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

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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?

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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 alumninum 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.

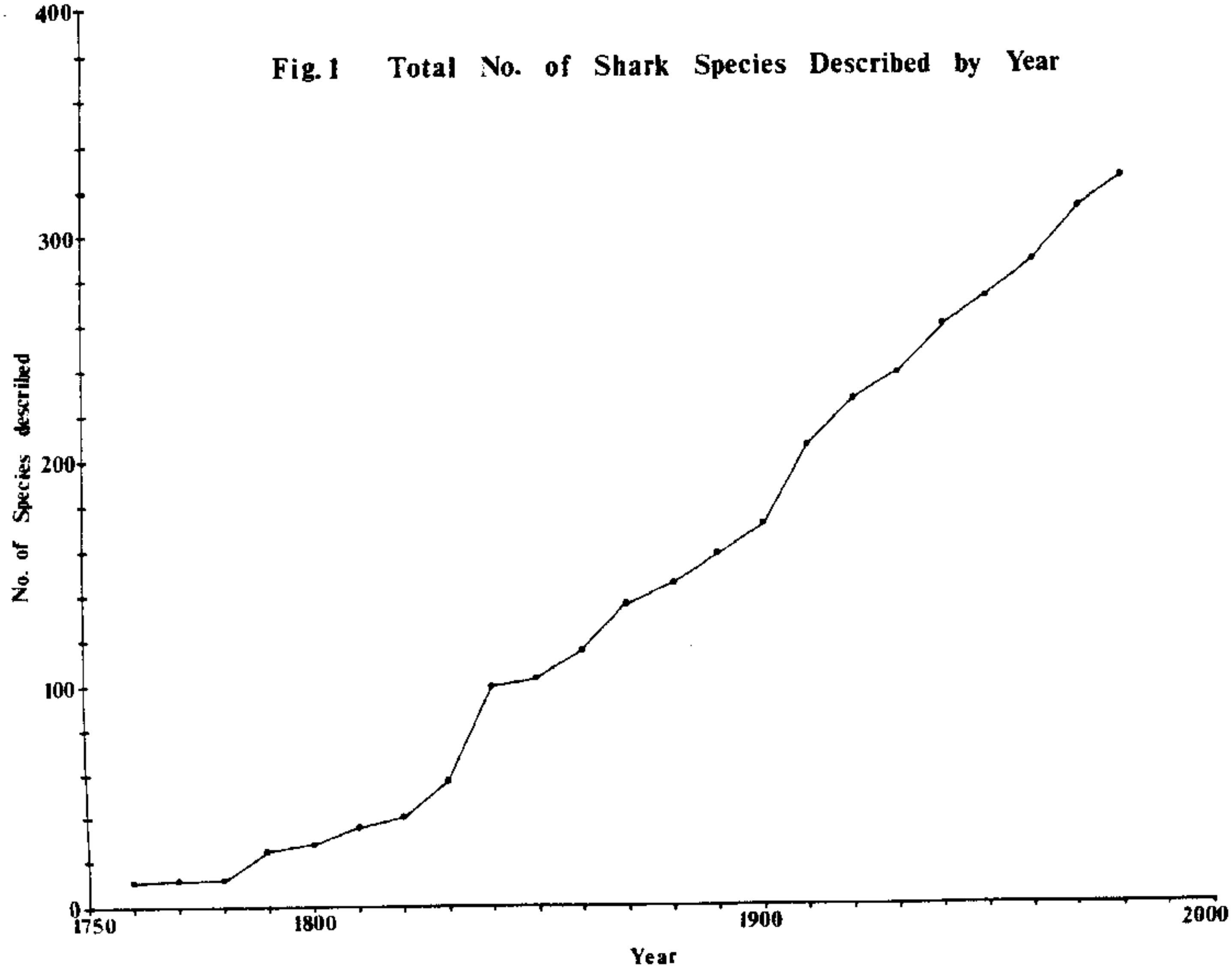
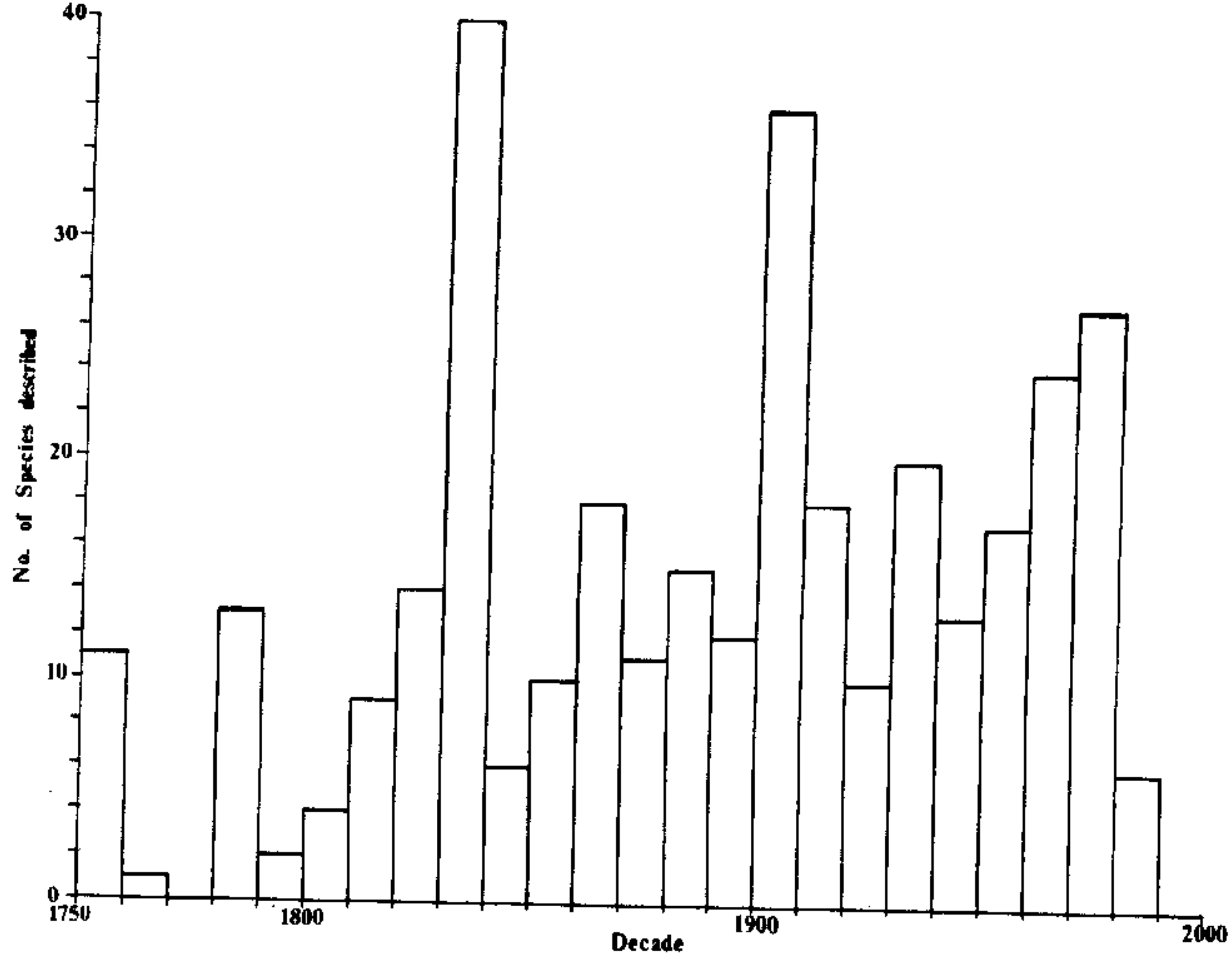


Fig. 1 Total No. of Shark Species Described by Year

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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