recapture studies also provide valuable information on individual variation in growth

Numerous authors have reported on growth increments based on field-tagged and recaptured elasmobranchs, but often no information is available in these reports about how vertebral band counts related to this growth information.

Marking of Anatomical Features Relative to Growth

Many investigators have used tetracycline to mark bony structures in fishes for evaluating the subsequent time sequence and deposition patterns in these calicified hard parts. Beamish and McFarlane (1983) strongly urged that this technique be a requisite portion of any age verification or validation study, whether it is used in conjunction with laboratory grown or field recaptured organisms.

Laboratory Growth Studies with Tetracyline Marking. Laboratory growth studies on elasmobranchs using tetracycline are few and the results provide interesting information relative to the growth of the species studied. In most studies, the tetracyline marks indicated that bands were deposited seasonally but that individual growth varied a great deal. However, for angel sharks, bands were deposited in their vertebral centra as a result of somatic growth rather than any predictable seasonal, annual, or other temporal phenomena (Natanson et al. 1984) The use of tetracycline in laboratory-reared elasmobranchs holds great promise but the influences of tetracycline and the laboratory conditions on growth need to be seriously considered.

Field Growth Studies with Tetracycline Marking. Tetracycline has been used as an internal mark in several tag-recapture studies to determine the time sequence of band formation. This technique may provide more natural growth information than laboratory studies with tetracycline, but the chances of obtaining tag-returns with good tetracycline incorporation are lower.

The studies which used this technique have indicated that elasmobranchs generally deposit one pair of growth bands (one opaque and one translucent) each year (e.g. Smith 1984).

Chemical Studies of Calcified Structures

The fourth general approach to verifying temporal periodicity of growth zone formation in elasmobranch structures involves analysis of the chemical structure across the centrum to detect historical chemical events which occurred during growth and deposition processes.

Microanalysis of Calcium and Phosphorus. This technique uses x-ray or electron microprobe spectrometry to measure such elements as calcium and phosphorus, which may be correlated with opaque band deposition and seasons and has been used to date only to study growth zones in centra of spiny dogfish (Jones and Geen 1977) and gray reef sharks (Cailliet and Radtke 1986). Although this method is expensive and time-consuming, it provides valuable information which can be used to compare with growth information from other, more traditional and time-effective techniques. In addition, it can be used as a verification technique for evaluating the chemical composition of the cartilage at the outer edge of the centrum on different seasons.

Radiometric Age Determination. Another verification technique in this category involves using radioactive geochronologies to estimate the relative ages of different bands in the vertebral centra. This technique has been used commonly on invertebrates, but only once on bony fish by Bennett et al. (1982), who verified that the splitnose rockfish lived considerably longer than had previously been reported from traditional otolith growth zone studies.

Radiometric age determination has been investigated in elasmobranchs by analyzing for Lead-210 activities in inner and peripheral vertebral growth bands (Welden 1984, 1986). Comparison of inner and peripheral band activities yielded an estimated age for the individual specimen, which was then compared with the number of vertebral growth bands counted from x-radiographs and resin-embedded thin sections.

In elasmobranchs, at least two assumptions are necessary for radiometric dating to produce valid age estimates. First, the radionuclide must be incorporated at a constant or known rate over the lifespan of the organism, so that the initial activity of the system can be estimated. Second, the structure which incorporates the radionuclide (calcified cartilage) must act as a closed system with respect to that radionuclide. Once the radionuclide is incorporated into the structure, there must be no loss or gain except by radioactive decay.

The radiometric age determination technique has been variably successful for the four species tested (Welden 1986). Estimates of age of angel sharks and white sharks roughly agreed with other age determination studies, with the larger specimens of white sharks disagreeing more than the smaller ones. However, in leopard sharks and common thresher sharks, age estimates were too variable to be used, and hence must have limited value for verification of existing age estimates.

Thus, it appears that the radiometric dating technique was not completely successful in estimating age in these four elasmobranchs because at least one, and possibly both, of the essential assumptions were violated. Uptake of Lead-210 was apparently not constant and increased in larger individuals of all four species. Two possible reasons for this observed increase are shifts in habitat and diet with increasing age. Further, it is likely that the closed system assumption may have been violated in these organisms.

Therefore, present radiometric age estimates of elasmobranchs are not completely reliable indicators of age. Although radiometric age determination remains a promising technique for many aquatic animals, probable violations of the essential assumptions should be seriously considered. Ultimately, a more comprehensive understanding of the calcium physiology of the organism will be necessary to confidently utilize radiometric age determination techniques.

Future Directions

Most studies on age and growth of elasmobranchs have reported clear growth zones in their calcified hard parts, and ages have been estimated from these. However, as Beamish and McFarlane (1983) point out, estimates of age using these zones must be verified through several techiques. Samples should include all size/age classes and geographically separate populations. Beamish and McFarlane (1983) suggested that tetracycline marking, coupled with tag-recapture data from the field or laboratory, is the only true validation of age determination.

Some of the conclusions drawn from this summary suggest future directions to take in this subject. Many researchers have discovered considerable individual variability in age at size within species, thus indicating individual differences in growth rates. There are, in addition, considerable differences in the calcification patterns among species, with some being impossible to age (Cailliet et al. 1983), others easy to age, and yet others producing uninterpretable growth information. Radiometric analyses in four species have challenged the assumptions of a constant uptake and a closed calcified vertebral system with regard to Lead-210 and presumably other elements. It is known that bony fishes can mobilize their calcium. Our radionuclide data indicate that elasmobranchs may have the ability to resorb calcium from their calcified structures when it is needed elsewhere in the body or is unavailable extrinsically.

The role that endocrine systems play in calcium regulation has only superficially been investigated in elasmobranchs, especially as it applies to the deposition or resorption of calcified growth zones in their spines or vertebrae. Indeed, these kinds of studies are essential for a complete understanding of growth zone formation in fishes in general, and need to be performed on elasmobranchs. Otherwise, it will be impossible for us to understand the influences that physiological states of the organisms and environmental factors have on controlling the development of calcified zones.

Conclusions

A myriad of techniques is available for verification and eventual validation of age and growth information determined from analysis of bands deposited in elasmobranch vertebral centra. However, few of these, especially the more powerful, such as direct measurements of growth coupled with marking, have been applied to elasmobranch fishes. The statistical approach has been used the least, most likely due to the paucity of age and growth information available on these fishes. Direct measurements of growth have concentrated mostly on size frequency analysis and centrum edge characteristics, and these have been associated with large sampling programs involving fisheries. Laboratory growth studies have been few in number, but field tagging programs have resulted in several reasonable estimates of growth in the field. The potentially most informative approach, coupling direct laaboratory and field growth studies with internal marks such as tetracycline, has resulted in only a handful of studies, which concentrated on the few species amenable to laboratory conditions or survival after tagging.

The literature on age determination, verification, and validation of elasmobranch fishes indicates that much work needs to be done and should utilize as many of the available tools as possible. It is impossible to rear some species in captivity, and for other species, unreasonable to expect many tag returns. Thus, additional approaches need to be developed and utilized to assess growth in these organisms. Microanalytical and radiometric techniques promise to reveal interesting facets about the growth of elasmobranch fishes and will undoubtedly play a strong role in understanding growth of fishes in general. I further suggest that an emphasis be placed upon studies of calcium regulation in elasmobranchs so that a more comprehensive knowledge of growth in these fishes will be possible.

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Telemetering Techniques for Determining Movement Patterns in Sharks

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Abstract: Several telemetry systems are described which can be used to study the movement patterns of free-ranging sharks carrying ultrasonic transmitters. Examples are from studies of blue sharks (California), angel sharks (California), gray reef sharks (Micronesia), lemon sharks (Bahamas), and scalloped hammerhead sharks (Gulf of California). Standard "manual" tracking methods are effective when tracking single individuals for relatively short periods, but manpower requirements become prohibitive if continuous tracks of over one to several day-night cycles are required. Simple "pinger" transmitters are least expensive, and provide the shark's location and identity (based on signal frequency and pulse rate). Multisensor transmitters can, in addition, provide readout of shark's depth, temperature, swimming speed, compass heading, etc.

Long-term movements of numbers of sharks can be automatically "tracked" by an array of unmanned, bottom-mounted, data-logging monitors. These micro-processor-based units recognize the specific I.D. code of special sonic transmatters on the sharks, storing validated contacts and times-of-day. Shorter term movement patterns can be observed to a high degree of detail (accuracy of ± ca. 1 meter) in real time using a hyperbolic X-Y positioning system. The shark's sec-by-sec position is plotted by computer from times-of-arrival of the sonic pulses at 3 receiver/radio-relay units. Two-point net movements can be determined by timed-release, radio-float transmitters which, upon release, are detectable at many miles from shipboard, hilltop, aircraft, or satellite.

Human Impacts On Shark Populations

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Abstract: Most instances of human impact on elasmobranchs are direct acts of fishing, or otherwise killing or removing the fish from the population, dead or alive. Indirect impacts such as pollution of the water or destruction of food supply are not common.

Examples briefly discussed are: 1) the common skate, Raia [Raja] batis, fished to extinction in the Irish Sea; 2) the school shark, Galeorhinus galeus, of southern Australia, saved from effects of heavy fishing by good management; 3) the bull shark, Carcharhinus leucas, of the Lake Nicaragua-Rio San Juan System, greatly reduced numbers in Lake Nicaragua because of heavy fishing at rivermouth; and 4) the largetooth sawfish, Pristis perotteti, of Lake Nicaragua-Rio San Juan System, extremely heavily fished commercially for nearly 10 years before effective protection was provided. Control of fishing now promises recovery of lake population if there is persistance in a good management program.

Virtually all the instances of human impact on shark populations[1] in some way involve fishing, or in other ways killing or removing sharks from the total population. If they are taken alive for display or scientific investigation, it has the same effect on population numbers as if they were killed outright. If the approach is indirect, as by heavily polluting the water with toxic substances, the sharks may either be killed or driven out, in either case reducing numbers. If the subject species has very specific food requirements, the destruction of its prey species might have substantial impact. However, most, but not all, sharks are indiscriminate, opportunistic feeders, not highly dependent on one, or even a few species for survival. In any case, the fact remains that, with at most rare exceptions, the impact applied to shark populations by humans is in the form of untimely death by fishing.

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[1] In several examples, I have taken the liberty of extending "sharks" to include other "elasmobranchs." The Elasmobranchii include both Selachii (sharks) and Batoidea (sawfish, skates, rays).

Examples fall into two major categories: 1) Those designed to take advantage of the flesh for food, and various other commercially salable parts, products or uses, i.e., fishing for profit, for subsistence or for sport. (2) Those whose purpose is to rid a location, usually involving recreational activities and tourism, of the threat of shark attack.

Sharks provide a remarkable variety of products and uses valued by humans. Included are the flesh for food; fins for sharkfin soup; skin for leather; tourist curios as jaws, teeth, vertebrae; liver for its oil; whole shark for teaching, research, fish meal and fertilizer.

For one or more of these elasmobranch treasures, sharks have been fished, probably for as long as man and shark have interfaced along the shores of the islands and continents of the earth. Before the last decades of the 19th Century, even at this zone of interface, there was relatively little interaction between sharks and man. The human population was still relatively small and fishing was mainly by individuals for the use of families and small communities near the sea. Man was little more than another natural enemy with which the sharks had to cope.

It was only with the advent of well-equipped, powered boats with refrigeration that commercial fishing on a large scale came into its own, and this only in conjunction with greatly increased demand for protein for a human population that surged from about 1 billion sometime in the late 19th century to 5 billion at the present time.

It is this growth in commercial fishing, plus a parallel increase in sport fishing that accounts largely for the impact that man has on elasmobranch populations today.

Historically speaking, right up into the 20th century, people in general, and North Americans in particular, have always considered the planet Earth's resources to be virtually unlimited, and put there for them to take whenever, and in whatever amounts they chose to take them. It isn't surprising then, that this attitude was applied when shark fishing became profitable on a commercial level. Most fishermen assumed that the number of sharks was boundless, even as the ocean was boundless, and there were no plans whatsoever for limitation or management of the fishery. But it didn't usually take long to discover that the boundless aspect of both shark numbers and of the ocean was far from real. I want to cite first two of the early organized elasmobranch fishing projects. Curiously, both were conducted in large part for the satisfaction of man's hunger for fish and chips!

Around 1900, the common skate (Raia [Raja] batis) was plentiful in all parts of the Irish Sea (Herdman & Dawson 1902, cited in Brander 1981). Among many other species of fish, this skate had begun to be fished there commercially by various methods, primarily by trawling. This relatively unselective method has continued to be used up to the present time, but whereas the catch in general continues to make trawling economically feasible, the common skate has completely disappeared from the catch records for the Irish Sea (Brander 1981). None have been taken for at least 10 to 15 years. The disappearance of R. batis took place virtually unnoticed and without comment in the fisheries literature, according to Brander. By calculations based on various reproductive and life history parameters, the level of exploitation beyond which the stock would collapse can now be determined. According to Brander, this level must have been exceeded quite a few years ago in the Irish Sea. R. batis is still present, although in falling numbers, in waters contiguous with the Irish Sea, both to the north and south. However, there appears to be no possibility of its recovery in the Irish Sea, unless all forms of fishery in which it is caught are stopped. Since this course of action is unrealistic and impractical, R. batis appears to be doomed, and, according to Brander, this represents the first clear case of a fish brought to the brink of extinction by commercial fishing. Presumably, if the whole scenario had been started 75 years later and monitored carefully from the beginning, with our expanded knowledge of handling fish populations, the prognosis for Raia [Raja] batis might be considerably brighter.

A second example of an elasmobranch fishery pursued for profit is that of the school shark (Galeorhinus galeus, according to Compagno, 1984) of southern Australia. This fishery was started in 1927, like the preceding case, without a plan for management. However, it was carefully monitored from the beginning, and when an alarming reduction in catch took place in the early years, the situation was studied and a management plan put in place. It has continued to this time, with adjustments made as needed, employing the latest management methods. The school shark population shows no signs of exhaustion as long as it continues to be carefully monitored and adjustments made as necessary. It is expected to continue providing a sizeable annual harvest of a magnitude that maintains an adequate breeding stock. Its whole history has been well-documented, and readers who want more detail are referred to A. M. Olsen's papers of 1954 and 1959.

We shall now return to the second category of human impact applied to shark populations with the object of reducing the threat of shark attack. We do not have space to discuss shark attack itself, except to say that, as a direct threat to humans, its impact is miniscule, but its emotional and/or psychological impact is colossal. In a beach resort area, this may very quickly translate into tens of millions of dollars in tourist business lost, with one attack, fatal or nonfatal. It provides a compelling reason for taking actions such as those that have been commenced in various seaside recreational areas where many people's livelihood is directly at stake.

Such programs have been tried, sometimes with a high level of success, notably in Sydney, Australia, and Durban, South Africa. Both are located along excellent swimming beaches, where local residents, vacationers and tourists in general found the beaches ideal for swimming, sunning and picnicking. Unfortunately, sharks cruising by found picnicking equally attractive and both locations became notorious for an inordinate number of attacks on swimmers, frequently fatal. In Durban, the first attempts at protecting the valuable tourist trade from sharks began in 1952 (Davis & Wallett 1976; Holden 1977; Younghusband 1982). The efforts were not at first effective enough to prevent the worst series of fatal attacks in the history of record keeping at Durban, in 1957-58, when 7 attacks, 5 of them fatal, occurred within 107 days. Coastal tourism was virtually shut down, but the shark hysteria and attendant economic catastrophe eventually led, in 1964, to the establishment and funding by the provincial government of Natal of the Natal Anti-Shark Measures Board (NASMB). The Board's charge was simply to combat shark attacks, which it has done primarily by mesh-netting (meshing) of 43 major beaches in the province. There has been a dramatic reduction in the number of sharks caught per year, in spite of a relative increase in unit catch effort. The number of deaths from shark attack has also declined. From the inception of the NASMB in 1964, there were no deaths for 10 years, but then (1974) there were two. Since 1976 I have no figures. The program, now involving over 200 employees, seems expensive, but perhaps it is really inexpensive if viewed as a cost of maintaining a tourism industry of more than one-half billion dollars. The system is not claimed to be 100% effective and safe, but for the present it is the most effective in operation.

We shall now move on to two cases which I had the opportunity to observe personally, virtually through its entire history in one case, and through much of its more critical history in the other. These are the cases of two species of elasmobranchs that occur in a rather unique arrangement with each other as well as with their environment. They are both found in shallow, inshore situations in tropical or subtropical seas around the world, and both enter fresh water lagoons and streams, that latter of which they may mount, and even enter lakes if lakes are present. These are the bull shark (Carcharhinus leucas) and the largetooth sawfish (Pristis perotteti), both of which are found throughout the Lake Nicaragua-Río San Juan System. I have been studying both species since 1960, primarily through a tagging program in which about 3500 sharks and 377 sawfish have been tagged. Tag recoveries have shown that both species move freely through the river and between Lake Nicaragua and the Caribbean Sea, with no serious obstacles. They differ from one another in that the shark has its center of population density in the lower river and its mouths, and reproduces probably in brackish water nearby, but not ordinarily in the lake. The farther up the river, the less concentrated the population becomes. On the contrary, the sawfish is most plentiful in the lake, reproduces there, and the farther down the river one observes it, the less concentrated the population becomes. In the case of the shark, the population in the lake normally is maintained by recruitment from the coastal population, while in the sawfish population, recruitment is almost entirely by new individuals born in the lake. For a more detailed account of the overexploitation of either species, see Thorson (1976 and 1982).

First, concerning the bull shark population, solid evidence is scarce, but various bits of information suggest that the Lake Nicaragua shark population had been on a slow decline for several decades when I began my study in 1960. But they were still plentiful and we had little trouble obtaining sharks for tagging, both at San Carlos, Nicaragua, on the lake, at the point where the Rio San Juan leaves the lake, and at Barra del Colorado, Costa Rica, where the main branch of the river empties into the Caribbean Sea. There were indications of continuing decline, which accelerated in the late 1960's and continued through the 1970's. There had always been a little fishing for shark at Barra del Colorado, for local use and, sporadically, for small commercial ventures. But in 1968, 3 or 4 local entrepreneurs began buying shark the year around, for meat and fins, and sometimes skins. No records were kept, but certainly several thousand sharks per year were taken, which on a sustained basis, would undoubtedly have strong impact on the population centered around the river mouth. Only about 10-20% of the sharks that enter the river mouth are estimated to find their way up to the lake (Thorson 1982). Since the recruitment in the lake is entirely from this 10-20%, the lake population would be strongly affected by the population changes in the lower river. This was born out by my tagging records at San Carlos as well as by fishermen at the northwest end of the lake. There, until the mid-1960's, a few hours of fishing would yield several sharks; by the mid-1970's, one could fish several days without getting any. The lake sharks were in need of help, which was finally provided, at least as a token, by the new government in 1981 when they declared a two-year moratorium on the taking of sharks in Lake Nicaragua for profit. However, since the source of the population is primarily in Costa Rica, meaningful population management will have to come from Costa Rica. I know of no action taken there, nor have I heard what Nicaragua has done after the two-year moratorium expired.

Secondly, the sawfish population may very well have represented the greatest concentration of sawfish anyplace in the world through the 1960's, and to my knowledge had never been the object of any organized commercial fishery of any kind. In 1970, in 43 days at San Carlos, we took 252 sawfish for tagging, an average of nearly 6 per day. Several days we took 10 and on the record day, 23. During that year commercial fishing began. A small processing plant with equipment for drying and freezing meat was built at Granada (northwest end of lake) and eventually a small industry was born which, if properly controlled, could provide income for a modest number of workers. For a number of years, both companies operated thriving businesses. Gillnetting began along islands near Granada, but as fishing became less rewarding, it moved, step by step, along the north and east sides of the lake, until by 1971 fishing was near San Carlos and the south end of the lake, where sawfish were in greatest numbers. Until 1971, our catch of sawfish at San Carlos increased relative to the catch of sharks (whose numbers were decreasing because of heavy fishing at Barra del Colorado). But in 1972, following a year of gillnetting of sawfish in the south end of the lake, an unmistakable reversal of this trend took place, which became more pronounced year by year. By 1974, it was very difficult to catch sawfish in San Carlos. In five days there that year, I was able to get only one sawfish, and that only with the offer of $14 US for the first one brought in on the last day. In 1976-77 I had crews of 2-4 men at Barra del Colorado and 2-4 at San Carlos, for 12 months. During that time we got only 11 sawfish--almost one per month!

I first sounded the alarm in 1973, when the first signs of population decline had appeared, in a paper given at the annual meeting of the American Society of Ichthyologists and Herpetologists at San Jose, Costa Rica; and I talked repeatedly to the Director of Fisheries at Managua about the problem developing. Evidence mounted every year and the fisheries people tried their best to impose enforceable regulations. Unfortunately, the controlling interest in the larger sawfish company was owned by a very highly placed member of the government, who had no interest in conserving the sawfish, but only in exploiting it until it was no longer profitable. So fishing continued uncontrolled up till the last few months of the revolution in 1979. The new Nicaraguan Institute of Fisheries now owns the offending sawfish company, so has no problem in enforcing the program they instituted in 1980. This includes a 113,380 kg (250,000 pound) maximum catch and a four-month closed season to protect pregnant females and their litters. The maximum catch was too large and the closed season too short, but these objections became academic when, in 1981, I was last there, they placed a two-year moratorium on fishing for either sharks or sawfish in the lake. When leaving my requested recommendations, I advised that two years is a good beginning, but it will take at least a decade or two to bring the sawfish population back to a healthy condition, if indeed it will be that soon.

I have been unable to learn what has happened since the two-year ban on fishing expired in 1983. I believe that INPESCA will continue its attempts to bring the sawfish back to a level that will support a reasonable annual harvest indefinitely.

Given the continually increasing demands for food for a world population that is growing far too fast, we can look for greater and greater pressure on elasmobranch populations all over the world. We have seen how quickly and surely serious problems arise when an elasmobranch species is fished without restrictions. Most elasmobranchs are relatively slow-growing, require a relatively long period to reach reproductive age, and produce relatively few offspring, often with long gestation periods. Therefore mistakes take many years to correct. We have sufficient information and expertise on population dynamics now to prevent or correct most serious problems. It is incumbent on fisheries biologists and administrators to monitor commercial ventures with elasmobranchs, to be able to anticipate the crises that at times will arise, and be prepared to propose management strategies when needed. With watchfulness and prompt action we should be able to avoid some past mistakes and effectively and efficiently coax from each targeted species the optimum harvest without first threatening it with extinction.

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Shark Behavior

Understanding Shark Behavior

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Abstract: Of the many activities performed by animals, none draws more rapid and profound attention than predation. And, understandably, such an activity reaches its ultimate level when a given predator-prey relationship can force or has forced humans from their accustomed role as predators into the role of prey—in the sense of either self-survival or the survival of resources. One such relationship, probably better known than any other due often to sensationalism by the media, is that involving sharks. Although most of these predators are small and innocuous to humans, the simple word—**shark**—in any context often conjures up a vision of a marine monster driven as a machine solely by primeval instincts that serve only to reinforce its insatiable appetite. Such a perception is not only false, but its continued presence serves to hinder serious scientific inquiry. Unfortunately, it often occurs from a fatalistic bias that is based on information garnered through far more expedient means than that demanded by the scientific method. Ideas and feelings from knowledgeable persons can, at times, provide important speculations, but we must remember that such thoughts can in no way replace objective facts.

THE SHARK HAZARD PROBLEM

Shark lore has existed throughout history whenever sharks have directly influenced human endeavor. Tropical islanders, for example, have long been acquainted with the habits and movements of such animals so that they can predict where these predators may occur inshore. Interest in sharks was minimal, however, in the great population centers of the world even through the first third of the twentieth century. Human-shark interactions were not only rarely and sporadically reported over great expanses of coastlines but relatively little public news media existed to disseminate information rapidly to outlying regions. Ignorance about the ways of sharks extended even to supposedly knowledgeable scientists who questioned the impact of sharks upon any human interest.

Such blissful ignorance remained the norm except for one group of individuals, the coastal fishermen. Their interest in sharks was based not only on reduced catches due to such predators but also on the reasonable prices paid for sharks in certain regions. That interest, in turn, generated (between the early 1920s and mid-1960s) sporadic investigations by fishery scientists from several countries, e.g. the United States, England, and Australia (Holden 1977). These studies provided important information on catch statistics for various commercially important species and numerous intriguing facts and ideas about the behavioral activities of the sharks concerned (e.g. rhythms of activities, migratory habits, sexual and size segregation of schools and aggregations). Many of these reports, as well as the personal knowledge gained as a shark fisherman and a shark fishery manager, have been admirably summarized by Stuart Springer (1967). This body of knowledge provided the initial insight into the importance of sharks as highly successful predators in marine ecosystems and a group highly vulnerable to human exploitation.

Progress in understanding the behavior of sharks accelerated following the establishment, in 1958, of the Shark Research Panel by the American Institute of Biological Sciences (Gilbert 1960). The Panel was concerned with all aspects of the biology of elasmobranch fishes, but emphasis was directed at the shark hazard problem. Although the problem had been long recognized in certain regions of the world prior to the Second World War (e.g. Eastern Australia, South Africa), little concern existed elsewhere until that war brought about global use of the world's oceans. The shark problem continued despite the end to hostilities because of the ever increasing awareness of the importance of the oceans for recreational purposes.

THE REMARKABLE SENSORY WORLD OF SHARKS

Information concerning the predictability and control of shark behavior was clearly central to solving or, at least, reducing the hazard problem. However, the lack of suitable laboratory facilities and the near impossibility of conducting field studies on such swift and wide-ranging animals with the equipment available at the time caused behavioral scientists to direct their attention at the sensory systems that influenced the behavior of these predators. The first major paper on the behavior of sharks actually centered on these systems (Gilbert 1962). These investigations, the majority of which were conducted between the mid-1950s and 1970s, demonstrated not only the high sensitivity of sharks for environmental stimuli of all sorts, but also limitations of the systems as well.

Chemoreception

Sharks and the other elasmobranchs have long been known to possess a particularly acute sense of smell (Tester 1963). In fact, the lemon shark (Negaprion brevirostris) and the nurse shark (Ginglymostoma cirratum) have been shown to be extremely sensitive (1 part/million) to many chemical compounds (particularly electrolytes, amino acids and amines) and can clearly distinguish waters of different salinity (Hodgson and Mathewson 1978). If coastal species, in general, possess this latter capability, it might be an important mechanism for the differential movements and the geographical segregation often noted for different elements of populations at specific times of the year (e.g. nursery areas). Another important phenomenon was shown by the catshark (Scyliorhinus stellaris)--chemically-based recognition of tons-specific (Kleerekoper 1978). This, in turn, could constitute a mechanism for sexual segregation, as reported so often for sharks in fishery studies. Such a mechanism has been recently reiterated after direct observations of male grey reef sharks Carcharhinus amblyrhynchos moving along apparent odor trails produced by females of the same species (McKibben and Nelson, in press).

Vision

Physiological and anatomical studies of the visual systems of numerous species have shown, contrary to popular belief, that these systems are highly developed in many sharks (Gruber and Cohen 1978). The high sensitivity recorded for the lemon shark, for example (Fig. 1), and the rod-packed retinas of all the species examined point to the importance of night time (including twilight) habits for these animals. This has been corroborated repeatedly in both laboratory and field studies and particularly those involving field tracking by telemetry. In the latter cases, subjects predictably moved to specific areas apparently for purposes of feeding.

There is no question, however, that sharks will feed during the day if appropriately motivated and if given the opportunity. They are apparently highly attracted to brightly colored objects. McFadden and Johnson (in Gruber and Cohen 1978), for example, reported that survival gear painted yellow was highly attractive to free-ranging sharks while the same gear painted black was ignored. This does stand in contrast, however, to the results of a study reported by Gruber and Cohen (1978) in which silky sharks C. falciformis avoided bait on a fluorescent orange globe, but readily removed bait from a black globe and less frequently from a white globe. Meaningful field studies of visual ability and preference are extremely difficult to accomplish based on the variables which must be controlled. Nevertheless, such studies with sharks are badly needed to establish directly the importance of the visual modality to these animals.

Mechanoreception

Studies of mechanoreception by various elasmobranchs have included descriptions of at least two specialized nerve terminals located in the deep layers of the skin and in certain muscle masses as well as the sensory hair cells (neuromasts) of the extensive lateral line and those scattered over the head and body (free neuromasts or 'pit organs') and the inner ear. The neurophysiological and psychophysical bases of vibration sensitivity have also been examined in several species (Popper and Fay 1977; Roberts 1978; Corwin 1981). Present knowledge is still unclear as to the function of the lateral line and the free neuromasts, but there is no doubt that the neuromasts of both systems are sensitive to water movements (Roberts 1972). The systems probably play some role in coordination of swimming. This explanation is not totally satisfactory, however, as these fishes can swim normally even after the appropriate nerves have been cut (Boord and Campbell 1977). Those species of sharks studied have a hearing range from 10 Hz (= 10 cycles per second) to about 800 Hz (extending from about 1.5 octaves below the fundamental frequency of the lowest key to that of G5 below high C on the piano, see Fig. 2). Since adult human hearing extends from about 25 Hz to around 16000 Hz, humans hear many sounds that sharks cannot hear. On the other hand, sharks can detect certain very low frequencies that humans cannot (Myrberg 1978). Numerous field investigations have demonstrated that sharks can rapidly move to specific sources of vibration (table 1). The animals usually approach the sound source between 30 sec and 1 min after the onset of transmission from distances beyond the limit of visibility (20 to 30 m in clear water). Such rapid reactions explain why nearby sharks can appear from any direction often shortly after a speared or hooked fish begins struggling. Low frequency vibrations which are irregularly pulsed are also produced by the strumming of cables and set lines and by humans when struggling in the water. Such actions are reasonable sources of attractive sounds to nearby sharks. It is equally important to realize, however, that another element of any attractive sound is its loudness or sound level. Probably most natural sounds of interest to sharks are produced such that no energy exists above the threshold of detection at distances much beyond 25–30 m. However, synthetic sources having exceptionally loud levels may well attract such predators from distances far beyond that limit. Sounds can also cause sharks to withdraw rapidly from a sound source under specific circumstances (Eibl-Eibesfeldt and Hass 1959; Myrberg et al. 1978; Klimley and Myrberg 1979). Although there are clear species differences regarding levels of arousal at such times and also differences based on individual size, members of at least three species (the lemon shark, the silky shark, C. falciformis, the oceanic whitetip shark, C. longimanus) have rapidly withdrawn from a nearby sound source when confronted with a sudden increase (20 dB or more) in the level of transmission. This response seems highly adaptive, since a successful predator when rapidly approaching a sound source might well change its behavior if the sound suddenly changes unexpectedly, i.e. the expected flow of information changes. Sharks cannot simply stop swimming and so withdrawal appears to be the appropriate response. Unfortunately, the level of such response decreases as the size of the predator increases. Also, sharks rapidly learn to ignore sudden increases in sound level. Nevertheless, understanding that qualitatively similar sound can produce both approach and withdrawal explains apparent contradictions in the literature where in one situation animals rapidly approached a source, while in another, they withdrew.

Electroreception

Electroreception constitutes still another dimension of the sensory world of sharks, but one that we cannot easily identify with, since humans possess no comparable system. When one considers the behavioral implications of the electrosensory system in elasmobranchs, one soon realizes that these border on the incredible. The significance of the electrical sensitivity of sharks and their relatives first became evident when members of the group were observed to "home in" on bioelectrical fields emanating from prey (Kalmijn 1966, 1974). Threshold gradients measuring 0.01 V/cm at the time have now reached

0.005 V/cm (Kalmijn 1981). Such sensitivity is unique in the animal kingdom and there can be no doubt these weak electrical fields have great meaning to these predators. The ampullae of Lorenzini located on the head of all elasmobranchs constitute the receptors for this remarkable system (Fig. 3) (Dijkgraaf and Kalmijn 1963; Murray 1974). Field experiments on the shallow water dogfish (Mustelus canis), the oceanic blue shark, (Prionace glauca) and the swell shark (Cephaloscyllium ventriosum) have all demonstrated that these animals indeed detect and take prey by the use of electroreception (Kalmijn 1978, Heyer et al. 1981; Tricas 1982). Fortunately for the prey of sharks, the magnitudes of bioelectrical fields fall off very steeply over distance and so even in the case of a human body, the gradient is below threshold sensitivity beyond a distance of about 1 m. Nevertheless, indications exist that attacks on humans and their equipment may be elicited or guided by electrical fields that resemble those of natural prey. Recent experiments conducted on the stingray (Dasyatis sabina) by Blonder (1985) have shown that although members of the species are electroreceptive, they did not discriminate between prey (shrimp—Penaeus sp.) and non-prey (tunicate—Molgula sp.) solely on the basis of emitted bioelectric fields. Also, galvanic currents produced by the close association of dissimilar metals are clearly within the sensitivity range of elasmobranch electroreceptors. Since testing has, as yet, not involved such currents, one cannot predict the nature of the response in their presence; they may inhibit attacks by providing unexpected change (see above) or they may even constitute "supernormal" stimuli. Only future research will provide us with the answer.

Other tiny voltage gradients, well within the dynamic range of elasmobranch electroreceptors, also exist in the world's oceans. Ocean currents, by flowing through the earth's magnetic field, create electrical fields through electromagnetic induction as does any body for that matter, e.g. a shark moving at a speed of 2 cm/sec (Fig. 4). Since such fields possess voltage gradients ranging from 0.05 to 0.5 V/cm and they are dependent on the direction of movement, sharks have all that is necessary to endow them with an electromagnetic compass sense. Accordingly, Kalmijn (1978, 1984), after initiating preliminary observations on the leopard shark (Triakis semifasciata), completed a series of exacting experiments which showed that the stingray (Urolophus halleri) was fully capable of geomagnetic orientation. Whenever consideration is given to long distance migrations, one often considers the possibility that animals are somehow directing their attention to the earth's magnetic field. Sharks certainly can attend to that field and we now know something about the mechanism involved. It is at least reasonable to assume that the long travels that have been documented for many species of sharks by John Casey and his co-workers over the years (The shark tagger...summaries. National Marine Fisheries Service, Narragansett, Rhode Island.) are the result not of lost and aimlessly wandering animals, but rather of well-oriented animals moving to other regions for unknown reasons. Actually, the well known migrations of so many elasmobranchs, as well as their often uncanny homing abilities (e.g. McLaughlin and O'Gower 1971, Klimley 1981) may well have as their basis the possession of a highly tuned geomagnetic compass—one component of their sophisticated electroreception system.

Learning Abilities

Studies of the sensory biology of elasmobranchs have provided great insight into the behavioral actions of such animals. They have also supplied us with direct evidence of learning capability. Psychophysical experiments have almost invariably employed learning procedures to determine threshold levels of sensitivity or discrimination. The success of such studies attests to the fact that elasmobranchs can rapidly learn a wide variety of tasks (Figs. 5 and 6) (Clark 1959; Wright and Jackson 1964; Aronson et al. 1967; Banner 1967; Gruber and Schneiderman 1975; Graeber and Ebbesson 1972). Habituation, a common form of simple learning, also has been shown by sharks during field tests of sensory function (figure 7) (e.g. Myrberg et al. 1969, 1978; Nelson et al. 1969; Nelson and Johnson 1972). No longer can such animals be viewed as creatures of primitive instincts with little or no capacity to learn through experience. Such knowledge aids in explaining certain behavioral differences often observed in the field, for example, those between juvenile and adult sharks. Juveniles are almost invariably more aggressive that adults. Their activity levels are also often higher and their actions often more erractic and unpredictable than those by adults of the same species. Reasons for such differences are unknown, but their nature reminds one of those observed in the young animals of many other species, in which behavioral modifications occur through learning experiences as individuals grow to maturity.

SHARKS IN CAPTIVITY

Clark (1963), while reviewing the distribution and longevity of sharks in captivity around the world, reported that more than 50 species had been held in aquaria for at least up to several months. Nevertheless, until recently only a relatively few hardy benthic species consistently survived under such conditions for long periods of time (e.g. more than one year). These include several hornsharks (Heterodontus spp.), certain leopard (Triakis spp.) and catsharks (Scyliorhinus spp.), the sand tiger shark (Odontaspis taurus) and the western Atlantic nurse shark (Ginglymostoma cirratum). Despite these successes, the consensus has been that most sharks are not only difficult to collect and transport but, once in captivity, they often refuse to feed and die shortly thereafter (Essapian 1962; Clark 1963; Gruber and Keyes 1981). Severe haematological changes can readily occur in sharks during and after capture and consequently critical research data may actually be based on abnormal animals (Martini 1974, 1978). Fortunately, the knowledge that has been gained over the last 15 years has provided ever greater success in maintaining captive sharks, including the larger and more pelagic species (e.g. those of the genus Carcharhinus). Proven techniques for transporting sharks to distant locations are now available, as are the means for maintaining high water quality during captivity. The requirement that sufficient space be provided for periods of unimpeded movement, prophylaxis (Keyes 1977; Herwig 1979), and the use of dietary supplements to correct deficiences brought about by using certain food (table 2) (Gruber and Keyes 1981) are just a few of the practices that are now employed to maintain subjects at a level of health comparable to that found under natural conditions.

Although knowledge about the factors that control feeding behavior could perhaps be considered most critical for the health of sharks held in captivity, surprisingly few studies have been directed at this important field. Also, food is often used as the reinforcer for appropriate behavior in psychophysical tests of sensory capabilities. Such testing relies on the experimental control of motivation through an understanding of the ad libitum rate of food intake. Yet, until recently, little or nothing was known about ad libitum feeding by sharks under uncontrolled conditions, let alone under controlled conditions. Graeber (1974), using outdoor pools, suggested a 15-day peak in food intake for juvenile lemon sharks, while Longval et al. (1982), providing similar animals with a recirculating water system with precise control over light, temperature, salinity, and flow rate, found a consistent 3.5 to 4 day peak in food intake with additional but uncertain peaks at 7 and 28 days (lunar periodicity?). The four-day peak was generally preceded by a gradual 2-3 day rise in food intake and followed by a precipitous drop in intake. This suggested that after an animal is sated, it takes a few days for the appetite to become reestablished. Although the results of the two studies differ, they both clearly show that food deprivation and satiation are important in the food intake behavior of sharks. These and other studies (e.g. Graeber and Ebbesson 1972) leave no doubt that Springer (1967) wrongly believed that hunger motivation does not exist in sharks. It certainly does exist and it has been a most useful tool in discovering new facts about these animals.

The natural feeding behavior of sharks rarely has been observed, the one significant experimental study of such behavior in free-ranging sharks being that by Hobson (1963). Perhaps such rare occurrences of feeding during the day point to the period of darkness (including twilight) as the major time for that activity by most of these predators. If true, innovative techniques will be required to examine the behavior. Such rhythmic activity, if demonstrated, would not come as a surprise, since sharks are certainly no exception when it comes to demonstrating the universality of rhythms in biological systems (Fig. 8) (e.g. Hobson 1968; Standorra et al. 1972; Klimley and Nelson 1984). Controlled studies on locomotor rhythms in elasmobranchs have been confined, however, solely to the hornshark, (Heterodontus francisci) and the swellshark (Cephaloscyllium ventriosum) (Nelson and Johnson 1970; Finstad and Nelson 1975). In both cases, clear circadian rhythms with a strong endogenous component were evident (Fig. 9). Various diel rhythms as well as seasonal rhythms are also readily apparent from many studies and they certainly aid in predicting at least certain behavioral events. Although the significance of such rhythms remains unclear in many cases, the diel rhythms in locomotory activity appear directly related to feeding. And it is this activity that often is referred to in cases of human-shark interactions (Zahuranec 1975).

HUMAN-SHARK INTERACTIONS

Much has been written about the dangers posed to humans by sharks, with large sections of books being devoted to the subject (Gilbert 1963; Davies 1964; Budker 1971; Baldridge 1974; Ellis 1975; Hass and Eibl-Eibesfeldt 1977;

Wallett 1978; Sibley et al. 1985). A major assumption running through much of the early literature held that shark attacks on humans are motivated by hunger. Baldridge and Williams (1969) were the first to question this assumption based on a peculiar finding that consistently appeared in many of the cases listed in the International Shark Attack File (Baldridge, 1974). These cases involved apparent bite and run or slash-type wounds seemingly to inflict damage but not to remove flesh. In numerous cases, the resulting wounds, though severe, showed no loss of flesh. Often such attacks appeared as if only the teeth of the upper jaw made contact with the victim. The facts seemed inconsistent with the idea that hunger was the underlying motivation for the attack. As Baldridge and William pointed out, "If hunger motivated (such) attacks, then the shark or sharks involved were certainly inefficient feeders."

Other instances of attack apparently motivated by factors other than feeding have since come to light following the bold speculation by Baldridge and Williams. These particular cases have all involved the gray reef shark (C. amblyrhynchos). They are unique in that a highly stereotyped motor pattern termed "the exaggerated swimming display," preceded the attacks (Fig. 10) (instances are known, however, where no such display was seen prior to attack). The display, apparently signifying threat, varied in intensity depending upon the specific situation facing the animal at the time. Maximum intensity was shown when a shark was closely approached and especially if it was cornered, i.e. its avenues of escape were cut off. (Johnson and Nelson 1973; Nelson et al. in press). The display, though not seen during periods of feeding, resembles an exaggerated bite and it appears to have been derived from the feeding act. Although only the gray reef shark performs the full display, Hobson (1964) noted the early stages of the display in Galapagos shark (C. galapagensis), while Myrberg and Gruber (1974) noted a similar but far less intense display (the hunch) by captive bonnethead sharks (Sphyrna tiburo) (Fig. 11) and blacknose sharks (C. acronotus) and by free-ranging silky sharks (C. falciformis). In all instances, the display was seen in potentially agonistic situations, such as when a new shark was suddenly placed in the near vicinity of a group of residents (the first two cases) or when diver approached individuals shortly after entering the water (the third case).

Since these displays have been found to be neither site-dependent nor related to feeding activity, their significance remains unclear. However, I do remember once reading a recommendation to swim rapidly toward an approaching shark, since such behavior on the part of potential prey (me) would likely confuse the onrushing predator (the shark), causing it to break off the attack and move away. Apparently the author who recommended such an action had not attempted such a maneuver at a gray reef shark. Further studies are needed to clarify the function of such displays, but the danger that exists for divers making direct observations of such actions forces extreme caution and innovative techniques to prevent harm to personnel. That gray reef sharks are so aggressive despite their relatively small size (usually 1 to 1.5 m long) stands in contrast to that observed in other species both in waters where grays abound as well as elsewhere (Allee and Dickinson 1954; Hobson 1963; Myrberg and Gruber 1974; Clark 1981; Nelson 1981). One rarely sees overt aggression such as attacks, chasing or apparent threat. Even during active feeding, including the infamous "frenzies," sharks seem interested only in getting the food rather than competing with one another, such that access to the desired item(s) is earned by winning an aggressive interaction. Aggressive behavior could be expected if sharks, such as the gray reef, defended exclusive areas. No evidence exists, however, that members of any species are territorial. Perhaps such behavior is due to individuals attempting to maintain a position of relative dominance in specific areas. This is suggested by recent evidence that female gray reef sharks show elevated aggression and exaggerated swimming displays in pupping areas. However, males and females, far distant from such areas, show the same behavior. Perhaps such animals are simply defending themselves from possible predation by large moving objects in their vicinity. Defense of such a "personal sphere" has been suggested by several authors. The story appears even more complex, however. Although the display is extremely difficult to elicit in feeding situations, Johnson (1978) has observed it in a feeding interaction between a moray and an apparently frustrated gray reef shark. Thus, considering all the evidence to date, the heightened aggression in such sharks seems to be caused by several motivating factors, including competition and antipredation. Since gray reef sharks are often found in packs, feed opportunistically, and are known to feed on their own kind, any mechanism that can increase fitness through competitive and antipredatory tactics must have high selective advantage.

THE SOCIAL BEHAVIOR OF SHARKS

There exists for many the view that the typical shark moves as a solitary hunter throughout its domain. Although this is either true or probable for certain large species (e.g. basking, white and tiger sharks), many others move in groups. One of the most spectacular instances of such behavior is that of the scalloped hammerhead (Sphyrna lewini). Populations of this species form daytime schools offshore of several islands and seamounts in the Sea of Cortez (Klimley and Nelson 1981, 1984; Klimley 1985). These predators apparently possess mechanisms that provide them the means to reach and then remain at specific locations within their extensive feeding ranges during relatively inactive non-feeding periods. Recent evidence gained from the movements of lemon sharks in the waters of Bimini, Bahamas, also suggests the existence of similar but less spectacular refuging areas (Gruber 1982). That sharks, such as hammerheads, can somehow pinpoint specific geographical locations in waters of great depth seems astounding, but considering their elaborate sensory capacities, such a feat should not be surprising.

It is axiomatic that when animals congregate in groups, social interactions will follow. Unfortunately, relatively little information exists about the social behavior of sharks, since few instances of direct observation have been made under conditions in which such behavior might be expected. Instances of interspecific, social hierarchial associations have been reported, but one must remember that such cases of apparent dominant-subordinate relationships may be reflecting subtle instances of antipredatory behavior on the part of the subordinates. Intraspecific social hierarchies have also been reported (Allee and Dickinson 1954; Myrberg and Gruber 1974) and in at least one instance (bonnethead sharks), females tended to shy away from males regardless of size (Fig. 12). Reasons for such shyness are unclear, but based on the physical damage that males apparently inflict upon females during the mating period, it is little wonder that females give them wide berth. The social hierarchies investigated to date have been shown to be size-dependent. Although this might suggest again that antipredatory mechanisms are operating, such an organization is also typical of those hierarchies examined thus far in other fishes, regardless of their feeding habits.

One might actually question why adult sharks would congregate in packs or schools at any time. One can understand why small sharks might do so, since a relatively tight aggregation would reduce the chance of predation upon any given individual. Such an argument wanes in importance, however, as individuals reach a size such that there exists a low risk of predation. Perhaps the answer rests with the fact that food often occurs in widely separated patches and an optimal strategy for any given individual might be to associate with others so that it can take advantage of the extended sensory capabilities of the group. Such an advantage could be extended even further if social facilitation occurs (i.e. enhancement of a given action by one individual in the presence of others showing the same action) and such a phenomenon is well known in sharks (Springer 1967; Myrberg et al. 1969, 1972; Johnson 1978).

The ultimate social activity in sexually reproducing animals constitutes mating behavior. The relative scarcity of observations of such behavior in sharks suggests that it occurs primarily during the nocturnal period. The few cases which have been observed during daylight show that despite the widely separate taxa involved, similarities exist among the behavioral actions shown by the pairs and in the orientation of members one to another (*Scyliorhinus canicula* Bolau 1881, Schensky, in Gilbert and Heath 1972; *S. torazame* Ucida 1982; *Heterodontus francisci* Dempster and Herald 1961; *Carcharhinus melanopterus* Johnson and Nelson 1978; *Ginglymostoma cirratum* Klimley 1980 (Fig. 13); *Triaenodon obesus* Uchida 1982; Tricas and LeFeuvre 1985). All instances of copulation have occurred on the substrate, save that reported by Clark (1963) for the lemon shark (*N. brevirostris*) (a presumed copulation). In most instances, the male maintains a bite-hold on one of the pectoral fins of the female during actual copulation, no doubt to maintain relatively consistent orientation as regards the placement and maintenance of the clasper (the intromittant organ) in the cloaca. Fresh wounds, often found on the dorsal surfaces of adult females, also strongly suggest that pre-mating activity includes harassment by males (Springer 1967; Clark 1981). Perhaps it is for that particular reason in blue sharks (*Prionace glauca*) the hides of mature females are more than twice as thick as those of males of the same size (Pratt, in Clark 1981).

THE BEHAVIORAL ECOLOGY OF SHARKS

One of the major ways to understand the activities of any animal is to understand its role in the ecology and the bio-economics of the community of which it is a part. This is particularly the case for predators, since they can exact both stabilizing and oscillatory influences on ecosystem dynamics. Thus, it is difficult to comprehend that except for ecologically related investigations conducted on catch-statistics by several federally directed fishery efforts, few detailed ecological studies of sharks exist (Clarke 1971; Waas 1971; O'Gower and Nash 1978; Gruber 1982). This is likely due to major limitations facing such studies. Many species are not only relatively rare in most areas, but are wide-ranging in their often turbid habitats, shy (in most instances) and fragile (re: capture and transport). Ways must be found to overcome these problems before important advancements can be made in the ecology and the behavioral ecology of these animals. One such way is the use of ultrasonic underwater telemetry (Thorson 1971; Nelson 1978; Gruber 1982; McKibbon and Nelson in press). The excellent information that already has been gathered about the activities of selected species points to a most profitable future for any behavioral or ecological study employing such instrumentation. Other tools include small 1- or 2-man submersibles (Nelson 1981), underwater television (Myrberg 1973), stereophotography (Klimley 1981), specially designed boats (Gruber 1982) and even tethered balloons (Ross Robertson, pers. comm.). Often such tools require a reasonable financial base for the research programs of which they are a part, but the rewards gained by their use can far outweight their costs.

Analyses of the structural components of behavior, i.e. the stereotyped action patterns shown by animals in general, have provided insight into the underlying causes for various activities of sharks (Johnson and Nelson 1973; Barlow 1974; Myrberg and Gruber 1974; Tricas 1982, 1985; Klimley 1985). The methodologies and ideas inspired by the fields of ethology and behavioral ecology will surely provide continued growth of our knowledge about not only the causes of shark behavior but also about the function and evolution of the behavior. This is particularly the case when considering one major void in our knowledge about shark behavior. We are well aware that sharks can intercept a variety of signs (chemical, acoustical, electrical) from their prey and use them for their own purpose. However, we are totally ignorant about the ways that sharks use signals to communicate with one another. Is it possible that certain sharks might even attempt to communicate with their prey, using deceptive signals (see Myrberg 1981 and below)? If we knew something about the communication processes used by those predators, it might be just the means for controlling or at least directing important aspects of their behavior.

Body markings for example, are often used throughout the animal kingdom for purposes of communiciation (Sebeok 1977). Is it possible that the distinctive body markings of shark are used for such purposes? In certain cases, such markings may well be used as camouflage (e.g. disruptive coloration). However, many sharks show specific regions of pigmentation, such as along the edges and the tips of fins, that do not suggest functional camouflage (Fig. 14). Do these marking patterns have a social function? Do they provide important cues for species recognition (see Bass 1978; Johnson 1978)? What other communicative functions might they serve?

As one of many who has dived among sharks, I have been intrigued by the variety of body markings shown by these animals. For the purpose of accelerating interest in this particular aspect of the behavioral ecology of sharks, I would like to advance an idea about the possible function for the white fin markings of one species, the oceanic whitetip shark C. longimanus (Fig. 15).

While conducting acoustical experiments on oceanic sharks over the deep waters of the Tongue of the Ocean, Bahamas, during the mid 1970s, we often encountered oceanic whitetips that had been attracted to underwater loudspeakers transmitting various sounds. After arrival, these sharks moved slowly, almost lethargically, about the area. Their movements appeared uncommonly effortless compared to the movements of other sharks that we had observed over the years. The slow movements were deceptive, however. Oceanic whitetips could move with astounding speed for distances exceeding 50 m. Rapid movements were seen in several instances, e.g. after biting the steel loudspeaker or immediately after a sudden, loud sound was transmitted from a nearby loudspeaker. Attaining such high speeds could explain, at least in part, something long known about this particular shark--their prey often include some of the fastest moving oceanic fishes (e.g. tunas, various scombroids, dolphinfish and even white marlin). It is highly likely, however, that this shark cannot simply overtake such rapid moving prey in a test of speed nor sneak up on them in the clear open waters. One hypothesis has already been advanced to answer this intriguing problem (Bullis 1961): oceanic whitetips move into the surface schools of small fishes at the time when these schools are being preyed upon by the larger high-speed fishes. As the latter leap about feeding on their prey, they literally jump into the open mouths of the sharks. Although the hypothesis is viable, I must admit skepticism based on the requirement that a shark must be precisely positioned at the end of the trajectory of a leaping fish to achieve capture.

My alternate hypothesis is based on a visual effect that I often experienced while observing oceanic whitetips as they ranged throughout the surveillance area. Upon questioning other divers at the time, they also confirmed the effect that I now relate. As long as such sharks remained close by, their form was unquestioned. However, as they moved to the limit of visibility, my eyes were constantly drawn to their white-tipped fins, with the concomittant result that the grayish, countershaded bodies became indistinct. Actually, the shark-form disappeared unless attention was riveted on it. Accordingly when that form became indistinct, attention became immediately focused on the white-tipped fins, clearly visible as three to five spots moving in close formation. Occasionally, when two whitetips moved closely together at such distances, a "school" of white spots was seen moving through the clear waters. The effect was particularly striking during periods of low light when the spots stood out in far greater contrast that the darker body of the shark. Now comes the speculation--if the eyes of a human and those of several oceanic fishes are not too dissimilar as to general levels of sensitivity and acuity, the perceptual change that occurred (i.e. the white-tipped fins of a shark becoming a "school" of white spots) were considered, at a distance, to be a small school of appropriately sized prey, rapidly moving predaceous fishes might well move on a "bee-line" toward such "prey." Then, if such high-speed swimmers happened to reach a point where the sudden high-speed acceleration of the oceanic whitetip could overcome veering by the onrushing fish, **the latter could become the unexpected prey of the "spots."** I hypothesize that the above-mentioned scenario is true. The white spots of the oceanic whitetip shark might well be species-recognition marks. However, they appear also to possess another function as well—they are lures for attracting rapidly moving visual hunters into the near vicinity of their owners. Such a function explains also why the first dorsal and pectoral fins of the oceanic whitetip are so conspicuously large that they are often called "paddles." One way to improve the effectiveness of any lure is to increase its size so that it can be seen over a larger area. This would increase the probability of prey being attracted and thus provide the selective pressure necessary for increasing the size of the spots by increasing the size of the fins. One cannot disagree that the large pectoral "paddles" likely play an important role in the "gliding" movements of such sharks and that the large median dorsal fin likely adds stabilization to sudden, rapid forward movement (Weihs 1981). Nevertheless, apparently whatever forces initiated the increase in fin size, the spots benefited since their increasing size would lure prey from ever greater distances.

Thus, two hypotheses are now available to answer how oceanic whitetip sharks obtain their unlikely prey. Perhaps someone will come up with a truly neat experiment in the near future to test these and perhaps other hypotheses. Only by such means will this fascinating puzzle finally be answered.

FUNCTIONAL MORPHOLOGY OF THE SHARK BRAIN

Since we are now aware that sharks and their near relatives possess many of the attributes ascribed to the so-called "higher vertebrates," we, who study fish behavior, are pleased that yet another so called "truth" about elasmobranchs has been recently debunked. Sharks and their relatives were long considered as primitive feeding machines. Thus, it was perhaps not unreasonable to accept the "fact" that such animals have pea-sized brains. Accordingly, when early anatomists looked at the brains of a few species, specifically those most commonly available, i.e. the spiny dogfish, Squalus acanthias (a member of the most primitive group of living sharks, the squalomorphs) and the spotted catshar, Scyliorhinus canicula (one of the most primitive members of the galeomorphs), they did indeed find small brains. Such results, plus typological thinking, resulted in the initiation and the perpetuation of the myth that all elasmobranchs had brains similar in size to these species.

We can thank Glen Northcutt and his associates for the demise of this myth (Northcutt 1977, 1978). They demonstrated in elegant fashion that many elasmobranchs possess brains fully comparable in size to those of many avian and mammalian species (Fig. 16). Although any elasmobranch might be "pleased" to have the true story finally be told, they, as a group, are now part of another fascinating problem—long known, but never solved. The allometric relationship between brain size and body size among vertebrates does reflect, in a rough sense, a phylogenetic sequence, but that relationship has no known biological significance (Gould 1966, 1971; Jerison 1973). Information provided by elasmobranchs could possibly aid in clearing up this mystery.

Those galeomorph species studied generally have a two-fold to six-fold increase in brain:body ratios over that shown by all squalomorphs examined thus far; and the most highly evolved galeomorphs possess the highest known ratios among sharks. In like fashion, among the batoids, the primitive rajiforms possess low brain:body ratios, while the more advanced myliobatiforms have far greater ratios. The latter even exceed those of any known shark (Fig. 17 and 18) (this may change as the sample size increases, G. Northcutt, pers. comm.). In conversation with Dr. Northcutt dealing with these facts, we considered the idea that the allometric relationship between brain size and body size is reflecting some process(es) related to metabolic activity. This provides a fascinating set of questions since differences in metabolic activity (or efficiency) are likely among different groups of elasmobranchs. For example, do egg-layers and placental types have different levels of metabolic activity and do these reflect differences in brain:body ratios? Do squalomorph and galeomorph sharks differ in metabolic rates? What about rajiform versus myliobatiforms? Is locomotor activity somehow reflected by the brain:body ratio? It will be astounding if any of these questions is answered by a simple yes or no, since the questions themselves are likely far too broad in scope. Nevertheless, the elasmobranchs seem to be a group that might well provide some extremely interesting answers to some long standing questions in biology.

CONCLUSIONS

Our knowledge about the behavior of sharks is still relatively sparse and it is based on information from precious few species. Yet, that knowledge is vastly greater than what was available only a few years ago. Many facts have replaced the speculations and myths that were so intimately associated with these animals for so many years. Fortunately, the field had a group of pioneering workers: Perry Gilbert, Albert Tester, David Davies, Otto Lowestein, Sven Dijkgraaf, Stuart Springer, Leonard Schultz, Irenaus Eibl-Eibesfeldt, Eugenie Clark, Sidney Galler and others, whose interest and dedication provided the programs of research during the 1950s and 1960s that formed the groundwork for many of the studies mentioned in this report.

The number of scientists working around the world on behavioraly related studies of sharks has always been small, but even that number appears now to be dwindling. This may well be the case because such studies are often frought with serious difficulties, due largely to the nature of the animals themselves. Sharks are wide-ranging and inhabit a concealing medium. They are relatively swift swimmers and often move alone or in very small groups. Many species of interest are abundant only at remote geographical locations. Members of most species are fragile, requiring careful capture and transport, large holding facilities with highest water quality, and appropriate diet. Finally, many of the most interesting species, from the standpoint of humaninterest, are formidable and dangerous. When observers must enter the water in their vicinity, severe measures must be taken to assure their safety. These and other considerations, when taken together, often result in shark studies being long-term in nature, with data accumulating often too slowly for many of today's scrutineers and their associated funding agencies. Important advances in our knowledge of shark behavior will surely be made in the near future, so long as they are not deterred by the very processes that provided the means to reach our present level of understanding.

Table 1. Summary of experiments in which sharks were attracted to an underwater transducer (speaker) during playback of low-frequency, pulsed sounds[a] (from Myrberg 1978).

Family and species	Common name	Sound[b]	Author(s)
Alopidae			
Alopias sp.	Thresher	HF (N)	Nelson & Johnson (unpublished)
Carcharhinidae			
Carcharhinus sp.		FN (A)	Nelson & Gruber 1963
		FN (A)	Richard 1968
		FN, SqW (A)	Myrberg et al. 1969
C. albimarginatus	Silvertip	FN (A)	Nelson & Johnson 1972
C. falciformis	Silky	FN (A)	Nelson et al 1969
		SpF (N)	Evans & Gilbert 1971
		FN (A)	Myrberg et al. 1972
			Myrberg et al. 1975*a*
			Myrberg et al. 1975*b*
			Myrberg et al. 1976
C. leucas	Bull	FN (A)	Nelson & Gruber 1963
C. longimanus	Oceanic whitetip	FN (A)	Myrberg et al. 1975*a*
			Myrberg et al. 1975*b*
			Myrberg et al. 1976
C. melanopterus	Blacktip reef	FN (A)	Nelson & Johnson 1970
		FN (A)	Nelson & Johnson 1972
C. menisorrah	Gray reef	SpF (N)	Brown 1968
		FN (A)	Nelson & Johnson 1970
		FN (A)	Nelson & Johnson 1972
C. springeri	Reef	FN, SqW (A)	Myrberg et al. 1969
Galeocerdo cuvieri	Tiger	FN (A)	Nelson & Gruber 1963.
Negaprion brevirostris	Lemon	FN (A)	Nelson & Gruber 1963
		BbN (A)	Banner 1968
		FS (N)	Banner 1972
Negaprion fosteri	"Lemon"	FN (A)	Nelson & Johnson 1972
Prionace glauca	Blue	HF, StF (N)	Nelson & Johnson
		FN (A)	(unpublished)
Rhizoprionodon porosus	Sharpnose	FN (A)	Richard 1968
		FN, SqW (A)	Myrberg et al. 1969
Triaenodon obesus	Reef whitetip	SpF (N)	Brown 1968
		SpF, StF (N)	
		FN (A)	Nelson & Johnson 1970
		FN (A)	Nelson & Johnson 1972
Lamnidae			
Isurus oxyrinchus	Mako	HF, StF (N)	Nelson & Johnson (unpublished)
Orectolobidae			
Ginglymostoma cirratum	Nurse	FN (A)	Richard 1968
		FN, SqW (A)	Myrberg et al. 1969
		FN (A)	Nelson et al. 1969
Sphyrnidae			
Sphyrna sp.	Hammerhead	FN (A)	Nelson & Gruber 1963
S. tiburo	Bonnethead	FN (A)	Nelson et al. 1969

[a] Taken in part from Nelson and Johnson 1972.

[b] Types of artificially produced (A), and naturally recorded (N) pulsed sounds: FN, filtered random or white noise; BbN, broadband noise; SqW, square waves; SpF, speared struggling fish; HF, hooked struggling fish; StF, stampeded group of fish; and FS, fish sounds.

Table 2. Dietary supplements for captive sharks. Many of the vitamins and minerals are furnished in a single multivitamin tablet. Vitamins A, B_1, C, E and ferrous gluconate were separate tablets. These supplements have been used successfully for four years on lemon sharks and nurse sharks, and for two years on bull sharks and brown sharks (from Gruber and Keyes 1981).

Dietary addition	Dosage per kg animal weight per week
A	3570 I.U.
B_1	210.0 mg
B_2	0.39 mg
B_6	0.23 mg
B_{12}	0.9 mg
C	37.5 mg
Calcium pantothenate	0.6 mg
Choline	Trace
D	150 I.U.
E	37.5 I.U.
Ferrous gluconate	11.25 mg
Folic acid	Trace
Inositol	Trace
Kelp (iodine	18 μg
Niacin	0.6 mg

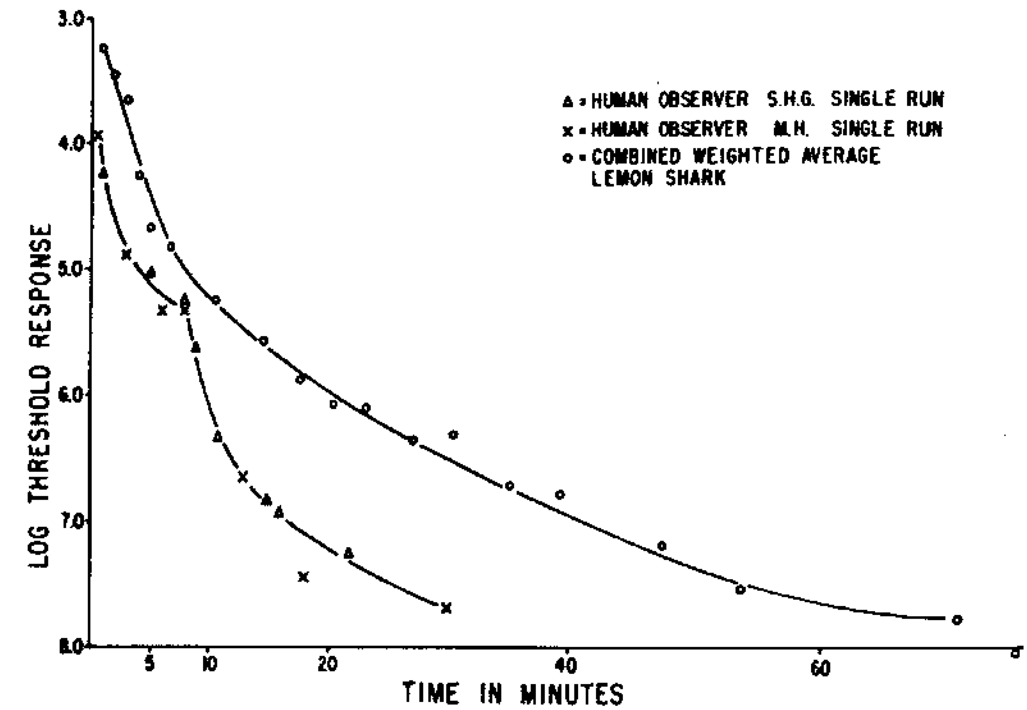

Figure 1. Comparison of the sensitivity to low light level and the time course of dark adaptation in the lemon shark Negaprion brevirostris with two human subjects. The points along the human curves represent single subjective thresholds obtained on the same apparatus used for testing the sharks. The single shark curve is an average of eleven curves (130 threshold determinations) obtained on five subjects. Note that the sensitivity shown by the sharks equals that attained by the human subjects; however, the sharks showed a slower time course of dark adaptation than that shown by the human subjects (from Gruber 1967).

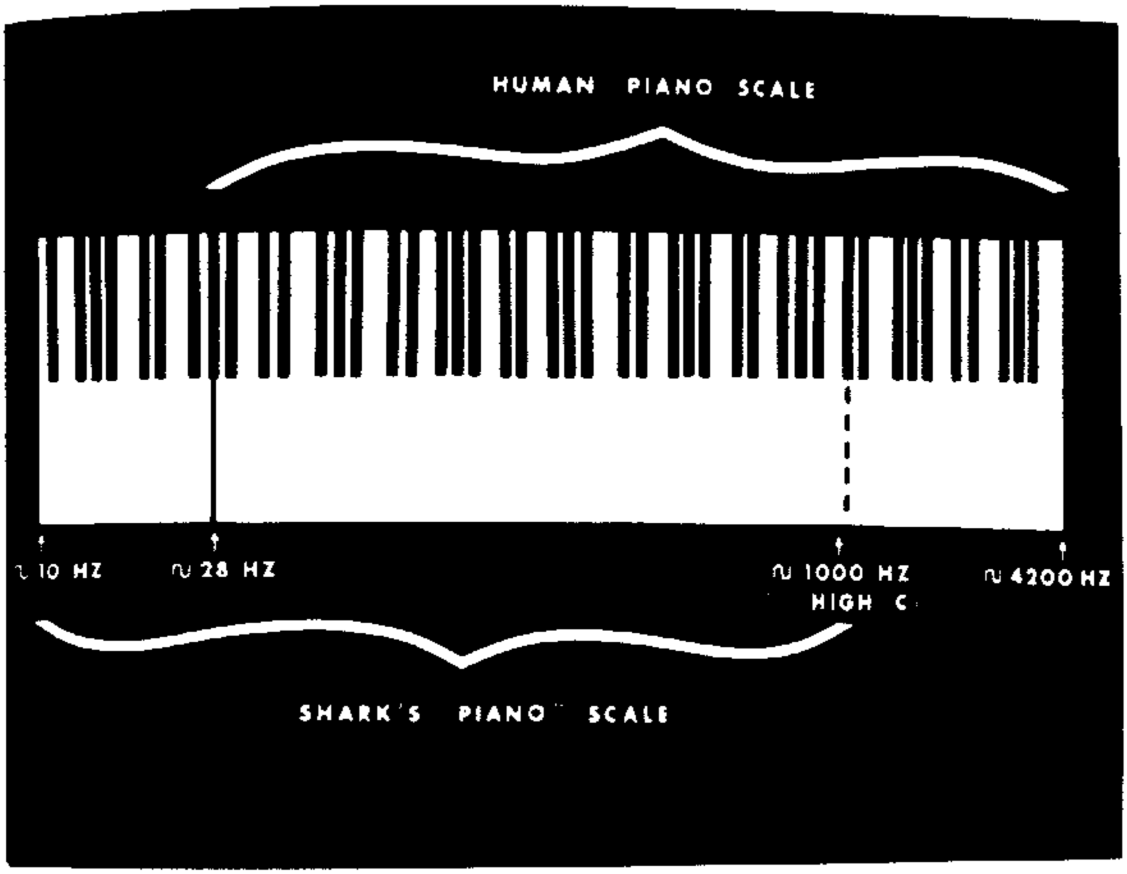

Figure 2. The extended range of low frequency hearing by sharks studied beyond that of human hearing is illustrated by the analogy to a piano scale. The frequencies shown are the approximate fundamental frequencies of the keys directed to by the arrows. Human hearing extends far beyond that of the highest fundamental frequency of the human piano scale; sharks probably do not hear frequencies higher than about 800 Hz.

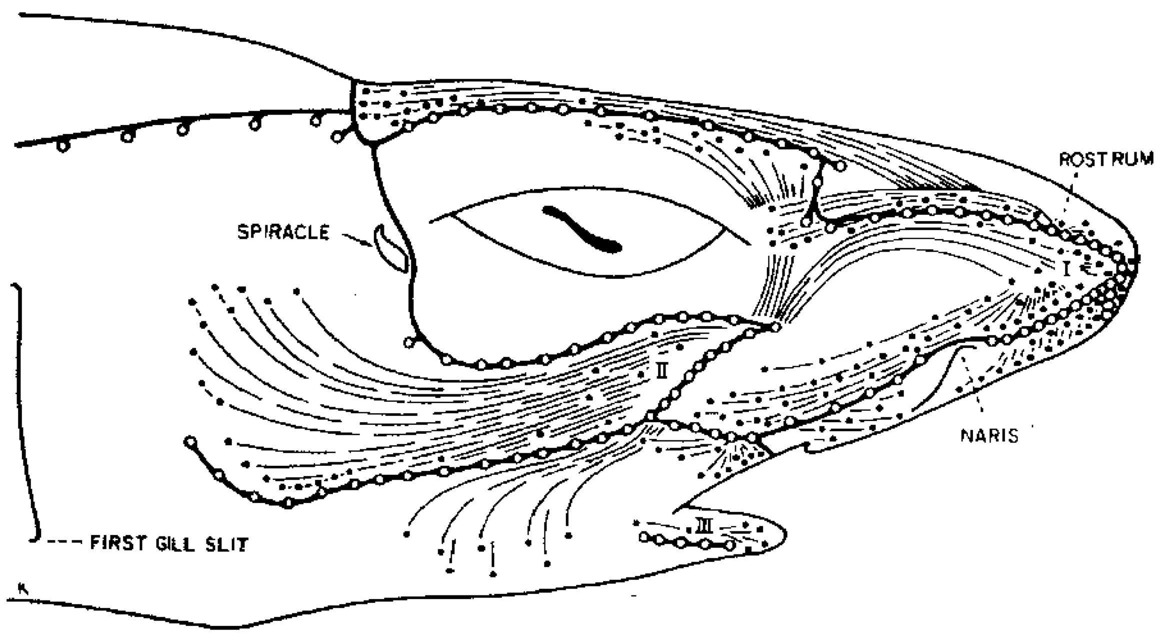

Figure 3. **Ampullae of Lorenzini and lateral-line canals in the head of the dogfish shark** Scyliorhinus caniculus. The opening of the Lorenzinian ampullae (solid dots) form a dispersed pore pattern. Each gives access to an often long jelly-filled canal (broken lines) ending in a blind sensory swelling. The lateral-line canals (in heavy black) contain the mechanoreceptive neuromasts. They connect to the outside through lineraly arranged skin pores (open circles) (from Kalmijn 1978).

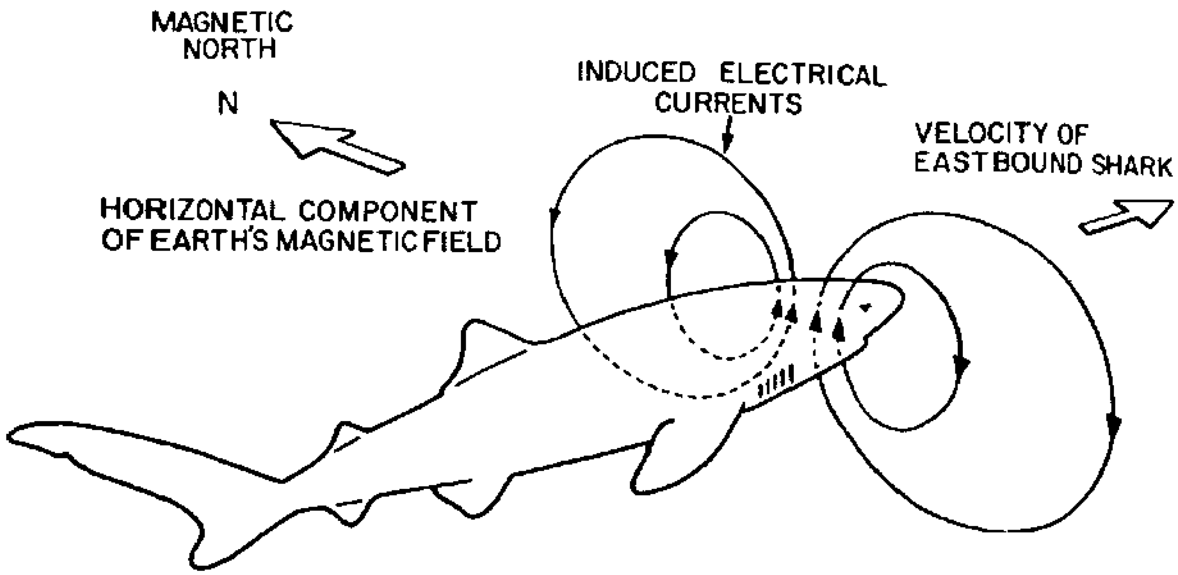

Figure 4. A shark swimming through the earth's magnetic field induces electric fields that provide the animal with the physical basis of an electromagnetic compass sense (from Kalmijn 1978).

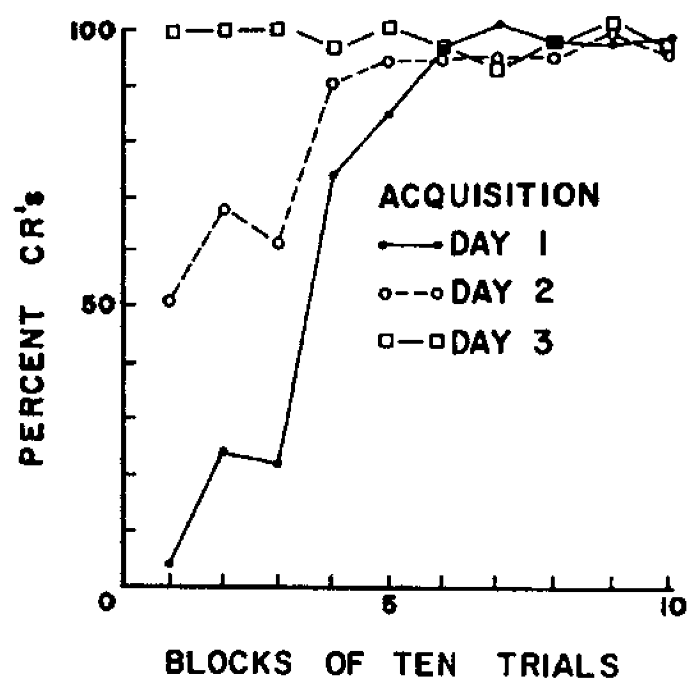

Figure 5. Course of acquisition of a classically conditioned movement of the eyelid (nictitating membrane) of the lemon shark (Negraprion brevirostris). Training consisted of pairing a flash of light with a low voltage electric shock 100 times a day (i.e. 10 blocks of 10 trials). Three days of training are shown. Note that the sharks reached nearly 100% conditioned responses by the 60th trial of the 1st day (from Gruber and Myrberg 1977).

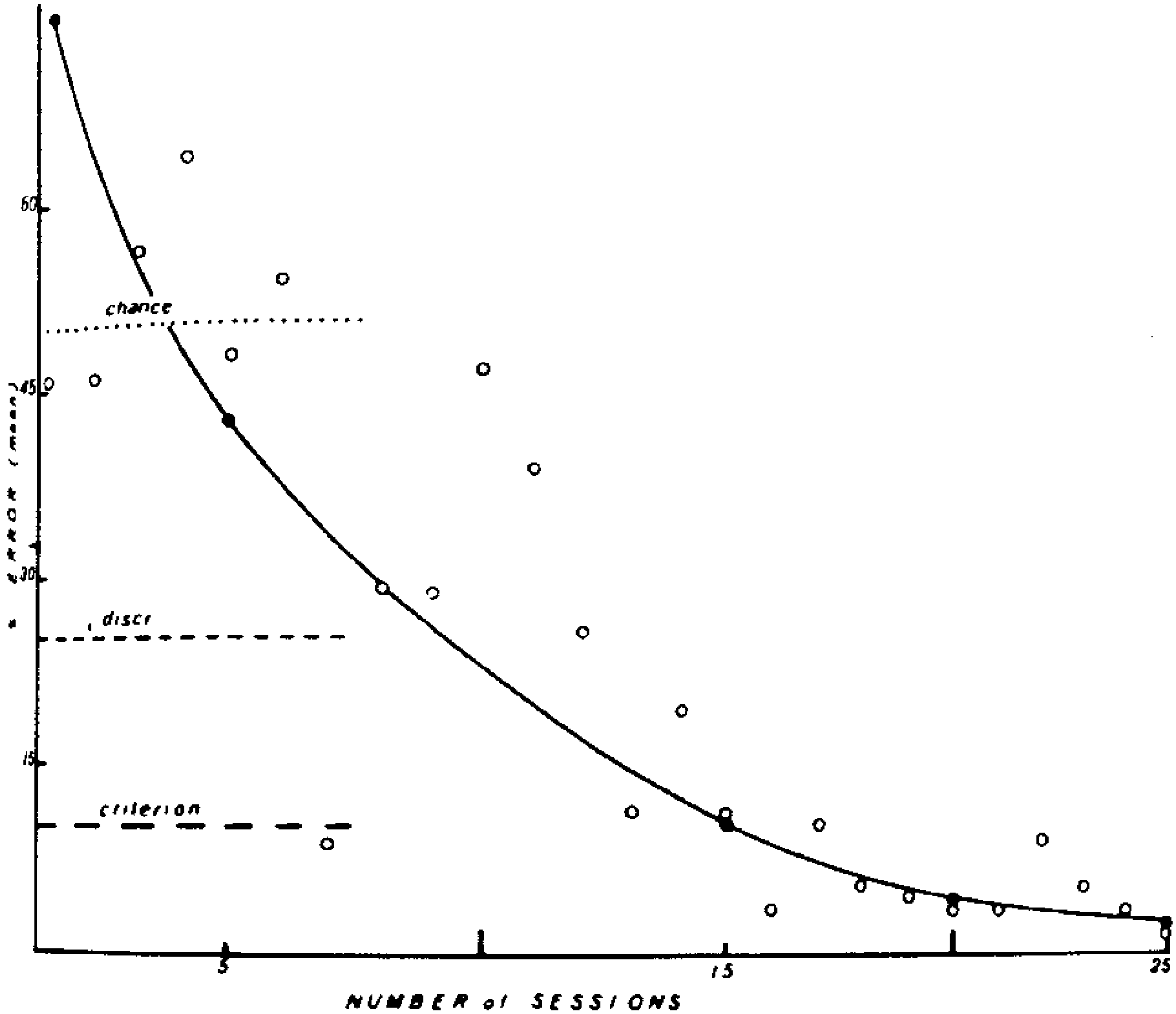

Figure 6. Instrumental learning curve of the lemon shark (Negaprion brevirostris) on a brightness discrimination task. Open circles represent mean % errors for six animals; closed circles were calculated from a standard curve-fitting procedure. Learning is signaled by the reduction in errors, i.e., choosing the dimmer of two lighted patches. Chance refers to random choice, i.e., the 50% correct level. Discr. refers to the 75% correct limit of discrimination usually acceptable in phychophysical testing while Criterion refers to the arbitrary 90% correct level chosen in the study (from Gruber and Myrberg 1977).

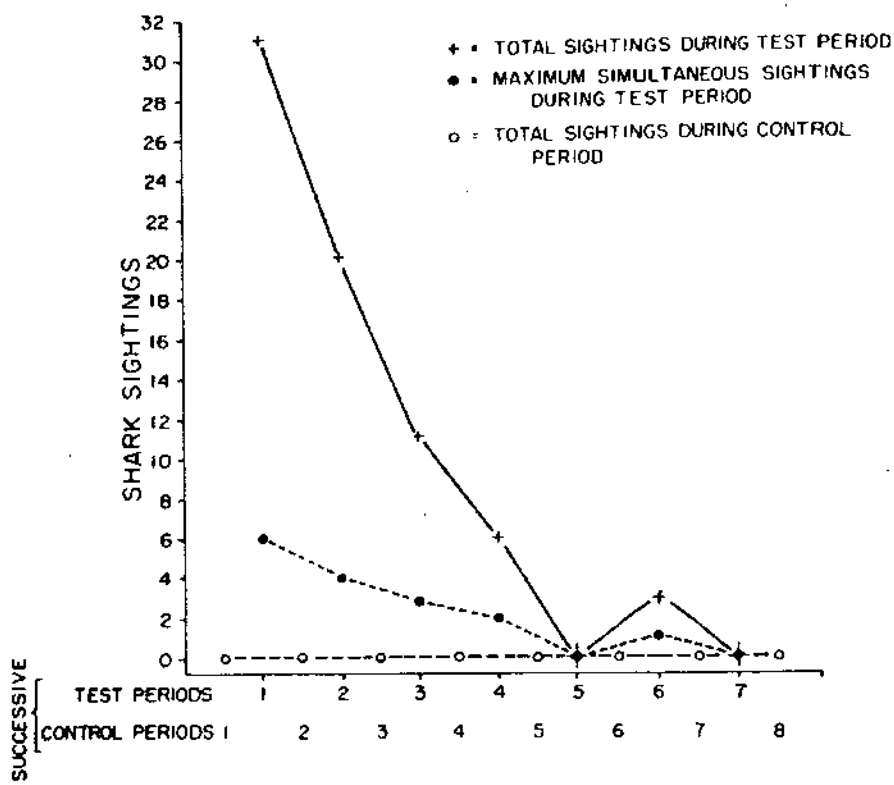

Figure 7. Decrease in sightings of free-ranging sharpnose sharks Rhizoprionodon sp. through successive test periods using sound as an attractant. Sound consisted of constant level, irregularly pulsed, overdriven 80 Hz sine waves (biphasic, symmetrical, and distorted square waves). Each test and control period--3 min. (from Myrberg et al. 1969).

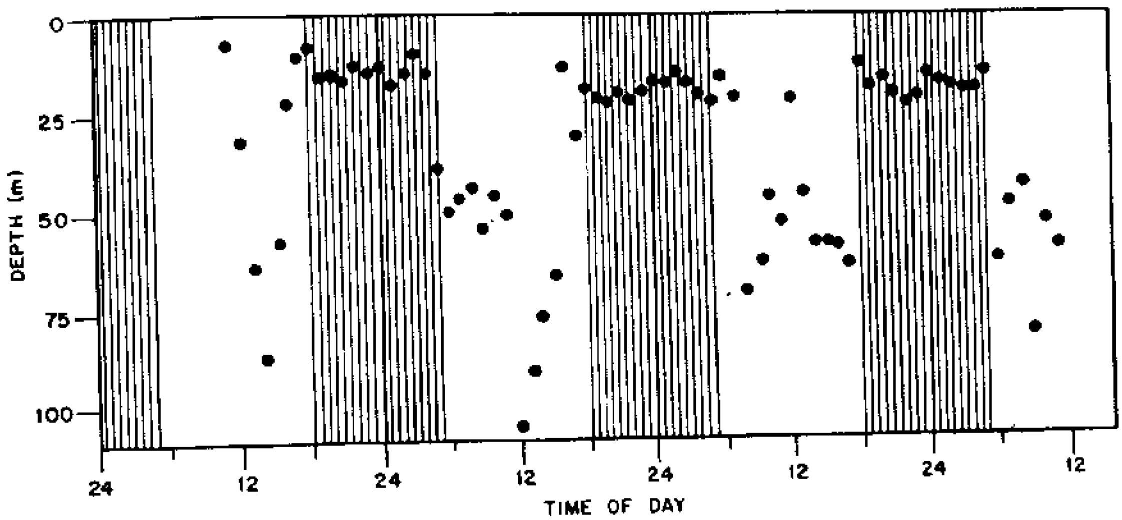

Figure 8. Rhythmic duirnal movements of one free-ranging, gray reef shark <u>Carcharhinus amblyrhynchos</u> tracked continuously for 72 hr. by acoustic telemetry (Rangiroa, French Polynesia). Shaded areas indicate times from sunset to sunrise. Note the distinct correlation between depth and time of day. First point is at the site of transmitter application (self-ingested in bait) in shallow water to which the shark was bait attracted (from Nelson 1978).

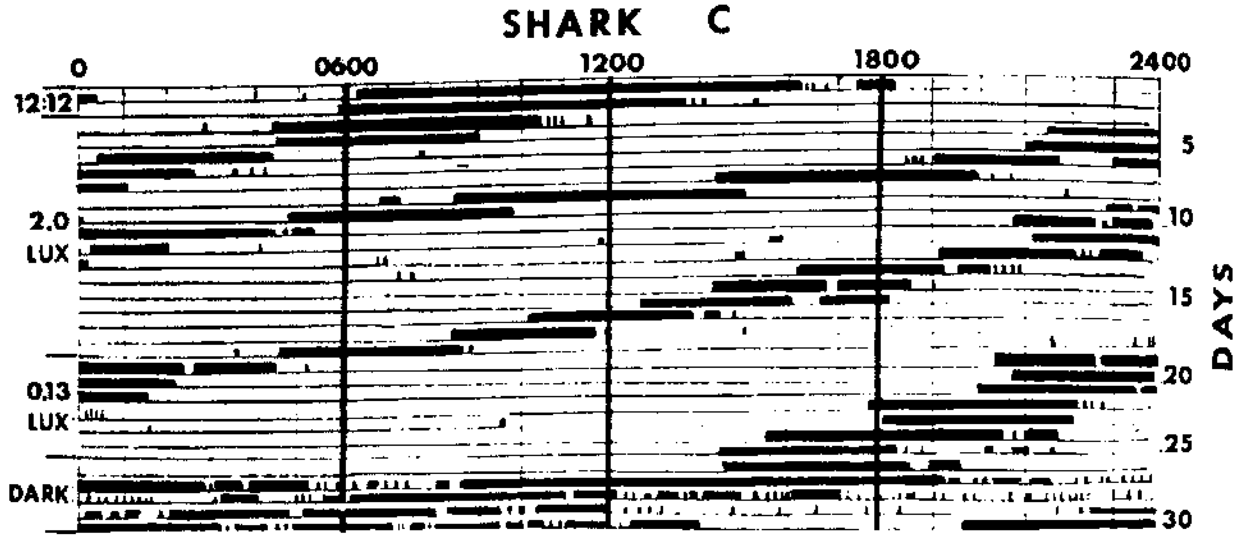

Figure 9. Laboratory demonstration of activity rhythms in a horn shark Heterodontus francisci as a function of light level. On day 5, the animal was placed in constant illumination of 2.0 lux (bright) and later in dim illumination of 0.13 lux. The solid bars across the graph represent motor activity steadily drifting out of phase with the time reference. Such drift is evidence favoring an endogenous circadian rhythm (from Finstad and Nelson 1975).

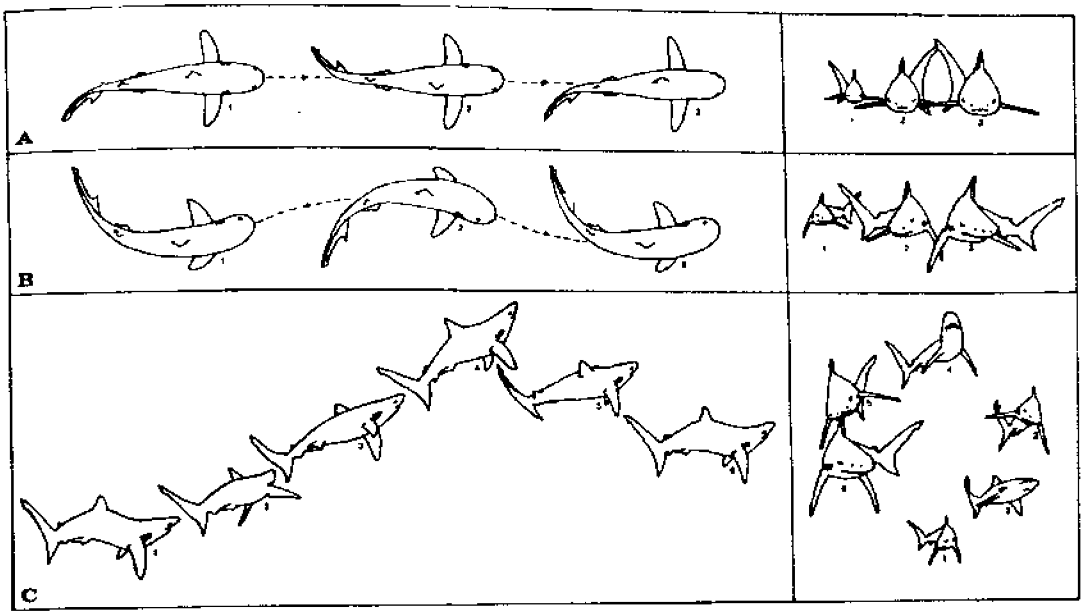

Figure 10. Comparison of normal and display swimming modes in the gray reef shark Carcharhinus amblyrychos: A. normal swimming; B. display, laterally Exaggerated Swimming and C. display, Rolling (1-2-1-2-1) and Spiral looping (1-6). Rolling, although similar to the initial phases of Spiral Looping, is distinct in that the shark returns to a level display attitude without entering into the up and down path seen in Spiral Looping (from Johnson and Nelson 1973).

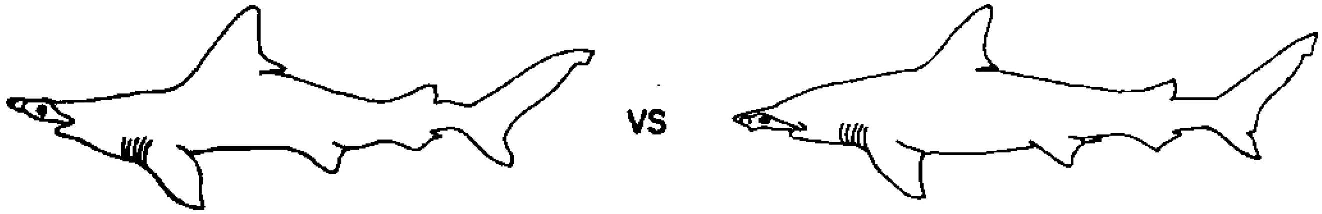

Figure 11. The agonistic display, Hunch (left figure), versus the normal posture (right figure) of a bonnethead shark Sphyrna tiburo. Note that the former consists of a riased head, lowered pectoral fins, raised back, and lowered tail fin. These same components are also seen in the Exaggerated Swimming display of the gray reef shark Carcharhinus amblyrynchos, where they are more highly developed (modified from Myrberg and Gruber 1974).

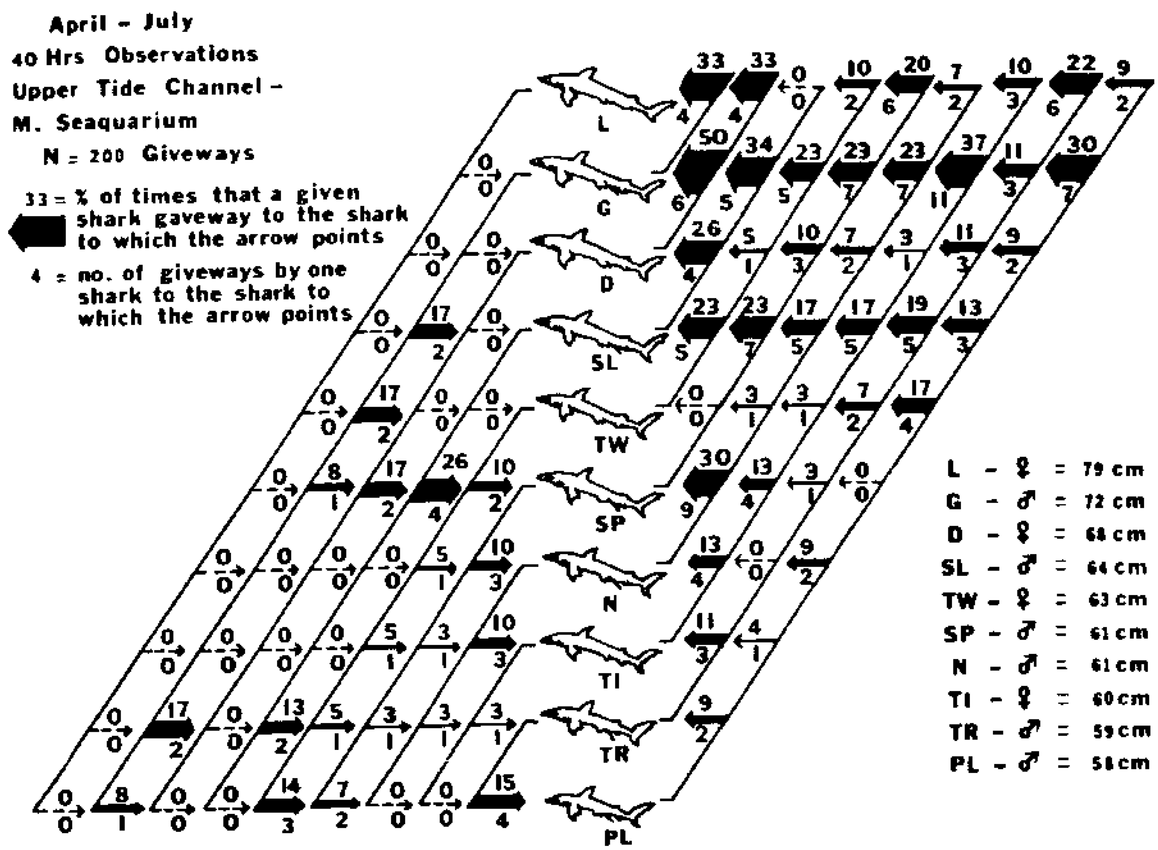

Figure 12. Social organization and dominance hierarchy in a captive colony of ten bonnethead sharks Sphyrna tiburo. In the diagram, sharks are ranked in order of descending size. Two diagonal lines are associated with each shark (except the largest and smallest). Each solid arrow points to the (dominant) shark that did not give way during a head-on encounter with another (subordinate) shark (source of the arrow). The thicker the arrow, the more frequently the former shark dominated the encounters with the latter shark. Sex also played a role in the hierarchy; note the consistently thicker arrows pointing to G, SL, and SP (i.e. the larger males) (from Myrberg and Gruber 1974).

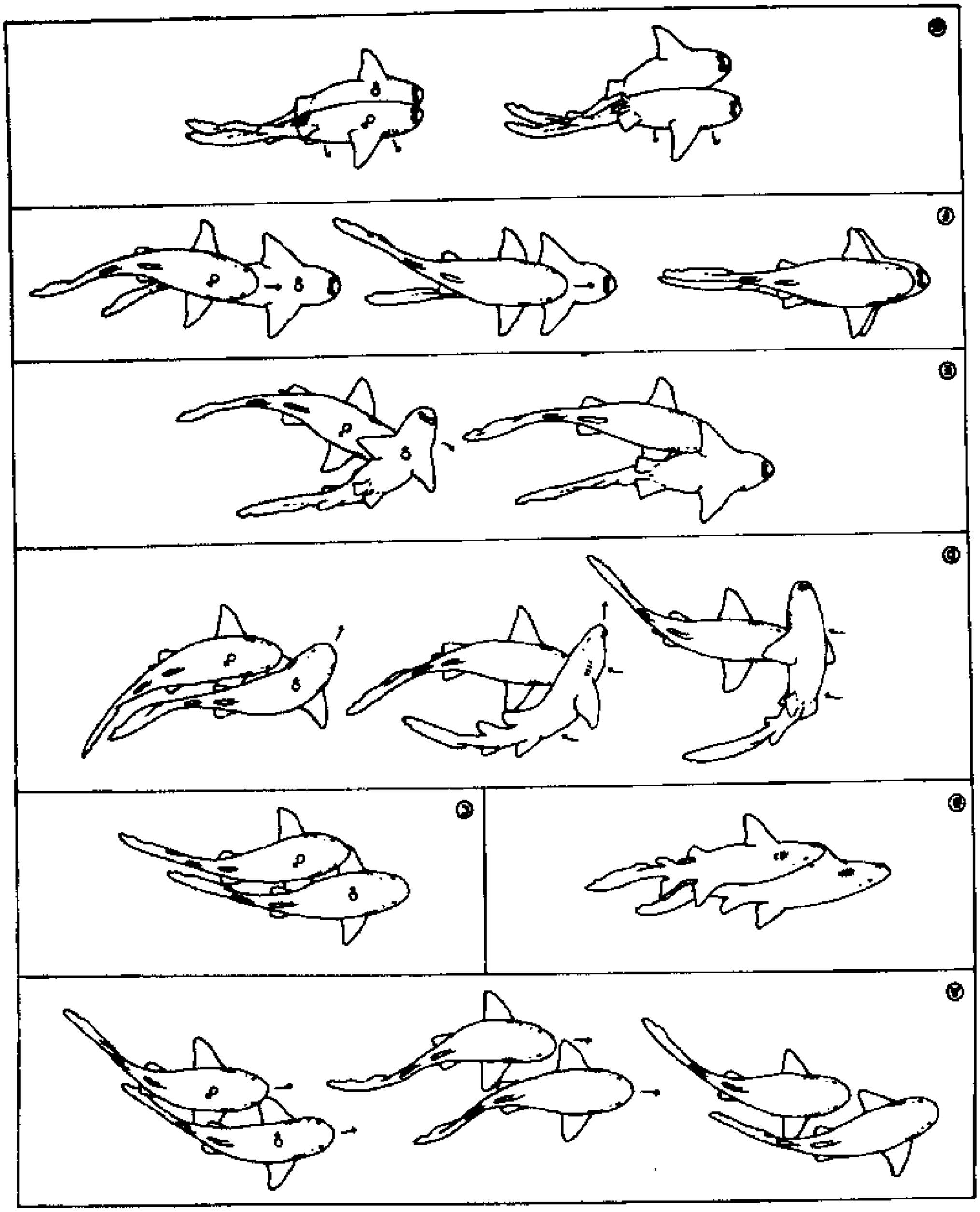

Figure 13. Courtship patterns and movements associated with copulation in the nurse shark Ginglymostoma cirratum: A) Paralled Swimming; B) Pectoral Biting (side view); C) Pectoral Biting (top view); D) Pivot and Roll; E) Nudging, Lying on Back (female); F) Male on Top (of female); G) Lying on Back (male, female). The actions are lettered in the order of their usual occurrence (from Klimley 1980).

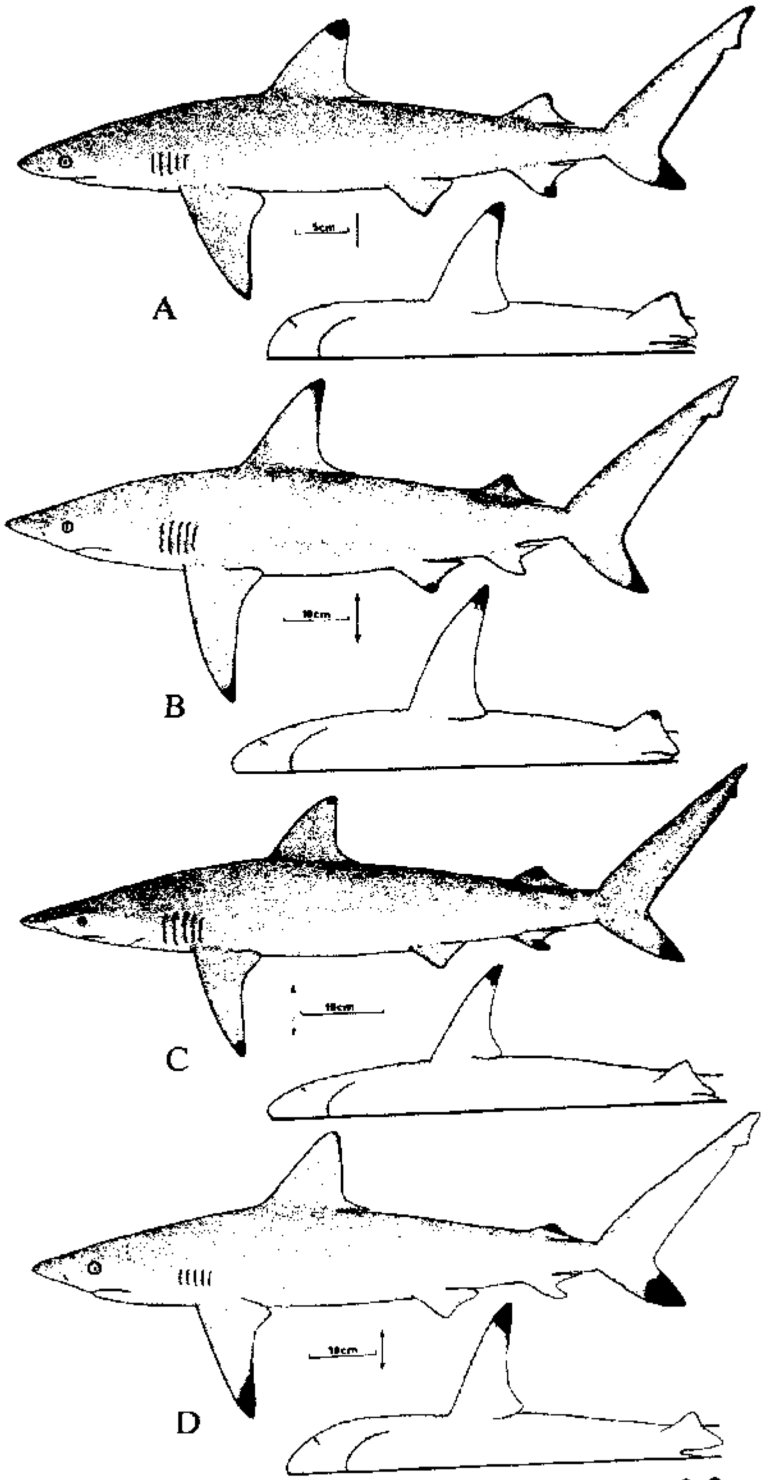

Figure 14. Comparison of the markings of four species of Carcharhinus from the southwest Indian Ocean: a. C. melanopterus; B. C. limbatus; C. C. brevipinna; D. C. sorrah (from Bass 1978).

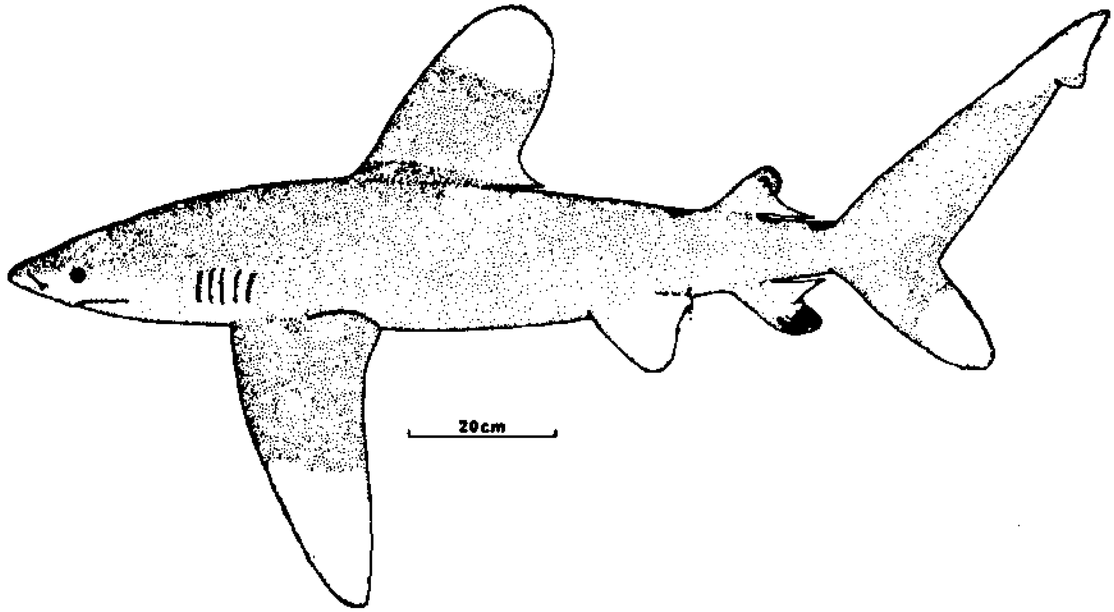

Figure 15. The oceanic white tip shark, C. longimanus). Note the large white regions of the fins and the large size of the first dorsal fin and the pectoral fin (compare with those shown in figure 14) (modified from Bass 1978, based on photos taken by the author).

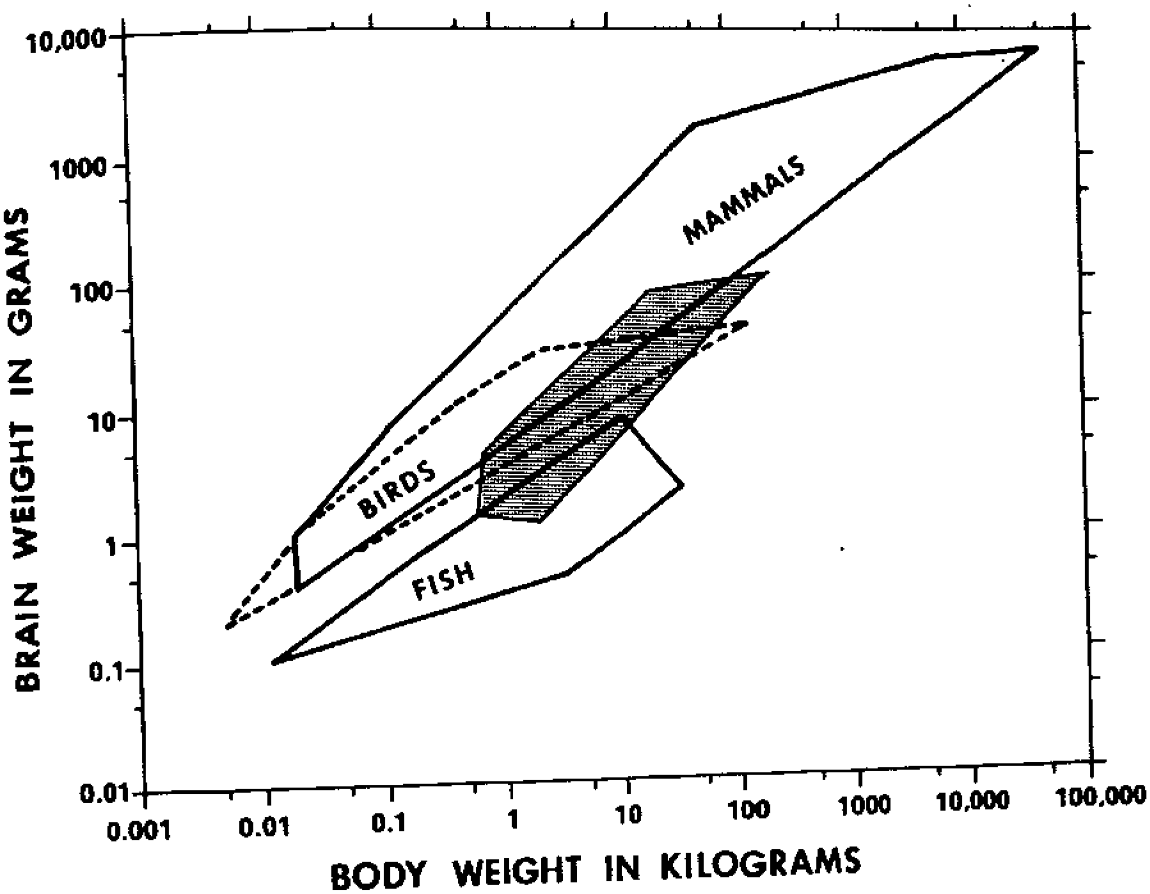

Figure 16. Brain and body weight for four vertebrate classes expressed as minimum convex polygons (each enclosing all ratios for a given class, see Jerison 1973; Northcutt 1978). Stippled polygon encloses elasmobranch brain-to-body ratios and overlaps polygons for bony fishes, birds, and mammals (from Northcutt 1978).

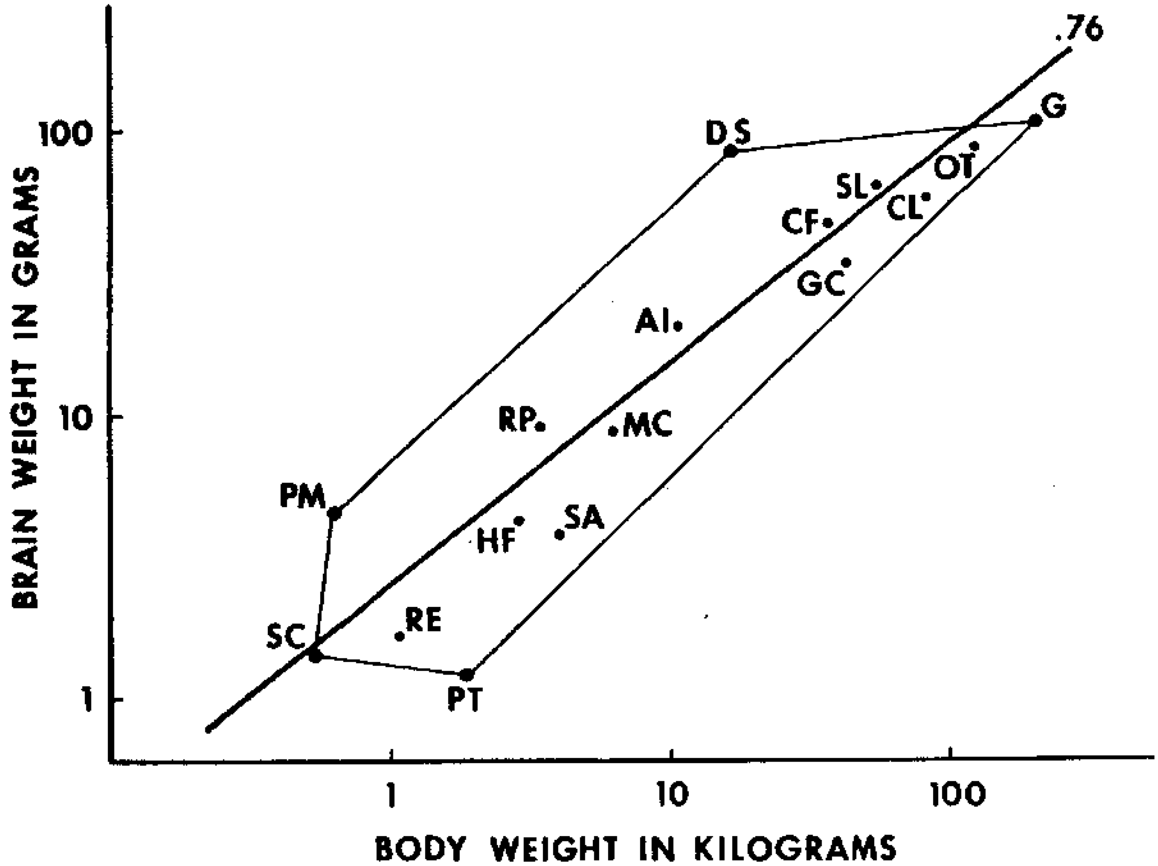

Figure 17. Detailed elasmobranch minimum convex polygon, illustrating positions of various taxa. Interspecific coefficient of allometry is 0.76 with a coefficient of determination of 0.86. AI, Aprionodon isodon; CF, Carcharhinus falciformis, CL, C. leucas; DS, Dasyatis sabina; G, Galeocerdo cuvieri; GC, Ginglymostoma cirratum; HF, Herterodontus francisci; MC, Mustelus canis; OT, Odontaspis taurus; PM, Potamotrygon motoro; PT, Platyrhinoidis triseriata; RE, Raja elanteria; RP, Rhinobatos productus; SA, Squalus acanthias; SC, Scyliorhinus caniculus; SL, Sphyrna lewini (from Northcutt 1978).

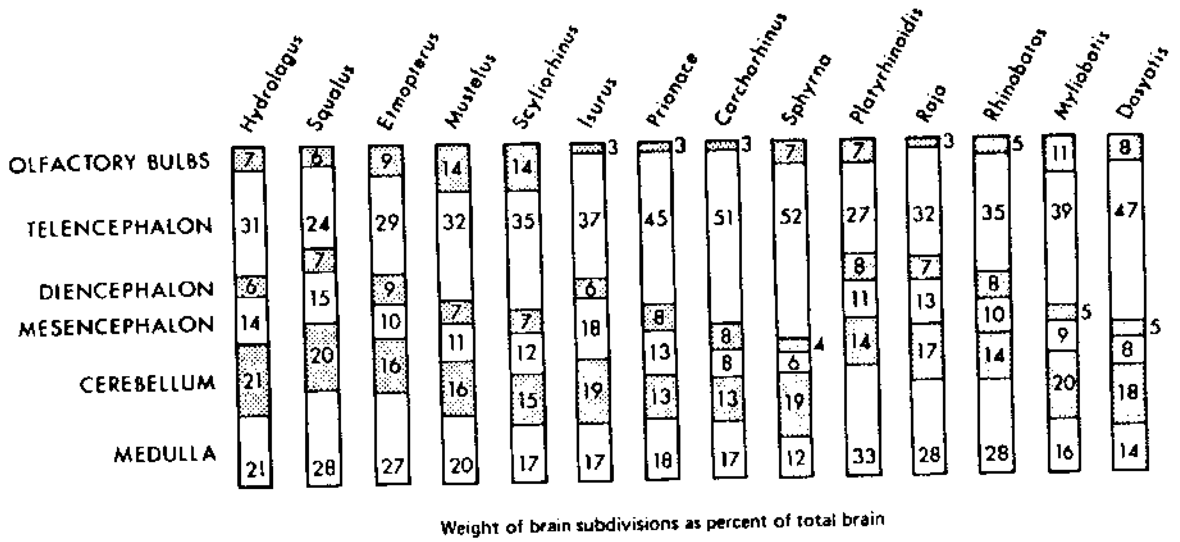

Figure 18: Relative development of major brain divisions in a number of cartilaginous fishes: Hydrolagus colliei, Squalus acanthias, Etmopterus hillianus, Mustelus canis, Scyliorhinus retifer, Isurus oxyrinchus, Prionace glauca, Carcharhinus milberti, Sphyrna lewini, Platyrhinoidis triseriata, Raja eglanteria, Rhinobatos productus, Myliobatis freminvillei, Dasyatis centroura from Northcutt 1978).

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The Significance of Sharks in Human Psychology

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Abstract: This paper examines the history of the shark as a mythological and religious creature, tracing legends and rituals that have included projections of the shark in the course of human history. A clinical investigation of the terror and fear associated with the portrayal of sharks in current media and popular literature, along with selected reflections on the shark as a particularly unique, symbolic carrier of repressed human emotion is addressed.

Introduction

> When a man sought to know how he should live, he went into solitude and cried until in vision some animal brought wisdom to him. It was the Holy One, in truth, who sent his message through the animal. He never spoke to man himself, but gave his command to beast or bird, and this one came to some chosen man and taught him holy things. These were the sacred things given to us through the animals. So it was in the beginning.....
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> Letakots-Lesa, a Pawnee Indian in a conversation with Natalie Curtis, an anthropologist, in 1907 (Campbell, 1983)

In 1971 I met my first shark. It was early January. I was three months away from being married and had hitchhiked with my younger brother down through Mexico over the New Year's break. Early one sun-filled morning we took a rickety Mexican bus north from Acapulco with plans to spend a leisurely afternoon at an isolated but well-known beach about 45 minutes north of the city. After a few hours swimming in the surf, I was laying on the beach, casually sipping a bottle of Mexican beer, when I heard a sudden burst of shouting, all, of course, in Spanish. Sitting up, I quickly became aware that everyone was out of the water except for my 14-year-old brother who now was swimming about 25 yards off shore. I saw the crowd shouting and pointing,

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trying to catch his attention. At first baffled and puzzled, I recognized for a split second the outline of a fin cutting through the water, then, again, and again, making a wide circle around him. Heart pounding, stomach queasy with panic, I yelled a warning in English and moments later he was on shore, safe but shaken. Later during that ten-day trip we were robbed by thieves and became sick with dysentery, but nothing will ever compare to, or match, the pure terror of those moments for me on the Mexican coastal beach. The memory, as one might imagine, has been told and retold at family gatherings. Only last summer he and I shared the story with a dinner table of wide-eyed teenage cousins in Michigan. Each time, of course, the shark becomes a little larger, the dorsal fin closer, the danger more intense. But such are what legends are made of.

It is July, 1985, late afternoon on rough seas 30 miles off the Oregon coast on a 52-foot charter boat and I watch a white-haired retired school teacher land a thrashing blue shark just south of Nelson Island. Sid Cook, coordinator of this Sea Grant conference and professional guide for the trip, will remember my words as I watched, mesmerized by that creature's clean white underbelly, glistening, alive, fighting, being lifted up into the boat against a setting western sun. Amidst the shouts of triumph and glee by the crew in response to a successful hunt, I am overwhelmed, almost embarrassed, with awe at the shark's raw, wild beauty. I whisper to myself quietly, repeatedly, "Beautiful...beautiful...."

These two quite different encounters and experiences provide a framework for this brief, playful, but hopefully insightful examination of the history of the shark as a psychological, mythological, and religious creature. Tracing the development and profusion of legends and rituals that have involved these creatures during the course of human history, the following considerations seek to integrate certain clinical observations regarding the high degree of terror and fear that dominates portrayals of the shark in current media and popular literature. This study also highlights selected reflections on the unique role that the shark appears to have carried for repressed, exaggerated emotions, both historically, but even more critically, currently, in contemporary Western society.

The Shark in Legend and Ritual

The shark has long held a fascinating place in the story of human beings and their relationships to creatures of the sea. These predators of the deep have been regarded down through human history as vengeful gods, to others as guardian spirits, to still others, cunning devils. Legends, Pacific island tribal rituals, and religious rites appear to reflect a bi-polar (good-evil) understanding of the shark's power and presence.

In the Solomon Islands, deified sharks lived in sacred caverns built with stone altars in lagoons. Ancient rituals often entailed the sacrifice of human victims.

Along the Vietnamese coast, among the scars of the Vietnam War, craters and abandoned rusting tanks, one can still find temples made of stone to honor

"Ca Ong" (the whale shark) who is believed to cruise and protect the long and winding tropical shoreline.

In Pearl Harbor dredging operations for a dry dock in 1907 uncovered remnants of an ancient shark pen. When the $4 million structure collapsed because of unsure foundations midway through the project, local native peoples whispered among themselves that the Queen Shark was bringing her wrath down on the construction companies.

Among native populations in the South Pacific, a close and unique relationship has developed over hundreds of years. A.J. Laplante, in the period between 1928 and 1943, recorded that islanders in the Figi Islands could subdue sharks by kissing them. Twice a year when the natives made a drive for food during tribal feasts, or when they wanted to make the swimming areas safe from sharks, he wrote:

> The night before the drive the man who wants the shark fishing done goes to the house of the chief, who is also a sorcerer or medicine man. There they enact a ceremony which survives from their oldest beliefs. This ceremony includes the presentation of Kava, a mildly narcotic beverage made from juice extracted from a ground root. The next day the natives drive the sharks into a large net, the shark kissers wade out, seize the man-eaters, kiss them on their up-turned bellies, and fling them on to bank. Among native people, it is taken for granted that once a shark is kissed upside down, it will be safe, cooperative, and harmless.
>
> McCormack et al. 1963

For the Hawaiians, sharks are frequently seen as incarnated ancestors, and among the Tongans, a neighboring island people, divers who regard the shark as a guardian spirit continue to dive among them, for commercial reasons, with no fear. There remains no record of any attack, rumored or otherwise.

Hamilton Green, Makah tribal member and longtime resident of the tiny whaling village of Neah Bay, located out on the edge of the Olympic Peninsula in Washington, tells a story handed down through his ancestors, that, on the other hand, represents the dark and threatening nature of these roaming carnivores of the sea. Off the edge of Cape Flattery, he says, there is a rock formation which marks the place where a great monster fish (a great white shark) was said to have been killed by the supernatural warrier Klady after being taken into the shark's belly and carving out the shark's heart from the inside with a mussel shell (Green, 1985).

Tall tales have, of course, grown up around the shark's mysterious reputation for its nomadic traits and well-documented ability to travel great distances. Sailing ships often left a trail of garbage behind them followed by sharks, and, for centuries, sailor's imaginations were fired by superstitious terror. Mark Twain told a story, for instance, that was believed for years as fact. Supposedly, by catching a shark near Australia that had swallowed a newpaper in London ten days before, one Cecil Rhodes obtained advanced information about a rise in the wool market and thus made prudent investments that were responsible for his ability to amass his vast fortune!

The Shark as Myth and Symbol

The word "shark" is as hazy as the origin of the ancient shark family itself. Apart from more specifically scientific categories and designations such as Carcharodon carcharias (white shark) and Lamna ditropis (salmon shark), etymological roots point to certain characteristics of the shark itself. "Schurke" is the German word for villain, the Anglo-Saxon root "sceron" means "to cut or shear." Since Elizabethan times, frequent images and meanings have accompanied casual popular usage of such terms as loan shark, pool shark, card shark, and business shark. The sound of the term itself is sharp and carries a harsh, piercing note of emergency, terror, surprise, and cunning.

Below is a sample of images that are associated with the word "shark," and gleaned by the author from an informal sampling of commercial shark fishermen, educators in the oceanography field, and residents from a typical urban environment.

From a Samoan Island businessman

danger
man-eater
scavenger
killer

From a chef in an exclusive hotel

recipes
marketability
customer comments
price structure

From a hotel maintenance worker

great white
"Jaws"
fishing
teeth

From a commercial shark hunter (sport)

money
tackle
weather
mako

From a university student

teeth
fin
"Jaws"
fish

From an Alaska State Fish and Wildlife worker

deep water
helpless
white foam
frantic swimming

There are two rather intriguing aspects or patterns that emerge from the preceding responses. The first is that none of the respondents has ever witnessed an attack by a shark on a human being nor has ever had an acquaintance who has experienced such a traumatic event. A second note of interest is the remarkable similarity of images regardless of the wide variety of their personal vocation and life experience, some of which reflected a strong reality factor in terms of working with the sea in practical scientific and commercial endeavors.

The responses might suggest that the shark as an image of terror and destruction might be more influential than the actual experience of the shark as a specific, biological creature with distinctive habits and characteristics. What is disconcerting is that this holds true with persons who work in close proximity with sharks themselves.

One can witness the collective aspect of this phenomenon in recognizing that among traditional Japanese culture, one of the gods of the storm is the Shark Man. In fact, the shark is so terrifying in Japanese legends that when the Chinese looked for a symbol to paint on their war planes while raiding the Japanese during World War II they chose the leering face of the Tiger shark, and these planes became known throughout the world as "flying tigers." In actuality, they might have been more appropriately nicknamed "flying sharks."

There are, upon closer examination, peculiar characteristics about the shark as a creature of the deep that point to several specific reasons that underlie the shark's reputation as a potent symbol of power and fear. Among them could be considered these four:

1. The shark is, in a very real way, "king" of the primordial seas. Human beings have lived perhaps a million years. Shark fossils go back as far as 350 million years, and their structure and biology has remained basically unchanged. The shark is the largest fish in the sea (the whale is classified as a mammal).

2. Unlike most creatures of the natural world, the shark has the unique characteristic of feeding on its own kind. It knows no natural predator except a killer whale and an occasional swordfish.

3. The shark holds an amazing, remarkable, tenacity for life. Gaffed, shot, harpooned, and even gutted, its jaws can still rip and cut the hand or leg of a careless fisherman.

4. It lives at great depths in the ocean and is constantly on the move. Jacques Cousteau in his famous study, **The Silent World**, writes, "From my own experience covering many varieties, I can offer two conclusions: First, the better acquainted we become with sharks the less we know them. Two, one can never tell for certain what a shark is going to do. Because they are more a potential than an actual danger to a diver, they lead the swimmer to a disregard for them that can prove to be fatal." (Cousteau, 1952)

The Shark as Projection

One of the more fascinating discoveries that emerges from any serious study of the shark and its impact on human consciousness is the contrast between expectation and fact, image and data. There are basic fundamental contradictions. Among them is the simple acknowledgement that the International Shark Attack File, which monitors all shark attacks on an international basis, has tracked less than 1500 actual shark attacks since 1560 A.D. Twice that number will die from AIDS this year in the United States alone. Fifty thousand will be killed each year in traffic accidents on our own nation's roads. Airline catastrophes cause the death of at least that many persons in any given year. Then why the inordinate fear?

In the scientific discipline of psychology, the study of human behavior, there is a phenomenon, identified by analysts, as projection. It colors all human relationships and is often subtle, sometimes humorous, frequently dangerous.

Projection was first identified and defined in a formal way by Sigmund Freud, the father of modern psychology, at the turn of the century (Nicholi 1978). Simply speaking, it is a common and important action of the personality that involves taking that which one cannot or will not internalize or accept and "projecting" that characteristic or emotion onto another person, place, or thing. Examples can be found in large families where there is frequently someone, usually a child, regarded as the "bad seed." This individual carries, in many situations, the unconscious negative projections for the rest of the family. Sociologists identify the same parallel among criminals or delinquents in a social system. The projection, in that instance, would involve "bad" or "dangerous" individuals who need to be removed from society. This is a less threatening alternative than recognizing that the great majority of "criminals" are products of abusive families, poverty conditions, and violence which is often indirectly related to the inadequacies of any social system that demands unhealthy degrees of conformity and standardization.

Animals, too, carry projections, as we all are aware. In my own family, our golden retriever is the focus of a lot of my own projected feeling of frustration. The other day when I was shouting at him, my six-year-old daughter approached me and asked, "Dad, why are you talking to Pippin like that?" Now she didn't know the fancy name for projections, but she knew something was wrong, out of balance.

And so we might ask ourselves, if with a smile, is our friend the shark getting a rap? Is there something that is carried by our imagination and fear that meets us in our sometimes diabolic fascination with this king of predators? I suggest that in this question lies the opportunity to look closer at ourselves. Three possible issues present themselves in this regard, and each of them holds implications not simply for the potential future of a commercial shark fishing industry, but also in terms of an integration of our own psyches as children of a modern world.

First, contemporary attitudes toward the shark reflect a hostile attitude toward nature. Few people celebrate the fact that sharks play an important and invaluable part in the great ecological cycle. From a more balanced perspective, they are the greatest carnivores of the sea—a vast collective, natural, organic, disposal system. All we tend to see, however, is potential death, terror, and destruction. Our dominant posture of fear and domination of the shark may suggest a basic alienation from the natural world. Certainly the parallel extinction of both animal and plant species in the natural order would suggest such. The full implications of such an analysis, of course, remain to be explored, but the danger of an antagonistic attitude toward nature reflects an increasing and dangerous split in the psyche of contemporary man himself.

A second projection mirrors itself in the possibility that the shark is, for most of us, representative of a terror of the unknown. The fear of the shark may be directly linked with a fear of the deepest parts of our own being, traditionally linked to and honored by religion, but in more modern times, usurped by materialism, technology, and the resulting desperate need to conquer and control. The fear of the shark, protrayed by such movies as "Jaws" and its subsequent exploitive sequels, may reflect a fear of our own inner instinctual world.

The third issue that emerges takes shape as a warning that we implicitly receive from native groups, in this case island people, who have continued far longer than us, to live close to the earth and to the cycle of nature itself. As we have seen in our earlier exploration of legend and symbol, the shark has carried for them a bi-polar attraction and repulsion. In other words, for the more primitive psyche, the shark has always carried <u>both</u> a negative and positive projection. In contrast, to children of a modern world it carries an almost exclusively morbid, negative meaning.

In the centuries-old symbol system of Asia and Africa, archeologists have deciphered certain symmetrical forms which carried important meanings for the world as ancient cultures understood it. One such little known geometric form was the "mandrola" (Fig. 1) (Cirot 1967). For primal peoples, the circle was the basic dimension and shape of reality, a sign of wholeness, seasonal change, biology, psychology, and ecological balance. But an accompanying perspective on the basic nature of the life process involved the mandrola.

This symbol entailed a recognition of a certain polarity and tension underlying nature and virtually all human relationships. The intersection of two dimensions (light vs. dark, male vs. female) is the area of the mandrola. It is a sacred space and ancient peoples chose several animals and creatures to represent this two-faceted experience. One was the snake, another the bear. The third, interestingly enough, was the shark. This recognition corresponds to a long-time custom of the Samoan islanders who eat shark as a "chieftain's food." In other words, the shark itself may carry for the human species a potential connection to an untamed, primitive and beautifully powerful world that lies deep within our own collective psyche.

This may account for the fascination of the "hunt" for the shark and the renaissance of its study and power. It also carries an implicit warning perhaps that the shark will never permit itself to be domesticated and produced commercially for consumption. Among native peoples, its mystery and elusiveness, its unpredictability, beauty and terror, protect and enhance its symbolic power as the great predator of the seas. For those with different more utilitarian agendas, I will watch with interest in years to come, but my bet will be with the elusiveness and final victory of an animal that remains mysterious, free, and untamed. Not unfit for human consumption, but, in a unique and mysterious way, too "sacred" for such.

Acknowledgements

The author would like to thank Mr. Hamilton Green for conversation regarding legends of the Makah tribal people, Neah Bay, Washington.

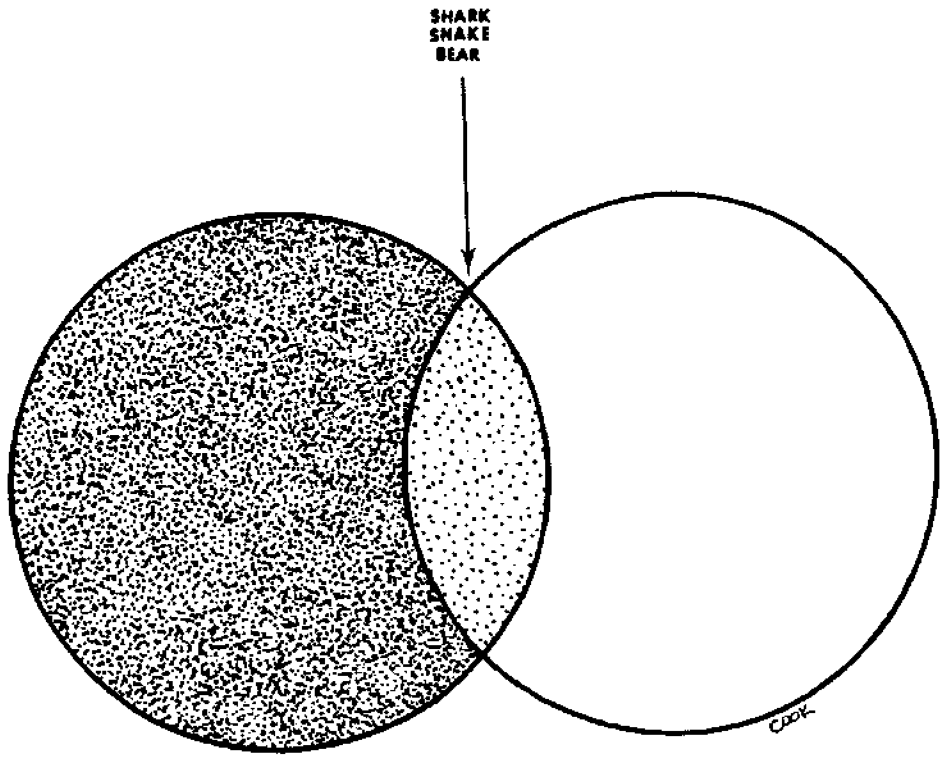

Figure 1: The Mandrola Symbol

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Pacific Coast Shark Attacks: What is the Danger?

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Abstract: Since 1926, sixty-one unprovoked shark attacks have been recorded for the California-Oregon coasts. Attacks are also known from off Baja California, Mexico but reliable information for this geographic area is incomplete or sketchy. No shark attacks are known for Washington, British Columbia, or Alaska - it is probable that this record will not stand

Recent attacks involving humans have included surfers, skin divers, scuba divers, and swimmers. Wind surfers and ocean kayakers have not as yet been implicated; it is likely that these modes will be affected in future encounters.

There has been much recent speculation regarding increased numbers of white sharks off our coast. This concept is not supported by recent human-shark interactions. Of 37 species of sharks occuring in the eastern North Pacific (north of Mexico), only six or seven are potentially dangerous. It is the great white shark, <u>Carcharodon carcharias</u>, which is of greatest concern.

The probability of an encounter, by a surfer, diver, or swimmer, with a dangerous shark is exceedingly low; there is an average of only two attacks per year (range 0 - 7). Measures which can lessen the incidence of potential encounters can hopefully be gained from the analysis of shark attack data.

The Forensic Study of Shark Attacks

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Abstract. The infant science of forensic shark attack investigation and analysis traces its origins to the formation of the Shark Research Panel by the American Institute of Biological Sciences (AIBS) and the U.S. Navy in 1958. In the ensuing 28 years, a group that has never numbered more than 300 field investigators has begun to untangle the myths of attack-related behavior, advancing us from the realm of observation toward one that is quantifiable and empirical.

Historical Background

Shark attacks have been recorded at least as far back as the writings of the Greek historian Herodotus in 492 BC (Burgess 1970). Since little scientific information existed on sharks until recently, the reporting of such incidents resided largely in the realm of popular myth, superstition, and fanciful speculation (Gilbert 1963; Gilbert et al. 1967; Baldridge 1974; Ellis 1976; Wexler 1982). Sharks and bears, among a small group of wild animals, have traditionally represented such a mysterious and unfathomable force in nature that nearly anything that is attributed to them is accepted without critical testing (Jon Magnuson, psychotherapist, pers. comm.). Because sharks inhabit a concealing environment in which humans have been awkward and temporary visitors, they have resisted mankind's attempts to understand and to dominate them better than most animals (Myrberg 1976). As with other things that man cannot control, he assigns them stereotypical "human-like" (anthropomorphic) characteristics which tend to reduce the value and magnificence of these animals or to convey characteristics to all sharks which may, under specific conditions, apply only to single individuals. In formal logical arguments, this would be referred to as both a "fallacy of hasty generalization" (invalid argument predicated upon an example which is not representative of the group) and a "fallacy of composition" (invalid argument that occurs when certain characteristics of the parts are construed to be also characteristics of the whole) (Hurley 1985). In the case of shark behavior such arguments might take the common form, "a shark viciously attacked a man last Saturday, therefore all sharks are vicious man-attackers."

When all of this is further viewed in the context of the public's affinity for media reporting of seemingly sensational events (Steve Boyer, Bellevue Journal-American Newspaper, pers. comm.), it is not difficult to see how legends have grown without much regard for the degree of reality contained in them. This has seriously interfered with our understanding of cause-and-effect relationships in shark attack behavior toward humans.

Though humans have undoubtedly interacted with sharks down through history, it has only been in the twentieth century, more particularly since World War II, that there has been a keening of interest in the scientific community toward unlocking the secrets of attack behavior. The vast preponderance of the work in the infant science of forensic shark attack investigation and analysis has been completed since the formation of the Shark Research Panel (SRP) by the American Institute of Biological Sciences (AIBS) and the U.S. Navy in 1958 (McCormack et al. 1963; Miller and Collier 1980; Compagno 1984). Prior to the mid-1950's the major interest in sharks centered upon finding effective means of preventing attacks through the use of mechanical barriers (Australia) and chemical deterrents (U.S. Navy during World War II). Little effort was directed toward discovering underlying causes and effects related to ways in which human behavior might affect shark behavior. Most information entering the scientific record was gathered from military debriefings of personnel stranded at sea (Llano 1957) and from passive accounts derived from newspaper clippings without field investigators being able to interview victims and survivors first-hand (Miller and Collier 1980; Bernard Zahuranec, U.S. Navy, pers. comm.).

One of the first detailed on-site investigations of shark attacks by a qualified field observer was made after the fatal white shark attack upon Barry Wilson at Monterey Bay, California, in December 1952. The investigation, which was conducted by Rolf L. Bolin of the Hopkins Marine Station at Pacific Grove, California, was prototypic in its thoroughness and by its application of an in-depth analysis of contributing factors of weather, chronology of the attack, rescue efforts, possible causes of the attack, photography of the victim's wounds, and full medical description of the injuries (Bolin 1954). This investigation marked the beginning of application of forensic scientific methodology to shark attack analyses.

Yet the work of Bolin was the rare exception and not the rule in the mid-1950's. No system that hinted at a uniform approach to investigation or a central repository for case files existed; therefore, no comparison was possible nor was sufficiently defensible data available to begin the process of quantifying and qualifying shark attack behavior. In 1959 the SRP initiated a program to investigate and categorize information on worldwide shark attacks knows as the Shark Attack Files (SAF) (Gilbert et al. 1960). The SAF represented the formal birth of the science of forensic shark attack investigation and analysis. A number of important "tools" were introduced through the SAF:

1. the attempt to record all attacks worldwide;
2. the development of a standardized questionnaire which requested all pertinent physical data attendant upon the attack;
3. the solicitation of assistance from a physician or scientist near the scene to document the attack;
4. centralization of all shark attack information;

5. statistical comparison of the accrued data in the files; and
6. screening of incoming reports for spurious or doubtful accounts.

Application of these tools allowed researchers to make some preliminary recommendations about shark activities and human activities that might provoke attacks (Gilbert et al 1960; Gilbert 1963; Schultz 1967; Baldridge 1974). Baldridge and Williams (1969) were able to bring into question a long-held belief that shark attacks were acts of feeding behavior. Through analysis of data in the SAF, they were able to establish that for every attack that could be linked to feeding (bite contact with both of the shark's jaws and/or removal of substantial amounts of the victim's flesh) three attacks could be linked to defensive behavior (raking of victim with the upper jaw only and little loss of flesh). Where before precious little information had existed about shark attack and then mostly limited to advice that bore almost no relationship to reality (Cousteau 1812; McCormack et al. 1963), large numbers of books devoting themselves in part to the phenomenon became available (Gilbert 1963; Davies 1964; Budker 1971; Baldridge 1974; Ellis 1976; Wallet 1978; and Sibley et al. 1985).

As more sophisticated scientific techniques have been adapted to use in the investigation of shark attacks, particularly since the late 1970's, knowledge of this phenomenon has grown almost exponentially. In-field investigations have been increasingly applied to North American and South African attacks (Wallett 1978; Miller and Collier 1980; Cook 1980; Cook and Brzycki 1981; Martini and Welch 1981; Cook and Frank 1984; Lea and Miller 1985; Cook et al. 1986; Cook et al. MS). These investigations have been enhanced by application of "soft" x-radiography of surfboards (Cook et al. MS), testing of blood samples imbedded in the foam core of a victim's surfboard (Lea and Miller 1985), advanced analyses of concurrent weather (Cook 1980; Cook and Brzycki 1981; Cook and Frank 1984; Cook et al 1986), analyses of physical oceanographic conditions, and complex medical or autopsy work-ups (Wallett 1978; Cook 1980; Cook and Brzycki 1981; Martini and Welch 1981; Lea and Miller 1985).

The concept of forensic shark attack investigation and analysis will be discussed along with several current techniques of study and their advantages and limitations.

Forensic Shark Attack Investigation Defined

In the broadest context, forensic science is "the application of analytical techniques in medicine, chemistry, biology or other scientific disciplines to establish evidentiary facts necessary for the effective dispensation of criminal and civil law" (Turner and Hilton 1949; Walls 1974). However, the application of forensic science to shark attack investigation hardly ever involves violations of criminal or tort law, although the famous "Shark Arm Murder Case" in Australia in the 1930's stands as a notable exception (McCormack et al. 1963). Therefore, we need a somewhat different definition of forensic science when applied to shark-human interactions. For the purpose of discussion in the context of the current paper, the following definition is offered: "Forensic shark attack investigation is the application of analytical scientific techniques to accurately quantify and qualify information obtained from attacks upon humans and animals with the purpose of discovering underlying causes and developing effective means to reduce the likelihood of future attacks."

Chronology of the Investigation

The following investigational procedure has been developed by Dr. Robert N. Lea, California Department of Fish and Game, and the author to support their work with shark attacks on the Pacific Coast of the United States. It is designed to garner the most detailed information available. While to some field investigators this may seem to be a "lot of work just to record a shark attack," it is structured on the supposition that in the more obscure and seemingly unimportant information often omitted from investigations may lie the key elements to understanding what causes sharks to attack.

There are three principal phases to the investigation: 1) post-attack field investigation, 2) offsite data collection and analysis, and 3) reporting.

Post-Attack Field Investigation. This phase involves visiting the site of the attack, collecting field data and physical evidence of the attack and first contacts with the principal parties to the attack. The primary tasks are:

1. Identifying Principal Parties: This can be accomplished by contacting the police, sheriff, or other agency having law enforcement jurisdiction, hospitals, newspaper accounts, and/or the county medical examiner's office (when fatality occurs). Principal parties include the victim, on-site witnesses, paramedics, doctors, police, the U.S. Coast Guard, and/or the coroner.

2. Contacting Principal Parties: Either by telephone, mail, or preferably in person, all parties to the shark attack should be contacted and interviewed. Time is a key element here. The longer the time interval that elapses between the attack and the interviews the less the value will be of the information the field investigator obtains. The reasons for this are: that accounts tend to change as they are repeated over time due to memory lapses and more importantly "reprocessing" of the memories of the incident. It is not uncommon for a victim to be uncertain of events and the species of the attacking shark soon after the attack. However, one month after the attack, due to reprocessing, the shark becomes first a great white shark (Carcharodon carcharias) then, with retelling of the story, a 3 m...4 m... 5 m... sized individual. This is greatly enhanced in those cases where the victim or survivor-witnesses learn that the media wants to make them into celebrities or that they can make money from an "I survived the jaws of death" story (see Wexler 1982). Interviews should be carried out as soon as practicable after the attack but not more than three weeks thereafter. Be sure

to obtain all the information you can get at the time of interview, including impressions of water conditions, noting of animals in the water near the attack site, possible contributing factors (dead animals, garbage, fishing activities, processing waste or other possible attractants).

3. Obtain Physical Evidence and Field Data: This includes reports from paramedics, police, doctors and autopsy findings (if applicable), water temperatures at the attack site, water samples (in sealable jars) for salinity analysis, inanimate objects bitten by the shark (surfboards, oars, waterskis, floats, etc.), and personal gear worn by the victim(i.e., wetsuits, etc.). Reasonable care should be taken not to further damage personal effects or gear. The items should be returned to their owners as soon as possible after the investigation.

4. Photography: Where possible photographic records should be made of the attack site (if near shore), physical items that are too large to transport to the lab for analysis, and other pertinent subjects. Two excellent books are available for reference: **Scientific and Technical Photography** (Blaker 1975) and **A Field Photography** (Blaker 1973).

5. Autopsies: In those cases where the victim dies as a result of the shark attack, an autopsy will usually be performed by county or state medical examiners or federal laboratories specializing in the deaths of federal employees and military personnel. Although it is difficult for most of us to view the bodies of victims of traumatic injuries, if at all possible the field investigator should attend the medical examination of the body. Much important information can be obtained in this manner, particularly from the observation of damage to bones and internal organs. If it is acceptable to the next of kin, you should obtain photography of pertinent injuries (Bolin 1954).

Offsite Data Collection and Analysis. This phase involves collection of statistical and mean-annual information about contributing factors, analysis of physical data, analysis of meteorology and statistical treatment of physical information to attempt to determine the species of the attacking shark and its relative size and weight. The primary tasks are:

1. Salinity Analysis of Water Samples: This task should be carried out quickly to avoid the possibility of concentration due to evaporation from improperly sealed jars. Depending upon the equipment you have available to you, you may want to carry out the analysis yourself or "farm" it out to an analytical lab. Most marine chemistry books and oceanography books describe the techniques for completing such work.

2. X-radiography of Inanimate Objects: Often objects are bitten by sharks during the course of an attack. These items are very

valuable to the investigator because they contain at least a partial impression of the shark's jaw and possible tooth fragments. Prior to the late 1970's the only methods that were readily available for examination of shark-bitten objects were blind-probing and/or destruction of the object to remove all foreign material. The disadvantages of blind-probing are that it tends to distort and deepen the areas of penetration made by the shark's teeth, thereby giving false impressions of the true size of the tooth, and the probe may crush small pieces of tooth, rendering them useless for identification. The physical tearing down of the object to recover foreign materials has often been applied in the past. It is undersirable because it requires the total destruction of the object. Often in the case of surfboards, for example, the owner either wishes to repair and reuse the board or keep it for a memento of the encounter. This destructive form of examination is highly unpopular with owners of such objects, and often will color their decisions to release the board for forensic examination (Cook et al. MS). Scattered attempts were made in the 1970's to apply x-ray techniques to the examination of shark-bitten boat hulls and a surfboard with variable success (Cook 1980), but no uniform method was derived to maximize the promise of this technology. To address this problem a system was developed by the late Dr. John Kelley of Oregon State University, Dr. Barbara Watrous of Oregon State University, and the author for utilizing "soft" x-ray techniques characterized by low kilovoltages and long exposure times. This technique produces very high resolution radiographs with high photographic densities that enhance very small differences in radio-opacity of low density objects. The advantages of this technique over previous methods of examining surfboards and similar objects are:

1) the process is non-destructive;
2) a map of locations of foreign objects as small as 1 mm in the surfboard is obtained;
3) areas of greatest bite force can be determined from compression of the foam core which alters radio-opacity; and
4) topography of the shark's teeth can be ascertained, which may aid in species identification (Fig. 1) (Lea and Miller 1985; Cook et al. MS).

Limitations of this technique lie in equipment requirements and need for a properly outfitted x-ray room; however, this can be overcome in part by utilizing the services of medical x-ray facilities or those at universities and commercial laboratories. The only constraint is that the investigator must specify that this procedure requires low power (30 kvp) and long exposure times (270-540 mAs). "Patient exposure times" are not critical as the target is inanimate.

3. Physical Examination of the Shark-bitten Object: The object should be measured for length, width, and thickness. Next the position of

the shark bite should be recorded with respect to distance from a clearly identifiable reference point. Then the overall dimensions of the bite impression (width and depth onto the object) should be measured (Fig. 2).

Individual tooth impressions should be measured for length, width, and depth of penetration. To determine depth use a blunt, straight-tipped probe. Sharp-tipped probes are unsuitable as they tend to pass through the bottom of the impression for some distance, thereby yielding erroneous data (Fig. 3).

Center-to-center distances between adjacent tooth impressions can be determined by placing probes in the center of the tooth marks and measuring between them (Fig. 3).

Often blood stains have been found on styrofoam surfaces exposed during attacks. It was long assumed that the blood was the victim's. In part this is probably true; however, blood has been found embedded in the foam core of surfboards bitten by sharks in cases where the victim was entirely uninjured. Many sharks have a tendency toward "pulpy" gum tissues that bleed easily. Undoubtedly shark blood often remains as an artifact of the attack. Recently investigators have begun to look at the possibility of using such blood samples to identify the attacking species (Lea and Miller 1985; Robert Lea, California Department of Fish and Game, pers. comm.). Clearly this technique needs more work to be brought to fruition. However, given the likelihood that sharks can be separated by species based upon unique hematological characteristics, this presents exciting prospects for future forensic work.

4. Weather and Oceanographic Data: Two of the most neglected topics in the reporting of shark attacks have been meteorology and physical oceanography. In part this has been due to reliance upon news clippings in many cases where no on-site investigator was present (passive reporting). But also this has been the result of field investigators being unaware of the available resources for this information. Especially in the United States, extensive literature and ongoing data collection services have become available in the past 15 years with advances in satellite-remote weather and oceanographic sensing systems. Increasingly, foreign nations are also placing satellites in stationary (geosynchronous) orbits for the purpose of collecting weather and oceanographic information (at present France, China, and Japan launch satellite payloads for commercial clients). For North America, information is currently available on sea surface temperature and temperature anomalies from the METOC CENTRE, Maritime Forces Pacific (British Columbia) and Maritime Forces Atlantic (Nova Scotia). The National Weather Service (NOAA) (Washington, D.C.) provides a variety of weather information and also many types of oceanographic information

collected from NOAA operated satellites and surface stations (Figs. 4 and 5). This information may also be obtained from regional Ocean Service Centers (OSC's) operated by the National Oceanic and Atmospheric Administration (NOAA).

5. Assessing Medical/Law Enforcement Data: For the most part, this information should be presented without amendment by the investigator in the final report on the attack. There are some exceptions, however, of which the investigator will need to be aware.

Law Enforcement Data: Unless the shark attack results in serious injury or death to the victim (when an officer will be assigned to handle an investigation for police, sheriff or other authorities), the law enforcement report on the incident will probably be the result of a report by the victim at the station. It will probably be short with a notation that no follow-up investigation need be taken. Inaccuracies may be noted by the investigator in the report, but it must be remembered that the police report can only be as good as the information communicated by the involved parties.

Medical Data: Data recovered by medical personnel as a result of treatment of injured victims or autopsy findings in the case of fatality nearly always will be presented by the investigator without substantial qualification of the data. The possible exception to this is that spacing between tooth impressions in wounds, especially in severe wounds or if a body has been recovered after putrefaction has begun, is exaggerated by a process known as "spreading." In the case of severe wounding the dimensions of the damaged area will appear to be larger than they actually are due to unnatural flexure of the body section involved as a result of loss of support in the area of the excised tissue. This was observed in the case of a dead harbor seal (Phoca vitullina richardii) which was bitten by a white shark on the central Oregon coast in the 1970s. On cursory examination the wound appeared to be a single bite of nearly 1 m width due to a massive loss of tissue along the body wall. Closer examination revealed that there were two overlapping bites that had been greatly exaggerated by spreading of the wound (Carl Bond, Oregon State University, pers. comm.). Similarly individual tooth impressions may be exaggerated by flexure. An analogous example of this would be in the case of cutting into a piece of meat with a knife. Though the knife is narrow-bladed, and hence the cut is narrow when the meat rests on a flat surface, if one were to pick up the meat and bend both ends down relative to the center, the cut area will assume a triangular cross section (Fig. 6). In the case of putrefaction the wound area will be exaggerated due to the breakdown of soft tissues along the cut surface of the wound at a higher rate than uninjured adjacent areas. Interpretation of medical data can be provided by attending physicians or the medical examiner; however, additional references may prove useful. Some of the books available on the subject include Camps and Cameron (1971), Morse et al. (1984) and Polson et al. (1985).

6. Treatment of Statistical Data: Depending upon how much information you have available to you, i.e., bite impressions in inanimate objects, weather data, etc., you may wish to apply statistical tests to determine length and probably weight of the attacking shark or significant deviations from "normal" weather and sea conditions. In the case of length:weight ratios, a good source for general shark information is Compagno (1984) and for specific information on white sharks, Tricas and McCosker (1984).

7. Photography: Photographic records of objects examined in the follow-up analysis of the attack provide very valuable information for other researchers and for your own future reference. The importance of the scientific application of photography to the science of shark attack investigation cannot be overstated. The photographic references already mentioned will aid you in obtaining the highest quality pictures.

Reporting. This is the final phase of the investigation, but certainly not the least important. The best investigation will prove of little value if the information cannot be conveyed to other researchers and interested parties in a usable form. A workable format used in reporting investigations on the Pacific Coast of the United States contains the following elements:

1. Introduction (contains pertinent supporting information on the subject matter to be covered);
2. General Background (contains location, attack site physical oceanographic information);
3. Attack Scenario (contains a narrative chronology of the events leading up to and including the actual attack);
4. Particulars of the Victim (physical description);
5. Investigational Procedures (contains all pertinent data on methodology applied to investigation of attack);
6. Analysis of Data and Discussion (self-explanatory);
7. Conclusions; and
8. Appendices (contains names, addresses and phone numbers of all persons involved in attack and all persons involved in the investigation of the attack, photostatic copies of all medical and law enforcement reports, all meteorological and oceanographic reports submitted during the investigation, and a polyethylene (archival quality) slide page (contains all color slides of injuries, surfboard damage, wetsuits, etc.).

The inclusion of black and white photography in the body of the report and suitably reproducible pen-and-ink drawings of site location, bite damage, and other pertinent data is essential (Figs. 7 and 8).

Toward a Uniform Shark Attack Reporting System

In recent years the International Shark Attack Files have had to rely largely upon "passive" additions and have been greatly hampered by the lack of funds to support their active maintainence. As persons to whom the files have been entrusted have retired, the files have been shifted to new locations which has further complicated the process of accessing information (Bernard Zahuranec, U.S. Navy, pers. comm.). At the writing of this paper the files are maintained at the Underwater Accident Center (NOAA), University of Rhode Island, Kingston, Rhode Island 02882.

To address the problems of maintaining the files and improving the system of investigating and reporting shark attacks, the American Elasmobranch Society has undertaken to develop a uniform worldwide network of scientists and interested field investigators. If you are interested in participating in the reporting network contact Mr. Ralph S. Collier, American Elasmobranch Society, P.O. Box 3483, Van Nuys, California 92407 (213) 995-7966.

Conclusion

The application of forensic scientific methods to the investigation and reporting of shark attacks holds the potential for helping researchers to better understand the phenomenon. While the use of forensics in this context is still an infant science, new techniques are being adapted and evolved all the time. As of 1986 "tools" include x-radiography, photography, sophisticated weather and ocean analyses, and increasingly uniform techniques of gathering physical and chemical data. While it is a recognized fact that shark attacks are a rare occurrence compared to the number of persons utilizing the oceans every year, they still represent a hazard to work and recreational use. Work to create a uniform worldwide reporting system will surely benefit people using the oceans in future years, especially in the area of psychological reassurance.

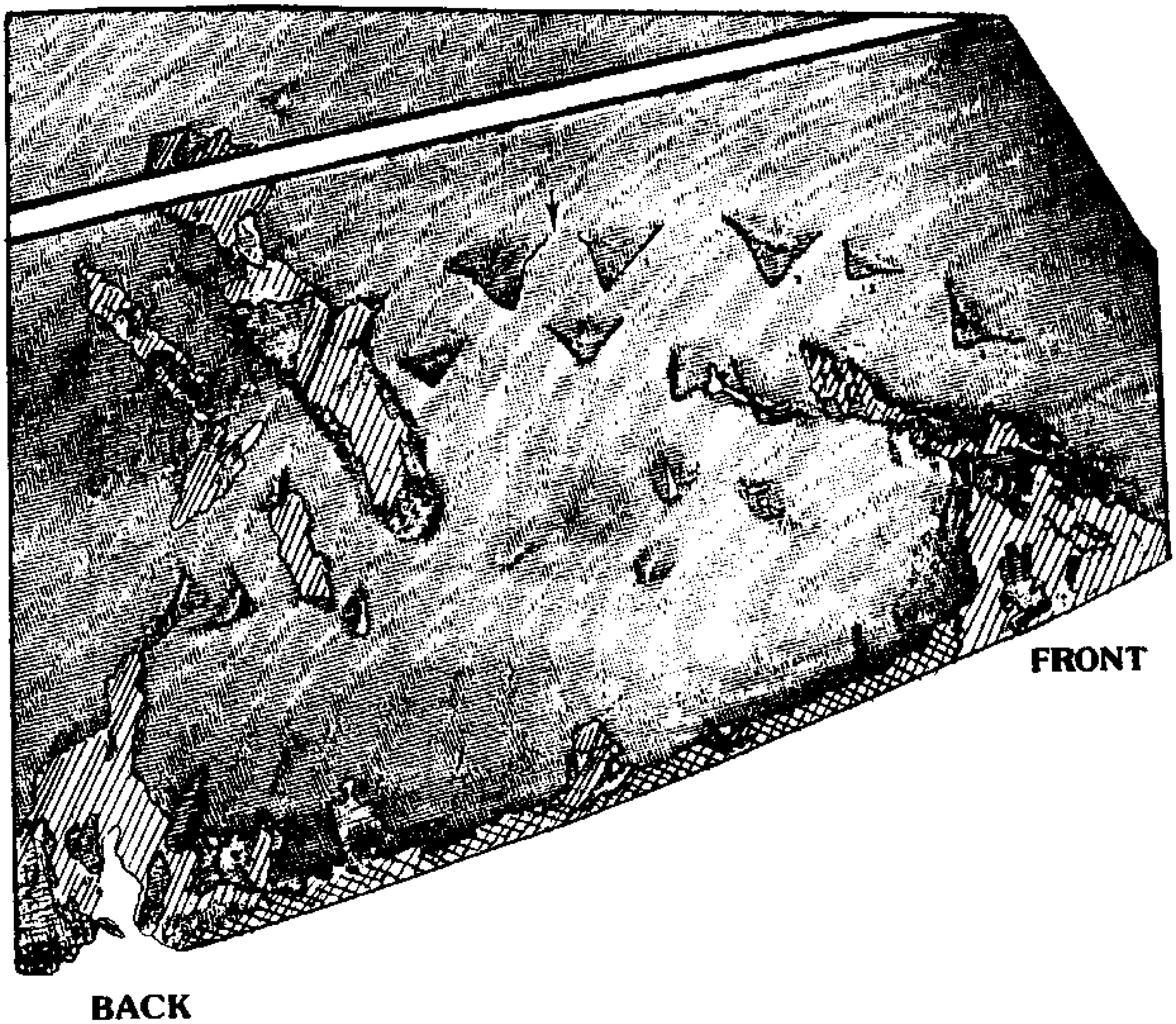


Figure 1: Facsimile of positive image of a radiograph of a white shark bite in a surfboard showing topography of the upper right jaw (teeth 1, 2, 3, and 4). Drawing is about 34% of actual size of bite (Cook and Frank 1984; Lea and Miller 1985). Cross-hatched areas represent sloping surfaces at board edge. Lines represent areas compressed during bite (crushing damage).

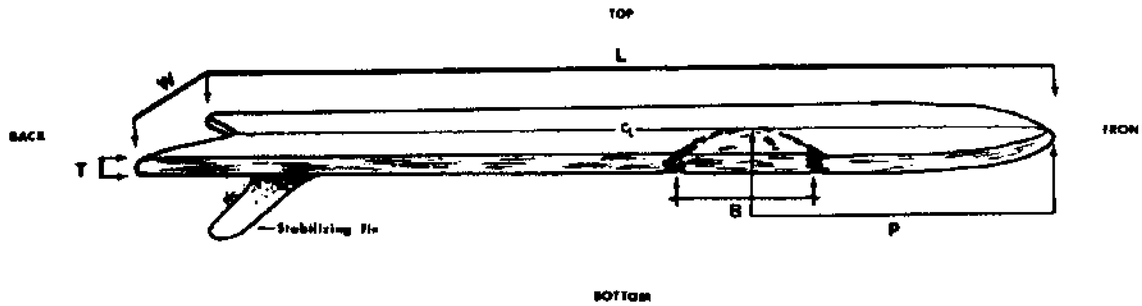


Figure 2: Diagrammatic oblique view of shark-bitten object showing the areas to be measured during the investigation. A surfboard has been illustrated here, but the techniques can be applied to an object of any shape. L = length of board; W = width of board; T = thickness of board; B = width of bite from the center of the deepest penetration on each side; P = positioning of bite from its center to the nearest clearly identifiable landmark (front of board); C_L = centerline of board.

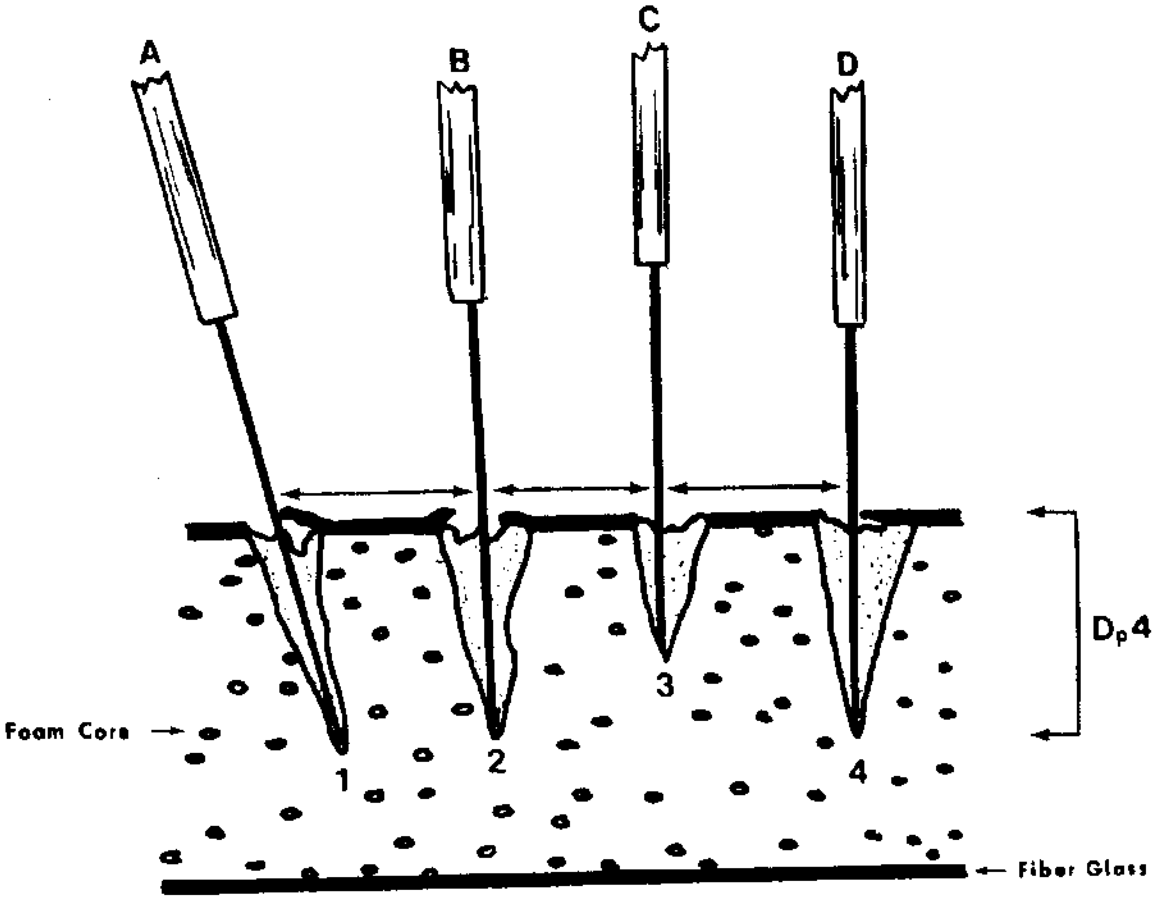


Figure 3: Diagram of method of measuring depth and center-to-center distances of tooth marks in surfboard or other soft-cored objects. Tooth marks are numbered. Measuring probes are lettered. The distances from probe to probe should be measured at the surface of the surfboard or other object to avoid inducing errors caused by non-parallel tooth marks (#1). Probe C at tooth mark #3 is illustrated in an incorrect position to one side of the impression. In such a case, three errors would result: 1) the impression would appear to be shallower than it is; 2) the distance between probes B and C would show a center-to-center distance for teeth #2 and #3 that is too small; and 3) the distance between probes C and D would show a center-to-center distance for teeth #3 and #4 that is too large. Dp4 = correct depth measurement for tooth impression #4.

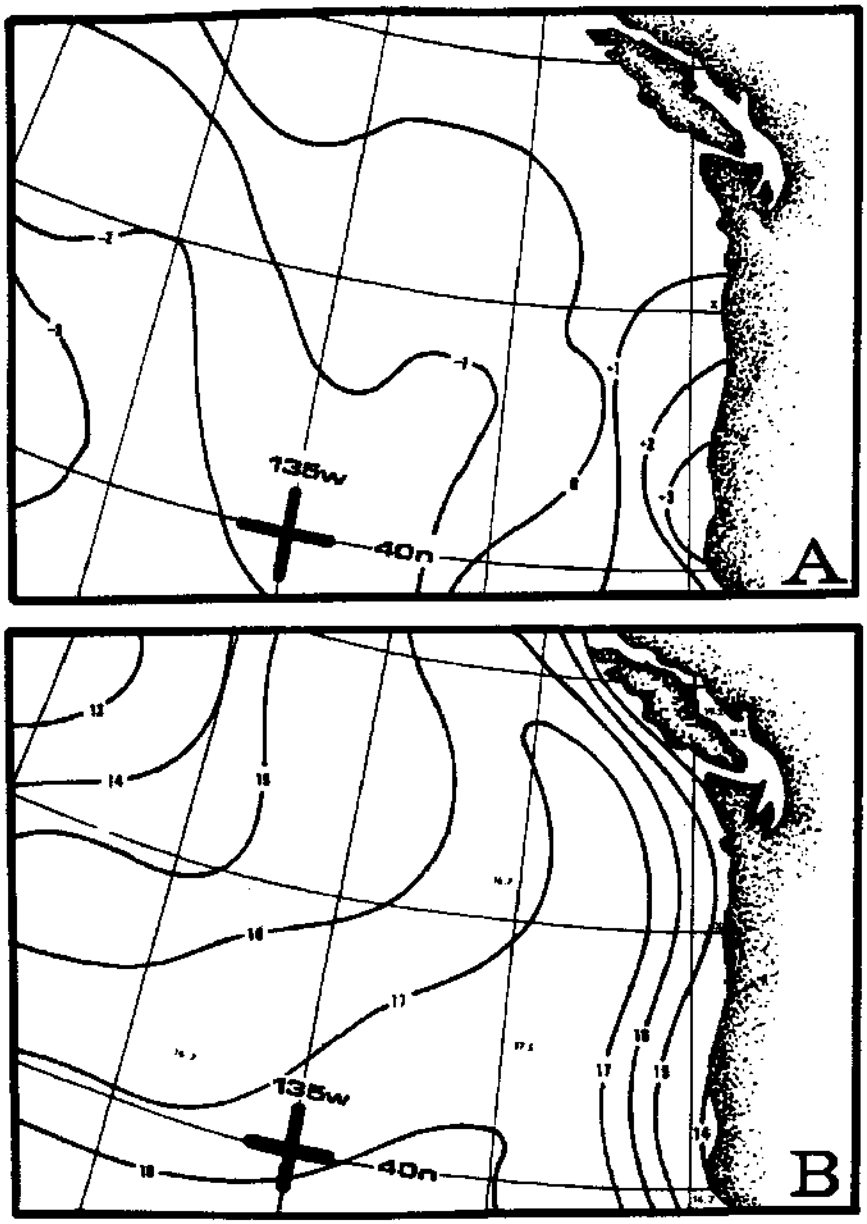


Figure 4: Examples of information on sea surface temperatures provided by the METOC CENTRE/MARITIME FORCES PACIFIC, British Columbia. A = Monthly sea temperature anomalies in °C. B = Isothermic map of sea surface temperatures in °C with point temperatures for selected monitoring stations in the North Pacific. X = the site of the white shark attack upon Randy S. Weldon on 20 August 1983 (from Cook and Frank 1984).

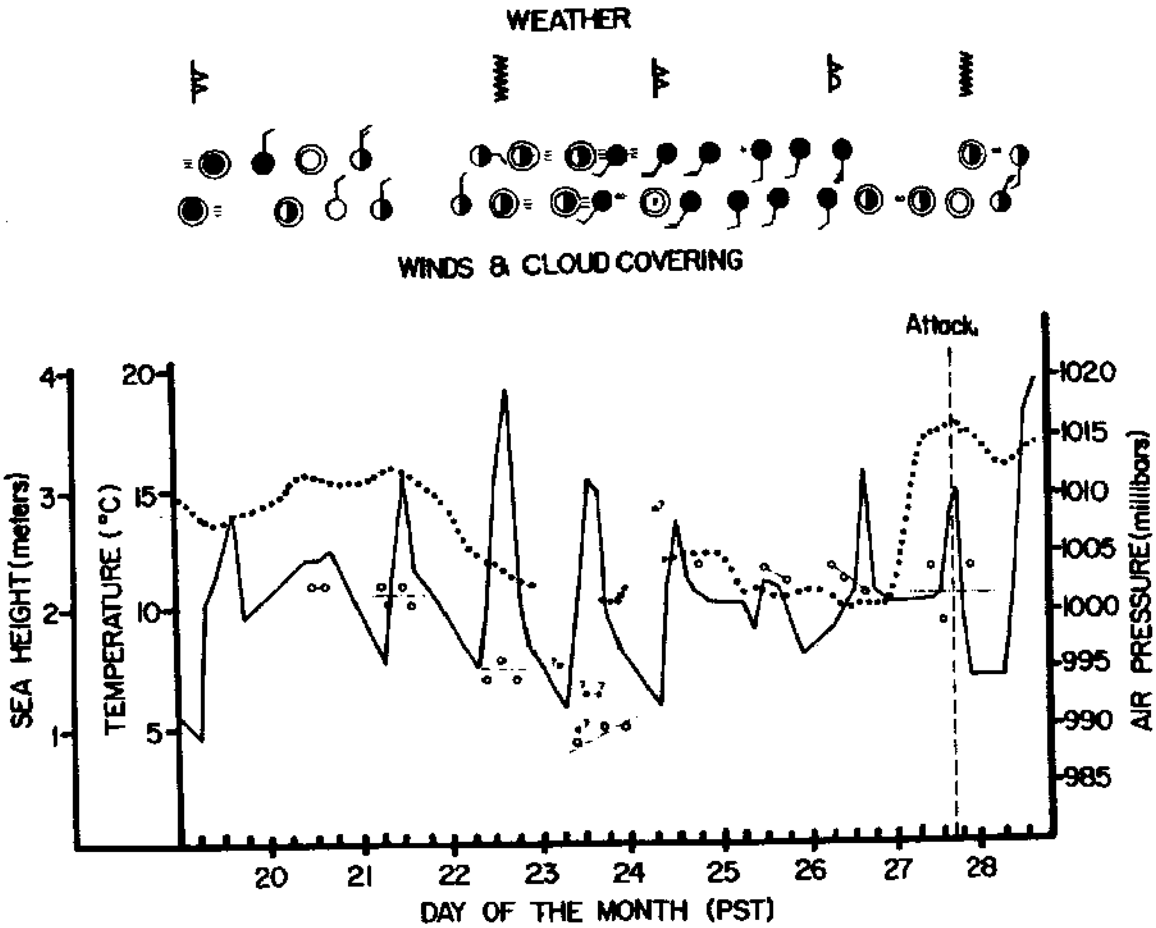


Figure 5: Composite graph of concurrent weather at the time of the white shark attack upon Christopher Cowan at Winchester Bay, Oregon. The solid line represents diurnal air temperatures. The dotted line represents barometric pressures. The open circle/hashed line combinations represent average sea heights. This information was provided by the United States Coast Guard. The wind, cloud cover and weather information was provided by the Atmospheric Sciences Department at Oregon State University (Corvallis) from U.S. Weather Service data. For complete treatment of this material see Cook and Brzycki (1981).

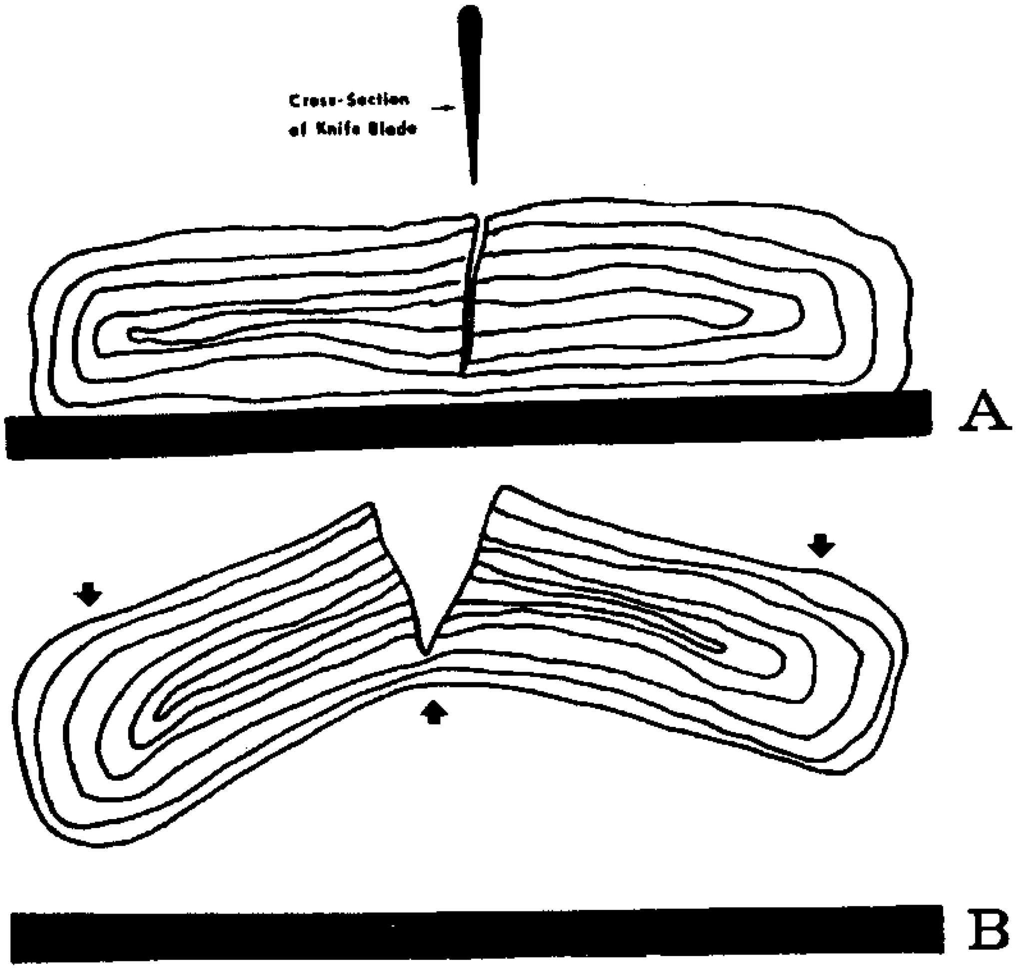


Figure 6: Demonstration of "spreading" of a cut surface in a piece of meat (diagrammatic). The meat has only a narrow cut in it from the knife blade (shown in cross-section) so long as it remains on a flat surface. However, once it is picked up and the ends depressed, the cut surface assumes a triangular cross-section due to distortion.

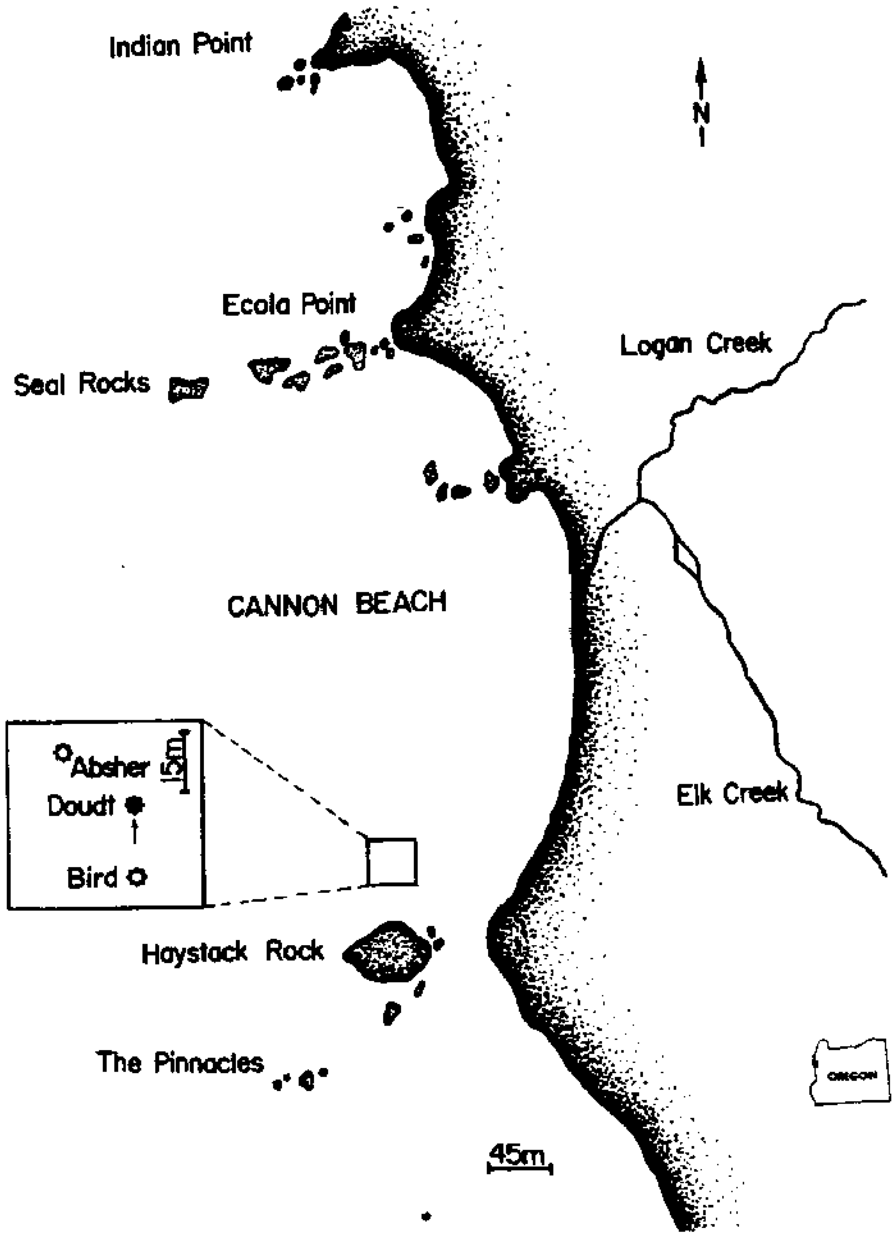
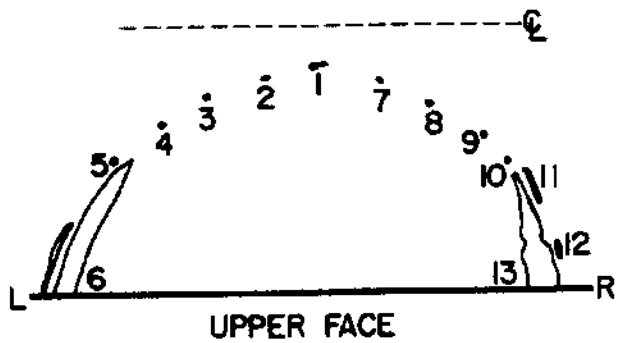


Figure 7: Drawing of the site of the white shark attack upon Kenneth Doudt at Cannon Beach, Oregon. Such maps should include all pertinent information regarding important streams and rivers, locations of geographic reference points, etc. The map should be drawn to scale and insets of the position of the attacked parties and an inset of the attack site on a larger geographical reference (in this case Oregon state map) should also be entered (Cook 1980).



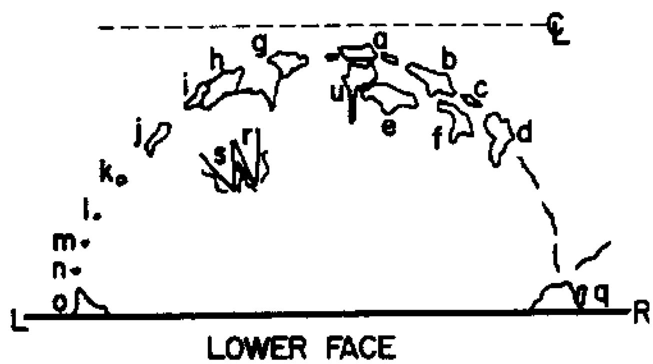


Figure 8: Diagrammatic view of damages to upper and lower surfaces of the surfboard involved in the white shark attack upon Kenneth Doudt (27 November 1979 at Cannon Beach, Oregon). Even if you include photographs of the damage, you will need to have some master drawing with reference points on it to explain your center-to-center measurements of tooth marks. This will also aid you in identifying where tooth fragments and other foreign materials of interest were recovered from the surfboard (see Cook 1980).

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Sharks and the Media

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Abstract: The shark is a creature tailor-made for media sensationalism. As typified by the great white, it's a huge, primitive, carnivorous force whose diet occasionally includes people, or at least that's the popular view. The average journalist's definition of news is: an event that concerns people, and is occurring now. Unfortunately, sharks generally become an event that concerns people only when a person is eaten by a shark.

That provides the media with the opportunity for "man-eating shark" stories, and newspapers and television in particular take it, generally without plugging in a lot of scientific information for perspective. Though journalists are professionals at gathering information, they aren't shark specialists. They have mere hours—or even minutes—to get the basic information and get it on the air or in print. If the event falls into the category that journalists call the "holy shit" story, meaning it's guaranteed to make the reader mutter "holy shit" when he sees it, so much the better. A shark attack can draw that expletive from just about anyone.

But that reaction is the shark professional's window of opportunity to get solid scientific information before the public. Journalists—believe it or not--are trained to give their readers or viewers as much background as they can, to put the basic events in an accurate context for the public. When stories break, they welcome help from professionals in the field. But the key is the time peg, the fact that an event is happening now, whether it's a shark attack or a trend in shark research or shark-people interaction, such as more people swimming, scuba diving and surfing, thus coming into more frequent contact with sharks. Without some kind of time peg, a story isn't news.

As shark professionals, you need to recognize those time pegs when they occur and make yourselves available as competent news sources. If it's a breaking story, contact whichever reporter is covering it, or simply the editor in charge of the newspaper or television newsroom. Be prepared to talk not just about sharks in general but about how shark behavior relates to that particular incident. Be prepared to speak in terms anyone with no special scientific knowledge can understand.

There are additional windows of opportunity besides simply attacks. Trends in scientific research are of interest. So are such developments as shark fishing and shark cooking. If it's a growing trend, reporters want to know about it. They may not be able to use the information right away, and maybe not at all, given the many topics, events and special-interest groups that compete for time, attention and news space. But if nothing else, you've made a personal contact, and when a reporter needs information he's liable to come back. Any reporter is only as good as his sources, and that means you.

The title of this talk is listed as "Debunking the Myths: Sharks and the Media." But I'm not going to debunk any myths about sharks because I think you already know them. Instead, I'm going to show you a bit about how the media works so you can use it to debunk those myths yourself.

Unfortunately for debunkers, the most popular myth has a sound basis in fact. That's the man-eating shark. When most people hear the term, they don't think of the 306,125 mt (675 million pounds) of shark that people ate worldwide in 1984. Instead, they think of the approximately three dozen times annually that sharks attack humans.

And like it or not, the shark, particularly the great white, is the heir of the Moby Dick tradition. It's a huge, powerful, mysterious creature that rises from the ocean depths to crush human beings like nutshells. "Jaws" was born out of this, and of course it also enhanced it.

Even some of the minor parallels between "Jaws" and "Moby Dick" are striking. Conveniently, both the whale and the shark are white. In the book, Quint, the shark-fishing captain is killed by the shark after being caught in the harpoon line much as Ahab was strapped to Moby Dick. And the actor who played Quint in the movie must have taken his cues from Gregory Peck playing Ahab, though there was a lot of "snoose-chewing wild west bad guy" mixed in.

Our modern society is less well equipped to separate "Jaws" myth from fact than the "Moby Dick" readers were in the 1800s. Whaling was a common industry when "Moby Dick" was written. Everybody knew whales killed whalers, and residents of New England seacoast towns probably knew personally men who had died or at least been to sea. They probably knew enough to realize the whales didn't stalk men who had died or had been at sea. They probably knew enough to realize the whales didn't stalk man deliberately. But, we don't live that close to nature anymore. Look at the way the movie "Bambi" has cast a rosy, unrealistic glow over modern views of deer and hunting. That's the kind of influence something like "Jaws" can have on fears and myths concerning sharks.

The rarity of shark attacks and our lack of knowledge about sharks in general only fuels those fears and myths. That's reflected in the media's treatment of shark stories. By any definition, a shark attack is news. The fact that it is so rare only makes it more newsworthy. Can you imagine finding a story on page 4 of your July 3 newspaper that begins: "Approximately 350 people are expected to die during this year's July 4 holiday on the nation's beaches as a result of shark attacks. That's down from a high of 425 in 1976 before the 55 mph speed limit prevented so many people from getting to beaches more quickly...."

We see that kind of story every year for auto deaths. The difference is that after 50,000 every year we've become more immune. Whether it should be that way or not, auto deaths are somewhat old hat, just as whaling deaths probably were in the 1800s.

Further, shark attacks fall into the category of news story that Ben Bradlee, editor of the Washington Post, defines as the "holy shit" story. For those of you who never hear of Bradlee, he was the Jason Robards character in "All the President's Men." Anyway, that kind of story is one that makes you mutter you-know-what as you sip your morning coffee. Bradlee was mainly talking about investigative stories, like defense contractors billing the Pentagon for $650 wrenches, but the category is broader than that. There's no question that shark attacks can draw expletives from just about anyone.

Journalists are always looking for stories with that kind of impact, that kind of shock value. For a few years I was at the paper in Bend, a town of about 25,000 about 135 miles southeast of Portland, Oregon, across the mountains. Down there I worked with a guy who had a real nose for stories like that. Bend is a nice little town--hunting, fishing, skiing, logging, tourism, etc. Well, this guy found a Hell's Angels chapter there. But he always said his real ambition was to cover a shark attack in the Deschutes River.

I don't have to tell you that stories are sometimes played to give them more impact than they deserve. One of the best examples comes from my very own newspaper. The Bellevue Journal-American is a suburban daily with a circulation of 27,000 that tries to be lively and still reflect its conservative Republican readership. It used to be a lot more lively than it is. Since this example occurred, the management has changed, and this wouldn't get past the present high sheriffs. And I can't take any credit for this because I wasn't there at the time. For my career, that's probably fortunate.

Anyway, several years ago the paper ran a front-page five-column color photograph and story of a certain critter causing trouble for homeowners in our area. The photo of this critter had some small headlines on it that read: "They came from Canada with little warning....They can kill your grass in a matter of days....I didn't think it could happen to me, said one Redmond homeowner....But it did." And in three-inch-high red letters that looked like the title credits to "The Blob" was the punch line--"Attack of the Lawn Killers."

The critter was an ordinary woolly caterpillar. They were pretty thick, I guess. If a caterpillar can rate that kind of treatment, the sky's the limit for a shark.

I think some of that shows up in a **Time Magazine** story that ran on November 19, 1984, called "Dangers of the Red Triangle." The story discusses an increase in great white shark attacks along the northern U.S. Pacific coast after Labor Day 1984. I've talked to a couple of people who were interviewed for the story who say that its slant is skewed, and some of its biological information is simply inaccurate. They say the real name of the area is the White Triangle, for great white sharks, not red for blood. They told **Time** that if there had been an increase in seals and sea lions in the area it would have been too recent to have allowed an increase in the birth and survival rate of shark young. They said sharks play a natural role in the environment and shark attacks are extremely rare. Their comments were stuffed into the last paragraph in a six-paragraph story. Oh, yeah--the photo with the story is a shark with its mouth open.

I suspect part of the problem with the story's treatment is that the information was gathered by a reporter in Los Angeles, but the story was written by an editor in New York. I suspect another problem--probably the major one--is that **Time** had a preconceived notion of the story they were looking for. They found at least one expert who backed up their notion, and the information that didn't jibe suddenly took a back seat. At least it did make it into the story.

Besides editor pressure, another place where slanting or outright errors can occur is headlines. It may come as a surprise to some of you that the reporters who write the stories don't get to write their own headlines. That's done by copy editors. They're the ones who decide how the stories will fit together and what size and length the headlines will be. Those headlines can vary depending who's writing them.

Let me give you some examples from a story by Hillary Hauser of the **Santa Barbara News-Press**. The story was sent out over the Associated Press wire and ran in a number of other papers. The original headline in the Santa Barbara paper said, "Is seal, sea lion boom luring more sharks?" That headline is a fair representation of what the story said.

Things deteriorated from there. One other paper's headline was in the ballpark: "More seals may mean more sharks."

Then came "Experts say seal population is drawing great white sharks....A growing debate over what causes white shark proliferation." And the worst, "Great white sharks infesting waters off Santa Barbara." By the way, "infesting" should be banned from use with the words "shark" and "waters." I've heard "shark-infested waters" so often I wonder if there's any other kind.

Headlines also can be just plain inaccurate. The one from my paper, which again I can't claim credit for, is the best example of that: "Sharks, seals harassing divers." The story's slant was on sharks. The seals harassing divers in addition to serving as shark food was a minor part.

I've spend a lot of time so far criticizing my own profession, but now I'm going to tell you that you have much less to worry about in talking to the media than you might think, and that its treatment of shark issues depends in large part on you.

The reason you have less to worry about is that despite what I've said, journalists have some of the higher ethical standards around. If they wanted to make money telling lies and screwing people over, they'd have gone into advertising. There are always arrogant, unscrupulous, incompetent people in any profession, but journalism has less than most fields. They want to report the news accurately and fairly, and they feel they have almost a sacred obligation to do so. They spend more time debating ethics and criticizing themselves than most professions.

The reason the media's treatment of shark issues depends largely on you is that a journalist is only as good as his sources. The more knowledgeable people he talks to, the better his information--and his story--will be. You're the sources.

So how do you go about it? First, by making contact, or by making yourself available when a reporter contacts you. And any newsworthy incident involving sharks is your window of opportunity.

A good example occurred in September 1985 north of Miami, Florida. Two kids went fishing in the Atlantic, and one apparently was eaten by a shark as he was swimming around the boat. At least that's what his companion said. The kid said he saw a fin, and the water was red with blood for five or 10 minutes after the shark pulled the alleged victim under.

Not likely, said a state marine patrol captain. Sharks generally attack from below so you don't see a fin. And blood dissipates in water extremely fast. The "victim" was found a couple of weeks later in Los Angeles, where he'd gone after stealing his girlfriend's car, jewelry and gasoline credit cards. He'd also taken out $200,000 in life insurance on himself made out to her, which she didn't know about.

The incident doesn't have to be an attack. If you're involved in shark research, or any trend involving sharks, that's a potential news story. Sid Cook's development of sport shark fishing along the Oregon coast has gotten several articles in newspapers in the area. Hillary Hauser's story is a good example of using scientific information--the increase of seals and sea lions followed by the increase in sharks--as the basis for a fair, well-balanced story.

Russell Sadler, a well-known Oregon commentator and columnist, once told a conference of wildlife biologists something I think is applicable here. "Don't think that because you're scientists and we're laymen that we're not interested in what you're doing," he said, or words to that effect. "Let me know when you think you've got something interesting. Help me do my job better."

When you're being interviewed, you can help yourself and the reporter in a couple of ways. Be prepared to explain things clearly in words anybody at a cocktail party could understand. Reporters have to deal with many topics on which they aren't experts. The more nontechnical you can make your explanations, the more chance you have of getting your points across. Welcome stupid questions. They insure nobody looks stupid in the story.

Speak slowly. Pause now and then. Give the reporter time to record what you're saying. Speak in shorter sentences. If you can say something that's short and clear, it has a better chance of being used as a direct quote just as you said it. Reporters prize good quotes. They tell the information, liven up stories, and hold the readers' interest.

Recognize that the process is probably going to involve your information being merged with information from other sources. It may be balances with people--even other experts—who don't agree with your point of view. Don't blame the reporter for that. If experts can't agree among themselves on technical, biological information, about all the reporter can do is present each side of the issue as fairly as he can. Sometimes, as with the **Time** article, that may not be done as fairly as it could have been.

Be accurate, and be aware of what you're saying. In researching this talk, I saw one expert quoted on shark attack behavior as saying that great white sharks rarely swim faster than three miles an hour, while a good human swimmer can swim four miles an hour. Maybe so, but not for many yards. I think I'm a good human swimmer. At least I competed in a one-mile open water swim two months ago that drew 700 people. If there had been a shark at the back of the pack, I'd have been eaten in the first quarter mile, along with a lot of other people. The winner's time was exactly 20 minutes, which I guess means he'd have been nipped at the finish.

Lastly, remember that a story is often put together under incredible deadline pressure. That's a problem for journalists as well as sources, but it isn't going to change. It's the nature of the business.

And it is a business. We're a public service, and we have an obligation to be accurate, responsible, helpful, and fair. But we also have to give our readers what they're willing to buy, because, if we don't, we won't be around. You'll never see a mainstream news organization going to the limits that something like NBC TV's "Ocean Quest" has and calling it journalism or documentary.

For those of you who don't watch television, that's the multipart mini-series where the divers wear chain mail suits and go into shark feeding frenzies, or try to provoke a great white shark into making an attack. That's pure sensationalism for profit. It probably will make a lot of profit. Evel Knievel has made a pretty good living doing things like that for years.

But at the same time, I think it's indicative of what the public will buy that the acknowledged best newspaper in the United States—and probably the world—isn't the circulation leader in its own home town. The **New York Times** has a daily circulation of about 900,000. The **New York Daily News**, a tabloid that would love to cover a shark attack in the Hudson River, has a daily circulation of 1.5 million.

This business side of journalism is something news people don't like to deal with. We want to report the news, not sell it, and that's what we try to do. But it does mean there may be some entertainment mixed in with the information. The goal is to keep the entertainment angle in perspective, to make sure that the information--the news—always comes out on top. We'll never be perfect, buy we'll usually be close. When it comes to sharks, we need your help.

Recent Advances in Protecting People from Dangerous Sharks

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Abstact: Virtually everyone who goes into the ocean is afraid of shark attacks. Thus, there has always been great interest in protecting people from dangerous sharks. Passive protection in the form of repellents or barriers are the most practical for the average person. "Shark Chaser," a chemical repellent package developed by the U. S. Navy during World War II was the first successful repellent protection but was withdrawn from service in the 1970's because it lacked total effectiveness. New chemical repellents based on research into the milky secretions from a Red Sea flatfish, the Moses Sole, give promise of resulting in a truly effective shark repellent. For some specialized uses, where the high cost is warranted, a recently developed "chain mail" suit of stainless steel links or one incorporating high strength Kevlar may also provide effective passive protection.

[1] For additional detailed information on this subject consult: Zahuranec, B., editor. 1983. Shark repellents from the sea. American Association for the Advancement of Science, Westview Press, Boulder, Colorado.

Shark Fisheries and Utilization

U. S. Shark Fisheries and Markets

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Abstract: Shark, highly valued as human food overseas for generations, is finally gaining acceptance in the U. S. marketplace. With demand increasing steadily, it is anticipated that shark catches will continue to increase gradually in all regions. Because of this new strong interest in shark potential, U. S. shark fisheries and the usage of shark by retail and food service purveyors are being monitored.

Shark! Why is it that the very mention of the word seems to fascinate and terrify both young and old alike? True, sharks on occasion attack people. Our morbid fascination with this phenomenon is constantly exploited in movies, magazines and newspapers. Meanwhile, with little fanfare, people in the United States are beginning in a big way to eat shark. There has been a truly remarkable increase in recent years in the demand for shark.

Yesterday we were enlightened about shark biology and shark attack behavior. Today, I am going to share with you how the image of shark is beginning to change. Oh, I'm not going to say people are not still wary of sharks--but, their attitude about eating them is changing.

I've been monitoring shark markets for about two years and I'd like to share some of what I have learned.

Our commercial catches are still small; reportedly less than 9070 mt (20 million pounds) in 1984. However, landings of certain species are increasing every year and ex-vessel prices have risen to levels that are attractive to fishermen. In the past, pioneering fishermen have been forced to abandon shark because ex-vessel prices were too low. Now, there's a chance that we may have continuity of supply.

Sharks occur off all our coasts and, between the regions, there is a year-round supply. This is very important because the U.S. market seems to prefer fresh shark meat.

The Northeast and Middle Atlantic produce mainly dogfish and rely heavily on exports to the United Kingdom and West Germany, markets now being threatened by competition from non-U.S. sources. With the strength of the

American dollar, foreign countries are often able to undersell U.S. companies. Therefore, some U.S. companies are looking into domestic markets for dogfish.

Shark landings have increased in eight of the nine South Atlantic and Gulf of Mexico Coastal states every year for the past five years. In Florida in the mid- 1970's, catches were around 23 mt (50,000 pounds). Last year 544 mt (1.2 million pounds) were landed in Florida, an astronomical increase. My region relies entirely on domestic markets. Species include, but are not limited to, brown shark, Atlantic sharpnose, blacknose, blacktip, silky, mako, dusky, lemon and thresher. Brown sharks probably constitute the largest part of the catch in Florida.

Handling live sharks is hard and dangerous work and fishermen expect good wages for their effort. When the U.S. market was small, ex-vessel prices were often too low to keep vessels interested in the fishery. Now, properly handled shark is obtaining a good price--usually in the range of $0.50 to $1.50 per pound depending on the species. Price is also influenced by the amount of landings on a given day, since much is sold fresh. For some fishermen shark is the major income during the months of July and August. It has been a life saver.

East, West and Gulf coast dealers all report that the U.S. market for shark is growing and that demand for fresh meat is exceeding the supply.

Several Florida dealers are specializing in making small air freight shipments of fresh meat to restaurants, supermarkets, seafood markets and seafood wholesalers around the country. One dealer has increased his weekly sales from 0.45 mt (1000 pounds) to 23 mt (50,000 pounds).

All has not been well on the supply side, however. Lack of demand for frozen meat has been a problem and could affect future growth. Several dealers, unable to provide a continuous flow of fresh meat to their best customers, have dropped the item in frustration. While many people believe that frozen meat is tastier and less chewy than fresh, the market still demands fresh shark.

Retail chains around the country are reporting excellent consumer acceptance for fresh meat. Shoppers are paying from $3.86 - $8.27/kg ($1.75 - $3.75/pound) and up for steaks and fillets, and many ask for shark even when it isn't in the display case.

Albertson's, Kroger's, Publix, Piggly Wiggly, A&P and Family Mart are a few chains that tell me they are doing well with shark.

Albertson's, for example, is using shark species from all coasts and importing white shark from New Zealand. Shark is one of its best seafood movers and demand is increasing every day.

Kroger has introduced shark successfully in several states.

Piggly Wiggly is not concerned with species, and shark is among its best-selling seafood items. This chain is cutting shark logs to customers' specifications because it believes that too much moisture is lost when precut steaks and fillets are displayed.

A&P resisted offering shark until numerous customers encouraged it to add the item in selected stores. Mako and whitetip steaks are now best-sellers for A&P at $8.80/kg ($3.99/pound).

Shark fillets and steaks are appearing in more restaurants as public awareness of the virtues of shark meat increases. Here are some examples:

The Oyster Shanty in Tampa, Florida, is serving shark at $4.95 al a carte, and $7.45 for a full dinner. A weekly column in the St. Petersburg Times that features small restaurants and lunch places on the Suncoast recently reported, "The shark was so good we may cut down on our grouper consumption and order shark every once in a while instead. Shark is not fishy, yet it doesn't taste like chicken. It's mild and mellow, but not bland."

The Crab Shack in Ellenton, Florida, has shark on its menu as an exotic food. An entree is $7.50 and appetizer $3.25.

Red Lobster Inns of America, one of the nation's fastest growing seafood restaurant chains, is currently using fresh shark on its fresh fish of the day menu. When shark is not on the menu, customers ask for it. Entree prices range from $7.95 to $9.95.

Anthony's Fish Grotto in San Diego, California, a leader in introducing new species, reports very strong demand for shark.

Don and Charlie's Restaurant in Scottsdale, Arizona, is serving a shark entree for $12.95 that happens to be moving very well.

A fine Italian restaurant in Minneapolis, Minnesota, features a blacktip shark entree at $13.95--one of the highest priced items on its menu.

Up to now, I have said very little about the most valuable by weight and sought after shark products, the fins.

The greatest care must be taken in their removal and processing so as not to lose the high price commanded by a set of well cared for fins.

A set of fins consist of one dorsal, one lower caudal lobe and two pectorals. The fins are used by orientals to make shark fin soup and are by far one of the most expensive food items in the world. The orientals believe that shark fin soup is a key to maintaining a healthy and youthful appearance. It is served by rich and poor alike to welcome in the Chinese New Year and to celebrate other festive occasions. It is also considered by some to be an aphrodisiac. So, if you want to whet your sexual appetite, shark fin may be your cup of soup--provided you can afford it at $20 or more a bowl.

Markets for shark teeth and jaws appear to be limited. Reportedly, shark jaws are popular curios which retail for up to $400 each, depending on size. Large sharks such as tiger, bull, makos, white sharks and others that have heavily calcified jaws are the best jaws for drying. They make interesting, if dangerous to clean, conversation pieces. This market is easily over supplied. Teeth from larger sharks are sometimes mounted in gold or silver settings and sold as jewelry items.

Shark skin is one of the toughest natural hides in existence. Shark leather after tanning is more durable than cowhide and pigskin. Shark leather is primarily used for footwear and leather accessories such as wallets and belts. Unfortunately, the skinning process is labor intensive and up to this time has not been considered profitable by U.S. fishermen. Consequently, at the present time most shark hides are being imported from Mexico and other countries.

The demand for shark blood is also limited. Pharmaceutical and research laboratories are using only small quantities. Interestingly, researchers are trying to understand why cancer and coronary disease are practically non-existent in sharks.

At one time, vitamin A derived from shark liver oils was one of the most valuable shark products. However, the development of synthetic vitamin A in the 1940s has virtually eliminated the demand for this product. Throughout the world, shark oils are used in the manufacture of paints, cosmetics, lubricants and medicines.

Shark corneas have been used as successful substitutes for human corneas.

An artificial human skin made in part from shark cartilage has been used to treat burn victims. The product was developed by MIT and the Massachusetts General Hospital.

In summary, shark is becoming popular in the United States for several reasons. First, most Americans prefer white, flaky, mild tasting seafood, such as shark. Second, shark is available year round. This is important to supermarkets and restaurants, who are catering to the current "fresh is best" trend. Third, shark is a lean fish—low in fats and cholesterol. This appeals to consumers concerned with eating healthful foods. Fourth, shark is easy to prepare and lends itself readily to all cooking methods. Finally, and most important of all, shark tastes good!

Most firms have been handling shark for a relatively short period of time; however, they believe that demand for shark will continue to grow.

Consumers like its taste, appearance and ease of preparation and are attracted by its nutritional value. The number of seafood distributors, grocery chains, seafood markets, restaurants and institutions handling shark is growing daily. Quality control is improving, and everyone agrees that good quality will be the key to future market growth.

So, overall, the outlook for shark is very promising.

We are putting the bite on shark rather than the other way around, and our revenge is sweet!

U.S. Shark Fishing Methods and Gear[1]

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Abstract: Sharks are taken around the world with a variety of different gear types. The most common types of gear utilized are gill nets and longlines, although they are also harvested with seines, trawls, and handlines. The optimal method varies with the species sought, local bottom conditions, and the economic capabilities of the participants in the fishery.

The gill nets used for shark fishing are typically of large mesh size (7-25 inch stretch mesh) and are used in California and Oregon for the capture of thresher and blue sharks, and in Chile and Peru for the capture of mako sharks. Gill nets are currently being reintroduced along Florida's east coast. Gill nets set for sharks in inshore waters are usually fixed in position with anchors (figure 1), while those fished offshore are usually suspended from flotation buoys and allowed to drift (figure 2). Gill nets can be more effective than longlines at moderate to high shark population densities, particularly when chummed or baited; however, they are more cumbersome and expensive. Gill nets may be used to catch any size shark, depending on the mesh size.

Gill nets are not selective in the types of marine animals they capture. Consequently, many non-targeted and non-salable fishes, as well as marine mammals, tend to become entangled and killed. In fisheries such as the California pelagic shark and swordfish fisheries, the use of such gear has been controversial (see Bedford, this volume). In addition to non-selectivity of gill net in the California fishery, there is also some concern regarding excessive exploitation of target stocks with such gear.

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[1] This paper is drawn largely from an article by the senior author appearing in **Shark Fishing** (1985) by Florida Sea Grant, Gainesville, Fl. That publication is available for a charge of $2.00 from Florida Sea Grant.

In California, bottom gill net is also used in the fishery for the California angel shark (Squatina californica). (For further information, see the paper by John Richards in this volume.) Small sharks are often caught inshore in small mesh gill nets as an incidental catch to fisheries for pompano, spot, croaker, Spanish mackerel, mullet, bluefish, etc. They often cause extensive damage to gear and have been known to completely destroy monofilament gill nets. These sharks are often discarded by the fishermen because of a lack of market.

Longlining involves the attachment of baited hooks at regular intervals along a line or wire mainline which is deployed behind a moving vessel. Basically, a longline consists of a mainline, usually several miles long, from which baited hooks are suspended. The baited mainline is either supported in the water column by floats (surface longline) (figure 3) or fished on the bottom with one or more marker buoys (figure 4). Longlining may be carried out over a wide variety of vessel capabilities ranging from a small boat employing a manual process to set about 100 hooks to a fully automated, multi-thousand hook large vessel operation. Longlining is particularly effective for capturing large species of shark. For the purpose of this paper, we will use the Florida longline fishery as an example. Both surface and bottom longlining have been used successfully in the shark fishery in Florida. Many sharks are taken as an incidental catch to the swordfish longline fishery and because of this incidental catch, many fishermen have taken an interest in the possibility of a directed fishery for sharks.

There do not appear to be large populations of small sharks on Florida's East Coast such as those associated with dogfish fisheries in New England. Thus trawling has not been employed to harvest sharks in Florida.

The use of pelagic or bottom trawls has been quite successful in the capture of schooling sharks, such as the spiny dogfish (Squalis acanthias). The principal U.S. fishery for dogfish using this gear is found in the Pacific Northwest, off Washington and British Columbia (Jeff Kombol, Arrowac Fisheries, pers. comm.). In the past several years, work has been undertaken to develop trawl fisheries for dogfish in New England and the mid-Atlantic states (see Grulich, this volume). Trawl gear is generally not suitable for larger sharks and not economical for species that do not strongly school.

Handlining has been tried from time to time in the Gulf fisheries for shark, but it does not seem to be attractive economically to U.S. fishermen. Handlining is, however, one of the principal methods for commercial fishing sharks in the Third World. Fishermen in Mexico's Sea of Cortez handline (and longline) for a wide variety of carcharinid and sphyrnid sharks (Bendix 1977). In Puerto Rico, fishermen using handlines from small open boats routinely catch large carcharinid sharks, such as the tiger (Galeocerdo cuvieri) (Compagno, 1984).

The primary methods of commercial U.S. shark fishing are pelagic (floating) and bottom longline.

Gear Description

Since 1980, a small-scale directed fishery for sharks has developed on the Florida East Coast. The vessels used in this fishery usually participate in other seasonal fisheries to supplement their annual income. The vessels range from 11 to 15.5 m (35 to 50 feet) in length and use surface and/or bottom longlines. The typical longline operation fishes one or two days per trip and carries a crew of 2 to 4 men. The longline consists of one primary mainline varying from 1.67 to 10 km (1 to 6 miles) in length, made of 4.8 to 6.4 mm (3/16 to 1/4 inch) hard-lay tarred nylon. The mainline is stored on a hydraulically-operated spool and strung with pulleys to facilitate set and retrieve. Hook lines (called gangions) usually are made of 11 m (2 fathoms) of multistrand steel cable ahead of the hook (figure 4). The gangions are usually stored in barrels and are attached to the mainline with snap-on connectors. Loop protectors are used at the connection of the hook and gangion, and sacrificial anodes (zinc) are placed on the hook to minimize corrosion. Hooks are usually large, 3/0 or 3.5/0 shark hooks. Between 300 and 500 hooks are set and the vessels usually make 1 or 2 sets per day. Hooks are spaced relatively close together (between 31 to 93 m [100 and 300 feet] apart). Bait is extremely variable. Bluefish, bonita, mackerel, mullet, and squid are common; however, the fishermen often use other types of bait depending on their availability. Buoys are usually a combination of high density bullet-shaped foam and polyethylene balls attached directly to the mainline with snap-on connectors on 28 to 30 m (15-16 fathom) leaders. When bottom longlining, the leaders are of sufficient length to keep the buoys on the surface and the mainline on the bottom. For pelagic longlines, the leaders are 10-30 m (5.4-16 fathoms) long. Fifteen or twenty marker poles with strobe lights and radar reflectors called "high flyers" are attached at each end of the mainline.

Fishing Methods

Longliners fishing on the east coast of Florida usually begin a trip in the early evening. The fishing grounds are usually in 28 to 112 m (15-60 fathoms) of water. Typically the longline gear is set after dusk. A set begins with baiting and placing the gear in the water, then retrieving the gear after 2 to 10 hours of soak. The soaktime varies depending on the expected catch rate and the intent to make an additional set.

The mainline is led off the spool and a high flyer is clipped to the first end and cast overboard. As the boat moves ahead, the mainline is fed off the spool. Hooks are baited and gangions are clipped on the mainline as it feeds over the stern. Buoys are clipped on the mainline at proper intervals as the line passes astern. A buoy is usually attached to every tenth hook for bottom longline. For pelagic longline, buoys are placed every 150-200 m (500-650 feet). The setting operation takes from 30 minutes to 3 hours depending on the length of mainline. Two or three men usually are required to bait hooks, uncoil and clip on gangions and buoys, and operate the hydraulic spool. After the line is set, the vessel will usually anchor next to the high flyer for the evening and the crew sometimes will handline for snapper/grouper.

At dawn, the haul back begins. The highflyer is picked up and the mainline is attached to the spool. As the vessel moves slowly along the line, the line is retrieved and the gangions and buoys are removed as they come aboard. When hooked sharks are brought alongside, the boat is stopped until the fish is gaffed and brought aboard. Dead sharks and hammerheads are usually cut free. The live sharks are hauled onboard with a winch.

Butchering begins immediately and should be accomplished as soon as possible. The shark is first immobilized by severing the spinal cord, then the tail is cut off to allow bleeding. Some innovative fishermen have designed a special lift and restraining device to assist this operation. Care should be taken so as not to drop the tail overboard before recovering the lower lobe of the fin. After the flow of blood from the tail stops, the shark is gutted and brought aboard. The head and fins are cut off, the belly flaps are removed, the carcass is washed, and the belly cavity is cleaned and de-slimed. It is especially important to remove the kidney (along the roof of the belly cavity). At this stage, with the head and fins cut off, the product form is called a "log." In order to provide the best quality meat, the butchered shark can be immersed in a salt water-ice slush. The most proficient crews take 7-15 minutes from the time the shark is brought alongside to the time the logs are placed in the salt water-ice slush.

The fins should be washed and trimmed of all meat and either iced or prepared for drying. The wet fins, quite valuable ($3-$6), are not as perishable as the flesh. After the haul back, the vessel either heads back to port or prepares for another set. The fish are usually left in the brine tank for 2-4 hours. If the vessel makes another set, the fish are taken out of the brine tank and stored in the hold belly side down and packed on clean ice.

The fishery for sharks along the southeast Florida coast appears to be seasonal with the highest catch rates taking place during the fall and winter months from Sebastian to the upper Keys. Production for a vessel fishing 400 hooks during this time varies between 1,000 and 4,000 pounds per set. Catch rates ,or sharks caught per total hooks set, typically range from 8-12%; however, up to 20% of the hooks may catch fish during the winter. During the summer, warmer water temperatures seem to cause the sharks to migrate to deeper water (cooler temperatures) or out of the area, and catch rates decline below profitable levels. At surface temperatures above 23.9°C (75°F) in 28 to 112 m (15-60 fathoms) catch rates usually decline. Catch rates are also affected by the number of vessels fishing a given area. Catch rates decline by as much as 50% after a set has been made; therefore, fishermen do not return to the same area until a suitable length of time has passed (several weeks to a month). Thus shark fishermen try to coordinate their fishing activity.

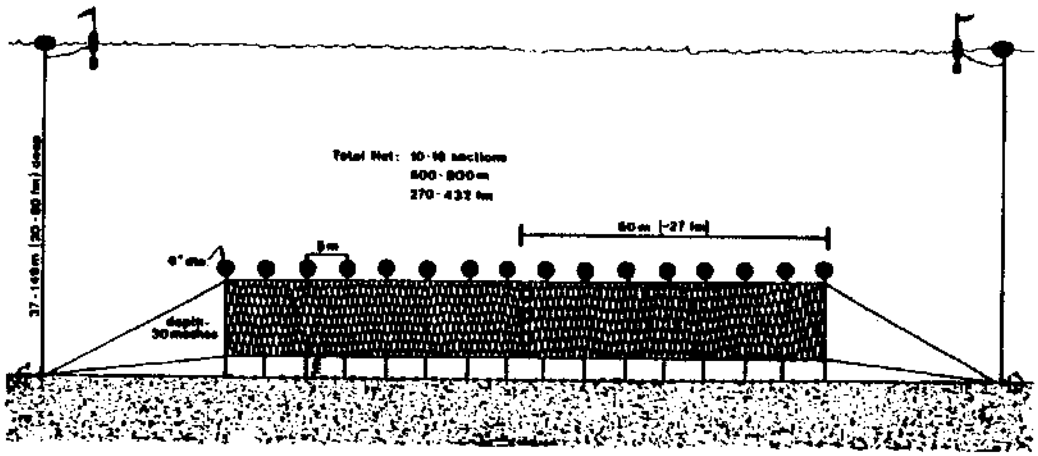

Figure 1. Diagrammatic view of bottom gillnet used for sharks (after <u>Pacific Fisherman</u> 1943a).

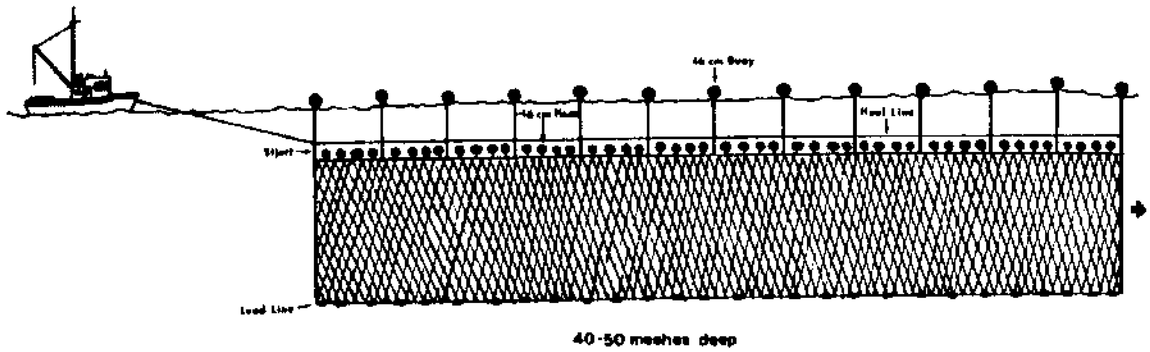

Figure 2. Diagrammatic view of pelagic (drift) gillnet used for sharks (after Pacific Fisherman 1943b).

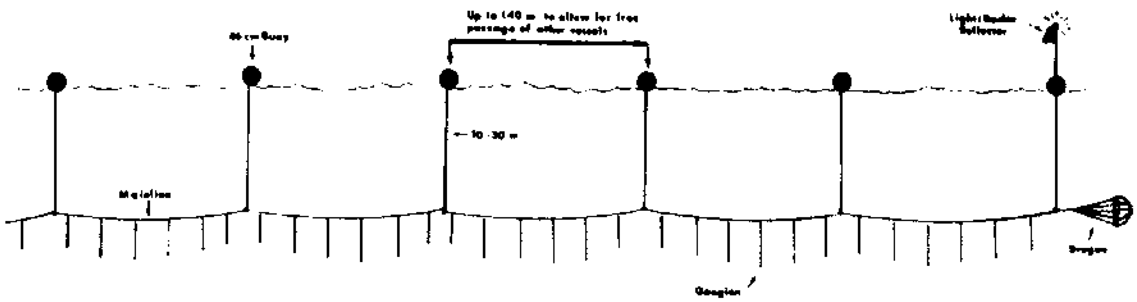

Figure 3. Diagrammatic view of pelagic (offshore) longline used for sharks (after Jensen 1981).

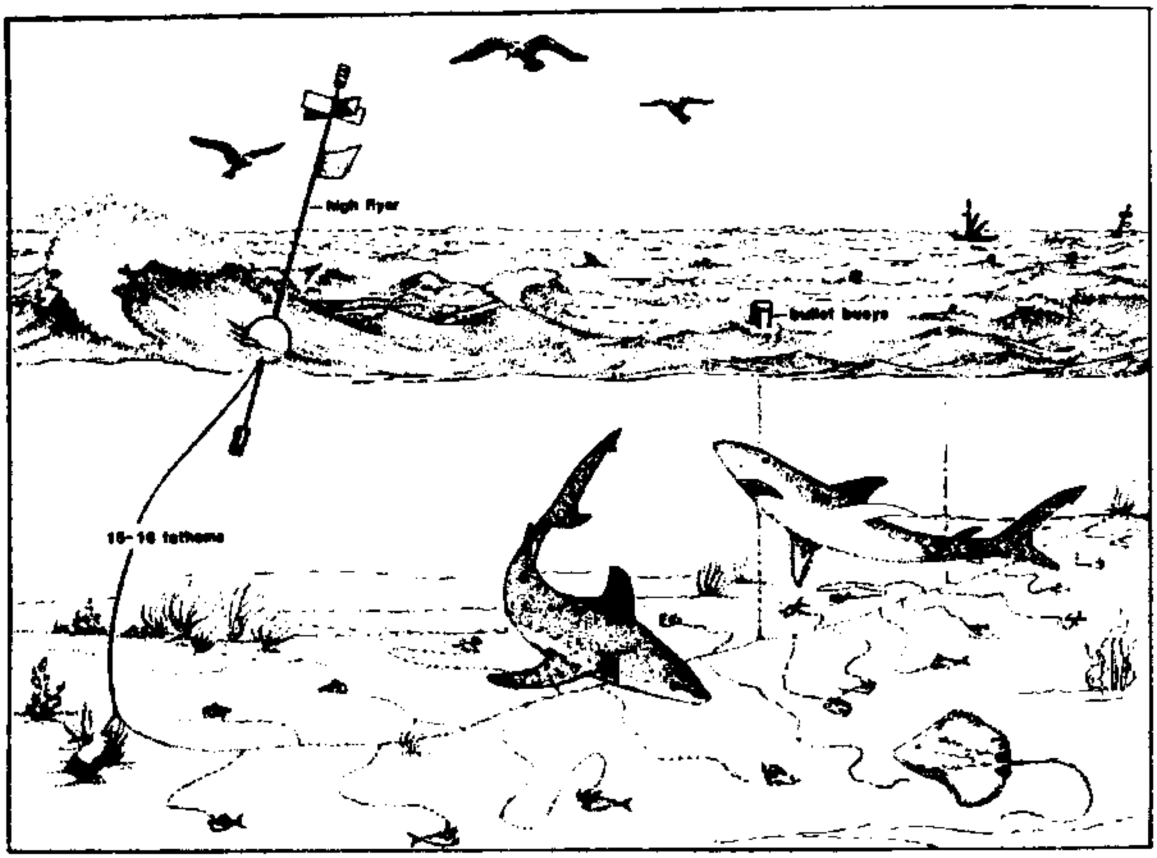

Figure 4. Bottom or coastal longline gear for sharks.

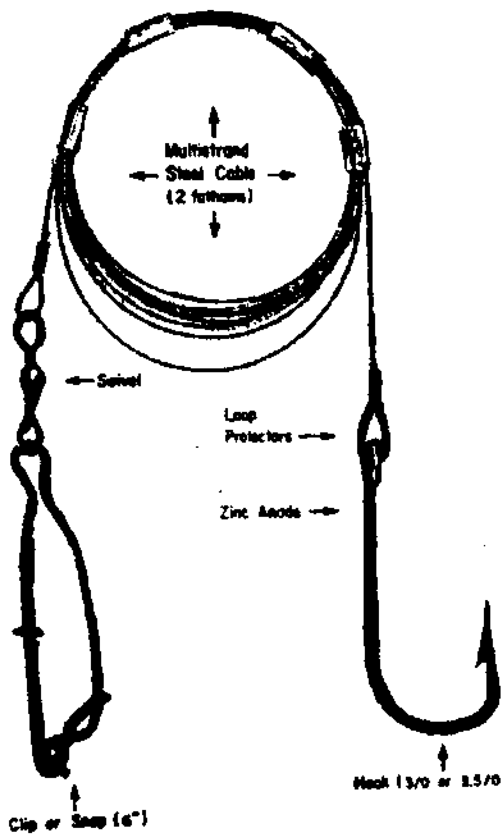

Figure 5. Hook and gangion arrangement for shark longlining.

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Developing a Localized Fishery: The Pacific Angel Shark

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Abstract: The transformation of the Pacific angel shark (Squatina californica), an incidentally caught and discarded "trash fish," to one of the most highly sought after commercial shark species in the Santa Barbara Channel is described. Development of the fishery took place within the fishing industry beginning in 1977. Local landings of dressed angel shark totaling 149 kg (328 pounds) were reported that year. By 1981, Santa Barbara landings rose to 117,024 kg (258,037 pounds) with this figure more than doubling within three years to 276,771 kg (610,281 pounds) in 1984. The 1985 landings are expected to exceed 454,000 kg (one million pounds). Local efforts in working out processing methods, product development, marketing and preparation are described. Development of fishing gear, onboard processing, factors influencing landings and cooperative fisheries investigations are also discussed. As with many other elasmobranchs, angel shark life history information is limited and the future of the fishery will very likely depend on cooperative efforts to obtain data which can lead to a sustained yield management plan.

Introduction

One of the most sought after sharks in southern California, the Pacific angel shark, Squatina californica, was, only ten years ago, a neglected and maligned "trash" fish that had commercial value only as crab bait. The development of the angel shark fishery is a success story that can be attributed to a unique form of cooperation between a processor and several commercial fishermen, each mutually sharing risks and benefits. The meteoric rise in popularity of this shark as a food fish are described, as are the development of processing methods, various products and marketing strategies. Development of fishing gear, onboard processing, factors influencing landings and recent biological studies are discussed. A cooperative fishery investigation, initiated at the request of members of the fishing industry and its importance to the future of the fishery is reviewed.

Description

Angel sharks, skatelike in appearance, are well adapted to life as a bottom dweller (Fig. 1). They are a relatively small shark, attaining a recorded maximum length of 1524 mm (5 feet) and a weight of 27 kg (60 pounds) (Miller and Lea 1972). Angel sharks caught commercially in the Santa Barbara Channel range between 914–1219 mm (3-4 feet), most commonly about 1067 mm (3 1/2 feet) total length. The approximate weight range is between 9 kg (20 pounds) and 16 kg (35 pounds).

Distribution, Range and Known Habits

The Pacific angel shark ranges along the west coast from southeastern Alaska to Baja California. It is also found in the Gulf of California and is reported to occur off Peru and Chile (Miller and Lea 1972, Eschmeyer et al. 1983). Eleven species of the genus Squatina are found in temperate waters in various parts of the world (Herald 1967), with commercial fisheries for angel shark reported in European and Mediterranean waters (T. Genovese, Commercial Fisherman and Luciano Corazzo, Fisheries Researcher, pers. comm.).

Angel sharks are usually found lying partially buried on flat, sandy bottoms and in sand channels between rocky reefs during the day. The Pacific angel has been reported to range in depth from 1 to 200 m (3 to over 600 feet). Pittenger (1984) observed the species frequently between 15 to 40 m (50 to 130 feet) around Santa Catalina Island. Fishermen working the northern Channel Islands report most of their catches are between 9 m (30 feet) and 75 m (240 feet) (I.F. Castagnola, Commercial Fisherman pers. comm.).

Angel sharks are nocturnal, moving from a few meters to 7.3 km (4 nautical miles) per night. However, individual sharks have been observed to remain in the same place with no apparent movement from one to ten days (Pittenger 1984). Pittenger noted that movements of angels near Catalina were usually in one direction, following the shoreline of the island for several nights at a time before changing direction. Recently, a tagged angel shark, at large for 3 1/2 years, was reported to have moved from the coast near Goleta, California, across the Santa Barbara Channel to the west end of Santa Cruz Island, confirming local fishermen's commonly held belief that angel sharks traverse the channel and can move between islands (R. Reid, Commercial Fisherman and Dr. G. Cailliet, Fisheries Researcher, pers. comm.).

Major prey items of angel shark reported by Pittenger at Catalina Island in summer were the queenfish (Seriphus politus) and the black smith (Chromis punctipinnis) and the market squid (Loligo opalescens) during winter. Fishermen in the Santa Barbara Channel report the mackerel (Scomber japonicus) and Pacific sardines (Sardinops sagax caeruleus) are commonly found in angel stomachs during the fall and early winter, along with squid which predominates during the winter and spring.

Incidental Catch - A Dangerous Nuisance to Halibut Fishermen

For at least 40 years before the beginning of the fishery in the mid-1970's, angel sharks were considered a dangerous nuisance to inshore set trammel net fishermen seeking the California halibut (Paralichthys californica). Because angel sharks prefer the same type of habitat as the halibut and share many of the same food items, they were caught incidently in both trammel nets and trawls. Roedel and Ripley (1950) state that "this shark which has no value, is taken in drag nets along the coast. It has powerful jaws and consequently is respected by fishermen." Stuster (1976) quotes net fishermen as classifying angels as a "junk" fish along with spiny dogfish (Squalus acanthias),the swell shark (Cephaloscyllium ventriosum), skates and rays. Often coming up alive and entangled in the outer meshes of the trammel net, they would be killed before the fisherman would extract them from the net. Avoidance of being bitten was one of the reasons cited for dispatching the shark, but another practical reason was to keep the sharks from reentering the net on subsequent sets. It is not known how many angel sharks were killed during these early decades, but some fishermen estimate the numbers to be in the tens of thousands or more.

By the early 1970's, the angel was being utilized as rock crab bait, but because of its odd shape and reputation as a "junk" fish the angel was ignored as a potential food source until the right combination of people got together in 1976.

Early Fishery Development—Primary Phase (1976—1982)

The catalyst needed to begin the fishery involved a persistent fisherman with knowledge of the value of the genus Squatina as a food fish and a progressive processor willing to listen and experiment.

The persistent fisherman was Tony Genovese, skipper of the halibut trammel net vessel Carol Lee, who had knowledge of an angel shark fishery in Italy and knew it was a high quality food fish if handled properly. He convinced Santa Barbara processor, Mike Wagner, owner of Seafood Specialities, to try it in his retail market and agreed to provide several free fish each week to test consumer acceptance of the product. It took only six weeks before customers would consistently purchase the small weekly supply of angel shark fillet at $1.74 per kg (79 cents per pound). The initial ex-vessel price was 33 cents per kg (15 cents per pound) for dressed fish.

At this point, Wagner had several problems to overcome before a serious fishery could be established, the first of which was to find ways of maintaining the quality of the shark onboard the fishing vessels. Other problems included: (1) finding a method of efficiently cutting the odd shaped shark; (2) convincing seafood distributors, restaurant chefs and consumers to try it; and (3) finding uses for the various odd shaped pieces that remained after the thick back fillets were sold.

On-board Processing: Key to Quality

The word of a potential market for angel shark spread quickly around the Santa Barbara waterfront, and it did not take long for those fishermen already selling halibut to Seafood Specialities to develop a method of dressing the shark at sea (Fig. 2) and a system for assuring that a high quality product was delivered to the processor.

During trips of three to five days, fishermen take only angels the last day or two to keep the time onboard at a minimum. The sharks are cleaned and dressed immediately after the fish are landed and the net is reset. The dressed carcass, weighing approximately 50% of the live weight, is iced or kept cool and moist on deck with wet burlap until delivery. The heads and fins may be saved as bait for rock crab trappers.

The opportunity to sell the angels was a boon to fisherman, as the return on the incidental catch would at least help to cover trip expenses and often more, depending on the needs of the market. By offering to buy angel shark, the processor provided fishermen an incentive to sell their more valuable halibut to him, assuring a steady supply.

Shoreside Processing: Key to Profits

Wagner offered his top filleters an incentive and a challenge to find an efficient method of cutting the angel shark. The incentive was the opportunity for more hours of work, thus more pay when other fish were scarce; the challenge was to be the first to develop a cut that would make the larger fillets look similar to rockcod fillets that lay flat in the retailers case. Two of the filleters, Gabrial Martinez and Lois Contratas, took up the challenge and were soon cutting angel sharks in record time with little waste other than skin and cartilage.

The tail section was found to yield pieces that could be portion controlled for the fish and chips trade and the remaining odd pieces were purchased by another Santa Barbara firm and made into angel shark jerky. With rock crab fishermen continuing to take the head and fins for bait, only a small amount of the shark is not utilized.

The method developed initially required about 27 different cuts and achieved a recovery rate of about 50% of the dressed shark (25% of the live weight). The process has since been refined with recovery increased by another 10%. Persons interested in a demonstration of the process should contact Mike Wagner at Seafood Specialities in Santa Barbara.

Handled with care, dressed and iced at sea, angel sharks yield a firm white fillet with a good flavor, excellent quality as a frozen product, and a long shelf life (currently about 11 days after being dressed).

Marketing

Consumers in the 1970's were becoming more aware of the health benefits of fish products. As the demand for these products grew, fish processors and wholesalers began seeking additional sources of high quality fish protein (Cailliet and Bedford 1983). The initiation of an offshore drift gill net fishery for thresher shark in 1977 seemed to be the key to satisfying this new demand. The growth of a seasonal thresher shark fishery and the wide consumer acceptance of this shark as a food fish were important precursors to the development of a market for the angel shark. Until 1985, thresher led all other species of shark in consumer demand and sales in the Santa Barbara area (Michael Wagner, pers. comm.).

As supplies of thresher diminished in the winter, Wagner was able to convince local seafood retailers and restaurants to try angel shark as an alternative. With success in local markets, he began to sell angel fillets to distributors in central California, developing a volume market on a regional scale. By 1982, retail prices ranged from $3.53 to 3.75 per kg ($1.60 to $1.70 per pound) and ex-vessel prices had increased to 77 cents per kg (35 cents per pound) in Santa Barbara. Angel shark became the second most sought after shark during the winter and spring. It was at this time that conditions were ripe for expanding the fishery and marketing effort.

Secondary Phase of Development (1982—1985)

One restraint to expanding the fishing effort for angel shark was a processor-imposed quota on the trammel net fishermen, based on market demand, during the early development phase. In the winter of 1982, Seafood Specialties eliminated the quota to fill orders for their volume customers. This action led to a significant change in fishing operations, encouraging fishermen to begin "targeting" on angel shark, following a method using singled-walled large mesh gill nets developed by Santa Barbara fishermen Robert Reid and Mike McCorkle.

Evolution of Gear and Methods

Nets

The first "target" net was built by Reid and McCorkle using second hand single-walled, nylon swordfish gill net with 30.5 cm (12 inch) mesh and No. 18 twine. Reid and several other fishermen have now switched to a heavier nylon twine (No.24 to No.30) and some are using mesh sizes to 40.6 cm (16 inches), stretched diagonally.

A typical "target" net will be about 13 meshes deep and 366-549 m (200 to 300 fathoms) long. Plastic floats, spaced 1.8 m (6 feet) apart on the corkline and a lead line with 29.5 to 38.5 kg/183 m (65 to 85 pounds/100fms) serve to stretch the net vertically. The addition of "suspenders" (lines woven vertically through the net and attached to the corkline and lead line at intervals of 1.8 meters (6 feet) are frequently used to pull the net down, causing it to become baggy and increase the tangling properties of the single-walled net. Nineteen meter (20 fathom) long bridles attached to 13.6-40.8 kg (30-90 pound) Danforth or similar type anchors keep the net "set" in place. The weight of the anchor depends on the length of the net of "gang" (usually made up of several smaller nets or "panels" which can be replaced if major damage occurs). Attached to the anchors are buoy lines at each end of the net, usually with two high density foam buoys and a weighted flag buoy to mark the location of the gear (Fig. 3).

Because of its selectivity for market-sized angel shark, this gear is not used by fishermen who are primarily interested in halibut. Either the traditional three-walled trammel net or 21.6 cm (8 1/2 inch) monofilament single-walled gillnet are used along the south-central coast.

Vessels

The vessels used in this fishery have either a traditional fan-tailed displacement hull with a hydraulic net spool mounted on the aft deck or one of the newer Radon or Wilson planing hulls with the net reel mounted forward, allowing the net to be set and retrieved over a bow roller. The planing hulls have the advantage of speed in moving to and from the fishing grounds, while the displacement hull has a greater hold capacity.

Increased Communication and Cooperation

Following the development of the "target" net came equally important changes in the fishing strategy and the relationship between the processor and the fishermen. To increase the quality and shelf life of the processed shark, Wagner encouraged the "target" fishermen to make overnight sets and to pull their nets at least every other day. Since angel sharks often remain alive in a net for several days, fishermen can pull their nets early in the morning and land a very fresh, dressed shark ready for processing early the same afternoon.

Regular radio contact between the processor and fishermen also helps to fine tune the system. When the market order is open, the fishermen lets the processor know the amount of product to expect several hours before making port. This allows the processor to contact his distributors, arrange to have his processing crews ready and make shipping arrangements before the sharks are landed. When markets are limited, the processor will institute a quota for each vessel, but will continue to contact potential buyers in the morning, often increasing the quota if additional sales are made. Any angel sharks caught beyond the quota are returned to sea alive.

Air Freight and Sharing the Economic Risks: Keys to Market Expansion

A major factor in expanding the market for angel shark products beyond California was the airline industry's recognition of the profit potential in shipping seafood and the advent of very reasonable air freight rates in the early 1980s (Mike Wagner, seafood processor, pers. comm.). The cost for shipping 122 kg (270 pounds) of fish in a standard "EH" container dropped as low as $0.29/kg ($0.13/pound) in 1985. With this favorable rate, Wagner can ship fresh angel shark to major northwest cities within 24 hours (36 hours to east coast destinations) of being taken from the sea and still maintain a fair profit margin.

Supplying distributors with free samples was the second important factor in expanding sales of Squatina. Wagner points out that this approach carries a significant risk, but several fishermen were willing to forego immediate payment for their catch to give the processor time to test the method. This risk sharing involved a willingness to gamble and a good deal of trust between the fishermen and processor.

Expansion of Processing

With the success of Seafood Specialities, several other south-central coast processors decided to give angel shark a try. By late 1984, market demand was high, though training crews in the cutting technique remained a major factor inhibiting growth of the fishery outside of Santa Barbara. This situation changed when one of the originators of the technique, Gabrial Martinez, went to work for a Ventura firm in early 1985. By the end of 1985, the number of processors buying and cutting angel sharks had grown to nine. This expansion of the market encouraged additional set gillnetters from ports both north and south of Santa Barbara to begin concentrating their efforts on angel shark. This increased effort resulted in landings of over 362,811 kg (800,000 pounds) of dressed product by September of 1985 (Fig. 4).

Factors Influencing Landings

Unlike the pelagic shark species, angel sharks remain relatively close to shore and available to the gillnet throughout the year. During the development phase of the fishery, availability of the species was never limiting. Rather, bad weather, removal of nets during whale migrations, availability of other lower priced species affecting market demand (i.e. thresher shark and Pacific halibut) and increasing restrictions on set nets have been the primary factors limiting the landings. Fishermen changing to other fisheries, such as the drift gillnet swordfish and thresher shark fishery have also affected landings during the summer months.

Expanding Biological Knowledge: Key to Sustained Yield Management

Prior to the initiation of the angel shark fishery in California, there were only a few scientific papers written on the species, most of which were taxonomic, though Limbaugh (1955) and Standora and Nelson (1977) provided field observations on behavior and movements of the angel shark in southern California waters.

During the development phase of the fishery, two additional studies were conducted which increased life history knowledge of Squatina californica and raised a number of salient questions relating to sustained yield management of the southern California population.

Pittinger (1984) completed a comprehensive master's thesis on the movements, distribution, feeding and growth of a population of angel sharks residing around Catalina Island, though most of his observations were of larger specimens which showed very slow growth (3.5 cm/yr for sharks with a mean size of 108 cm).

With the cooperation of Santa Barabara commercial fishermen and processors, Natanson (1984) also completed a master's research project aimed at determining the age, growth and reproduction of angel sharks in the Santa Barbara Channel. Following an elasmobranch aging technique verified by Cailliet et al. (1983), Natanson utilized tetracycline to mark the deposition of bands on the vertebral column and found that band deposition was not related to temporal growth as in certain other sharks and rays. The study added significant information on reproductive biology and juvenile growth and development, but the age-length relationship remains a puzzle to researchers.

Cooperative Fishery Investigations

In 1979, because of an expressed interest by the fishing industry, the author, in cooperation with Dr. Gregor Cailliet of Moss Landing Marine Laboratories, biologists with the California Department of Fish and Game, Santa Barbara-based set gill net fishermen, Seafood Specialties and researchers at the University of California at Santa Barbara, began a low budget tagging study to obtain information on angel shark distributions, migrations and growth rates. Originally funded by the California Sea Grant Marine Advisory Program, the project was merged with Natanson's (1984) study which was partially funded by Sea Grant and later continued by Dr. Milton Love of Occidental College with funding provided by the Santa Barbara County Fish and Game Commission. Commercial fishermen provided vessel time and technical assistance, and Seafood Specialties served as a central collection point and depository for specimens. All tag returns were voluntary and fishermen were found to be willing cooperators in returning tagged specimens in return for information on the sharks.

Two attempts were made to obtain additional Sea Grant funding during the development of the fishery to resolve the aging question and to develop the pertinent biological information needed for a rational fishery management scheme for S. californica (Cailliet 1982, per. comm.; Love and Ebeling 1985, pers. comm.). Each time proposals were rejected with the reasons, among others, that the fishery was too small and localized to justify funding.

In the winter of 1985, the Department of Fish and Game agreed to offer a reward for tags and several other processors and fishermen have agreed to participate in the tagging operations. The current objective is to expand the tagging effort as quickly as possible to provide information which will be of use to both fishermen and managers.

Future of the Fishery

To date, fishing effort has been concentrated along the mainland coast of Santa Barbara and Ventura Counties and around the northern Channel Islands, especially Santa Cruz and Santa Rosa Islands. The 1985 landings are expected to exceed 454,000 kg (1.0 million pounds) dressed weight which equates to approximately 90,000 angel sharks. Though there is a good probability that the fishery can expand to the north and south of the Santa Barbara Channel, there is a growing concern within the industry and among fishery managers that the northern island populations may not withstand the current fishing pressure. There has, however, been recent evidence from a tag return that mainland coast angel sharks do cross the Santa Barbara Channel and mingle with island stocks.

The future of the fishery, especially in the Santa Barbara Channel, hinges on obtaining the additional life history information needed to develop a sustained yield mangagement plan for this now quite valuable shark.

Acknowledgements

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Special thanks to Gregor Cailliet of Moss Landing Marine Laboratories who initiated and encouraged important life history research and to Lisa Natanson, Greg Pittenger and Shane Anderson for providing biological data and field observations. Illustrations are by Laurie Marx of the Santa Barbara Museum of Natural History.

My appreciation goes to Milton Love, Chris Dewees, John Sunada, Karen Worcester and Diane Pleshner who took the time to review the manuscript and to Laura Manning and Margaret Kullin for covering many progammitic tasks while I was writing.

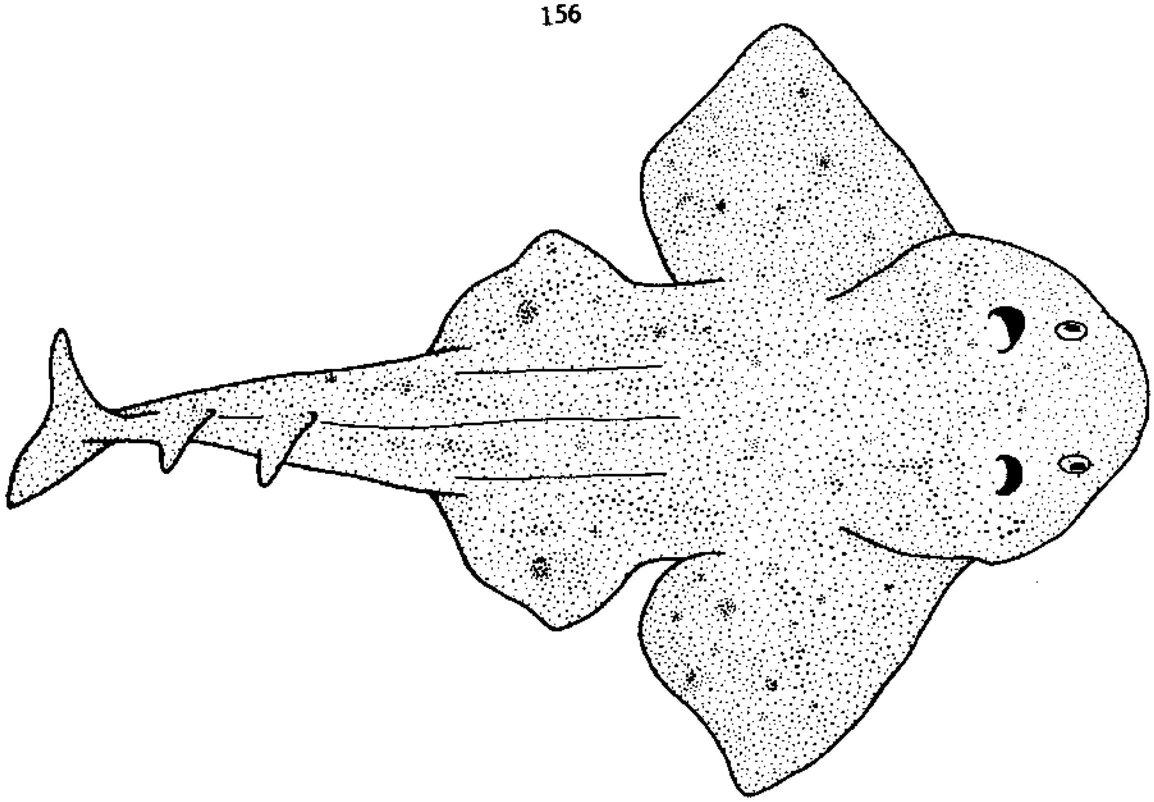

Figure 1. Pacific angel shark, Squatina californica.

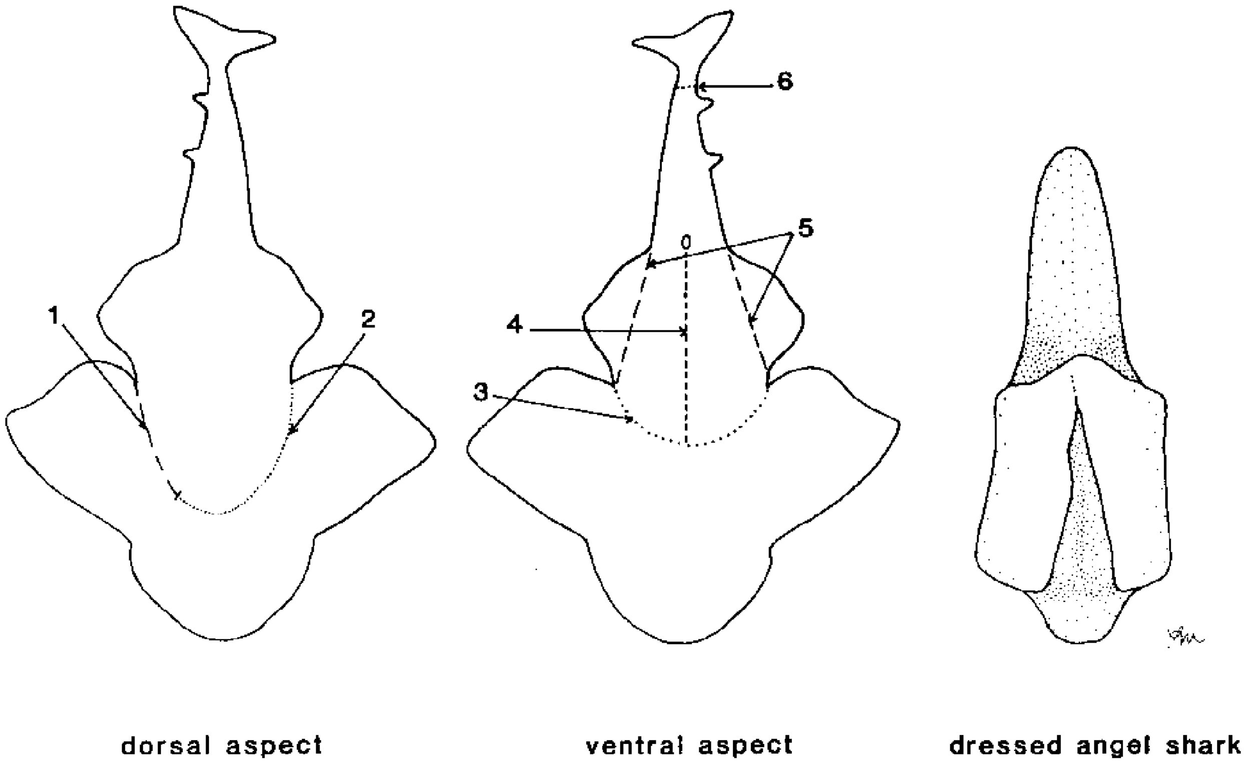

Figure 2. On-board processing of angel shark

1. a. Shark is positioned with head toward fisherman, belly side down.
   b. Lift right pectoral fin and cut from posterior edge toward head.

2. Continue the cut past pectoral fin around base of skull to posterior edge of left pectoral fin.

3. a. Turn shark belly side up and cut left pectoral fin from posterior edge across to right fin.
   b. Remove head, cutting through spine.

4. a. Insert knife under skin at top of belly and cut toward anus.
   b. Grip intestines and cut posterior attachment.
   c. Cut anterior attachment and remove intestines.

5. a. Turn shark belly side down and cut skin of pelvic fins close to body.
   b. Turn shark belly side up and sever left and right pelvic fins.

6. Grasp tail, bowing it toward you and cut at the posterior edge of the 2nd dorsal fin to remove tail.

7. This proceedure should take 1-2 minutes per shark depending on the skill of the fisherman. A dressed shark is approximately 50% of the live weight.

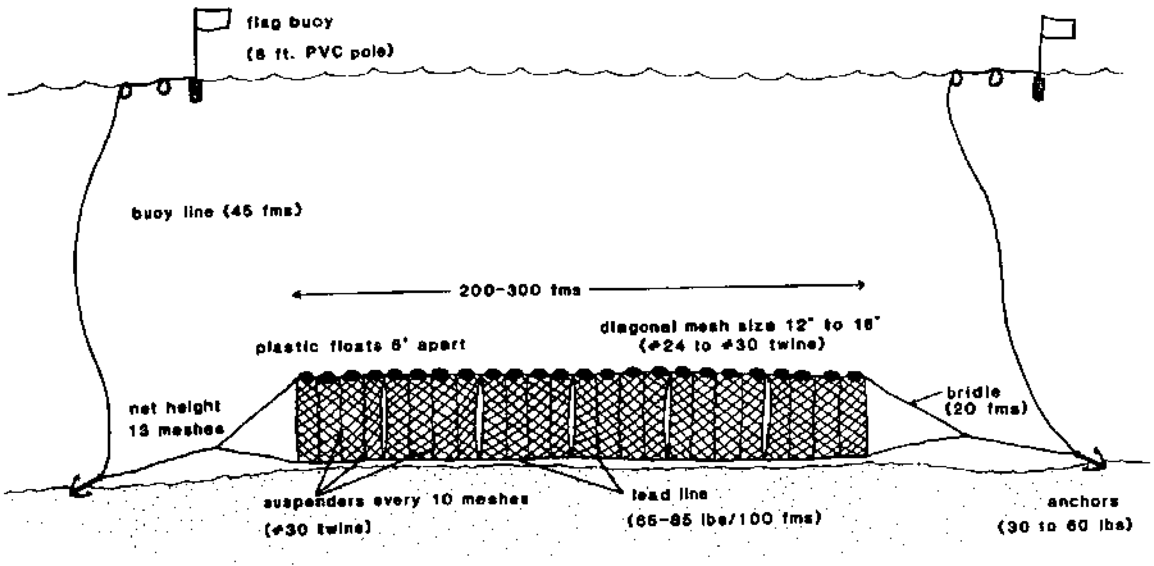

Figure 3. Set gillnet designed for catching Pacific angel shark.

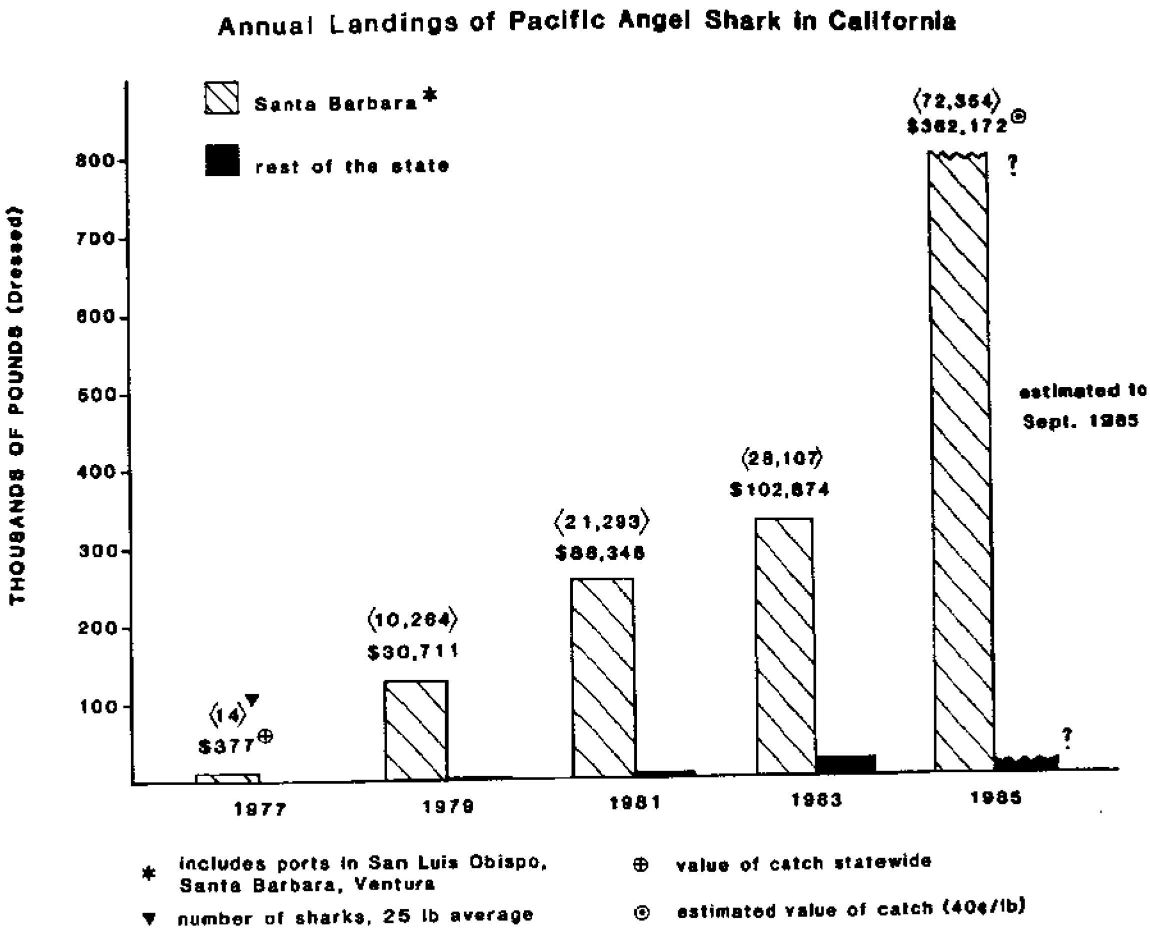

Figure 4. Angel shark landings for Santa Barbara area and the remainder of California from 1977 to 1985.

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Shark Management: A Case History— The California Pelagic Shark and Swordfish Fishery

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Abstract: One group of fishes, the elasmobranchs, have proven to be particularly troublesome throughout the history of attempts to manage long-term sustained fisheries.

A fishery for the common thresher shark, *Alopias vulpinus*, began to develop off the coast of California about 1977. Large mesh gill nets, deployed to take thresher sharks, also proved to be an effective gear to take swordfish, *Xiphias gladius*, a far more valuable commercial fish. Four separate attempts to legislatively manage the developing shark fishery were dominated by the efforts of interests groups more concerned about controlling the swordfish resource than the shark resource. Despite these repeated attempts to manage, the thresher shark resource declined.

Examination of the reasons why this shark resource declined reveals that conditions existed early in the development of the shark fishery that pre-disposed its failure These same conditions, i.e. rapid development of a fishery, slow growth, low reproductive potential, have led similarly to failures of other shark fisheries. Due to the extreme vulnerability to over-exploitation of elasmobranch fishes, attempts to manage sustainable shark fisheries should proceed only through some type of experimental design which emphasizes careful deliberation before expansion is allowed.

Introduction

It has been observed that the discipline referred to as population biology is not an exacting science. It is an observational science in which one gathers information about the state of things, such as they are, and uses this information in an attempt to predict the future. Generally speaking, both the observations of the current state of things and the resultant predictions do not tend to be precise. This lack of precision is due largely to the fact that one is rarely allowed to see, and measure directly, the population in question. As a result, our knowledge of most fish populations, particularly those in the ocean, might accurately be described as not much more than educated guesses.

Under the best of conditions those involved in the management of fisheries use these best guesses to formulate management plans. In the real world, the best of conditions are seldom encountered. The imprecision built into the assessment of most fish populations leaves even the best of plans vulnerable to criticism by one or the other resource user groups. Competition among various special interests groups often plays a dominant role in the formulation of fishery management plans.

The history of fisheries management has had success stories and failures. One group of fishes, in particular, has proved to be very troublesome throughout the history of attempts to develop and maintain successful fisheries. Elasmobranch fishes, the sharks and rays, have so far defied attempts by managers to sustain long-term fisheries (Ripley 1946; Barraclough 1948; Olson 1959; Parker and Stott 1965; Holden 1968, 1974; Anderson 1985; Berkeley and Campos, MS). It is for this reason that I will endeavor to describe a recent case history of the development and attempts to manage a shark fishery off the coast of California. Hopefully other managers may benefit from a description of the key events which were largely responsible for the formulation of regulatory controls over this fishery. In doing so, it is also hoped that it will become evident that another approach to the management of elasmobranch fisheries is needed.

The Fishery

The California pelagic shark fishery began in 1977. Records indicate that as many as 15 vessels using drift gill nets began landing quantities of thresher shark (Alopias vulpinus) in that year (Cailliet and Bedford 1983). The fishing gear was patterned after that used in the soupfin shark (Galeorhinus zyopterus) fishery of the late 1930's and early 1940's.

Both fisheries utilized a large mesh gill net to entangle sharks. The main difference was the method of deployment. The thresher shark fishery employed a drifting net in near-surface waters, while the soupfin fishery anchored the net to the bottom. A more important distinction was that in 1977, for the first time, shark had gained acceptance as a quality food fish and was now sought for its meat. The pre-World War II soupfin fishery had been entirely directed at obtaining shark livers for their high vitamin-A content (Ripley 1946).

The new thresher shark fishery offered needed relief to many fishermen financially trapped in other economically or biologically depressed fisheries. The potential for rapid growth was evident. That potential was further enhanced by the discovery that these same nets were an effective means to capture swordfish (Xiphias gladius), which was and remains, pound-for-pound, the most commercially valuable finfish along the entire coastline.

So important was this discovery that for many fishermen the thresher shark soon became only a secondary target.

The Controversy

As early as 1978, the prospect of commercial gillnetters taking large numbers of swordfish provoked a hostile response from portions of both the recreational and commercial fishing communities. Recreational interests charged that gill nets were not selective and were taking marine mammals and striped marlin (Tetrapturus audax), a fish which was designated by law for recreational use only.[1] Representatives from the traditional swordfish harpoon fishery claimed that gill nets would deplete the swordfish resource, especially in the limited fishing area available in southern California.[2] They also pointed out that under existing law swordfish could be taken commercially only by hand-held harpoon, and they alleged that swordfish were being taken by gill nets but were being reported as harpooned.

Prior to the introduction of these nets, no other major commercial or recreational shark fishery existed, and so the fact that large quantities of thresher shark were also being landed did not cause any particular conflict between different user groups.

In response to the growing discontent, the California Department of Fish and Game (CDFG) submitted a proposal to the California Fish and Game Commission (FGC) on December 6, 1979, which would temporarily ban the use of gill nets on swordfish harpoon vessels for a period of 60 days, during which time recommendations could be drafted for the conduct of an experimental fishery. The FGC denied this temporary ban, but directed that the CDFG prepare a report on the issue, including possible management recommendations for consideration at its March 7, 1980 meeting.[3]

Opponents to the use of gill nets to take swordfish seemed convinced that the swordfish was in jeopardy, but, regarding sharks, urged only "that a study should be conducted to determine the status of the thresher shark resource off southern California."[4] However, prior to the FGC's March 7, 1980 meeting, letters were received stating a "concern that there will be a depletion of the shark resource with proliferation in the use of drift gill nets."[5]

At the FGC meeting of March 7, 1980, the CDFG submitted a report which included a proposal for a one-year experimental swordfish gill net fishery, limited to 25 permittees. The proposal did not address the issue of potential

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1 Minutes of the California Fish and Game Commission, Dec. 6, 1979.

2 IBID.

3 IBID.

4 IBID.

5 Minutes of the California Fish and Game Commission, March 7, 1980.

over-fishing of the thresher shark, owing to the fact that the Legislature had previously granted the FGC management authority over the taking of swordfish, but not sharks. It was not altogether clear how a limited swordfish fishery might affect the thresher shark fishery.

On April 3, 1980, the FGC met in San Diego to hear public testimony on the experimental fishery proposal. By this time, the issue of using gill nets to take swordfish had grown into a conflict of major proportions. After a debate, which included lengthy public testimony, the Commission decided against implementation of the experimental fishery proposal. However, this decision did not affect the take of thresher sharks with gill nets. The Commission decision simply meant that swordfish could not legally be taken by drift gill nets. In subsequent months the incidental, but illegal, take of swordfish by shark drift gillnetters continued, along with claims that these fish were "harpooned."

Unrestrained by any limit on the number of participants, by mid-1980 approximately 100 vessels were engaged in the pelagic shark and "swordfish" fishery. Thresher shark landings had risen to 1.5 million pounds annually. Swordfish landings would amount to about 1 million pounds during the 1980 season. While the latter catch was not unusually high, rumors persisted that a growing percentage of the swordfish landings were actually gill-netted fish. If this were true, then the incentive provided by swordfish undoubtedly added to the fishing pressure on thresher sharks as well.

The rapid development of the thresher shark fishery was beginning to concern some CDFG biologists. But owing to the belief that this shark was pelagic and highly migratory, it was generally agreed that there was time to learn more about this species before recommending any measures that might prove to be too restrictive.

AB 2564 (Kapiloff)

The controversy over swordfish had a very polarizing effect throughout the industry and its various interest groups. One group, the Billfish Protective Association, represented the interests of some of the traditional harpoon vessel operators. This group appealed to California Assemblyman Kapiloff, from San Diego, to sponsor legislation that would regulate the take of swordfish by gill nets. Assemblyman Kapiloff agreed to introduce a bill which would attempt to resolve the swordfish/gill net controversy. Legislation that would somehow restrict the use of drifted gill net appealed also to the National Coalition for Marine Conservation (NCMC), Pacific Region, an organization representing primarily sport fishing interests. A series of meetings followed between these anti-gill net forces, the shark drift gillnetters, Assemblyman Kapiloff's staff, and representatives from the CDFG. Over a period of five months, Assemblyman Kapiloff's Bill was revised at least one dozen times (Fleming 1983), and finally resulted in the introduction in the California Legislature of Assembly Bill 2564, which contained the following key provisions:

1. A drift gill net permit system, limited to those persons who could prove: (a) participation in the shark fishery during the calendar years 1978 or 1979; or (b) that a "significant investment" was made prior to May 20, 1980.
2. A mandatory observer program for all vessels operating simultaneously under both the drift gill net permit and the harpoon permit.
3. Drift gill net vessels could retain incidentally caught swordfish, but the fishery would be closed if the number of gill-netted swordfish exceeded 25% of the number of swordfish taken by harpooners.
4. A study would be conducted to determine what impact the fishery would have on the shark resource.

The CDFG recommended passage of this bill, noting that it contained provisions that would limit the entry of new participants to the shark fishery and did provide an opportunity to study the shark resource.

In September 1980, Assembly Bill 2564 became law. Through the observer program, this new law provided a mechanism to study the thresher shark, and during the following two years after its passage, much was learned about the life history of this species. What was learned was that reproduction in this shark is very slow, only four pups annually (Bedford MS). Perhaps even worse, in light of the expanding fishery, was the discovery that 95% of the fish being landed were smaller than a newly matured female. In 1981 thresher shark landings reached 2 million pounds and it had become evident that the legislative attempt at "limited entry" was not working. The undefined term "significant investment" was proving to be a loophole. The number of drift gill net permits had risen to 150.

The Federal Fisheries Management Plan

In accordance with the United States Fisheries Conservation and Management Act of 1976, the Pacific Fishery Management Council was directed to prepare a Fisheries Management Plan for pelagic sharks and billfish. The final version of the preliminary plan was completed and scheduled for review and possible adoption by late 1980. This document concluded that the swordfish population was in good condition and that no management action should be taken. It also concluded that any attempt at unilateral management would be ineffective since other nations, most importantly Japan, harvest the majority of swordfish taken annually from the eastern Pacific Ocean. The plan made no specific recommendations regarding the thresher shark, concluding that little is currently known about stocks in the eastern Pacific.

In October 1981 the Pacific Fisheries Management Council concluded that there was no need to adopt a management plan, noting that the present pelagic shark and billfish fisheries were conducted entirely in waters off the State of California and that the state was currently managing these fisheries. The plan was indefinitely "shelved."

Senate Bill 1573 (Beverly)

The Kapiloff Bill was due to expire in September 1982, and so by mid-1982 competing interest groups were once again engaged in a heated debate over the management of this fishery. There were now over 200 drift gill net permittees. Thresher shark landings were approaching 2.3 million pounds for the year.

CDFG biologists had become very concerned about the prospects for a continuing thresher shark fishery and wanted some kind of a real cap on the increase in shark fishing effort. On the other hand, it was felt that the restrictions on swordfish landings by gillnetters could not be supported on the basis of resource limitations (Bedford and Hagerman 1983). The California Gillnetters Association agreed on both points and asked Senator Beverly to carry a bill on their behalf. Senate Bill 1573 (Beverly) was introduced. If passed it would place a moratorium on the issuance of new permits and would, for the first time, allow for "targeting on swordfish."

Meanwhile, the NCMC had very successfully mounted an anti-gill net campaign through southern California's numerous boat and fish and tackle shows and had obtained approximately 20 thousand signatures on a petition to ban gill nets outright throughout California waters. Unable to achieve such a ban before the expiration date of the Kapiloff enactments, the NCMC indicated they could modify their position to one of support for SB 1573 (Beverly) if it was amended to include some provision for a swordfish quota.

Opposing interests were gathered together once again over the commercial drift gill netting issue in a meeting called by CDFG. A compromise on the issue of a swordfish gill net quota proved to be difficult. The resource was believed to be in a very healthy condition and able to sustain increased harvests, but the NCMC seemed to have captured public opinion with their anti-gill net campaign and were in a position to demand some kind of a catch quota. Eventually a compromise was reached that tied swordfish and shark landings together during the first half of the season. Specifically, it required that during the period May 1 through September 15, each gill net vessel could land, during any one month, no more swordfish, by weight, than shark. The reasoning behind this quota seems to have come from the fact that swordfish were still regarded to be an incidental catch in the thresher shark fishery, and would tend to discourage gillnetters from targeting on swordfish during the traditional swordfish harpoon season. This would mean that in order to justify gill netting swordfish, it would be necessary to land an equal amount of thresher shark. The fact that the swordfish population was acknowledged by all involved biologists to be in a healthy condition, while the health of the thresher shark was in doubt, seemed to be lost on the participants to this dispute. Of some consolation was the trend that the thresher sharks appeared to be more available early in the season, whereas swordfish were available later in the year. From the standpoint of resource conservation, the best interests of the thresher shark population would be served if this entire provision proved to be an unneeded paper gesture. This bill also contained a concession on the part of the gillnetters to close the month of April to shark gill netting. April was known to be an important month for thresher shark "pupping," and so it was believed that an April closure would be a valuable concession. After much consideration CDFG concluded that it was the best possible compromise that would likely arise from the previous deadlock, and so recommended its passage. In September 1982, AB 1573 (Beverly) became law. For the first time, a moratorium on the issuance of new drift gill net (DGN) permits, which had increased to 230, was in place.

By the fall of 1984 it was apparent that the DGN swordfish fishery was a success. The previous season (1983-84) landings had equaled the all time record, and the current year was obviously going to produce a new record. By then it was equally evident that the thresher shark resource was in decline. Total thresher landings, which had peaked in 1982, now declined for the second year in a row. Four years of market sampling compiled into length-frequency histograms showed a successive shifting in modal size toward smaller fish. Catch-per-unit-effort indices were dropping as well. After having finally succeeded in capping the growth in the number of permittees, we were receiving signals that it was too late for the shark resource.

AB 3387 (Farr)

During the 1983 season DGN vessels followed the migration of swordfish into waters north of Pt. Conception. Their efforts were rewarded with profitable landings of large swordfish from areas as far north as San Francisco. Drift gill net vessels began unloading their catch at markets in San Francisco, Monterey, and Morro Bay. Local fishermen from these ports were encouraged at the prospect of a local swordfish fishery. Their attitudes changed rapidly when they discovered that the swordfish fishery was closed to new entrants. Fishermen from Monterey wondered why they could not catch swordfish using the drift gill nets off "their own coastline" when southern California fishermen could! Burdened by a recognition that the local salmon fishery was in trouble, causing financial hardship to many residents of the Monterey area, Assemblyman Farr introduced Assembly Bill 3387 which became law in the summer of 1984. It allowed another 35 permits to be issued for a central California drift gill net swordfish fishery. It could only be hoped that these new central California fishermen would not add significantly to the pressure on thresher sharks.

AB 2199 (Felando)

In the two seasons that followed the passage of SB 1573 (Beverly), it had become all too evident that the shark-swordfish quota was not a "paper gesture." Its effects were very real. Due to a combination of a declining shark catch during the summer months and the increasing awareness among gill net fishermen of when and where to catch swordfish, each year more fishermen found themselves in violation of the law. A growing number had their permits temporarily suspended for such violations. The potential for permanent revocation existed for many, threatening to sever their ability to make a living as drift gillnetters. Fishermen complained that it made no sense to threaten them with suspensions or worse when it was acknowledged that the swordfish resource could sustain increased fishing pressure.

On the other hand, more fishermen were willing to admit that the thresher shark fishery needed help. CDFG biologists began to talk about options, including the Director's authority to take emergency action when a resource is in danger of irreparable harm.

In the spring of 1985, Assemblyman Felando announced that he would introduce "clean-up legislation" to remedy some of the problems created by previous shark-swordfish legislation. The main focus of this bill would be to get rid of the shark-swordfish (50-50) quota, since it had proven to be unworkable. This was viewed by CDFG as an excellent opportunity to seek some kind of a reduction in fishing pressure on the thresher shark, as most fishermen now appeared willing to trade some portion of the declining thresher shark fishery for a more open swordfish fishery. This type of trade-off was incorporated into the proposed legislation, which gained for it CDFG support. AB 2199 (Felando) became law in September 1985.

Beginning in the 1986 season the prime thresher shark fishing months of June, July, and half of August will be closed within 75 miles of the California mainland to all drift gill net operations. On August 15, the drift gill net swordfish season will begin, unrestrained by any quota. Fishing effort directed at thresher sharks could be reduced by 50%. It is not known whether this reduction will allow stocks to slowly rebuild, but it is viewed as a move in the right direction. Swordfish landings are expected to increase.

Discussion

In the introduction, I promised to describe a case history of an attempt to manage a shark fishery. However, in reviewing the history of regulatory changes that have governed the conduct of this fishery, one is confronted with the uncertainly that what we have done might not satisfy the definition of resource management, at least not when judged against the standards inherent to its fullest meaning. It appears that our actions may have been limited to a far more restrictive interpretation of management, one in which we have most often defined our role as mediators to an ongoing dispute between user groups. The dispute we mediated seldom had anything to do with the thresher shark. The control of the swordfish resource promped the adoption or abolition of most regulation.

One might find reason to blame this failure to effectively manage a shark resource on any number of troublesome factors, given the volatile political atmosphere surrounding a fishery conducted near a major metropolitan center, especially if it were an isolated case. But the sad truth is that the scientific literature is beginning to be filled with examples of failures to manage shark fisheries (Ripley 1946; Barraclough 1948; Olson 1959; Parker and Stott 1965; Holden 1968, 1974; Anderson 1985; Berkeley and Campos, MS). Recognizing this, it becomes even more important that we examine why the present attempt to manage failed, because the actual causes are likely to be symptomatic of failures in other shark fisheries.

The approach towards management was similar with this fishery as with other kinds of fisheries. Landing records were kept from its beginning in 1977. By late 1980, data was being collected to define the life history of the thresher shark. By early 1981, fish were measured from commercial markets so that the size structure of the catch could be monitored. Attempts were made to construct a growth curve, so that portions of the catch could be assigned specific ages. Beginning in late 1980, commercial fishermen were required to keep logbooks, reporting on their fishing activity, so that indices of catch-per-unit-of-effort could be developed. Fishermen were even required to allow observers to accompany them on fishing trips, so that CDFG could gain some first-hand insight into this fishery.

So with all this data collection, why couldn't the developing problem be detected soon enough, or action be taken swiftly enough to head off the potential decline in the thresher shark population? (Landings peaked in 1982 and subsequently declined.) In order to understand why this particular attempt at management failed, and at the same time understand why shark fisheries have historically failed, one need only recognize two important differences between elasmobranch fishes and most teleost fishes. Unlike their distant relatives, reproduction in elasmobranches involves either live birth or a relatively few eggs. It follows that a strong relationship must exist between stock and recruitment. Secondly, growth in elasmobranch fishes is relatively slow and sexual maturity occurs rather late in life. Holden (1977) estimated that elasmobranchs mature at approximately 60% to 90% of their asymptotic length. The implications for fisheries managers of this combination of factors cannot be over-emphasized, for it necessarily leads to the important conclusion that the annual sustainable harvest can be no more than a small fraction of the existing stock.

Consider what this means to managers and fishermen alike. If the allowable annual harvest is limited to a small fraction of the existing stock of fish, then the initial harvesting rate, from a stock close to its carrying capacity, can easily develop beyond sustainable harvest rates. If continued, the resultant population collapse will occur quite suddenly.

The reason overharvest occurred, despite all efforts to monitor the thresher shark fishery, was precisely that "this fishery was handled in the same manner as other fisheries." That is, it was handled in a manner which might be appropriate with most teleost fisheries but is totally inappropriate for elasmobranch fisheries. It was treated as though, once signs of overharvest were detected, a reduction in fishing pressure by some amount would result in the biomass adjusting itself rapidly upwards, i.e., that the population is capable of rapid adjustment towards some new state of equilibrium. Signs of overharvest were detected, but even after taking rather extreme measures to reduce the total fishing pressure, it will likely be quite some time before this population is rebuilt.

The problems posed to would-be managers of shark fisheries are not unique; they are common to all fisheries. But, when dealing with sharks, the effects of an incorrect or late decision can result in a more pronounced and long-lasting decline in the resource. It is, therefore, imperative that one approach the whole problem with greater caution.

Given the high degree of vulnerability to overfishing, it would appear that the only rational approach to management of a developing shark fishery would be through some kind of carefully controlled experimental procedure. In the real world of economics, politics, special interests, governmental procedures, and rapidly developing fisheries, late involvement by fisheries managers in the development of shark fisheries is almost surely doomed to failure.

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The Developing Alaska Salmon Shark Fishery

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Abstract: The salmon shark (Lamma ditropis) is a large, highly mobile predator associated with the inshore and oceanic waters of the temperate North Pacific Ocean. The species is an apex predator known to feed on a variety of marine species, the most notable being Pacific salmon.

Salmon shark, as well as other lamnid sharks, are of biological interest due to their ability to thermo-compensate. The Salmon Shark may gain considerable predatory advantage over various prey species due to this thermo-compensatory ability.

The salmon shark is of economic importance due to the comparatively high value of its flesh in developing domestic markets and for the value of its fins in Asian markets. Other byproducts from this shark may prove to be of significant economic value as well.

This paper reviews the basic natural history of the salmon shark and provides a prospectus of its potential economic importance as a developing commercial fishery in Alaska. Also reviewed is the reference volume titled **The Development of a Commercial Shark Fishery: The Salmon Shark (Lamma ditropis) of the North Pacific Ocean.**

Introduction

The salmon shark (Lamna ditropis) is a large, free-ranging, epipelagic shark occupying vast expanses of the North Pacific Ocean. It is a member of the lamnid family of sharks and is related to a number of other well-known predatory species including the white shark (Carcharodon carcharias) and shortfin mako shark (Isurus oxyrinchus). The distribution of the salmon shark lies in the range of 40-60° north latitude, with both north and south coastal extensions far beyond this range. On the Pacific Coast of the U.S., the salmon shark is distributed to at least the latitude of San Diego, California, in the south and unofficially to the latitude of St. Lawrence Island in the north. The species occupies the entire breadth of the North Pacific and is considered to be one of the most numerous species within the epipelagic community residing within these cold northern waters.

Biology and Behavior

The biology and natural history of salmon shark populations occupying the eastern portion of the species' range are poorly known. Practical aspects of the natural history of this large oceanic predator are best known among the fleets of U.S. and Canadian fishermen targeting on various Pacific salmon species (genus Oncorhynchus). The ranges of this shark and Pacific salmon broadly overlap, as do those of other shark species, including the blue (Prionace glauca) and white sharks. The salmon shark undergoes marked seasonal migrations that closely parallel that of certain prey species, one of the most notable being sockeye salmon (O. nerka).

The salmon shark is known to attain lengths of at least 3.1 m (10 feet) with corresponding weight of 363 Kg (800 pounds). Unofficial reports suggest that salmon shark may reach lengths in excess of 3.7 m (12 feet) and weights of 454 Kg (1000 pounds) or more. In terms of general anatomy, this species is similar to most aspects of the general shark body plan. One important exception is that the salmon shark, along with other lamnid sharks, has become partially warm-blooded. The salmon shark and its allies have counter-current heat exchangers that permit the effective conservation of metabolic heat. This adaptation is reflected in various aspects of the behavior and physiology of this species. It also allows the movements of salmon shark to be relatively independent of water temperature and incurs a significant predatory advantage. The presence of warm body temperatures, however, presents the prospective shark fisherman with an important quality control problem. This shark must be rapidly cooled in order to retain meat quality.

The salmon shark is a euryphagous feeder, not specializing on any one prey species or species group. However, this species is best known as a predator of fish and squid. It is a major predator of sockeye, pink (O. gorbuscha), chum salmon (O. keta). As mentioned, the migratory patterns of this shark seasonally paralled those of sockeye salmon over major portions of its range. Although the distribution of this shark is directly related to the distribution of its major prey species, water temperature may exert indirect effects. This effect may be limited to the influence of water temperature on the distribution of prey species. The salmon shark is known to occur within a temperature range of 2-3° C (36-74° F). Surface aggregations of salmon shark in coastal waters begin to appear when sea surface temperatures increase to 10-11° C (50-52° F). It is interesting to note that silver salmon (O. kisutch), an important prey species, begin to appear in coastal waters at approximately this same surface temperature.

Several questions persist concerning the reproductive biology of this species. Most lamnid sharks exhibit the ovoviviparous mode of reproduction. These sharks employ internal fertilization, retention of energy-rich eggs without the development of placental structures, and live-bearing Some researchers have suggested that the salmon shark may be viviparous. Viviparity is marked by the formation of a placental or pseudo-placental link between the embryo and the maternal body. The maximum fecundity of the salmon shark is four pups over a reproductive cycle of 12 months. Some evidence suggests an even more extended reproductive cycle. This limited reproductive capacity suggests that this species may be easily affected by fishing mortality. Additional research is necessary, with particular attention directed at the reproductive capacity of discrete salmon shark populations.

Within the Gulf of Alaska, the identity of the salmon shark has frequently been confused with that of a related Atlantic species, the porbeagle shark (Lamna nasus). In fact, many veteran Pacific Coast salmon fishermen persist in calling this shark the "porbeagle shark." Some confusion has also occurred in differentiating between the salmon shark and white shark. The distribution of these two sharks overlap over significant portions of their ranges in northern regions. If the salmon shark is to become an important commercial species, it is important that the species gain its own identity. Also, the salmon shark, unlike related lamnid sharks, is not believed to be dangerous to humans. No attacks have been officially documented, although unofficial reports indicate close, non-lethal encounters of various types.

Salmon sharks are traditionally known to form seasonal aggregations at certain points along the Alaskan coastline. These areas include Aleutian Island passes, Kodiak Island bays, Valdez Narrows, the Copper River Delta, and many locations in Southeast Alaska. Surface occurrence tends to coincide with the 10-11° C (50-52° F) isotherm in the Gulf of Alaska. In the surface waters of Southeast Alaska the salmon shark is known to occur from May to November. The species is most common during the period June to September in this region. In these same waters, surface temperatures in excess of 11° C (52° F) increase the probability of the simultaneous occurrence of the blue shark with salmon shark.

In the western Pacific, salmon shark concentrations are often associated with oceanic frontal structures. The Oyashio Front in the northwestern Pacific is most notable in this regard. The eastern Pacific lacks similar major oceanic structures found to the west. Smaller, less conspicuous oceanographic structures will need to be used to indicate shark concentrations in Alaskan waters.

The migratory behavior of the salmon shark in the northeastern Pacific is poorly known. Much additional research is needed to understand the population structure of salmon shark in this broad region. It is believed that this species is distributed in an array of principal and accessory populations in a manner similar to that of other sharks. The proper management of this species will require precise knowledge of migratory behavior and population structure. The possibility exists that coastal salmon shark populations are not highly migratory, but may use deep thermal refuge areas in close proximity to the summer range. A major concern is that commercial fisheries targeting on salmon shark may drive small local populations to the point of extinction. The rapid demise of regional shark fisheries has been a chronic problem in many parts of the world.

The Emerging Fishery

Most people are not aware that the cold waters of the North Pacific harbor relatively large populations of epipelagic sharks. Salmon shark have become known primarily via their incidental capture in various salmon fisheries and observation of their predation on Pacific salmon. In this regard, salmon shark and similar predators, primarily blue shark, have been considered as major nuisances by commercial fishermen. The salmon shark has been implicated in the loss of trolling gear, severe damage to seines and gillnets, and the loss of hooked or netted salmon. For the most part incidentally captured shark have been discarded at sea. Prior to 1983 most fishermen and processors in Alaska were not aware of the commercial value of shark meat and byproducts. Even the valuable fins were not retained from incidentally captured salmon shark. The rate of incidental capture has been very high in certain offshore fisheries. The Japanese high seas salmon gillnet fishery in the general areas of the central Aleutian Islands incidentally harvests 25,000 salmon shark per year. The incidental capture of salmon shark in Alaskan coastal salmon fisheries is much lower, perhaps through mutual avoidance.

Prior to 1983 directed salmon shark fisheries have only existed in Japan. This fishery takes place in the vicinity of the Oyashio Front off the northeastern coast of Japan. However since 1983, a number of Alaskan fishermen and processors (Kodiak, Seward, Yakutat, Petersburg, and Sitka) have engaged in experimental shark fisheries. For the most part, these efforts have been successful in both harvesting and marketing salmon shark meat and selected byproducts (primarily fins). It is anticipated that a mature shark fishery will eventually develop from these pioneering efforts. Jim Parker, formerly an Alaska Department of Fish and Game biologist stationed at Sitka, is believed to have attempted the first pre-commercial shark harvesting experiments in Alaska. Parker participated in a productive test fishery in the Cross Sound (northern Southeast Alaska) area during the early 1960's.

Current work on the development of an Alaskan salmon shark fishery commenced with the "Southeast Alaska Salmon Shark Project." This project was financed by the Alaska Office of Commercial Fisheries Development and conducted by researchers from the Alaska Marine Advisory Program and the University of Alaska/Fairbanks.

The initial effort took place in Stephens Passage, a portion of the Inland Passage north of Petersburg, during the summer of 1983. The project was timed to intercept salmon shark migrations known to pass through this waterway during the July-August period. Surface aggregations of this species traditionally form at several locations along the eastern shore of Stephens Passage when sea surface temperatures approximate 10-11° C (50-52° F). Unfortunately, this research effort was beset by an environmental problem that ultimately proved to be insurmountable. The summer of 1983 throughout most of the eastern Pacific was marked by anomalous oceanographic conditions associated with the El Nino warm water phenomenon. Surface temperatures throughout Southeast Alaska were unusually high. The migratory patterns of many forage and predatory species, including the salmon shark, were altered by these conditions. During the research period, surface temperatures in the Stephens Passage area were in the range 11-13° C (52-55° F). Salmon shark and associated schools of Pacific salmon were distributed throughout the area rather than being concentrated in a limited number of traditional fishing locations. As a result of these conditions, the researchers were able to intercept very few shark.

Gear

The researchers made use of a hybrid floating longline system similar to that used in the experimental California blue shark fishery. The mainline was floated at preset distances from the surface through the use of buoy bags. The mainline consisted of segments of both standard halibut "groundline" of 7 mm (9/32 inch) diameter nylon and galvanized steel cable of 2.4 mm diameter (3/32 inch). Stainless steel gangions of 0.9-1.1 m (3.0-3.5 foot) lengths were used, each terminating with a mustad 12/0 tuna hook. The gear performed well, indicating that similar gear could be used on most small commercial fishing boats operating in these waters. However, the short length of the gangions and the weak mainline attachment provided by standard stainless steel snaps caused a high loss rate. The short fishing period resulted in the capture of one 173 Kg (385 pound), 1.8 m (6 foot) female. Based on the occurrence of straightened hooks and lost gangions, it is believed that an additional 27 sharks were hooked but not retained. An earlier researcher (Parker) estimated that a small commercial fishing operation could expect to capture 20 shark per day using floating longlines.

Marketing

The shark meat harvested and processed as part of this project was test-marketed in the Seattle area. The meat received positive reviews in this marketing area. Test results encouraged other fishermen to initiate similar experimental fisheries, the earliest beginning in the late summer of 1983. During 1984 and 1985, thousands of pounds of salmon shark meat have been marketed along the Pacific Coast. Southern California has served as a major market. Again the product has been well received. Salmon shark meat from the Copper River Delta was evaluated along with the meat from a wide variety of other commercially important sharks as part of this Sea Grant Shark Conference. Salmon shark and the Pacific angel shark (*Squatina californica*) received the highest reviews.

The development of a salmon shark fishery in Alaska will be based on the marketing of a number of products. These products include: meat (ex-vessel value expected to be approximately $1 per pound during the early part of the 1986 season), selected fins (value of the dried fins, excluding pectorals, is expected to exceed $8 per pound), hides (limited marketing efforts expected), blood serum (limited marketing opportunities present), and jaw sets (tourist trade). Marketing opportunities for salmon shark meat and fins appear to be particularly strong.

Conclusions

It is expected that a limited salmon shark fishery will develop in the Gulf of Alaska. Much of the catch will probably originate from incidentally caught shark that are retained by the Pacific salmon fleet. A significant and growing portion of the harvest will come from a small group of harvesters planning to target on salmon shark. A major difficulty facing these harvesters and marketers is that the shark fishery will take place simultaneously with Pacific salmon fisheries. Onshore processing and freezing facilities will be severely limited during this time. Limited processing capacity during certain seasons may curtail the development of a major salmon shark fishery in Alaska. A number of small floating catcher/freezer processors are now planning to commence operations during the summer of 1986.

Although it appears to be inevitable that a shark fishery will develop, a number of major management concerns persist. The population dynamics of the salmon shark need to be better understood before rational management strategies can be put into operation. Areas requiring additional research include population size, discrete ranges, migratory patterns, and reproductive capacity.

A comprehensive report, **The Development of a Commercial Shark Fishery: The Salmon Shark (*Lamna ditropis*) of the North Pacific Ocean**, is available dealing with the biology of the salmon shark and the development of shark fisheries in Alaska and along the Pacific West Coast. Sections in this "salmon shark manual" include the description of the natural history of the species, fishing strategies, quality control requirements, and marketing conditions. The manual provides a very thorough treatment of these various topics. This volume is available through the Alaska Sea Grant Program, Fairbanks, Alaska.

Synopsis[1]

Development of Gulf Coast Shark Fisheries

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The development of markets for shark in Texas has been different than in other parts of the United States. The market is characterized by a fairly strong sensitivity to oversupply and has required the Texas A & M University Sea Grant Program to put more effort into its development than others have devoted to similar fisheries in other parts of the country.

Awareness of shark resources in Texas waters is a direct result of the swordfish (Xiphias gladius) longline fishery. Sharks have often been taken as incidental catch in this fishery over the years. Some of the incidental shark species, such as shortfin mako (Isurus oxyrinchus) and the bigeye thresher shark (Alopias superciliosus), have always found ready markets. However, little effort was applied to developing these other species because it has been difficult to induce fishermen to target on shark when they could earn as much as $800 per fish for swordfish. In fact, gear was rigged specifically to allow sharks to break free until the past few years. It was a common view of fishermen that this saved a lot of time and trouble in wrestling with fish for which there was no ready market. Often up to 20% of the 300-400 hooks set on swordfish longlines would be bitten off by sharks.

Small markets did develop for the incidental shark catch in 1980, especially in Mexico. On occasion swordfish boats landed up to 21,700 kg (48,000 pounds) of dressed shark for which ex-vessel prices ranged from $0.77-$1.11/kg ($0.35-$0.50/pound). This price did not encourage targeting on sharks, but it did help pay the fuel bills of the vessels. One of the limiting factors in developing a consistent market for Texas shark in Mexico has been the fluctuation of the value of the peso. In 1980, the exchange rate was 12.5 pesos to the dollar. By late 1985, the peso had fallen to an exchange rate of 380 pesos per dollar.

Interest in sharks as a directed fishery resource in Texas increased about five years ago (1980) because of the decline of swordfish and bottomfish. Many types of sharks are considered recruitable to this fishery

[1] This paper was summarized by Sid Cook from a tape recording of Mr. Graham's presentation at the conference.

with the exception of hammerheads (Sphyrna sp.) and tiger sharks (Galeocerdo cuvieri), which have not been retained because their darker flesh and somewhathigher urea content makes them more difficult to handle and market successfully.

The test rigs used by Texas Sea Grant consisted of 226 kg (500 pound) test leader topped with 0.67-1.0 m (2-3 feet) of stainless steel wire. The gear was tested by commercial longline vessels.

Sharks taken with the gear are routinely shot to subdue them (the heart continues to beat for up to 20 minutes afterward, allowing the animal to be bled). The animal is then gaffed, brought on board, and the tail removed for bleeding. Then the shark is eviscerated, the head removed, and the fins recovered.

When fishing is good, cleaned carcasses are often left on deck rather than placed in the ice hold. This is a poor practice. The Texas fishery is sub-tropical. It is characterized by warm water temperatures and hot days, which greatly accelerate the deterioration of the shark if it is not properly cooled. This can be avoided by limiting the number of animals brought on board. Although it goes against a fisherman's grain, often it is best to cut loose excess sharks and let them swim away rather than to bring aboard more shark than can be handled in an efficient manner. Usually a vessel can handle about 1360-1810 kg (3000-4000 pounds) of dressed shark without any problem. Amounts over that figure are difficult to field dress rapidly and will tend to oversupply the market and be difficult to sell. A Texas Sea Grant researchers landed 2630 kg (5800 pounds) of dressed silky shark (Carcharinus falciformis) on a demonstration trip and had difficulty finding a market for it.

After a shark has been thoroughly cleaned, it should be cooled with some ice from the ice hold before being placed in refrigeration. Placing a warm carcass on ice without cooling it first will cause an air pocket to form around the fish and it will not maintain its quality. This is especially important because Texas boats often have to run 80 or more km (60 or more miles) from their home ports to fish for shark and trips of 5-6 days are the rule. On swordfish boats that intend to keep incidental sharks, the sharks are only retained for the last five days of the trip.

Many persons believe that the belly flaps should be removed from the shark during field dressing to prevent spoilage. There is some concern that removal of the belly flaps might increase the chance of contamination by increasing the cut surfaces. However, buyers will often insist that sharks have the flaps removed, and in such cases, the fisherman is left little choice but to comply with buyer specifications to be able to market the product.

There are no problems marketing the fins from Texas sharks as long as they are properly cleaned in the field (all meat removed with crescent cut). They should be hung on lines rather than left sitting on top of the wheelhouse or on hatch covers; experience indicates that they lighten considerable during frying and will blow away in brisk winds.

Another consideration in the development of Texas shark fisheries is that blacktip sharks (*Carcharinus limbatus*) often will congregate around shrimp trawlers. This very marketable shark could add to the revenue of the vessel if fished during times when the shrimp gear is not deployed. In tests by Texas Sea Grant, 317-361 kg (700-800 pounds) of dressed shark can be taken in as little as 40 minutes with jury-rigged longline gear.

The potential conflict between the shark fishery and the billfish fishery can be minimized by fishing for shark in the morning and swordfish in the evening. To discourage swordfish from taking shark baits, the bait is cut in half before being placed on the hooks. Shark will be attracted to this bait, but billfish will not.

Anyone entering this fishery must be aware that sharks can move considerable distances in short periods of time. You aren't likely to find large numbers of sharks in the same place they were located on your last trip. And in the case of silky sharks, the larger individuals are inshore (averaging 43 kg) and the smaller ones are offshore (averaging 13.5 kg). This is the opposite of most shark species.

In conclusion, let me emphasize that product quality is the overriding limiting factor in the development of this fishery. Efforts must be made at all points in the processing and distribution of shark to maintain both a high quality product and to avoid oversupplying the market.

Post-Catch Handling and Quality Control of Shark

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Abstract: All shark to be used as human food and to receive optimum benefits from its by-products must be taken care of immediately. The key to greater consumer acceptance will be quality. Because of its unique characteristics, shark must be handled with greater care. Fishermen are learning proper bleeding and refrigerating techniques which will result in larger and more dependable markets.

Shark will become popular throughout the United States when the food industry and public gain complete confidence in its quality. Inconsistent quality has been a major marketing problem in the past. Unlike red meat, if the consumer receives a low quality shark product he usually won't try it again. Especially if it's served in a restaurant. Consumers will not spend entertainment dollars on a seafood dinner of which they are not sure.

Shark meat has wonderful flavor. Unfortunately, it can be quickly and irretrievably lost when fish are mishandled at the time of capture. West coast fishermen and dealers learned this lesson many years ago. The Gulf and South Atlantic industry has been on the learning curve for the past five years. In my region today, successful shark fishermen are observing proper handling techniques scrupulously, and careless fishermen are having their catches rejected. Occasionally some bad shark meat finds its way into the market. But, generally, our quality control efforts are working.

The opportunity to make serious money fishing for shark has been a boon for many struggling fishermen in my region. So there is keen interest in developing this fishery and markets by producing training aids for fishermen and point-of-sale materials for purveyors.

In the old days it was believed that shark had limited food potential because it developed off odor and flavor too rapidly. We know now that shark meat has excellent shelf-life when it is handled properly. It is the high concentration of urea and TMAO in the blood of sharks that make proper handling so critical.

TMAO is a handy acronym for trimethylamine oxide. It is a substance, similar to ammonia, that causes the flesh of many marine animals such as sharks to deteriorate rapidly after death.

Urea is a substance produced in sharks as a by-product of protein metabolism. While urea itself is odorless, tasteless, and nearly non-toxic, it does provide a nutrient source for surface bacteria on the meat. The by-product (metabolite) of this use by the bacteria is ammonia. It is the ammonia derived from not removing as much urea and retarding bacterial action by preserving, freezing or refrigerating that ruins the flavor and odor of shark. For fishermen and processors experienced with bony fish, this has not been a quality control problem, as bony fish primarily rid themselves of nitrogenous wastes by the excretion of ammonia. Rapid bleeding of sharks in the field will greatly reduce urea levels.

It has been suggested in articles and cookbooks that mildly ammoniated shark meat can be restored to good taste by washing it in water and soaking it overnight in lemon juice, tomato juice or vinegar. However, be warned, this treatment is not always effective. Even if it was, first time consumers would not be inclined to buy shark a second time if they had to go through those steps to make it edible. And the industry should not expect them to do so.

On the other hand, good cooks don't mind doing things that make a good product even better. And marinating high quality shark meat in citrus juice or milk actually does enhance flavor.

Shark fishing is hard work and extremely dangerous. The snapping jaws and razor sharp teeth of sharks are capable of inflicting serious injury, and injuries have actually been sustained after the fish have died. So most fishermen learn quickly to work cautiously around sharks and how to preserve them to obtain the best possible price at the dock. Here's how they do it.

Fishermen work as fast as they can to "board" and butcher sharks while the fish are still alive and kicking, because they know that spoilage will occur rapidly after death. Efficient crews are able to "board" sharks and get them butchered and refrigerated in less that 15 minutes.

While it would seem prudent to shoot large sharks to render them less dangerous, (and indeed some small boat fishermen use this technique) few fishermen use this method. A loaded firearm can be more dangerous than a shark when one is trying to aim and fire it on a rolling, slippery deck. Most often, sharks are hoisted alongside and partially immobolized by hitting them on their snouts with a heavy wooden or rubber mallet. On occasion, they will hit them squarely on top of the head.

Bleeding and evisceration is done while the fish is hanging over the side, stunned but still alive. The caudal fin is severed, which enables the heart to pump most of the animal's blood through caudal arteries in about 3 minutes. Care is taken as the valuable lower lobe of the tail must be retained. When the blood flow stops, the fish is eviscerated and hauled aboard and deposited on the deck, preferably a safe distance from where the crew are hauling in new fish.

A crewman carefully straddles the shark, then cuts off its head. This severs the spinal cord. The belly flaps, valuable in small sharks but high-spoilage areas in large fish, are then removed. The carcass and belly cavity are cleansed of blood and visceral matter, usually by inserting a hose into the main artery and then thoroughly hosing down the carcass.

At some point during this operation the crewman removes the valuable dorsal and pectoral fins. Considerable care is taken to cut off the fins just above the meaty portion where they are attached to the body. If this is not done the meat remaining on the fins will spoil as the fins are drying, causing a tremendously offensive odor and attracting insects.

Remaining now is a headless, tailless, finless and eviscerated product that fisherman call a log, tube, loin or trunk. The butchering process, efficiently executed, requires only a few minutes.

The logs must be lowered to a cool temperature quickly. This is done by placing them in an ice/saltwater solution or brine tank. The solution is emptied and replaced frequently to avoid contamination. If fishing is good or the vessel plans to stay at sea for some time, the logs will be transferred to the hold when time permits. There they are placed belly down in clean ice, and ice is packed into the belly cavity.

This completes the steps that are necessary to preserve shark meat in pristine quality at sea.

As with any other seafood product, shark has an edible life of only a few days when it is held in the fresh state. Therefore, careful attention must be paid to sanitation and to storage temperatures as shark passes through the distribution chain. Shark does not require unusual care, however.

Cleanliness when handling shark or any other fresh seafood is extremely important because bacteria multiply at unbelievable speed in an unclean environment. In four hours it is possible for bacteria to multiply 4,000 times on products that are poorly handled.

Air-cooling of shark will not match the effectiveness of ice. The melting action of ice:

—removes heat from shark rapidly;
--lowers product temperature to near 0° C (32°F);
--creates a low-oxygen environment around products that slows down bacterial and enzymatic action, oxidation and deterioration; and
--washes away blood and other spoilage material.

Air cooling, on the other hand tends to dehydrate and oxidize fresh products rapidly.

As with any fresh seafood:

- —keep your ice supply covered to prevent dirt and other contaminants in the air from settling upon the ice;
- —cover containers of iced shark for the same reason;
- —when storing logs [shark carcass minus head, fins, and internal organs], place them in ice (belly down) and completely cover them with ice;
- —wrap processed shark products such as fillets and steaks before burying them in ice to prevent their juices from leaching out; and
- —put receiving dates on all shark products that you keep in refrigerated storage. This will insure that the oldest products are used first.

Some people believe that frozen shark meat is tastier and less chewy than fresh; however, market demand is strongest for fresh. Frozen shark has the normal storage life of other marginally lean fish. Never allow it to warm above −18°C (0°F). Store it at −23°C (−10°F) or lower for longest storage life.

To summarize, shark is unusually vulnerable to quality loss at sea if it is not bled and refrigerated quickly. Most fishermen have learned this lesson and quality reliability is improving. The normal care given other seafoods is adequate for shark as it passes along the distribution chain.

Consistent quality will be very important as new markets develop for shark around the country. One must remember that quality can not be improved from its present state and that quality lost can never be retrieved. People are trying shark for the first time and will form good or bad impressions that could last a lifetime.

Synopsis[1]

Shoreside Processing of Shark

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People tend to put processors in an unrealistic light that makes us seem to be more than we are. But ultimately, we are still fish peddlers. And one of our chief concerns is the marketability of the products we handle, for that determines what processing techniques we will apply. We must continually ask ourselves who will be purchasing our product. Will it go to institutions? School systems? Local or distant markets? High-end restaurants? The object of an efficient fishery is to land high quality fish that the consumer will buy at a price that will satisfy both the producer and the processor. These factors must operate in balance for a fishery to succeed. We will look at all aspects of production from catch to processing to end user.

Louisiana's estuaries accounts for about 25% of the total estuarine area of the United States. It is within this area that the Louisiana shark fishery has developed. The estuaries cover all of our coast, but are the most concentrated on the west and east approaches to the Mississippi River delta for a distance of about 170 km (100 miles). There are three principal areas in the local shark fishery: 1) inshore (comprising bays, bayous and estuaries) where waters are 1-3 m (3-10 feet) deep; 2) sounds (outer edges of estuaries) where the water is 3-7 m (10-20 feet) deep; and 3) deeper water (beyond the barrier islands) where waters are deeper than 7 m (20 feet). The largest and best developed fishery lies in the inshore area with relatively little development of the sounds and deeper water areas. Inshore development has occurred because production has been sufficient to provide for the needs of the fishing community and there has not been a pressing need to develop other shark resources.

The Inshore Fishery. This fishery principally produces small bull sharks (Carcharinus leucas) comprising 95-98% of the summer catch. Large bull sharks tend to have somewhat tougher meat than small individuals due to a fibrous membrane that is striated through the muscle. The best bull sharks are those in the 13.6-18.1 kg (30-40 pound) size class; they are euphemistically called "veal of the sea" to enhance their market appeal.

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[1] This paper was summarized by Sid Cook from a tape recording of Mr. Pearce's presentation at the conference.

The Sound Fishery. When you get into the outer estuary where the water is deeper than 4 m (12 feet), a completely separate fishery begins to develop. The principal species in this fishery are blacktip (Carcharinus limbatus) and spinner (C. brevipinna) sharks. These species are found in large numbers around the barrier islands also.

The Deeper-Waters Fishery. This fishery is nearly undeveloped, but includes large sharks such as the mako (Isurus oxyrinchus).

The Gear. Small vessels with shallow drafts are used in the shallow waters of the inshore fishery. They are usually 5-7 m (16-20 feet) aluminum, flat bottom boats, or 7-9 m (20-30 feet) beach skiffs with semi-flat bottoms. The fishery developed secondarily to the estuarine fishery for sea trout (Cynoscion sp.) and redfish (Sciaenops ocellatus). Both shark and gar (Lepisosteus sp.) are taken with damaged nets recycled from other fisheries. This is usually 7.6-10.1 cm (3-4 inch) mesh gillnet, which has proved to be good gear. "Salt tides" bring in large numbers of sharks during the summer months but tend to cause a decline in fishing for other species.

Most boats go out once or twice a day since the grounds are not more than one hour from the dock (usually less than 20 minutes away).

Field Dressing. The key to a successful shark fishery lies in the fishermen. Sharks have to be handled quickly on the boat. There is no way to recover bad fish once they have been delivered to the dock. First, the shark has to be headed and gutted on the boat. (The head is removed behind the pectoral fins.) Then the fish is thoroughly cleaned, leaving the belly flaps on the carcass. They can be removed later without damage to the shark. All offage (offal) is retained by the fisherman and taken back to the dock for disposal. Discarding offage in the water has caused a dramatic decline in the fishery in that area for some time. Next the fish is placed in a saltwater-ice slush to begin cooling it down. In this particular fishery, the shark usually is delivered to the dock within 20-60 minutes of the time it is killed.

Dockside Receiving. At the dock the shark is immediately transferred from the boat into another saltwater-ice slush. "Slushing" is important in maintaining a high-quality product. The use of ice alone does not sufficiently cool the fish quickly enough. In recent years, more boats in the inshore fishery have been equipped with refrigeration and water circulating pumps.

The fish is transferred to a truck as gently as possible to avoid mechanical damage and bruising. The method found to work best is to place a layer of ice, then a layer of shark, then a layer of ice, etc. It is important to keep the shark below 4.5°C (40°F). Temperatures above this will cause bacterial action on the meat to skyrocket.

The Quality Control Process. There are five quality control checks made on shark being brought in to Harlon's Old New Orleans Fish Company: 1) at dockside, the shark is assessed for odor and appearance; 2) the fish is checked for odor again before being unloaded at the plant; 3) each fish is handled and inspected as it is unloaded at the plant for mechanical damage and odor; 4) it is inspected for odor and smell as it enters the processing line; and 5) during post-processing/packaging, the fish is inspected for miscuts, ragged edges, and any other condition that might render quality fish unsightly. This is important, since the consumer generally buys fish by appearance over any other consideration.

Filleting. Any remaining fins are removed from the cleaned and cooled carcass. A normal filleting process is then used. Beginning at the end nearest the head, a cut is made toward the tail along the backbone. A second cut is made along the cartilage material at the edge of the belly cavity (skeletogenous septum, see figure 1). With this process 60-63% of the dressed carcass can be recovered as edible meat—a good yield for small-bodied sharks.

One of the most important steps in processing is the removal of the heavy "bloodline." It is unsightly and reduces the quality of the fillet dramatically. Several skinning machines have been tested for suitability for skinning sharks. Most machines of recent design and construction are not suited to use with shark as they tend to cut too thinly to remove the skin properly. Such machines don't even come close to removing the bloodline from the fish. At the Old New Orleans Fish Company, a Baader 50 skinning machine has been found to work the best. This machine employs a rotating blade and has a variable blade height adjustment. The cut can be adjusted to leave a suitably thick portion of flesh on the skin to completely remove the bloodline. All the sharks we handle are machine-skinned. This is much easier than hand-skinning due to the coarseness of the meat and toughness of the hide. The Baader 50 is also a conveyor-fed machine, which provides greater safety for employees over hand-fed machines.

The importance of proper market development cannot be overemphasized. Product preparation and packaging are determined by the how the buyer will use the fish. Portion control is important to institutional and restaurant users more than it is to retailers. Quantity is important to school lunch programs. There is no blanket method for marketing shark that I know. Each individual market and customer needs to be dealt with in a slightly different manner to assure that his or her needs are met. It is the responsibility of the processor to maintain good market efficiency. Since there is a seasonality to shark fisheries as with other types of fishes, backup supplies must be developed.

Market development should be geared to making the best use of all shark that is landed for two reasons. First, we need to build solid working relationships between the fisherman and the processor in order to keep a steady supply of fish. It is difficult to tell a fisherman you can only purchase 45 kg (100 pounds) of fish from him because you don't have enough developed markets to handle all of the fish he delivers. It is the job of the fisherman to obtain the fish and get it to the processor in the best possible condition, and it is the job of the processor to develop a reasonable market base in which to distribute it Second, we have to practice resource conservation; that is, we cannot waste a potentially salable resource by poor market effort.

School lunch programs are an example of an institutional market in which shark can be used. Schools will often request 70-85 g (2.5-3.0 ounce) controlled portions of shark because it is boneless and in quantity can be nearly as economical as bony fish fillets. The role of the processor in this setting is to be able to provide large quantities of frozen shark on the order of 13,600-18,100 kg (30,000-40,000 pound) lots. If the school district likes your samples, you must be able to deliver lots of this size on short notice. This will require careful planning and close working cooperation between the fishermen and processor. Shark for this market can be either blast frozen or mechanically frozen with little difference in the final product, except that there is a higher moisture loss in the mechanical freezing process.

In closing let me say that shark markets may expand more slowly than those for some exotic bony fishes; however, the U.S. consumer is primed to purchase shark and other new seafood products at the present time. So with prudent planning and perseverance, the processor and the fisherman will prevail.

Specialty Product Development Using Frozen Shark

Michael G. Haby[1], Valerie Z. Roach[2]
and Russell J. Miget[1]

Abstract: Information is presented about the activities undertaken in support of the introduction and adoption of hot-smoked portions and shelf-stable snack jerky manufactured from shark meat. Once the products were developed and refined, a proforma analysis of the economics of producing, processing and marketing the snack jerky determines whether adequate margins exist throughout the marketing channel so that the product can be "pushed" through the system. Next, the results of a survey of seafood smokehouse operators are presented along with the results of several taste tests conducted at various trade shows. These findings demonstrate that even though hot smoked shark and smoked snack jerky are prototype products, the responses are quite positive, and many participants express genuine interest in utilizing these specialty foods. Additionally, the current posture of regulatory groups concerning product labeling, product integrity, and processing of seafoods in Federally inspected meat plants is outlined. This may be important in seafood producing states such as Texas which have a large, diversified, specialty meat smoking infrastructure but lack a similar industry oriented to seafood. The paper concludes with a discussion of the different techniques which can be used to move the product into commercialization.

Introduction

Historically slow moving inventory, low ex-vessel prices and sporadic seasonal production (which reduces the opportunity for fresh meat sales) have been limitations in the development of a continual, directed fishery for sharks in the Western Gulf of Mexico. Because of these limitations, utilization of frozen (seasonally produced) shark in convenience and gourmet food products was evaluated as a means of increasing its value, thus partially removing it from the commodity-oriented level of competition. This paper

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outlines the various functions completed to date and suggests tasks which could make the production and sale of convenience snack jerky products manufactured from shark a reality.

The Jerky Manufacturing Process & Prototype Development

Butchering

Silky and dusky sharks (Carcharhinus falciformis and C. obscurus respectively), blast frozen as boneless, skinless slabs and held at approximately -27°C (-16°F) for five months, were removed from frozen storage, partially defrosted and sliced (transverse section) into 6.4 mm (1/4 inch) thick portions. Using this cutting method, the muscle striation runs through the strip with the length of the muscle fibers being determined by the thickness of the slice. Because of unavoidable hand contact with the raw slices, strips were rinsed with a shower spray.

Curing process

Several different cures were tried. The cure finally used was a 1:1 ratio of teriyaki sauce and water, 3% salt (NaCl), 0.4% onion juice and 0.4% garlic juice. The ratio of cure weight to product weight was 2:1. Shark strips were cured under refrigeration for approximately 16 hours. Once removed from the cure, each strip was lightly rinsed with fresh water and a medium grind black pepper was sparsely applied to each side. The pepper provided additional spiciness to the jerky and reduced the perception of saltiness. At this point the product was ready to be placed in the smokehouse.

Cooking schedule

Cured strips were placed in the smokehouse and air dried for 1/2 hour. This air drying step consisted of allowing the main blower to operate while the temperature was held at approximately 49°C (120°F), the smokehouse blower was activated, and the product was allowed to dry for 2 1/2 hours at 71°C (160°F). As a finishing step, the heat was turned off and the product was air dried for another 1/2 hour. At the end of the finishing stage, the product was removed from the smokehouse and allowed to cool on racks for approximately 45 minutes at which time it was vacuum packaged.

Laboratory analysis of shelf-stable jerky

A high-protein food marketed without refrigeration requires assurances that the product is microbiologically stable. The two major organisms which could represent a health hazard in shark jerky are Clostridium botulinum type E which is prevalent in the marine environment and Staphylococcus aureus which can result from human contamination during post-cook handling. Preparation of a shark jerky may provide the conditions necessary for the outgrowth of and toxin production by these organisms. These are:

a) an environment suitable for C. botulinum growth;[3]

b) lack of refrigeration which would ordinarily retard the growth of Staphylococcus aureus.

Adequate process controls need to be established to insure a safe product. Several controls exist. Heating the muscle to at least 66°C (150°F) will injure C. botulinum type E spores causing them to become less tolerant of salt. S. aureus generally tolerates higher salt concentrations than C. botulinum, thus a water phase salt percentage of 16%-18% is required to insure against postcook contamination problems[4].

Following manufacture of the jerky, several samples were vacuum packaged, stored at both 4°C (30°F) and 30°C (86°F), and sampled periodically for approximately three months. Salt and moisture content of the finished jerky were 9.94% ± .48% and 32.9% ± 3.8% respectively, with a water phase salt concentration of 23.5% ± 2.8%.

Both anaerobic and aerobic plate counts were conducted during the first 21 days of storage. Anaerobic agar, with and without 5% NaCl, was used for anaerobic counts. Standard methods agar (SMA) and SMA plus 5% NaCl were used for aerobic counts. After 10 days of storage, anaerobic counts had dropped to zero and remained so during subsequent sampling periods in the first three weeks. Therefore, anaerobic sampling was discontinued. With respect to the aerobic analysis, there was no significant difference in growth of colonies on media with and without 5% salt so the addition of salt to the media was also discontinued after the first three weeks of storage.

Aerobic plate counts were relatively stable over the 110 day storage period. Results, shown in Figure 1, are the average of two replicates.

Economics of Manufacture and Marketing

There are two questions which must be answered concerning the economics of manufacture and marketing:

a. Can purchase, storage, manufacturing and marketing margins be calculated that leave enough production incentive for the fishermen?

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[3] An anaerobic environment can be created with vacuum packaging and/or through chemical reduction of the product surface as compounds from the smoke react with it.

[4] Water phase salt is the percentage salt (NaCl) in the finished product as determined by the method described in sections 18.006, 18.009 and 18.010 of the Official Methods of Analysis of The Association of Agricultural Chemists, 10th edition, (1965) p. 273.

b. Does the manufacturing process build in too high a cost to the subsequent marketers of this product when compared to the substitute products found in the marketplace?

These questions can be answered on a preliminary basis by considering the hypothetical costs of manufacturing and marketing. The information in Table 1 indicates hypothetical production costs (cooking yields, direct and overhead expenditures), selling prices and marketing margins associated with such a product.

Table 1: Computation of Hypothetical Cost per Pound for Producing Shelf-Stable Jerky

Panel A: Proforma Processing Costs

Sales price	$9.02
Product cost	2.11
Processing costs	2.00
Post-cook yield	60%
Direct cost	6.85
Overhead	.50
Total cost	7.35
Freight	.20
Total delivered cost	7.55
Pretax net return	$1.47

Panel B: Margins and Product Costs for Mid-level Handlers

Wholesale distribution	
Product cost	9.02
15% gross margin	1.59
Wholesale sales price	10.61
Retail interests	
Product cost	10.61
33% gross margin	5.23
Retail sales price	15.84

Shark jerky would compete against a beef counterpart which carries a standard of identity mandated by the Meat and Poultry Inspection Division of USDA regarding the ratio between residual moisture after cooking and protein. According to the labeling standard, beef jerky must be drier than a similar seafood product so there may be some economic advantage for the processor who produces a seafood (shark) product. As indicated in the cost comparison between inside beef rounds and boneless, skinless shark fillets in Table 2 below, even though the shark initially costs 37% more than the inside rounds, (as of October 1985), the required moisture loss for the beef products results in it being significantly more expensive to manufacture than the same type of product made from shark.

Table 2: Comparison of Direct Costs Per Pound to Produce Beef and Shark Jerky

	Beef inside rounds	Shark b/s fillets
incoming cost	$1.50	$2.05
yields	98%	97%
beginning cost	1.53	2.11
processing labor	2.00	2.00
post-cook yield	40%*	60%
direct cost	$8.83	$6.85

* Percentage yield deduced from the mandated moisture/protein requirements from USDA.

Marketing

Marketing Planning

Most products which successfully make it through the prototype stage are then analyzed for potential customers' attitudes toward the product, how well the proposed product stacks up against competition, and the gross margins available to the mid-level trade (which significantly contributes to reseller interest). When planning for the marketing of any product, several questions should be considered. Specifically, what is the anticipated market, what are the characteristics of this market, and what activities must be performed to enter this market successfully?

The convenience store market currently retails a wide range of shelf-stable snack meat products. Because of the impulse purchase nature of the snack food market, convenience stores should continue their sales dominance in this product class. Since shark jerky is a product adaptation, the convenience store would appear to be the logical outlet.

Nationally, convenience stores are growing at an annual rate of approximately 20% with gasoline and ready to eat foods accounting for significant percentages of sales growth. Judging from the width and length of the ready-to-eat, shelf-stable snack meats line, the demand and the gross margin earned from the sale of this product line (both percentage and overall dollars) appear high[5].

From the manufacturer's standpoint, this segment of the retail food industry has one signficant characteristic which indicates the extent of access to the market: a low advertising to sales ratio. In a convenience outlet, product placement and limited point of purchase materials serve as promotion. Therefore almost any sized firm can participate since a large promotional budget is not a prerequisite.

At the manufacturer level, attention to package design as a point of sale tool and calculation of the net weights and prices is essential to be competitive in this venture.

Does This Product Have a Future?

As a surrogate to full test marketing, samples of smoked shark jerky were featured at the 47th Annual Texas Restaurant Association Convention and Trade Show held in San Antonio[6]. The jerky was served to trade show participants, and these testers were asked to rate the product in terms of flavor, texture and appearance. The appeal of the shark jerky was overwhelming!

Some 700 participants sampled the product. A ten point rating scale was used with 0 being least desirable and 10 being most desirable. Average scores

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[5]With the price of substitute products quite high, good gross margins are obtainable. Reported gross margins on beef jerky are 33%. Estimated gross margins on shark jerky are about 50%, so this should induce prominent placement in the outlet which contributes to impulse sales.

[6]While not specifically positioned as an appetizer in food service, it is interesting to note that the persons providing these ratings were professionals in the food service industry and are perhaps more critical of new products than persons without such a tie to the food industry. Specifically, people sampling the jerky included restaurant owners/managers, wholesale distributors, food brokers, food processors, dieticians and private caterers.

for appearance, flavor and texture were 8.91 $\pm$ 1.16, 8.86 $\pm$ 1.47 and 9.09 $\pm$ 1.18, respectively, or a total score of 26.86 (89.43%), indicating high overall acceptability. When asked whether the shark jerky would make a good happy hour-type snack, the response was a unanimous Yes!

The practice of predicting success or failure of new products is in essence conjecture. However, when evaluated in terms of manufacturing costs vis-a-vis' beef jerky, gross margins available to the marketing channel and preliminary consumer response, the opportunities for shark jerky appear promising. To date, no firm in Texas has committed to testing this idea, although several smokehouses have expressed interest in expanding their smoked meats line[7]. Whether this product is commercially produced will depend upon locating that processor who has the financial and marketing wherewithal to not only produce an acceptable product, but find the appropriate marketing techniques to place it next to checkout areas in the retail food industry's fastest growing sector.

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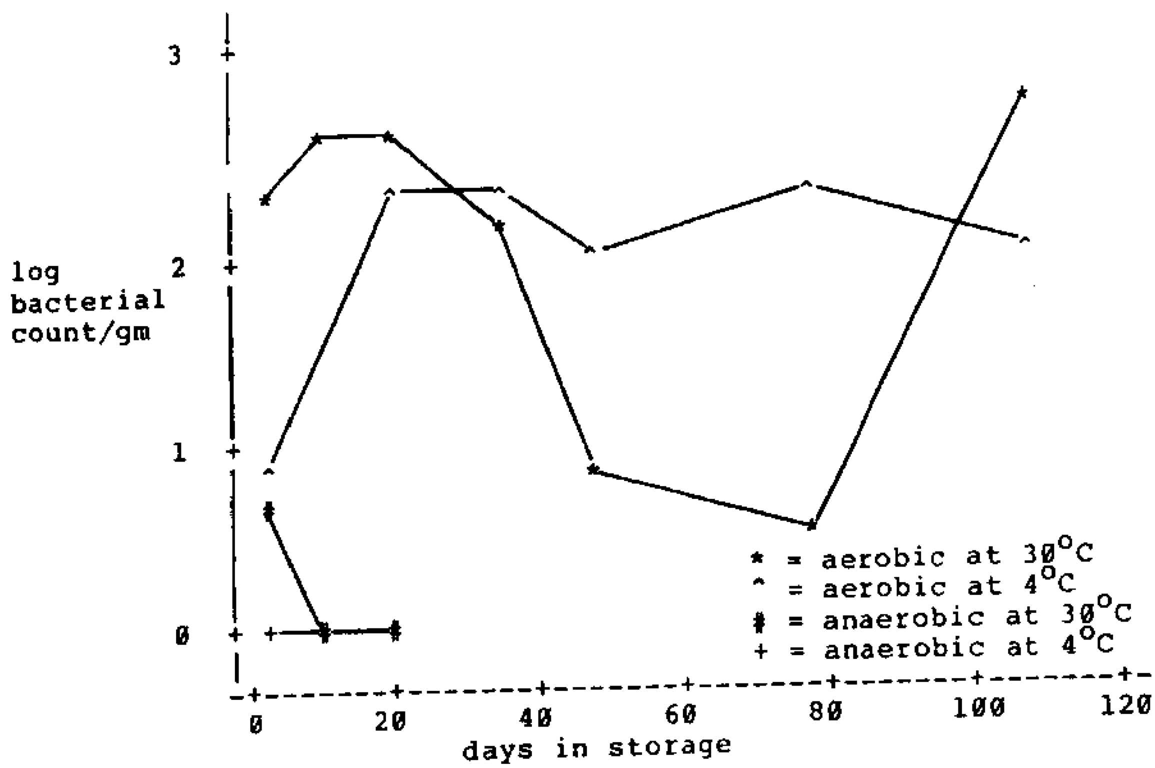
[7]Currently there are no firms in Texas which smoke fish and seafood. In working with the beef processing industry, we have faced two recurring questions: "Is shark meat available in the quantity and quality which I will need?" and "What regulations exist about labeling standards, using seafood in inspected meat plants, etc?" Our work has centered around work with Federally inspected meat plants as well as some smaller state regulated firms. The contention of both regulatory groups is that running a seafood product through the plant is permissible so long as the operations are separable. Conceivably, we envision a processor running the shark jerky on a day when he would not be processing beef.

Figure 1

Bacteriological Stability of Vacuum Packaged Shark Jerky stored at 30°C and 4°C



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Development Considerations for the Dogfish (*Squalus acanthias*) Fishery in the Mid-Atlantic[1]

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Abstract: In recent years, many of the traditional U.S. fisheries have experienced substantial declines in harvest rates. As a result of this decline, commercial fishermen are beginning to explore new fisheries and fishing concepts in order to obtain a reasonable return on their capital and labor. Recent trends in the industry have forced many vessels to move into underutilized fisheries which are usually characterized by high volumes and low ex-vessel prices. The dogfish shark (*Squalus acanthias*) represents one underutilized species which is currently harvested in New England and may offer potential for commercial development in the mid-Atlantic region. The development of a viable dogfish fishery will depend upon several factors including the availability of adequate stocks, use of efficient and economically sound harvesting methods, implementation of suitable methods of processing quality products, and the development of viable foreign and/or domestic markets.

Biological Factors Affecting Commercial Development

Dogfish are found in coastal waters from the Gulf of St. Lawrence to Georgia (Bigelow and Schroeder 1953; Dahlberg and Heard 1969). These sharks migrate to the mid-Atlantic from the northern part of their range as a part of an annual seasonal migration. Dogfish migratory movements appear to be associated with a temperature preference for bottom water of between 7° and 13° C (Jensen 1965) and are present on the continental shelf from the Delaware Bay to Cape Hatteras, North Carolina, during the winter months (Fig. 1).

Sharks exhibit slow growth rates, relatively long life spans, and low reproductive potentials. Annual recruitment into a given fishable size range may be a small percentage of the standing stock. As a result, the sustainable yield from a shark fishery may be substantially lower than that for a bony fish where fecundity is not generally considered to be a limiting factor (Colvocoresses and Musick 1980).

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Since dogfish are a relatively long-lived species and require several years to reach sexual maturity, the stocks must be carefully managed to insure that the harvest does not exceed maximum sustainable yield. To accomplish this management objective, the adult stock must be maintained at a sizeable level. Past work on the heavily exploited northeast Atlantic spiny dogfish has indicated that the maximum sustainable yield may be about 20% of stock size (Holden 1968). Recent studies on the spiny dogfish of the Northwest Atlantic suggest that 8% of the standing stock may be harvested annually. Given the current estimate of 300,000 mt (661 million pounds) in the standing stock, it is projected that the species could support an annual harvest of 24,000 mt (52 million pounds). This would represent a 480% increase over current harvest levels in the Northwest Atlantic (Nammack et al. 1985).

Foreign and Domestic Markets

Marketing is the key to success in any attempt to develop the dogfish fishery in the mid-Atlantic. Dogfish yield three primary products for sale to consumers: backs, belly flaps, and fins. These products are predominantly sold in foreign markets and each must meet very demanding specifications to maintain their market share.

Dogfish belly flaps fill a very specific market niche in the Federal Republic of Germany. Flaps are skewered, hung on racks, and smoked to produce a traditional snack food called "Schillerlocken." This product is sold in pubs, supermarkets, and fish houses and is sold only in West Germany. Consequently, there is a very limited market for belly flaps and the current market demand is between 1200 and 1500 mt (2.6 to 3.3 million pounds) per year.

The lack of breadth in the market and the specificity of use allows buyers to demand that belly flaps meet very exacting requirements. Generally, the flaps must be hand skinned to make them easy to skewer and smoke. If the flaps are machine skinned, a thin membrane oftens remains on the surface. The presence of this membrane can cause the flap to harden, making it difficult to eat, and prevents the Schillerlocken from attaining the traditional curling shape from which it gets its name. Flaps exceeding 10 inches in length are preferred and shorter flaps are penalized in terms of market price. Belly flaps should be packed in wax lined cartons with a poly-overwrap containing 18-20 kilograms per carton. Quality belly flaps are currently selling for 90 cents per pound ($2 per kg) F.O.B. U.S. East Coast. If the product is processed to meet the market's demanding specification, it is possible to secure stable relationships with individual buyers which can be very important in penetrating and maintaining a position in the market.

The fin market also offers very lucrative opportunities to shark processors. Shark fins are used to prepare a number of favorite Chinese dishes, the most popular of which is shark fin soup. The peak period for shark fin sales revolves around the Chinese New Year when most weddings and celebrations occur. Shark fins are sold throughout the world wherever large Chinese ethnic communities exist. Hong Kong, with a population of over 5 million Chinese, is one of the world's most important markets for fins. In 1982, 64 countries supplied 2,746 mt (6 million pounds) of fins valued at $245.4 million H.K. ($35 million U.S.) (Ka-keong, 1983).

The value of the fins is directly related to the care in handling and the thoroughness of the processor in carrying out the various steps necessary to prepare the fins for use in the major oriental dishes. There are three common cutting methods recognized by fin traders: the crude cut, the straight cut, and the half moon or concave cut which is preferred since this cut retains the whole fin with very little meat, making secondary processing easier and less costly (Fig. 2; Ka-Keong 1983). Most U.S. dogfish precessors use the crude cut to minimize labor costs. Fins are packed in 5 or 10 kg boxes and frozen for delivery to domestic and foreign secondary processors. Most shark fins are sold in sets which include a dorsal, two pectorals, and a tail fin; however, a set of dogfish fins includes only the pectoral and tail fins. Fins are more valuable when sold in sets, but U.S. East Coast processors do not provide matched sets. They choose to pack the pectoral and tail fins in separate boxes, leaving all secondary processing to their customers.

Shark fins are sold according to their size, thickness, and fin needle (collagen fiber) content. Since the quality and quantity of fin needles vary by species, grades and prices tend to be species dependent. The most valuable fins are obtained from the hammerhead and mako sharks, while small sharks such as dogfish are less valuable. Dogfish processors are currently receiving 80 cents per pound for crude cut and straight cut fins.

Since shark fins are so valuable, many speculators and brokers are attracted to the market. These individuals often speculate on supply and demand imbalances to turn quick profits. Another important market channel relationship exists between suppliers and restaurants. In Hong Kong, over 80% of the shark fins sold are consumed in restaurants. An additional 6 to 13% are sold in Chinese communities world-wide. Since the majority of the fins are consumed in restaurants, many suppliers develop strong relationships with individual owners or restaurant chains to ensure that adequate supplies will be available to meet their needs. Some large seafood restaurants import dried fins directly from fin processors for their own use (Ka-Keong 1983).

Dogfish processors can expect good prices for whole fins if they structure their processing activities to provide products which meet market standards. Processors must also understand their position in the market channel and position their products accordingly. If dogfish processors on the East Coast were to restructure their in-plant activities to complete the entire fin preparation process, the revenue contributed by fins could increase dramatically.

Dogfish backs must be marketed successfully if the dogfish fishery is to become economically viable in the mid-Atlantic. At the present time, backs are sold almost exclusively in foreign markets including the U.K., Belgium, France, Spain, West Germany, and Italy. Major suppliers include Norway, Turkey, the U.K., Canada, Japan, Taiwan, and the U.S. (BBH Corporation 1985). In 1974, approximately 20,000 mt (44 million pounds) of spiny dogfish and 4,500 mt (10 million pounds) of smooth dogfish fillets were marketed in the primary European consuming nations (Morris 1975). Recent interviews with industry representatives indicate that the current European market demand for frozen backs is between 11,300 and 13,600 mt (25 and 30 million pounds). Total shark imports for France in 1984 were 7,700 mt valued at $99 million (approximately 58 cents per pound). The United States provided 14% of this total, or 1088 mt (2.4 million pounds).

Dogfish buyers in Europe recognize three market catetgories: fresh, fresh-frozen European, and frozen non-European products. Buyers prefer fresh and frozen European products over non-European frozen products. This preference prevents U.S. products from competing directly with European products. A 6% duty is applied to the non-European Economic Community imported products (BBH Corporation 1985). These barriers have a dramatic impact on market price and place U.S. product in direct competition with lower cost products from Turkey, Taiwan, and Japan.

Dogfish is sold primarily as an instititional fish in France and England. It has long been popular in the English fish and chips market and a low cost alternative to haddock and cod and is also marketed directly to consumers as "rock salmon" or "huss." The French use the product in fast food restaurants and other institutional food programs. In each of these countries, price is the most important factor in penetrating and maintaining market position.

The United States is viewed as a low cost supplier to the European market. Domestic dogfish processors have not been able to differentiate their products from other foreign sources. The market for backs is very dynamic and buyers are very sophisticated in their buying practices. Dogfish buyers are aware of seasonal changes in supply, processing capabilities, and freezing and storage capacity, all factors which can affect shelf life and quality of the product. It is not unusual for buyers to manipulate their suppliers, who often are facing possible shelf life problems, to drive down prices. Buyers also realize that there are very few markets for dogfish backs and can determine the price for the products with relative ease, which tends to reduce competition.

The European market requires that shark be handled and packaged in a very specific manner. Any deviation from these practices will usually result in a price discount. Backs must be wrapped individually in poly bags and boxed in 12.7 kg (28 pound) master cartons. Packaging in this manner will allow the end user to thaw a few backs at a time for display purposes or to meet small orders. Boxing requirements are also important since many U.S. processors try to impose their own boxing and weight standards on foreign buyers, which may jeopardize sales. All dogfish backs should be graded in 1-2 pound and 2-4 pound lots and should be skinned with the bloodline removed. There is little or no demand for backs weighing less than 0.45 kg (one pound).

Processors currently operating in the dogfish market feel that market conditions would deteriorate rapidly should additional U.S. supplies become available. They are convinced that new supplies would only serve to increase competition among U.S. producers and allow foreign buyers to play one processor against another. Domestic producers suggest that any attempt to increase production should be accompanied by a domestic marketing and promotional campaign. An increase in domestic demand for dogfish would allow U.S. processors to alternate between foreign and domestic buyers based upon the most favorable market price.

A recent project sponsored by the Mid-Atlantic Fisheries Development Foundation could serve as a model for domestic efforts to promote the use of dogfish by consumers. Virginia Polytechnic Institute and State University, in cooperation with a local chain of Tidewater, Virginia, food stores, coordinates in-store promotional events with an extensive media campaign in an effort to stimulate consumer interest. In response to this effort, over 4535 kg (10,000 pounds) of fresh dogfish fillets were sold within a three-week period. Consumers were given the opportunity to evaluate the product as well as the primary factors influencing their decision to purchase shark. Their responses indicated that price, desire for variety, availabality of recipes, and in-store samples were integral to their decision to buy dogfish (Dean, et al. 1982). It should be noted that the product was marketed as shark fillets and the name dogfish was avoided in all promotional materials.

Even if consumers cannot be convinced to buy dogfish directly, they may represent a large target market for institutional users. Large institutions such as food processors, seafood chains, and school lunch programs are always searching for low cost sources of protein. Many of these groups could offer dogfish under a surname or simply as a breaded fish product similar to fish sticks or fillets. This market offers tremendous development potential for the entreprenuer willing to take the time to cultivate contacts with the primary buyers in these organizations.

Harvesting and Processing Considerations

Sharks have traditionally been harvested using three methods: trawl, longline, and gillnets. The optimal method varies with the species sought, local bottom conditions, and the harvesting and processing equipment available to participants in the fishery (Colvocoresses and Musick 1980),

Dogfish are harvested using all three methods at the present time. The Norwegians use longlines to harvest dogfish because it is a selective gear which allows them to catch large numbers of fish of acceptable market size while maintaining high product quality standards and avoiding losses of trawl gear in the rocky North Atlantic (Holmsen 1968). Gill nets are used primarily in the Pacific Northwest and to a lesser extent in New England. This gear can be quite effective for dogfish as long as the nets are run frequently to avoid a deterioration in product quality. The most effective gear for the mid-Atlantic region appears to be the trawl because the sharks are present in extremely high densities and the fishing grounds are very uniform, thereby reducing the risk of substantial gear loss. The current commercial fishery in New England is primarily a trawl fishery and early attempts to harvest dogfish in the mid-Atlantic used trawls as standard equipment. Since the mid-Atlantic fishery would have to be conducted during the winter months when sea conditions are at their worst, it appears that trawling with large, 22-28 m LOA (70-90 foot LOA) vessels represents the only viable means of harvesting dogfish in this area.

There are two possible alternative fishing strategies available for a commercial dogfish operation in the mid-Atlantic: (1) a directed dogfishing effort using trawlers which deliver whole product to onshore processors and 2) a directed fishery focusing on limited on-board processing which provides headed and gutted dogfish to an onshore secondary processing facility. The following analyses will review each of these alternatives and discuss their ramifications.

Historically, the fall and winter months have represented the most productive harvest periods in the mid-Atlantic offshore fisheries. If a dogfish fishery is to develop in the mid-Atlantic, it must provide expected returns equivalent to or greater than those expected from the average fishing vessel operating in the mid-Atlantic groundfish fishery. The traditional mid-Atlantic fishery is characterized by 4 to 5-day trips with an expected daily harvest of 1361 kg (3,000 pounds). Early in the fall this fishery is a nearshore fishery focusing primarily on fluke (Paralichthys dentatus). Effort is gradually shifted offshore to black sea bass (Centropristis striata) and scup (Stenotomus chrysops) as the winter season progresses. Interviews with industry representatives indicate that the dogfish fishery conducted in the mid-Atlantic in the early 80's operated with 1- to 2-day trips beginning in early December and continuing through March. The expected daily harvest averaged between 36-45 mt (80,000 to 100,000 pounds) of whole fish each day. Ex-vessel prices averaged 17.6 cents per kg 8 cents per pound and would have to be maintained at least at this level to sustain a viable commercial fishery.

A partial budget which identifies the net changes in costs and revenues for a vessel moving form the traditional fishery to a directed fishery for dogfish has been developed (table 1). The partial budget reveals that a vessel fishing for dogfish would expect a net increase in income of $14,204 over the four month period in spite of a 27% increase in crew share and operating costs.

The crew of the vessel would also expect to benefit directly from the shift in effort as the net crew share is expected to increase by $995 per member. This figure includes an increase of one additional crew member as well as an increase in fuel, ice, and food expenses. It should be noted that most of the increase in net crew share can be attributed to a waste disposal allowance which is traditionally awarded to the crew for hauling the dogfish waste offshore. If the waste is not dumped offshore, the dogfish crew would expect to receive $8,406, a net decrease of $1085 over the four month period. If the vessel operated with a crew size similar to Mid-Atlantic groundfish vessels, the average crew share would be expected to increase by $596 to $70,087, even without the waste allowance.

Several factors must be considered to properly evaluate the results of the analysis. Since the dogfish vessel will have trips of shorter duration, the vessel should be able to operate very effectively between the frequent winter storm fronts which are prevalent in the mid-Atlantic. This will allow the vessel to maintain its productivity during the winter months when other groundfish vessels have a difficult time making 4 to 5-day trips. Finally, the large harvest capacity per vessel expected in a dogfish fishery would have to be carefully coordinated with a shoreside processing facility in order to insure that the product could be handled efficiently while maintaining the required quality standards. New England vessels are currently limited to 18 mt (40,000 pounds) per day. In the past, the mid-Atlantic fishery did not operate under harvest quotas, but an expanded fishery might force the processing plant to impose harvest limits on dogfish vessels.

The possibility of handling a limited number of processing activities on-board the fishing vessel has also been explored. In New England, a few dogfish processors require harvesting vessels to head, gut and remove the belly flaps from the shark carcass while at sea. The partial budget provided for this basic scenario assumes that the vessel will receive 44.1 cents per kg (20 cents per pound) for these products (table 2). The analysis reveals that a dogfish vessel would realize an increase in net income of approximately $38,600 but would have to absorb significantly higher costs because additional personnel would be required to carry out the on board processing tasks. In spite of these higher costs, vessel revenues are expected to increase 74% and individual crew share should increase 50%.

Limited processing activities on a commercial fishing vessel can have a dramatic impact on the cost of shoreside processing (table 3). Waste disposal costs are expected to decline by 92% if on board processing is implemented. More importantly, the volume of waste which must be handled on shore would be greatly reduced and may allow the processor to use traditional waste disposal methods. Another cost which would decline dramatically is the direct labor expense attributed to processing dogfish backs. Since all heading and gutting will be handled at sea, direct labor will focus on trimming, skinning, packaging and freezing the shark products and would decline by approximately 17%. A similar savings can be expected from the general and administrative expenses, since many of these costs are related to personnel and facility costs. Not only will the labor and facility costs decline, but this production capacity can be released for use in other profit making activities

Conclusion

The dogfish population in the mid-Atlantic is capable of supporting a commercial fishery of modest proportions as market conditions would make it marginally profitable for vessels and processors to enter the fishery. The current market does not appear to be capable of supporting additional production without a substantial decrease in market price.

There are three primary factors which could substantially improve market conditions. The Northeast Atlantic dogfish fishery has experienced improved catch rates during the past year. Since most of this product is sold fresh, it has exerted downward pressure on all frozen dogfish prices. If this fishery were to continue its long-term downward trend, demand for frozen product should increase sufficiently to improve market prices. Another factor which has had a significant impact on U.S. product is the strength of the U.S. dollar relative to other currencies. Since dogfish is a relatively low value species, currency fluctuations play a very important role in the overall profitability of a dogfish processing operation. Finally, the lack of a domestic market puts substantial pressure on U.S. processors to sell frozen product in existing European market channels. The long term economic viability of U.S-based dogfish operations is dependent upon a continuing effort to promote the use of dogfish in domestic institutional and consumer settings. These alternative markets would give processors more leverage with their European customers and should serve to increase price levels for U.S. product.

Given the current market conditions, it appears that a mid-Atlantic fishery would be marginally profitable at best. Any improvement in market prices and supply conditions could serve as a catalyst for development. Should the dollar remain strong, domestic processors and fisheries development organizations should work together to introduce the product to U.S. consumers.

Table 1

Partial Budget - (Dec-Mar)

Current Activity: Participate in mid-Atlantic groundfish fishery
Proposed Change: Shift fishing effort to dogfish from groundfish

Positive Economic Effects
Additional Returns
30 Trips - 36,281 kg at 17.6 cents per kg (80,000 lbs of dogfish at 8 cents per pound) = $192,000

Reduced Costs

Electronics & Gear Maintenance -	$ 3,031
Captain's Bonus -	$ 7,578
Crew Share -	$84,579
Insurance -	$11,666

A. Total Additional Returns
and Reduced Costs $298,854

Negative Economics Effects
Reduced Returns
Average Gross = $2021/fishing day - $151,575

Additional Costs

Electronics & Gear Maintenance	- $ 3,840
Captain's Bonus	- $ 9,600
Crew Share	- $107,136
Insurance	- $ 12,499

Net Change in Income (A-B) = $14,204
to Vessel

Net Change in Income
Per Crew Member $995

B. Total Additional Costs
and Reduced Returns $284,650

Table 2

Partial Budget (Dec-Mar)

Current Activity: Participate in mid-Atlantic groundfish fishery
Proposed Change: Harvest and conduct limited on-board processing targeting dogfish.

Positive Economic Effects
Additional Returns
22 - 3 day trips - 27,211 kg at 44.1 cents per kg (60,000 lbs of H&G dogfish at 20 cents per pound) = $264,000

Reduced Costs

Electronics & Gear Maintenance	- $ 3,031
Captain's Bonus	- $ 7,578
Crew Share	- $84,579
Principal & Interest	- $20,660
Insurance	- $11,666

A. Total Additional Returns and Reduced Costs $391,514

Negative Economic Effects
Reduced Returns
Average Gross = $2021/fishing day - $151,575

Additional Costs

Electronics & Gear Maintenance	- $ 5,280
Captain's Bonus	- $ 13,200
Crew Share	- $147,312
Principal & Interest	- $ 22,037
Insurance	- $ 13,500

Net Change in Income to Vessel = $38,610

Net Change in Income Per Crew Member $4,172

B. Total Additional Costs and Reduced Returns $352,904

Table 3

Expense and Revenue Comparison for
On-Shore Processing Alternatives
for Spiny Dogfish (*Squalus acanthias*)

	Process Whole Fish	Process H & G Fish	Difference	% Change
Kg (Pounds) Delivered	45,351 (100,000)	18,594 (41,000)		
Kg (Pounds) of Finished Product	16,326 (36,000)	16,326 (36,000)		
Ex Vessel Cost	8,000	8,206	(206)	-2.6%
Direct Labor	4,630	3,850	780	16.8%
Indirect Labor	520	494	26	5.0%
Packaging Material	1,030	1,030	-	-
Waste Disposal	520	39	481	92.5%
G & A-Overhead	4,630	3,850	780	16.8%
Total Costs	19,330	17,409	1,861	9.6%
Total Revenues Current Market Conditions	20,980	20,980		
Total Costs	19,330	17,469		
Net Profits	1,650	3,511		
Net Return On Sales	7.9%	16.7%		

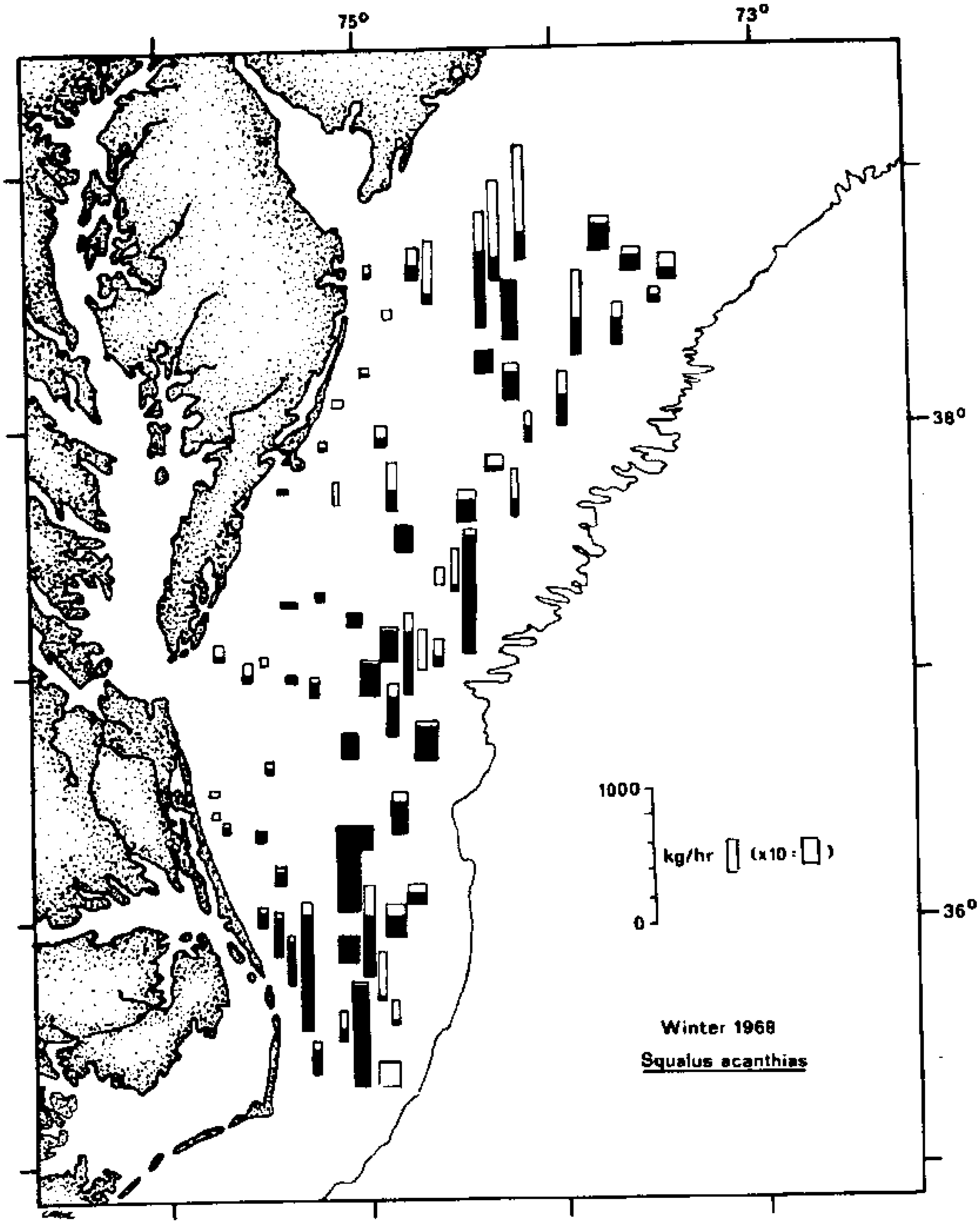

Figure 1. Catches of spiny dogfish (shaded portion) in terms of the proportion of total fish biomass taken during the winter 1968 VIMS Industrial Fish Survey, January 18–February 28 (after Colvocoresses and Musick, 1980).

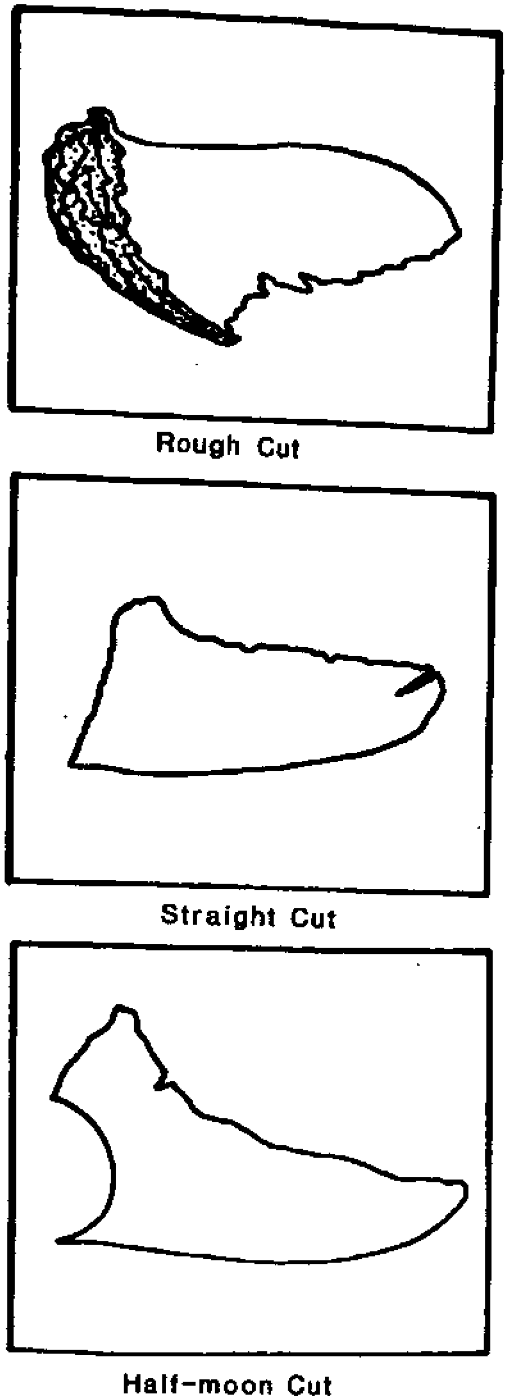

Figure 2. Common cutting patterns for shark fins (from Ka-Keong, 1983).

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Developing Minced Fish Products From Dogfish

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Abstract: In addition to such standard seafood dishes as patties, chowders, au gratins and thermidors, minced shark meat can provide a high-protein, low cholesterol alternative ingredient in a wide range of traditional products ordinarily associated with the use of "red" meat.

This potential should have special application in the diet-conscious general market as well as for health-oriented institutions for whom cost and product variety have become major considerations.

Limitations on institutional uses, in particular, need to be recognized but should not represent major obstacles to broader use of minced shark as a nutritionally valuable source of protein.

I am a former cook and restaurant owner and currently a public affairs consultant associated with your scheduled speaker, Chef Eric Benson.

Those of you who know Eric are well aware of his passion for this industry and how imaginatively he expresses that passion in the products he develops. He apologizes for not being able to be here. And, for embarrassment sake, it's just as well since some of the things that need to be said about our subject today involve highly personal experiences for him.

Several years ago, this tall man approached me in my establishment on the Oregon coast. He introduced himself as a retired chef. And he said he had some fantastic seafood ideas he wanted to discuss with me. I'm just sure! In the food service business, sooner or later you get to see them all.

He then proceeded to tell me that his career in the kitchen had been cut short by a heart attack—one that resulted in massive reconstruction of his chest cavity--and equally discouraging, one that forced him during his convalescence to eat some of the most unimaginative, God-awful, tasteless stuff he'd ever seen in his life.

Moreover, and most importantly, as a trained chef pledged to the service and well-being of other people, he now felt obliged to consider the accumulations of cholesterol that contributed to his condition and perhaps to that of untold others he had served during this culinary career.

Eric Benson's work since then has been devoted to the development of alternatives. And he didn't exaggerate with me. His seafood ideas have been fantastic!

I've recounted this rather personal experience to emphasize the point that when we think of "developing seafood products from minced dogfish" we have also put our finger on one of the most potentially valuable, virtually untapped possibilities for the entire seafood industry: the healthfood market!

Let me illustrate.

Most of us are familiar with Sid Cook's very fine cookbook of shark recipes. Other offerings are available through National Marine Fisheries and the Extension Services, as well as in some commercial cookbooks.

We've also had shark at our favorite restaurant on occasion and at this conference. As a cook of nine years, incidentally, my hat's off to Dick Horton, of the Portland Airport Sheraton Hotel, our chef last night.

The bill of fare for shark, in terms of taste, texture, combinations of ingredients and so forth, is remarkably good--batter fried shark (in Australia used widely for fish and chips); shark teriyaki; requin l'orange; shark mornay; scalloped shark; chowders and au gratins; and even the exotic sushimi and shark fin soup.

Ron Grulich (Virginia Institute of Marine Sciences) touched on special uses in Germany. And one of our next speakers will undoubtedly add to this bill of fare. Overall we can look forward to what I know will be some very fine additional contributions.

The reason for this variety (and thank heaven, shark is coming into its own) is that whether it's baked, deep fried, sauteed, smoked, barbequed or eaten raw, a good chef can do just about anything with shark that can be done with any other firmly-textured seafood.

But then, the question arises, "why?"

For the bill of fare mentioned earlier and for other traditional seafood menus, other species of fish are already available and more familiar to the fisherman, processor, retailer, and to the consuming public.

A fillet is a fillet is a fillet!

What happens, however, when we look at minced shark (dogfish in particular) as a high-protein, low-cholesterol alternative for health-conscious consumers, especially in an institutional context?

A range of products, now considered taboo because of their fat content and sometimes indigestibility, becomes highly appropriate and cost effective: in hospitals, convalscent and nursing homes, senior citizen centers, for health and athletically-minded individuals and others are now denied a bill of fare that already enjoys high consumer acceptability with the American public.

How much more so this is true for the American homemaker for whom convenience and ease of preparation have become understandable considerations in selecting pre-packed and pre-made products off the grocery shelf!

I would like to tease you with some possibilities. There's a word of caution, however. We have to think meat.

Examples utilizing minced dogfish are:

1) A protein base for spaghetti sauce;
2) Fillers for stuffed cabbage rolls, green peppers and whole baked tomatoes;
3) For tacos and enchiladas;
4) You fellows from Texas are going to use me as shark bait for suggesting this one: As chili con carne!
5) In "traditional" meat stews and potpies along with creoles and gumbos;
6) As lunchmeat and for sausage of all kinds—kielbasa, liverwurst, or pepperoni;
7) In lasagna, ravioli and other pasta casseroles;
8) In rice dishes, such as ragouts and paiella;
9) As swedish or sweet and sour meatballs;
10) Pickled, as with herring, for appetizers and salad bars;
11) Fillings for crepes Florentine, for example;
12) For oriental stir-fries or in Greek mousaka;
13) As liver substitutes for pates, mousses and tourines and
14) Corned beef hash!

You get the idea.

Most of these items and others yet to be explored are generally associated with "red meat." They all involve the generous use of vegetables, herbs and spices that tend to overpower whatever is used as a filler or base. Traditionally, it's been beef, lamb, pork or poultry.

We can substitute dogfish just as easily (probably at less cost) and certainly without the high cholesterol counts.

As a protein source, the abundant dogfish ought to be singing, "Anything you can do, I can do better."

If its brethren, the tuna, can be thought of as "Chicken of the Sea," if we can think of hamburger (which has nothing to do with ham), or if Harlon Pearce (Harlon's Old New Orleans Fish House) can conceive products such as "Veal of the Sea," then certainly, under a well-managed, biologically sound, and properly-marketed program, the dogfish can become "oceanburger."

We invite the advertising experts to play around with that one.

I don't mean to treat this too lightly. The need is there and so is the possibility.

In a world rife with hunger and malnutrition, and in our own country where past abundance has encouraged wasteful seafood practices, we must expand and diversify our protein base more efficiently. Use of dogfish provides such a possibility.

Most of us are well aware of the problems within the seafood industry from our own points of view. I don't want to make light of those either. In addition to biological, sociological and marketing problems, we are involved in an industry that appears to be economically "inelastic." Except for shrimp, lobster and other exotics, public demand and consumption does not necessarily increase proportionately to increased supply or lower cost. Dogfish products, prepackaged for hospitals, nursing homes, health food stores and schools, could, in our judgment, help bridge that economic gap.

At present, Eric Benson is cooperating with the National Marine Fisheries Service in Seattle and a private firm, Natural Resources Consultants, in developing alternative seafood products using pollock. He's found that the types of processes and techniques can also be applied to other underutilized species (such as hake and dogfish).

His findings seem especially appropriate since both hake and dogfish often end up in the same nets. We need processors who know what to do with these species when the fisherman brings them in as incidental catches. In Seattle, we think we've made some progress toward a partial answer.

Example:

1) Consume (clear broth): This product ought to be marketed as a "Chowder of Champions." It is basically made from fish scraps (discarded belly flaps and collars), spices, and vegetable additives (the kitchen sink, so to speak!). The simple process is known to French chefs as "consume double." I wouldn't be surprised if it's also known to a lot of moonshiners. It consists of successive reductions and clarifications of a basic stew until you have a clear, concentrated liquid with a great deal of flavor and potency. It could be used "clear"--as in post-operative meals in hospitals or as

a healthfood "cocktail." It can also be concentrated and frozen (similar to orange juice) or powdered and reduced to bouillon cubes. The techniques are not at all surprising. What is surprising is that very few of these seafood consumes are found in the general market compared to beef and chicken stocks. These are often used for soups or to give extra "body" to both sauces and sautees.

2) Meatballs and ground fish: These can be used for spaghetti, stuffed cabbages, ravioli, chili and breakfast sausages. For these uses, minced fish compares very favorably with "red meat" in terms of taste, color and cooking characteristics (with the obvious advantage of being virtually cholesterol free). It would make excellent "convenience" foods in supermarkets, especially for weight-watchers or health-oriented institutions.

3) Fish stix: People like to dip these into catsup, tartar and other sauces. The product can be deepfried or baked, and since it consists of 2/3 potatoes and 1/3 fish, it offers the kind of versatility that interests large food service institutions. The unique advantage is that, unlike french fried potatos which tend to become soggy as they cool, these fish stix remain crisp, firm and easily reheatable. We think this product, in particular, is ready for a major demonstration in a large school district. One can only speculate on the economic repurcussions if these are used in a system that feeds 50,000 children daily.

Eric Benson's operation is just beginning. Many of us have high hopes for a breakthrough in the way consumers view fish and fish products for economical, efficient and healthful sources of protein.

Finally, I have a personal word of assurance that responds to Dennis Bedford's (California Department of Fish and Game) paper with its fine cautionary notes.

We're not here today to sell products. We don't manufacture them except as samples. We are here to sell an idea and a possibility for the seafood industry. Years ago, I was privileged to work as an environmental activist in Washington D.C. A noted fisheries biologist recounted to me with horror the possibility that given our technology and long-term protein needs, we could literally catch every damned fish in the ocean. I've never forgotten it. Fifteen years later, it's reassuring to know that this has not yet happened. With intelligent management of our marine resources, imaginative and efficient use of species such as dogfish, this need not be our future.

Synopsis[1]

Fisheries and Use of Deep-Sea Sharks

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With the exception of the Japanese, the species of sharks which live in the deep ocean have largely been ignored by fishing nations. When we talk about deep-sea sharks, we are talking about those species which live in the twilight and upper limits of the aphotic zone below the euphotic zone (light penetrating zone capable of supporting primary plant production). We are not talking about very deep-dwelling sharks. Sharks of the zone in question are those species that have begun to lose the countershading of their upper and lower body surfaces.

Food is scarce in the aphotic zone and mesopelagic species have difficulty obtaining enough food to sustain themselves. One modification noted among deep-dwelling organisms to address this scarcity of food is a reduction of body tissues. Deep-sea bony fishes are the nearest thing to vertebrates without backbones of which we are aware. Muscle tissues are reduced also in most of these species of fish. Other modifications include huge eyes, bioluminescence (light generating capability), and "lures" (modified body parts used to trick potential prey species) as in the anglerfishes. These all serve to trick prey into coming close enough to the predator to make feeding more successful.

One of the few animals that retains a pretty good musculature, although it, too, is reduced somewhat, is the deep-sea shark. That these species of sharks have more body tissue mass indicates that they have adapted other mechanisms that aid them in securing food.

The Japanese have been eating shark for over 2,000 years. The agricultural museum near the Grand Isei Shrine has perhaps the finest collection of sharks from Japanese waters in existence. This collection includes the youngest known specimen of the basking shark (*Cetorhinus maximus*), a 2 m (6 foot) individual. The scientific study of deep-sea sharks did not get under way until Bashford Dean went to Japan and investigated the embryology of the frill shark (*Chlamydoselachus anguineus*), a mesopelagic species.

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[1] This paper was summarized by Sid Cook from a tape recording of Ms. Clark's presentation at the conference.

During World War II, the first major effort to harvest deep-sea sharks was undertaken by fisheries pioneer, Toshiro Kaneko, in Japan. The fishery proved to be profitable, bringing in many millions of dollars in the first few years of operation. Most of the sharks taken in that fishery were, and still remain, Squalioids primarily in the family Squalidae. Many of the species in that family are deep-sea types that are unusual to weird looking fishes. Because of their unusual appearance, they have often been referred to as sea monsters.

A number of years ago a dead carcass of an animal was brought aboard a Japanese trawler operating off New Zealand. It had a small head, a long neck, and broad, rhomboidal-shaped fins. It was initially reported as a possible confirmation of the continued existence of the plesiosaur, a prominent marine reptile from the Mesozoic Era (63 to 230 million years ago). The modern embodiment of this reptile is the elusive Loch Ness monster of Scotland. The carcass generated quite a lot of publicity when it was believed to be a sea monster; however, when it was shown to be a dead basking shark, the press did not pay much attention. Consequently, many people still believe that a plesiosaur carcass was recovered. Susumu Kato of the National Marine Fisheries Service told me that Japanese trawlers in New Zealand waters bring up as many as three live basking sharks at a time in their nets. The fishermen cut them loose to swim away. A key to the mystery of the sea monster carcass from New Zealand lies in a peculiarity of decaying basking sharks. These dead animals often float ashore with the gill slits and lower jaw having dislodged from the rest of the body, thereby giving the head a long narrow appearance. Moreover, these sharks have heterocercal tails (the backbone passes into the upper lobe of the tail); so when the lower lobes separate during decomposition, the tail appears to be narrow also. Rather than calling in members of the scientific community, authorities would have done better to call upon Japanese fishermen of the Nakiri district who have fished for basking sharks for many years. They could have identified the carcass very quickly.

The villagers of Nakiri and surrounding hamlets fish for basking sharks from February to April before changing over to tuna about the beginning of May. On one exceptional day in 1978, 88 baskers were taken, each running from 8.4-9.3 m (27-30 feet) and 7.3 m tons (8 standard tons) each. One fin from such an animal could easily provide enough cartilage needles to make shark fin soup for an entire hamlet or town. This is perhaps the only village group in the world that still hunts the basking shark for commercial purposes. The ever industrious Japanese have solved processing problems that have discouraged fisheries for this species elsewhere in the world (including California). All of the sharks taken in the village of Nakiri are males, which seems reasonable because the basking shark segregates by sex.

Of 350 known species of sharks only three are planktivorous (feeding mostly upon microscopic and very small free floating plants and animals): the whale shark (*Rhincodon typus*), a tropical epipelagic; the basking shark (*C.*

maximus), a temperate epipelagic; and the megamouth (Megachasma pelagios), a deep-sea species.

Of the planktivores, the basking shark has received most interest from commercial fishermen. It spends part of the year feeding at the surface and part of the year hibernating on the bottom at depths of 1,000 m (3,000+ feet) where it drops its gill rakers in preparation for growing a new set each year. I examined a shark at Nakiri at the beginning of the fishing season a number of years ago. The gill bars were naked, but a new set of rakers was about to erupt from soft tissue on the bar. The shark was a male with an impressive 1+ m (3.5 foot) clasper (male intromittent organ). When the base of the clasper was depressed, liters of spermatic fluid spewed forth.

The basking shark is also famous for its liver, which may account for as much as 25% of the animal's weight. The liver is valuable, because, as with other deep-sea sharks, it has a very high squalene content. Squalene is believed to play some as yet undefined role in the maintainance of deepwater sharks (Kreuzer and Rashid 1978). In shallow water species--i.e., those found in the upper 200 m (650 feet) of the ocean—there tends to be a higher vitamin A content and a lower squalene content. This is completely reversed in deep-sea species (Compagno 1984). Where squalene is 2%-5% of liver oil in shallow species, it comprises 70%-98% of the oil from the deeper dwelling varieties. Squalene has some remarkable properties, including emulsifying characteristics and other qualities that make it a highly desirable base for cosmetics. When you kiss someone wearing lipstick, you are kissing through a film of shark liver oil. Squalene is also used in the Far East as a health aid because it is believed by many to have powerful pharmaceutical properties (though this has not been proven by research yet). Without question, squalene oil has been the most valuable product from basking sharks in Japan.

The meat from basking sharks is cut into thin chunks and laid out to dry in wire baskets in the wind and sun. Although I did not see the whole process of preparing meat, I do not believe they brined the meat or carried out any process to remove urea. This surprised me at first. But, upon closer examination, I noticed that the meat from basking sharks is amazingly odorless. Another remarkable thing was that the processors made no attempt to bleed the animal, although this could have been accomplished easily. Further study revealed that the basking sharks had a low urea content when they came up from deep waters in the spring. This eliminated the need for the Japanese villagers to deal with the urea. Once the meat is dry, it is dipped in soy sauce and redried with a coating of sesame seeds. The final product is placed in a wooden box and sold for $8-$10. Since edible meat comprises 40% of the shark, this portion of the processing brings in a considerable amount of money. In fact so much money has been made by the family that controls the Nakiri plant that they now save only the livers and discard the remainder of the fish.

The cartilage is used for a food additive to produce health food and also in experimental work to develop an artificial skin to treat severe burns. For many generations in Japan, the cartilage has been reduced to a fine white powder and sold through health food dealers under a trade name which translates as "the 40 shoulders" (presumably referring to the aches and pains of stiff shoulders, etc., that begin to affect all of us after we reach midlife).

Basking sharks often congregate at places where two currents come together to form a current rip. The interface between two such currents is characterized by roiled water that is clear on one side of the rip and turbid on the other due to heavy plankton concentrations. Basking sharks will be found on the plankton rich side. Sometimes two or more basking sharks will swim at the surface in single file manner. To the uninitiated this can look like a sea serpent.

The megamouth is a recently discovered member of the plankton-feeding sharks. It was described as a new species in 1983. It appears to be a mesopelagic which on occasion comes up near the surface. So far only two specimens have ever been taken, one from Hawaii at 1,000 m (3,000 feet) and one near the surface during retrieval of a commercial net in California in 1985. As with other deep water fishes, the megamouth is probably widely distributed due to the homogeneity of physical oceanographic conditions at that depth over large areas. In this zone, the water temperature is 4°C (39°F), the maximum density of seawater. When more is known about this species, the Japanese will probably find a way to eat megamouth also.

While I was in northern Japan, I went with the fishermen of Yaizu on their deep-water fishery. They employ a 1,000+ m (3,500 foot) longline studded with small hooks as most of the sharks they catch are in the 27-36 kg (60-80 pound) class. They fish their gear at about 700 m (1545 feet) depth. One of the great advantages of the Japanese deep-sea fishery for sharks is that deep water is so close to shore in Tsuruga and Tsugami Bays. For the most part, the sharks are from the family Centrophoridae (gulper sharks). They are almost completely lacking in countershading. All members of this family are noted for their huge green eyes. Because these animals have no eyelids, they close their eyes by squinting.

Another shark taken in these deepwater sets by the Japanese was Dalatias licha, called locally "amazame." This species is related to the famed "cookie cutter" sharks (Isistius sp.) whose large fleshy lips and huge teeth in one jaw remained a mystery for a long time. These sharks are now known to attach themselves to larger marine animals, such as marlin, tuna, and whales and carve out circular plugs of flesh from their hosts (vertebrate ecto-parasite).

The Japanese eat considerable amounts of raw fish served as sashimi. The deep-sea sharks lend themselves to sashimi because they are low in urea. The Japanese also eat the squalene-rich raw liver from these sharks. Squalene-rich oil is also incorporated into a food supplement capsule known as the "marine gold" pill, which is touted as a curative for everything from hangover to cancer, athlete's foot to constipation, and probably some conditions for which there is no disease known (like general tiredness, etc). These pills are golden yellow or black with a shark printed on the side of the capsule. They cost $1 or more per pill.

Squaliolus laticaudus, the world's smallest shark, is also taken in Japanese waters. It is an incidental by-catch of the deep-water trawl fishery for Sakura shrimp. The shrimp are larger than these sharks that are taken with them!

Goblin sharks (Mitsukurina owstoni), a weird-looking or beautiful shark with an unusual shelf over the upper jaw, is also taken commercially in Japan. The shelf has an unknown purpose, but may be used to help the fish root out prey items buried in the mud on the sea floor. This has always been a favorite shark of mine, and I take every opportunity to look at specimens in collections to examine for stomach contents. One reason we have been unable to determine possible uses for the shelf is that these sharks have had empty stomachs when captured. In Japan I was graciously granted permission to examine a female goblin shark which was so rounded out that we believed her to be pregnant. Instead, to my delight, I found that she had a full stomach, the first such animal in this condition I have been able to examine.

In Bermuda we are working with deep-sea sharks, primarily the sixgill (Hexanchus griseus), for a National Geographic Society project. This shark is usually found at 600-1,000 m (1935-3225 feet) deep. We have examined one female that had been feeding on an obviously decaying whale. When we brought her aboard, she promptly belched and nearly drove everyone off the boat with the smell. During 1986 we will be working in the area off Bermuda on a telemetry project to track the sixgill in its deep travels.

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Culinary Delights: Preparing Shark in Restaurants and Homes

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Abstract: Shark meat is enjoying slow, but steady success in pleasing the palates of American consumers. With a few exceptions in restaurants and among those related to the industry, shark meat is regarded as a novel item served as appetizers or entrees or as a one-time event for "shock value."

Restaurants surveyed in several states responded to questions concerning availablility, pricing, portion control, preparation and clientele behavior. From all indications, consumers perceive and accept shark meat as a viable food item and are impressed primarily with the taste, texture and preparation versatility afforded them by the product.

Introduction

Preparation and acceptance of shark has come a long way in the last ten years, from a few restaurants serving it under the guise of "grayfish" or "deep ocean perch" to a multitude of restaurants who proclaim it proudly as shark and succeed with this proper acknowledgement. Today, it is becoming a widely publicizied fact that shark is excellent table fare.

This report, in two parts, will address restaurant use and response and consumers' attitudes toward shark meat as a food item.

Consumer Study

Data collected from restaurant chefs from 43 restaurants in Texas, Florida, and South Carolina revealed this information. Regarding preparation, the four major methods in order of preference were charcoal grilled, mesquite grilled, baked and fried. Serving size portions were reported as 142 g (5 ounce) and 227 g (8 ounce) selling from $3 to $12 per serving on the menu for lunch and dinner, respectively. Concerning supply, with the exception of Red Lobster Inns of America, where each unit is responsible for their own "fresh catch of the day" as a blackboard item, restaurants reportedly rely on wholesalers for product. None indicated they had difficulty in acquiring shark meat at any time of the year. Other than portion control and slight trimming, very little preparation is required before the product is cooked. The chefs declared satisfaction with the condition of the shark they received.

Mako was preferred above all other species; then black tip and white tip. In states where a "truth and menu" law is not in effect, mako is preferred, apparently because it looks like swordfish and can be priced and served as such. All the restaurants polled insisted on fresh only. When asked about customer reaction, many of the chefs reported a pleasantly surprised reaction from first time consumers of shark. The chefs said they believed about half the requests are repeat. There was no strong reaction reported from the kitchen staff. One interesting comment from a Hawaiian chef in Florida concerns a legend that it is taboo to kill shark. "Sharks own the waters" and are a respected fish and therefore are not purposefully sport or commercially fished by true believers of the legend.

1. Consumers show a considerable curiosity about shark. If provided with true and adequate information, people will view the possibility of eating shark with an open mind and will reserve final decision until they can actually taste it. Some exhibit skepticism, but as they learn more about it are eager to try it.
2. Male respondents appear to have a more positive attitude toward shark than female respondents.
3. People ranging from ages 20-50 (author's estimation of their ages) tend to be more likely to try shark than people over 50.
4. Black consumers consistently indicated less favorable responses than other races.

The value of one formal study in Texas was to provide the marketer with an idea as to how the consumer would perceive and accept shark meat as a food item. It was discovered that people with higher levels of education responded more favorably to the idea of tasting shark than the respondents with lower levels of education. Thus, it appears that people with higher levels of education will view shark meat as a food item more favorably than the less educated consumer. Higher income groups tend to be less adversely affected by the image of shark than lower income households.

Many consumers are unfamiliar with shark meat as a good-eating food product. However, consumers consistently appear to exhibit curiosity and then accept it after a successful taste encounter. Many know it is eaten but never considered eating it themselves.

Regarding preparation, shark meat is delicious prepared in many different ways and can offer hundreds of exciting preparation methods for the restaurant or home chef. Of course, whether or not the fish will be a success as a food item begins when the fish is landed. Immediate bleeding and icing is vital to the final taste and success of the recipe. In terms of quality, this is the most important factor to impress on a sport or commercial fisherman.

In previous recipe demonstrations and in testing the product at home and in the office, these preparations proved successful for the home chef: bouillabaisse, soup, stew, kabobs, dips, spreads, sandwich fillings, gumbo, blackened preparations, grilled and smoked. Other attributes that make shark appealing to consumers are its lack of bones, firm texture, novelty in serving and fine nutritional qualities. A fairly typical nutritional summary for 170 g (6 ounces) of shark is 125 calories, 30 g of protein, 0.4 g of fat and 0 g carbohydrate. According to the National Marine Fisheries Service, the cholesterol level is 16-23 mg per 100 g which is at least half that of most other seafoods.

From a culinary standpoint, shark has been called a "chef's dream." The extremely mild flavor conforms readily to many tastes with the use of herbs, spices and sauces.

It is an adventure to cook and will release one's imagination, even to the point of substituting it for beef, pork or chicken in a favorite recipe.

If you have previously enjoyed this product only in restaurants or at activities such as this conference, I encourage and challenge you to try your own hand at preparation of this fine seafood item.

Overview of U.S. Sport Shark Fisheries

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Abstract: Recreational aspects of shark fishing have been steadily gaining interest among mainstream U.S. sportsmen since the 1950's. These fishes, originally the object of scorn as "malevolent killers," have been increasingly recognized in recent years for not only their value as superb gamefish but also their potential as extraordinary table fare. What was once the purview of only a few hearty sportsfishing specialists in Florida and Texas has grown to include individuals of all skill levels and backgrounds from New York to California who have discovered what has become known as "the poor man's big game fishing." Various factors, such as tournaments, conservation efforts, and the formation of fishing clubs are examined with reference to development of the sport.

It wasn't many years ago that a discussion of this subject could be condensed into a matter of seconds. Until the 1950's there was no real sportfishery for sharks except by a few specialists in even fewer areas of the south--primarily Florida and Texas. Yet, since the 1960's shark fishing has been growing rapidly and there's still a world of potential for this unique sportfishery.

During the past 20 years I've written extensively about shark fishing and have made many converts. Invariably I label it "the poor man's big game fishing," and, despite all the fancy sportfishing craft that also participate, that's exactly what it is. In most cases, anglers can fish for sharks from small, seaworthy boats and with tackle that they already own or can use for other species for which they ordinarily fish. After getting their feet wet in shark fishing, many then move into more sophisticated (and expensive) forms of big game fishing.

Shark fishing in the Northeast was pioneered by Captains Frank Mundus and John Walton. Mundus operated out of Montauk in the 50's and popularized his "monster fishing" by appearing at the New York Sportsmen's Show each winter with a collection of jaws and teeth. At that time, few people realized that northeastern waters were chock full of sharks—associating those "killers" with tropical climes. In point of fact, the shark fishing was outstanding. It wasn't even necessary to go very far offshore. Walton used to run his boat, "Chief Joseph Brant," from the western end of Long Island Sound all the way east to Montauk (about 120 miles) just for a weekend of shark fishing. He set many records in the process.

Fishing clubs in the mid-section of Long Island caught on to the sport and were soon "sharking" well west of Montauk. By the early 1960's, the Bay Shore Tuna Club was sponsoring a shark tournament that quickly grew out of control. So many blue sharks were landed in the first contest that disposal became an incredible problem, and weigh-ins ran far into the night. The number of boats entering the Bay Shore Mako Tournament also grew beyond the capacity of the club to handle them. A limit of 150 had to be placed on entries, as well as a minimum size on blue sharks entered.

It was during this period that I started shark fishing. I'm happy to say that the attitudes displayed during those early years of sport sharking have changed almost completely. The people I fished with regarded all sharks as killers to be exterminated, even if they had no other use for them. All sharks were killed and most were dragged back to the dock—only to be dragged right back out for dumping. Only the makos were recognized as good eating.

Fortunately, that attitude has changed—and not a moment too soon. Primary credit for that belongs to Jack Casey and his fellow scientists who started studying sharks at Sandy Hook Marine Lab in new Jersey about that time and have continued to this day at the National Marine Fisheries Service lab in Narragansett, R.I. Once the scientific information was made known to anglers and the request for assistance in tagging came through, there was general cooperation in the program. Most importantly, anglers came to understand that the shark resource is a fragile one and that it must be treated with the same respect according to other favorite game fish.

While sharking as a sport grew rapidly on Long Island, it was slow to catch on in other areas. To be sure, there were areas where a few dedicated anglers really worked at shark fishing--usually from shore. Sarasota, on the west coast of Florida, and some of the Florida east coast inlet areas had their shark specialists, but real national interest was not sparked until the publication of Peter Benchley's novel "Jaws."

That book so caught the public's imagination that a demand for shark fishing charters developed almost overnight. Florida charter captains, who had regarded sharks with disdain and had always run away from them, found that there was good business in both charters and mounting of these primitive creatures. Whereas only a few Montauk charter captains had been bothering to go offshore for sharks, now just about everyone was seeking shark parties. Many started specializing in the sport.

Of course, all this didn't hurt Frank Mundus' business. The captain in "Jaws" was very obviously patterned after him. However, Mundus soon had plenty of company on the grounds, and it became necessary to go further offshore in order to find decent quantities of sharks. Trophy tournaments proliferated on Long Island. Reports of 1,000-pound makos and of great white sharks became front page news instead of simply an item for the fishing column.

Next door to Long Island, there had never been much interest in shark fishing in New Jersey. For some years the outdoor editor of the New York Daily News, Jerry Kenney, ran a New Jersey party boat specializing in sharks. Even the publicity he afforded the sport didn't have much effect. What really got things going in the Garden State was the development of money tournaments. Hoffman's Anchorage in Brielle started a mako tournament 12 years ago. At first they used gift certificates in the tackle shop as prizes, but it soon became a cash affair, and the pot started growing.

Before long Hoffman's had a $15,000 mako tournament, but it was oversubscribed so quickly that they added other contests. Now they have a $15,000 contest every week during the peak shark season. The success of that tournament inspired many others and New Jersey now offers a long list of June and July shark contests with purses ranging up to $50,000. That applies all the way from Leonardo and Highlands at the northern end of "the Shore" to Cape May at the southern tip.

The cash tournament craze has spread both north and south with shark fever. Long Island resisted the trend and stayed with trophies and prizes for a long time, but big money tournaments are now proliferating. The long-established Montauk Marine Basin Shark Tagging Tournament went to cash prizes for the first time this year.

Shark fishing has become an important sport along much of the east coast from Rhode Island to Florida, and has gained popularity in the Gulf of Mexico. California has good sharking opportunities (particularly for blue and thresher sharks), though little has been done about developing it so far. Ironically, the blue shark resource has been most utilized by the most specialized of anglers--fly fishermen. Even a decade ago, some fly fishermen in California found that blue sharks would readily take a fly after being chummed to the boat.

The potential for shark sportfishing is unlimited. Only in the New York-New Jersey area are the sharks heavily exploited and the grounds often "crowded." Though shark stocks are generally regarded as being in good shape, those of us who were fishing two decades ago are well aware that the "bloom is off the rose." For many years I would have bet that I'd never get skunked on a shark trip, even for only a few hours. However, that's no longer the case. We often struggle to come up with even a single shark, and it's often necessary to go far beyond where we used to enjoy consistent sharking. Nevertheless, this is still the most reliable big game fishing available, and charter skippers soon learn that newcomers to the sport don't have such high expectations. Fortunately, we've only scratched the surface of potential shark customers. Even a smaller supply of sharks should be sufficient to keep the business growing.

The problem now becomes one of assuring a supply of sharks for the every-growing sportfishery. In the New York-New Jersey area there is a conservation ethic fostered by Jack Casey and most of the outdoor writers and fishing club officials. The killing of sharks not desired for food or trophy is discouraged, and most tournaments operate on the "one big fish" basis rather than in terms of numbers. Furthermore, virtually all anglers cooperate with the National Marine Fisheries Service tagging program.

Unfortunately, that conservation ethic isn't as strong to the south where some contests still stress the killing of sharks. A greater threat to the shark population is the proliferation of longlines. There is now a good market for makos, and even the smallest specimens from longlines are boated. Most other shark species are discarded. While sharks have a better survival rate on longlines than other types of fish, longliners often kill them in revenge for eating their bait and hooks. That loss has never been quantified. As more longlines are set for tuna and swordfish, more sharks will be lost. For the present there doesn't seem to be any end to the increase in longline gear. This is an area in which the federal government must become more active before irreparable damage is done.

American anglers, spoiled by an abundance of other game fish, haven't taken full advantage of their shark fisheries, but they're beginning to do so. The economic impact of the fishery is already substantial in some areas. In New York and New Jersey it is just about all of the offshore sportfishing available in June and early July. Great quantities of bait are sold. Tackle purchases are quite significant. Fuel sales for this offshore sport are high. In fact charter captains count on the sharks to carry them through what would otherwise be a very slow period. At times it's almost crowded offshore, and a skipper has to work to catch fish once easily taken. Before the situation becomes any more acute, a shark management plan should be developed to deal with any real threats to the various species and to preserve a healthy stock for future generations of shark hunters.

Conference Summary

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At some meetings they want the best first while at others they want the best last. That decision did not have to be made at this one. You had the best first and last with my keynote and summary remarks. B.J. Putnam told me to say that. Regardless of what he said to say, all of you know the part in between was best.

We have had two very full days of fine presentations on a remarkable variety of subjects. There was something for everybody. Most of you were here for both days and heard the information directly from the experts. I don't need to dwell long on what you heard. My remarks will be relatively brief. The proceedings hopefully will be out in several months and you will be able to study the information in depth.

We heard why we have been talking about sharks. There is increasing interest in sharks by a great variety of people for many reasons. Scientists, recreational and commercial fishermen, processors, consumers, swimmers, and surfers all care about sharks. They want to learn more about these animals for a better understanding leading to wiser management, recreational enjoyment, profit from harvest, consumption, and greater understanding and safety while participating in water sports. Much has been learned in recent years about these fascinating fish and it was time to share that information with interested parties, for professional colleagues to compare latest results, and for others to meet the experts for possible later followup. All of those things were done very satisfactorily.

During the six talks on shark biology, recent findings in growth and aging studies based on vertebrae analysis were highlighted with appropriate qualifications on accuracy and emphasis on the pioneering approaches being tried. Short term and long term movements of sharks were related to various environmental conditions which are not precisely understood or measured. Telemetry, ultrasonic tracking, and conventional tagging all are contributing to our better understanding of shark movements and the reasons for them. Much is still speculation, but based on specific observations. More sophisticated equipment is continually being developed and used to extend our knowledge. A short course in life history of various sharks was presented. Examples of man's impact on three species apparently by overfishing and related subsequent disregard for sound biologically-based management in fresh-brackish-marine environment were discussed. Unusually good slides were key supplements to the presentations. Although some of the material was quite technical, the speakers did a particularly good job of explaining studies largely in layman's terms. The slow growing, long-lived nature of the creatures was repeatedly emphasized and must be remembered in the studies and exploitation of these animals. More technical facts are needed for verification of a number of hypotheses.

There were seven presentations on shark attack behavior. Each came from a different perspective, but there was general agreement that sharks are not the vicious man-seeking and man-eating monsters "Jaws" and a variety of media reports have indicated. However, they can and do present serious threats to the safety of persons in the water under certain conditions and in various locations. Appropriate actions to minimize danger were offered. Much remains to be learned about what triggers the frequently unpredictable actions of several species. Interesting views were offered on what triggers some alarming media reports on shark incidents and how they may be minimized. Science, mythology, and field observations were interwoven through the discussions. Equipment and procedures are being developed and tried for protection of persons in shark-inhabited waters with projected high success.

The eight presentations on commercial shark fisheries covered a very broad range of activities. The development of the angel, thresher, silky, and dogfish fisheries in different parts of the country, the problems encountered, the solutions developed, the options for the future, and the roles of fishermen, processors, peddlers, scientists, and managers must play were discussed. Frustrations of all were mentioned. Quality of the product from the moment of landing to consumption was emphasized as being the single most important factor in the entire process. All agreed the many species of shark are fine sources of protein, tasty, low in fat and cholesterol, and can compete successfully in the market place. Success will come if the stocks are not overfished, quality is insisted upon and maintained, and products responsive to the demands of the marketplace are developed at realistic prices. Innovative skippers can successfully integrate fishing for sharks with fishing for other species at appropriate times of the year and make it work. Landings of several species of sharks have increased very significantly in the past few years and the trend clearly will continue. An important problem not yet solved in some fisheries and areas is the establishment of a constant supply to continually satisfy the demand so customers once gained are not lost due to frustration in being unable to get product when they want it.

We were challenged to be innovative in developing different ways to serve shark with other foods and in other ways. A remarkable array of possible products was listed to whet our taste buds. The characteristics of shark as a foood are so impressive as to be almost unbelievable; everything you have ever wanted in a food and more. There seems to be no food preparation technique or product that shark flesh can't meet and maybe exceed. They can even turn it black while cooking and have it remain tasty. As you can tell, I have been convinced by the advocative experts in such culinary persuits. The potential seems to be unlimited. It looks to me like a win-win situation.

Deep sea sharks were suggested as a good possiblity for harvest as a presently underutilized resource. Huge basking sharks are now taken in Japan in a very profitable fishery and other stocks there and elsewhere have potential. Interesting pictures of some of these rarely seen species were shown.

The sport fisheries program concentrated more on quality than quantity. Clearly there is tremendous nationwide interest in recreational shark fishing for fun, food, and prizes. Considerable investments are made in this recreational pursuit. People who fish and those who watch—who want to see a big fish and particularly a big shark--participate but in different ways. All contribute to the economy and have needs to be satisfied. And in the process they will try eating shark for the first time and, if it is prepared properly, it won't be the last. Much useful scientific information is obtained by biologists as a fringe benefit of shark tournaments. The users feel more a part of the program and want it to be successful this way. We were shown a complete outfit used for shark fishing in Florida and endured some tall fishing tales in the process. The commercial/recreational relationship and competition for the same resource were mentioned.

There were about 140 people registered and probably a few more in attendance for all of the sessions combined. I don't know all the various categories of interest represented but I am convinced that if they were directed toward the subjects listed on the program, the individuals were pleased they attended. Each speaker contributed to the overall success in different ways. We heard facts, measurements, procedures, techniques, and methodology, and some lightly-founded hypotheses. Useful and interesting information was provided. I am confident members of the audience who had not eaten shark before but had the hors d'oeuvres at the cocktail party or the entrees at the buffet enjoyed these deliciously-prepared products and are interested in having more. Persons who were interested in developing commercial or recreational fisheries, markets, or new products gained much insight from the formal presentations and the informal discussions with appropriate speakers.

The atmosphere throughout was friendly and informal and many new friendships, and new contacts at the very least, were established which will bear fruit in the future. There is much agreement that the program was well done, worthwhile, and the time well spent. That is notwithstanding the fact that the next conference has not yet been planned. Thank you for attending and participating. Travel home safely and keep up your work on and interest in sharks.

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