SHARKS, SKATES, RAYS, AND CHIMAERAS

UNITED STATES
DEPARTMENT OF THE THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES
CIRCULAR 119

TABLE 1.--Maximum sizes of common species of sharks

Species		Maximum length (measured--U.S. coasts)	Maximum length (recorded--world)	Traditional maximum size from literature
Common name	Scientific name			
Sixgill shark....	*Hexanchus* sp.	15 feet 5 inches	---	26 feet 5 inches
Sand shark.....	*Carcharias taurus*	10 feet 5 inches	12 feet 3 inches	15 feet 11 inches
Porbeagle.....	*Lamna nasus*.....	10 feet	12 feet	12 feet
Salmon shark.....	*Lamna ditropis*	8 feet 6 inches	8 feet 6 inches	12 feet
Mako.....	*Isurus oxyrinchus*.....	10 feet 6 inches	12 feet	12 feet - 13 feet
White shark.....	*Carcharodon carcharias*...	18 feet 2 inches	21 feet	36 feet 6 inches
Basking shark....	*Cetorhinus maximus*	32 feet 2 inches	45 feet	40 feet - 50 feet
Thresher shark...	*Alopias vulpinus*.....	18 feet	18 feet	20 feet
Nurse shark.....	*Ginglymostoma cirratum*..	9 feet 3 inches	---	14 feet
Whale shark.....	*Rhincodon typus*.....	38 feet	45 feet	45 feet - 50 feet
Chain dogfish....	*Scyliorhinus retifer*.....	1 foot 5 inches	---	2 feet 6 inches
Leopard shark....	*Triakis semifasciata*.....	5 feet	---	5 feet
Smooth dogfish...	*Mustelus canis*.....	4 feet 9 inches	---	5 feet
Tiger shark.....	*Galeocerdo cuvieri*.....	13 feet 10 inches	18 feet	30 feet
Soupfin shark....	*Galeorhinus zyopterus*	6 feet 5 inches	6 feet 5 inches	6 feet 5 inches
Blue shark.....	*Prionace glauca*	11 feet	12 feet 7 inches	25 feet
Bull shark.....	*Carcharhinus leucas*.....	9 feet 10 inches	---	10 feet
Whitetip shark...	*Pterolamiops longimanus*..	11 feet 6 inches	---	12 feet
Sandbar shark....	*Eulamia milberti*	7 feet 8 inches	---	8 feet
Dusky shark.....	*Eulamia obscurus*.....	11 feet 11 inches	---	15 feet
Bonnethead.....	*Sphyrna tiburo*	3 feet 7 inches	---	6 feet
Great hammerhead.	*Sphyrna mokarran*	18 feet 4 inches	---	15 feet
Spiny dogfish....	*Squalus acanthias*	5 feet 3 inches	---	5 feet
Green dogfish....	*Etmopterus virens*.....	0 feet 11 inches	---	---
Midwater dogfish.	*Squaliolus* sp.	0 feet 7 inches	---	---
Greenland shark..	*Somniosus microcephalus*.	16 feet 6 inches	21 feet	24 feet
Sawshark.....	*Pristiophorus schroederi*.	2 feet 10 inches	---	---
Angel shark.....	*Squatina dumerili*	4 feet 5 inches	---	---

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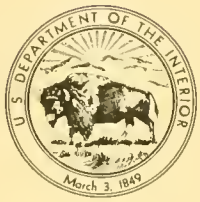
J. R. Thompson and Stewart Springer



FISH AND WILDLIFE CIRCULAR 119

BUREAU OF COMMERCIAL FISHERIES, Donald L. McKernan, *Director*

FISH AND WILDLIFE SERVICE, Clarence L. Pautzke, *Commissioner*

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ABSTRACT

A general introduction to the class Chondrichthyes is presented. Material included encompasses, in broad terms, characteristics of the class and of its components. General statements on reproduction, numbers and general distribution, size, food and feeding, sensory perception, structural adaptations to specific modes of life, and relation to man are included. A short, annotated list of references directs the reader to more specific and detailed sources for further study.

SHARKS, RAYS, SKATES, AND CHIMAERAS

By

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INTRODUCTION

Sharks, skates, rays, and, to a lesser extent, chimaeras--all grouped by zoologists in the single vertebrate class Chondrichthyes (cartilaginous fishes)--have been the subjects of interest for many years. On the negative side, the interest in many of these fishes has arisen largely from fear--fear of injury to fishermen and swimmers, fear of damage to fishing gear and equipment, and the fear that is a natural accompaniment of a lack of knowledge. On the positive side, the interest has arisen as a result of attempts to turn some of these fishes to economic advantage, and out of man's innate curiosity concerning the world around him.

Despite widespread interest, accumulation of adequate knowledge concerning sharks and their close relatives has been slow, and a large body of speculation and "old wives' tales" has arisen as a result of attempts to fill in the gaps. Obstacles to the study of cartilaginous fishes are many. Most of these fishes are pelagic, and many of them inhabit the open waters of the high seas where large ocean-going vessels are needed for their study. Many species are confined to relatively great depths where collection is difficult and expensive. Even those species that inhabit shallower, coastal waters require special collecting and handling techniques. They are difficult to keep in captivity, and their collection and study as living animals is quite expensive. But over the years, zoologists have succeeded in amassing sufficient data to outline, in greater or lesser detail, the characteristics and habits of many of the cartilaginous fishes.

This paper has been written as an introduction to the members of the class Chondrichthyes. The information contained has been drawn from the literature, from zoologists and fishermen of many countries, and from the personal experiences and observations of the authors. The purpose of the paper is to answer the many general questions asked fishery zoologists each year concerning sharks, skates, rays, and chimaeras, or if not to answer, at least to suggest further, more detailed sources of information. Toward this end, the text has been kept brief and general, and an annotated list of references has been included. In most cases, the reader who is sufficiently interested to pursue the subject beyond the confines of this circular will find more material in the references listed. He may also find clues to further research sources in the bibliographies contained in the references examined. To facilitate use, the references are listed by topic in an arrangement roughly paralleling the arrangement of the subheadings of the text.

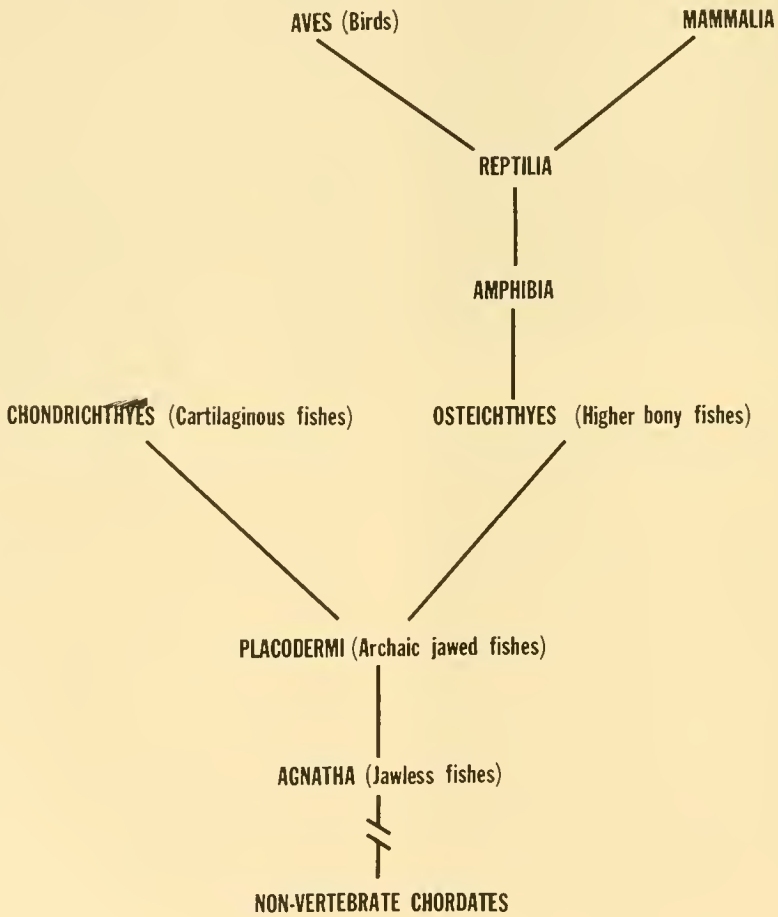
Terms commonly applied to cartilaginous fishes and other large marine

Note.--J. R. Thompson, U. S. Fish and Wildlife Service, Pascagoula, Miss., and Stewart Springer, U. S. Fish and Wildlife Service, Washington, D. C.

creatures are frequently subject to confusion. Scientific names of Greek or Latin derivation are frequently reduced to English form and used as English common names. *Chimaera* is such a name (derived from the Greek *chimair*, meaning goat), and it is useful because it covers all one closely related group of cartilaginous fishes including some known as ratfishes, some as elephant fishes, and others. *Elasmobranch* is another word (derived from the Greek words *elasmo*, meaning platelike or slitlike, and *branchia*, meaning gill) which has come into common usage and which refers to any shark, skate, or ray, but not to chimaeras. The anglicized word *selachian* (from the Greek term coined to designate fishes having cartilaginous skeletons instead of bone) has become even more restrictive and now refers only to sharks, not to skates or rays.

CLASS CHONDRICHTHYES, THE CARTILAGINOUS FISHES

Members of the class Chondrichthyes, the sharks, skates, rays, and chimaeras, possess well-developed lower jaws which set them apart from the lampreys, hagfish, and other lower vertebrates; and they possess skeletons which are composed of cartilage rather than true bone, a feature which sets them apart from the bony fishes and other higher vertebrates. The cartilaginous skeletons, however, are often made up of structural components that



"Family tree" of the vertebrates illustrating, in the opinion of many zoologists, the relations existing among members of the group.

are so stiffened with mineral deposits that microscopic examination and a knowledge of the developmental processes involved in cartilage and bone formation are necessary to determine that cartilage, not bone, makes up the skeletons. For this reason, we often speak of the "backbone" of a shark when referring to the hard, cartilaginous (but bonelike) vertebrae that comprise the structure that places the members of the class Chondrichthyes in the Vertebrata.

Fossil records of primitive fishes ancestral to present-day sharks, skates, rays, and chimaeras, date back, perhaps a quarter of a billion years, to the Devonian period (mid-Paleozoic era). Moreover, representatives of all of the presently existing families of cartilaginous fishes have been found in the fossil deposits of the early Tertiary period (early Cenozoic era)--good evidence that these fish families have been on earth at least a thousand times longer than the human family. This long geological history also indicates that the cartilaginous fishes can maintain themselves successfully in spite of changing environment and varying conditions of competition, and that they have been remarkably stable (in the biological sense of resistance to evolutionary change) since at least the Tertiary period.

Zoological definitions adequate to set off the classes of vertebrates from one another with precision, or to define the subdivisions of cartilaginous fishes, are necessarily long. To find the detailed and exact definitions required for taxonomic work, the reader is referred to one or more of the appropriate citations at the end of this circular. For general purposes, the following remarks should be sufficient to separate the major groups:

Sharks usually have the shape of a "typical fish"--a fusiform shape--and most of them are densely covered with small, toothlike scales called denticles which give the skin its rough sandpaperlike feeling. In addition, all sharks have from five to seven gill slits or external gill openings on each side of the head or neck.

Skates and rays have a more-or-less flattened appearance, and all except a few are either wholly or partially covered with denticles or spines, which may be scattered irregularly or arranged in definite patterns. All skates and rays have five gill slits on each side of the lower surface of the head-neck region.

Chimaeras, like sharks, are fusiform in shape. Unlike sharks, they are usually smooth skinned, although a few denticles appear on the young and may persist in some adults, and they have only one external gill opening on each side.

Although some sharks and rays enter fresh water for short periods, and a few customarily enter fresh water to give birth to their young, most species are exclusively marine. One species of shark is said to be established as a permanent resident of Lake Nicaragua, but this is exceptional. Most chimaeras inhabit deep water, and all live in strictly oceanic environments.

Reproductive processes are extremely variable in the class Chondrichthyes. Many members of this class are ovoviviparous and bring forth living young that have been hatched from eggs inside the oviducts of the mother. Once hatched, the embryos are nourished in a variety of ways. Some members are viviparous, or nearly so, and bring forth living young that have been nourished by substances in the mother's blood stream transferred to the developing embryo through a placenta. Some are oviparous and lay eggs encased in horny or leathery capsules, which are deposted on the ocean floor. Regardless of the developmental process, the number of eggs produced by a single cartilaginous fish is very small compared with the number of eggs produced by a single bony fish. But the cartilaginous fishes are able to maintain their numerical status quo, because their young, at birth or hatching, are much larger than the newly hatched young of most kinds of bony fishes and are, therefore, better able to defend themselves against predators. A

A great hammerhead from the Gulf of Mexico and her litter. Few sharks produce this many young at one time.

greater proportion of young cartilaginous fishes reach maturity for that reason.

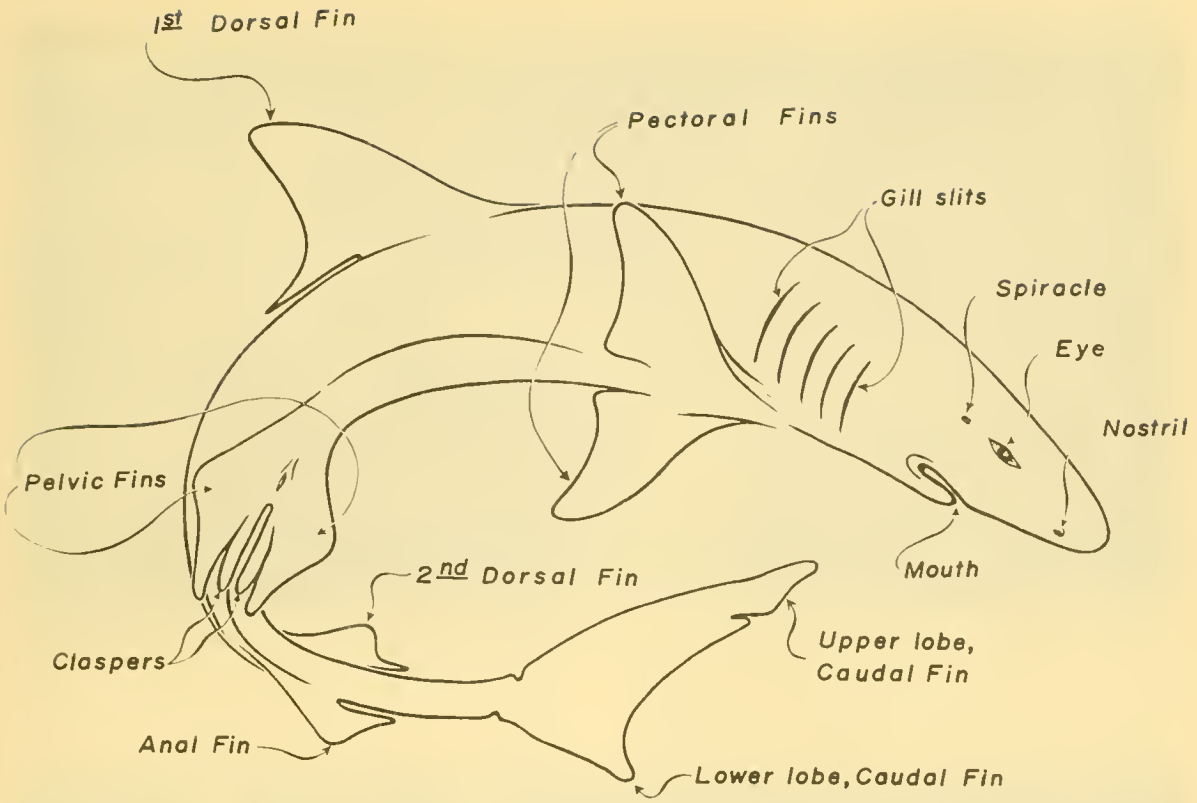
Fertilization is internal throughout the class. Internal fertilization is another mechanism by which the cartilaginous fishes make up for the small number of eggs produced. The chances of the eggs becoming fertilized are much greater when fertilization is internal than when it is external as with most bony fishes. Male chondrichthoid fishes are easily recognized by the presence of a pair of intromittent organs called claspers that arise from the inner margins or bases of the pelvic fins and usually extend beyond the tips of the fins in mature cartilaginous fishes.

SHARKS

Numbers and General Distribution

An estimated 300 species of sharks are recognized in the world today. In several instances, especially among the larger, far-ranging species, we have probably described the same sharks under more than one name. There are, however, undoubtedly other species existing that have not been given names as yet, particularly in the deeper sections of the ocean and in the mid-water realms which have not been thoroughly investigated.

A few species, including the Greenland shark and the Pacific sleeper shark, inhabit very cold seas, but the variety and number of sharks are greater in tropical and subtropical waters. Sharks are present in greater variety, and probably also in greater abundance, in moderate depths--from 50 to more than 500 fathoms. Some



A "typical" shark, illustrating terms used in description

sharks are found in much greater depths, although actual captures have not been made as yet in waters deeper than 1,500 fathoms (9,000 feet). There are also several species that inhabit very shallow waters along the coasts. These include some of the dogfishes, small blacktip sharks, hammerheads, nurse sharks, sand sharks, and sandbar sharks.

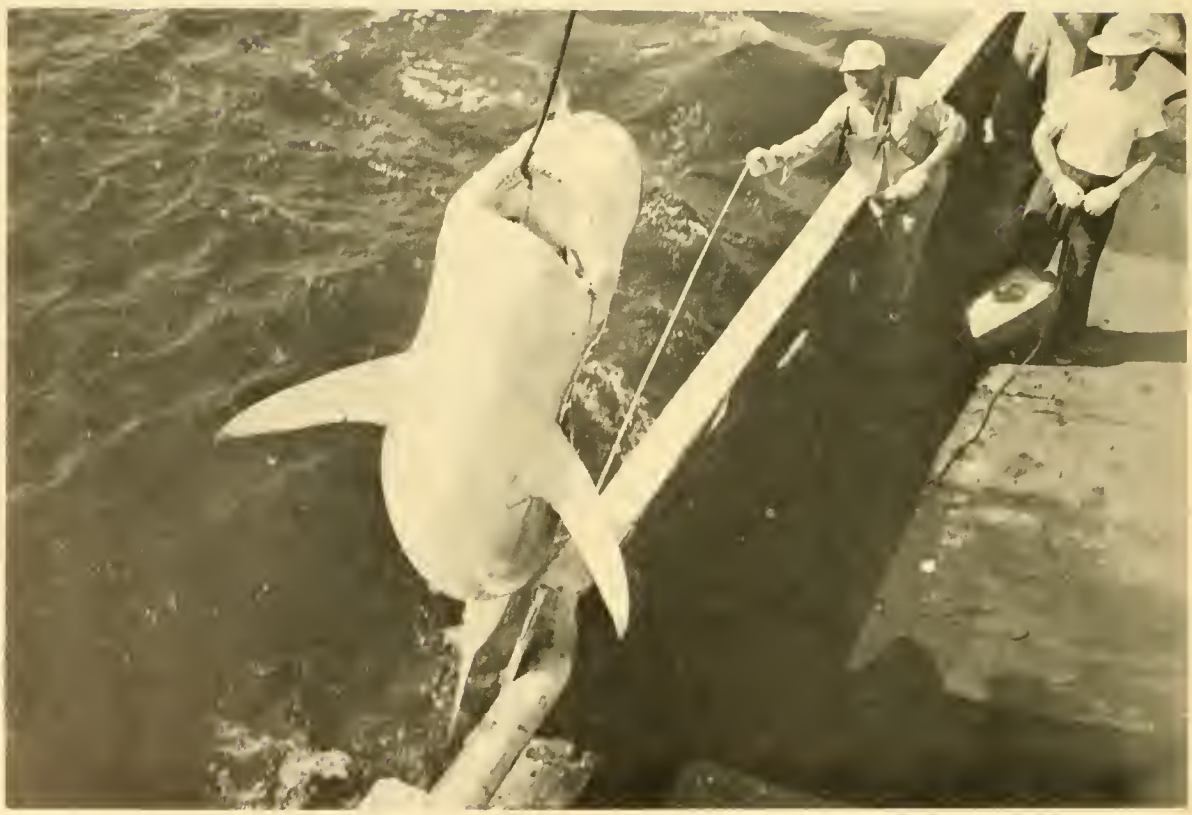
Abundance

Despite their appearance, at times, in great concentrations, sharks are not normally abundant in comparison with many bony fishes. In the United States the spiny dogfish, one of the smaller sharks, is common off the coasts of New England and the Middle Atlantic States in the Atlantic Ocean and off the coasts of Washington and Oregon in the Pacific Ocean. In these areas it is, at times, common enough to be a great nuisance to commercial and sport fishermen. The larger sharks are less abundant.

Size

A table on the inside cover of this circular lists the maximum recorded lengths and weights of many of the common species of sharks. Sharks range in size from individuals that mature at a total length of less than 1 foot to individuals that do not mature until they are many feet long and that may reach lengths of about 45 feet. One of the smallest sharks known, *Squaliolus* sp., lives only in deep water and apparently never reaches a length much in excess of 6 inches. The little green dog shark, *Etmopterus virens*, from the Gulf of Mexico, is full-grown at a length of about 9 inches, and newly born individuals are about 4 inches long.

The largest species, by weight, is the whale shark. Another large species, the basking shark, is somewhat less bulky, but about as long.



Top: A small spiny dogfish shark, *Squalus cubensis*, from the Gulf of Mexico. Many species of sharks are many times smaller than this species. Bottom: A large silky shark, *Eulamia floridana*, taken on a tuna longline. These large, oceanic sharks sometimes reach lengths of about 10 feet.

Most, or all, of the maximum recorded sizes contained in the table refer to female sharks, and, indeed, the females of all shark species studied for this attribute average somewhat longer with the average weight appreciably greater than that of males. On the Atlantic coast of the United States, for example, adult male sandbar sharks vary from 5 feet 10 inches in length to 7 feet 4 inches, whereas female adults vary from 6 feet to 7 feet 8 inches. This represents an average 5 percent longer length for the females, and this longer length is accompanied by an average 25 percent greater weight.

Food and Feeding Habits

All sharks are primarily predators in the sense that they all feed on animal life. The variety of animal life consumed, however, is almost limitless, and nearly all sharks excepting perhaps such forms as the specialized basking sharks, are secondarily scavengers. Some sharks appear to be indiscriminant in their feeding habits. Curiously, the largest known species feed on the smallest prey, and some of the smallest sharks consume relatively large creatures.

The huge whale sharks and basking sharks are primarily filter feeders. These sharks swim with their mouths open and strain or filter out small planktonic organisms as the water, coming in through the mouth, passes over sievelike gill rakers and out through the gill slits. Examination of stomach contents reveals that these large sharks filter great quantities of small crustacea and minute fishes in this manner, and such small prey constitutes the primary source of food for them. On the other hand, there is little doubt that the whale sharks also, occasionally, consume larger prey. Fishermen have reported that whale sharks, feeding at the surface on great schools of small fishes, occasionally trap tunas which are also feeding on the small fishes and which, in their quest for food, follow the small fishes straight into the whale shark's mouth. Observations from the Bureau's exploratory research vessel *Oregon* have confirmed this behavior. Whale sharks have also been observed to drive tuna fishermen out of their fishing racks. But on the basis of accumulated evidence, the whale shark is probably not ordinarily aggressive toward large creatures including man. It probably swallows large objects only if they are taken incidental to its regular feeding activities. This, however, is sufficient reason for treating these huge and powerful sharks with caution.

A few sharks, including the white shark and the tiger shark, normally attack large and active prey. Other sharks, including the smaller hammerheads, and small blacktip sharks seem to prefer crustaceans and small fishes. The tiger shark, which would normally be expected to obtain its food by active pursuit and capture of other fishes, sometimes haunts steamer lanes to gather in garbage. A large tiger shark, captured by the crew of the *Oregon*, contained not only food that had been thrown overboard several hours earlier, but also tin cans and milk cartons. Coastal fishermen frequently complain about sharks of several species which follow their vessels and tear up the nets to obtain the fish contained within.

Large sharks such as the white shark, the dusty shark, and the whitetip eat porpoises[1] when they can capture them. Porpoises are much faster than sharks and can outrun them or drive them away. If, however, a porpoise is weakened through fatigue or severe injury and is isolated, it may meet a sudden end in an attack by sharks. Observations, made from the Bureau's research vessel *Oregon*, have substantiated tales of porpoises actively driving sharks away from their young and of schools of porpoises, the members of which would take turns driving off attacking sharks and resting. At other times, however, porpoises and sharks may even feed together on trash fish thrown from a boat, and the porpoises apparently have sufficient

[1]Porpoises are marine mammals. The term "dolphin" is sometimes used for these animals, but "porpoise" is probably preferable because "dolphin" is used also to denote a bony fish commonly taken by sport fishermen.

confidence in their own speed and strength that they do not waste energy attacking the sharks when the sharks are not aggressive.

Some of the smaller species, including the deep-water green dog shark, are thought by some to hunt in packs, because their stomachs often contain the beaks of squid and octopus, representing prey too large and agile for these small sharks to kill and eat alone.

Sensory Perception

Studies on sensory perception of sharks have been difficult to carry out satisfactorily. In the broadest connotation, the senses of sharks are similar to those of other animals. The sense of smell is presumed to be highly developed and has been shown experimentally to play a major role in food finding. Sharks also have a sense corresponding to our sense of taste, but organs for tasting are widely scattered over the skin of the head and even other parts of the body. Although this sense is in some way related to feeding habits, it is possible that in sharks it serves other functions as well. Sharks' eyesight is apparently adapted best for the detection of movement, but their eyes are extremely complicated structures, adapting especially to low light levels.

Some sharks have calcareous bodies in the chamber of the inner ear which are presumed to be associated with the sense of balance. Sharks are responsive to noises and pressure waves, but the importance of sound and pressure differentials to sharks is not well understood. Experimental procedures to determine the roles of the ears (internal) and the lateral line organs have met with only limited success.

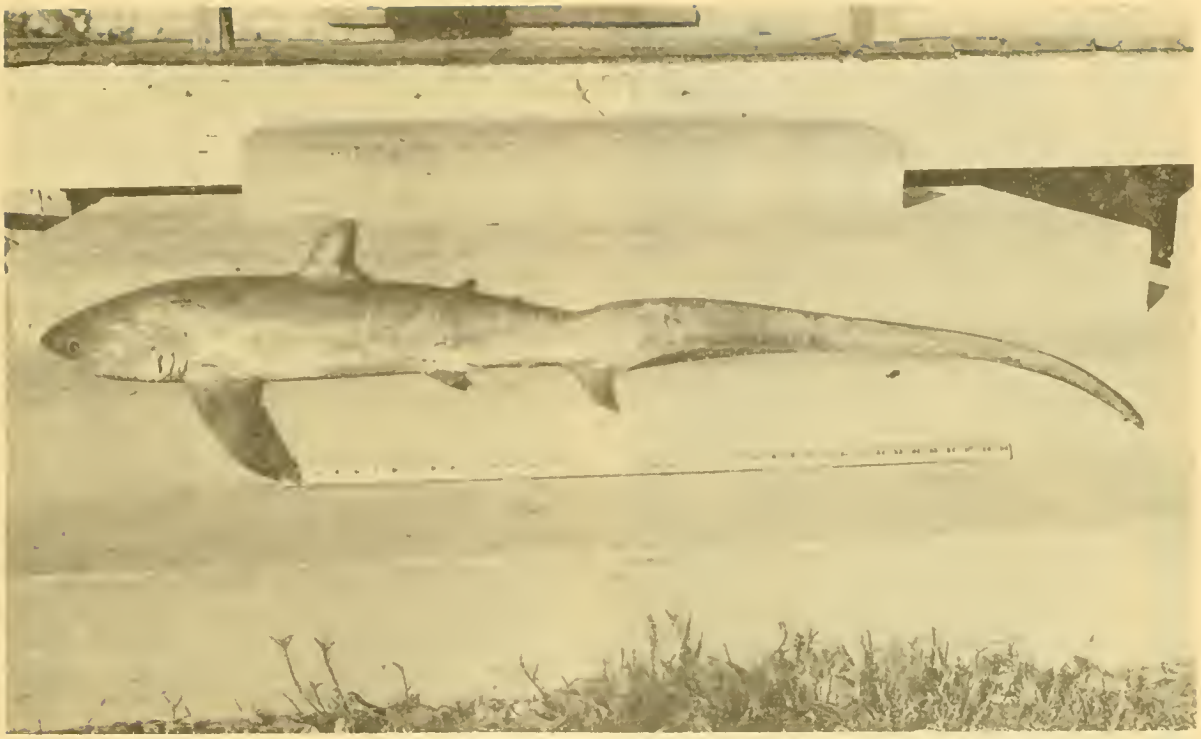
Sharks apparently have a very low intelligence level and many, if not all, of their activities are reflexive. The nervous system of the shark is decentralized to a much greater extent than it is in the higher vertebrates, and the areas of the brain usually regarded as thought centers are absent in sharks. Sharks have been shown experimentally to be capable of developing rather complicated responses to conditioning stimuli and may thus be able to learn at the reflex level.

Anatomical Features

In addition to the general anatomical features described in the introduction, each species of shark has its own structural adaptations. Many of these features can be correlated with a more or less specific way of life assumed by the shark species. A few examples of divergence from the generalized shark pattern and of adaptive features can be given here, many more exist.

The angel sharks, found on both coasts of the United States, diverge from the typical fusiform shape and display a flattened appearance characteristic of rays. A second raylike shark, although not flattened, is the sawshark of the deep waters of the Straits of Florida which resembles closely the sawfish of shallow coastal waters. Sawfish, though sharklike, are true rays. In spite of the superficial resemblance to rays exhibited by these two shark species, close examination shows that their more basic characteristics are those of sharks.

The thresher shark has a peculiarly enlarged and elongated upper caudal lobe which, according to fishermen observers, it uses to stun its prey by "threshing" around in a school of fish. Its tail is one of the toughest flexible structures developed in the animal kingdom. Many other correlations between anatomy and mode of life can be pointed out. Fast-swimming, oceanic sharks, such as the mako and



A small thresher shark, *Alopias vulpinus*. A 14-foot specimen of this species, recently taken was estimated to weigh approximately 500 pounds and possessed a caudal lobe measuring 7½ feet. The long caudal lobe is apparently used to stun prey.

the white sharks, are streamlined and possess large stiff pectoral fins for stabilizers. In contrast, most rather sluggish sharks, such as the cow sharks, nurse sharks, and even the bull sharks, are less streamlined and often more bulky, or display adaptations to other ways of life. The large whale sharks, which engulf and strain their prey in great volumes of water, have terminally placed mouths to better facilitate their feeding. The basking sharks have extremely wide mouths nearly terminal in position to better engulf and strain great quantities of water. Most other sharks have their mouths placed far ventrally.

Several deep-sea species, including probably the little green dog shark that lives at depths exceeding 1,000 feet, possess the ability to produce light in their otherwise totally dark environment.

Relation to Man

The relation of sharks to man stems from commercial utilization of sharks and shark products by man and from damage caused man by sharks.

Until 1950, a commercial fishery for sharks was carried on in the United States, on both coasts, and the annual catch reached a maximum of 4.5 million pounds landed on the Atlantic coast and 39 million pounds on the Pacific coast. The fishery was carried out chiefly to obtain the shark-liver oil which is rich in vitamin A. Byproducts of the oil industry included: hides, used for high-quality leather products; fins (of some species), sold as specialty food items; meat, salted or sold fresh as food for human consumption in some areas; carcasses, ground into meal; and teeth and vertebrae, cleaned and sold to curio shops. With the advent of cheaper sources of vitamin A, shortly

Removing the liver from a large silky shark.

prior to 1950, most of the commercial shark fishing operations in this country were suspended.

Sharks interfere with commercial fishing operations in many instances. In the Gulf of Mexico, sharks occasionally cause severe economic losses through their habit of biting and tearing the trawl nets to get at the catch. An estimated 20 percent loss in salable fish due to shark damage has been cited for the tuna longline fisheries of the world. Also, in many localities, the seasonal abundance and the local concentration of some species of sharks force cessation of gill-net operations and otherwise influence the choice of gear and the location of fishing grounds.

In 1958 the American Institute of Biological Sciences (AIBS) inaugurated a Shark Research Panel for the purpose of studying all aspects of the biology of elasmobranch fishes. One of the functions is to compile a shark-attack file. Records accumulated through this effort show that, in 1959, there were 39 shark attacks on man involving at least 18 fatalities.

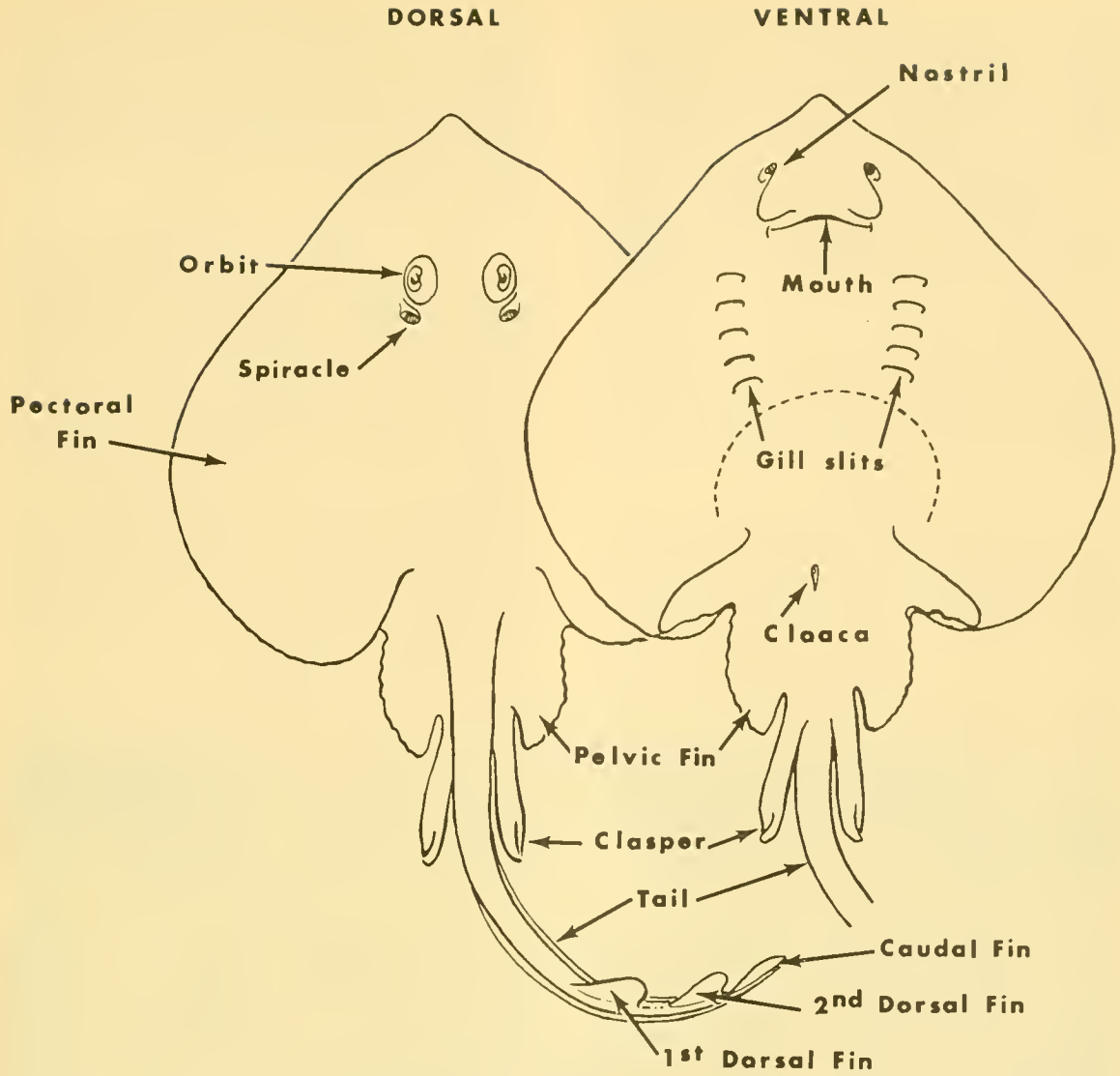
SKATES AND RAYS

Numbers and General Distribution

Included in the same group with the skates and rays are the sawfishes, guitarfishes, electric rays, stingrays, eagle rays, and mantas. All told, probably about 400 species of the group are known.

The group as a whole is widely distributed. Like the sharks, more species, and probably more individuals, are found in tropic and subtropic seas than in colder waters; but there are several species that do frequent the cold-water regions of the world, including some skates that live in water as cold as 29° F. Skates, rays, and their close relatives may be found from the shoreline to a depth of about 1,500 fathoms. At least one species occasionally splashes along the very edge of the sea, on the tide line of the beaches, in search of the small crustaceans that characterize the tidal zone. Below 1,500 fathoms, our knowledge of the bottom fauna is scanty, but, if skates and rays are present, they undoubtedly are very scarce.

The eagle rays, mantas, and a few others are capable of tremendous leaps from the water, and authentic reports are available of these large fishes towing moderate-size vessels for relatively great distances at high speeds. Other skates and rays probably rely on short bursts of speed followed by periods of drifting or lying quietly on the bottom rather than on sustained high speed or swimming power. Even the mantas, usually seen only on the surface of the water, probably spend some of their time resting quietly on the bottom. Stingrays *(Dasyatis)* are bottom dwellers and are sometimes found partly buried in the sand with only the eyes and the area surrounding



A generalized skate illustrating terms used in description.

the spiracles visible. But there are exceptions--one species, at least, is pelagic. The pelagic stingray, *Dasyatis violacea*, has been taken by Bureau research vessels in both the Atlantic and Pacific near the surface hundreds of miles from land.

Although basically marine fishes, a few species of stingrays have taken up residence in the lower parts of some rivers in Florida and South America, and sawfishes frequently enter fresh water--often for prolonged periods.

Abundance

In numbers of individuals, the skates and rays compare more favorably with the sharks than with the bony fishes. They are abundant locally and seasonally, but cannot be considered abundant inhabitants of the seas in general. Stingrays are often sufficiently numerous along the coasts of South and Central America, in the Caribbean, and on the coastal trawling grounds of the southern portion of the United States to constitute a serious nuisance to commercial fishing operations. They are also found around some bathing beaches,

where they take a yearly toll in injured bathers. Some skates are found off the coasts of the northern European countries in sufficient abundance to support small but continuous foodfish fisheries.

The larger skates and rays are apparently less numerous, but our knowledge of their abundance is based, for the most part, on incidental sightings of these creatures from coastwise vessels. Claims of great local abundance of eagle rays, mantas, and similar fish are often based more on the great amount of publicity given a few sightings than on actual numbers.

Size

The mantas, reputed to reach a breadth of 22 feet and a weight of over 3,000 pounds, are the largest fish of the group. Sawfishes are also quite large and may reach a total length of 22 feet, although actual verified records do not exist for specimens this large (see table on the inside cover). At the other end of the range there are a few species of ray and torpedoes that never exceed a few inches in breadth.

Food and Feeding Habits

Most skates, rays, and closely related forms are bottom feeders, and crabs, shrimp, other crustaceans, clams, and worms constitute their principal food items. Many skates capture prey by swimming quickly above the victim, dropping down on it, and preventing its escape by covering it with their winglike fins. Some of the more sluggish rays appear to lie in wait for their prey--half covered with sand, and many of the members of the group seem to prefer to feed only at night.

Sawfish feed primarily on and in the bottom, which they scrape and dig up with their saws, but they also feed in open water, where they capture their prey by slashing their saws around in the midst of schools of fish.

A few rays--principally the devil rays and mantas--feed on pelagic shrimps, mysids, and small school fish. On rare occasions the devil rays appear to scoop up their prey with the help of the cephalic extensions of their pectoral fins, and folk legend, apparently based on fact, states that they will even wrap their wings around anchor cables.

The electric rays and torpedoes possess the structural organization and the ability to transmit an electrical shock. The mechanism by which this is achieved is not completely known. It appears to involve an increase in activity of the nerve-muscle complex, common to all animals. Release of a demonstrable electric discharge is a heightened example of a prevalent phenomenon. A nervous response involves an electrical impulse traveling along a pair of nerve fibers and acting upon a section of the brain (at one end of the circuit) and a muscle (at the other end). The "electric organ" of torpedoes is a wing-shaped mass of modified muscle tissue, richly innervated, lying in the forepart of the body on either side of the vertebral column. A so-called "electric lobe" in the brain completes the nerve pathway. Textbooks of comparative or general physiology may be consulted for further particulars.

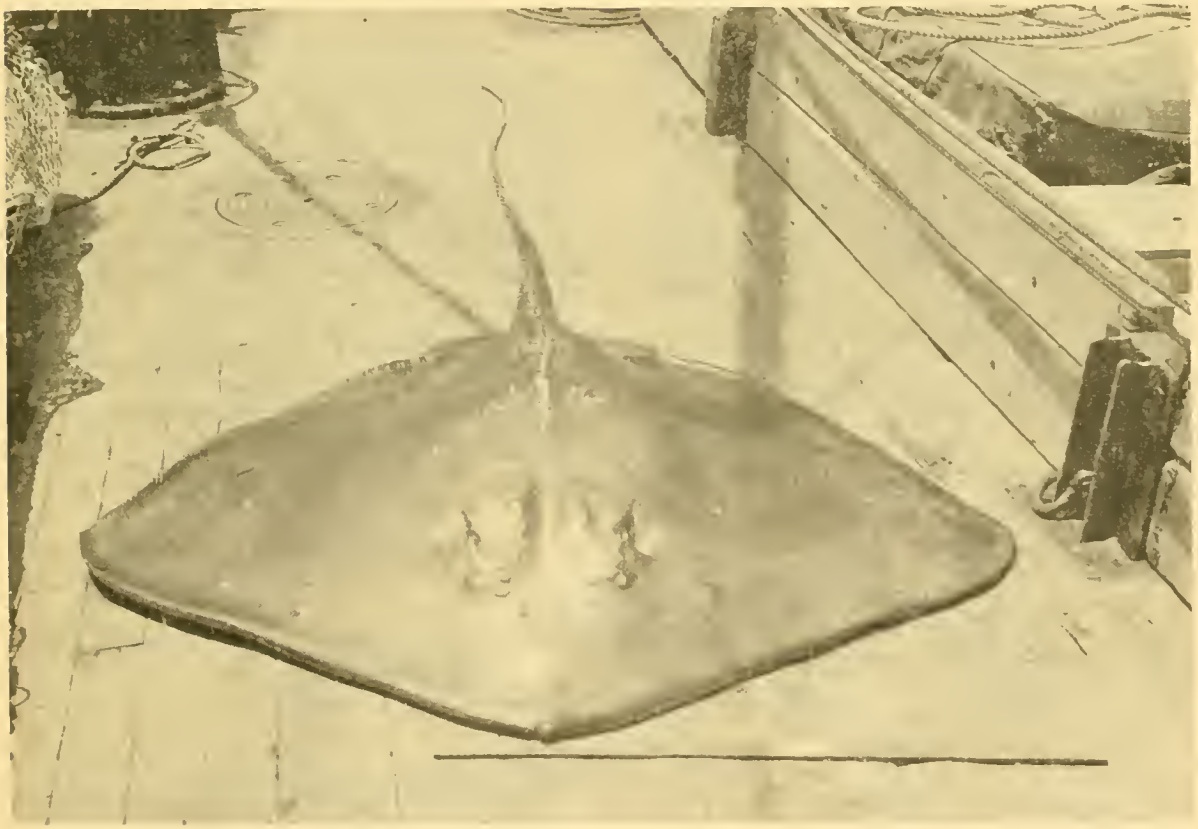
The Atlantic torpedo, a relatively large ray which reaches a length of nearly 6 feet and may occasionally weigh as much as 100 pounds, is said to have produced a discharge amounting to 220 volts. This is probably very nearly the maximum discharge to be expected from a ray and is much less than the maximum reported for electric eels. Very little is known about the discharges of other electric rays and torpedoes, except that the discharges of the electric ray are pulsed and delivered in rapid succession--very similar, in principle, to the mechanism used in present-day applications of electricity in commercial fishing. Examination of stomach contents of a number of electric rays and torpedoes suggests that the discharges are used in food getting, for the size of many of the fishes found in stomachs is larger than would be expected on the basis of more ordinary means of capture.

Anatomical Features

Perhaps the most outstanding anatomical feature of many members of the group is the wide expansion of the pectoral fins, a feature which gives the fish a disclike shape. The gill openings are entirely on the ventral surface, with no portion of them extending above the plane of insertion of the pectoral fins. The sharklike rays, including the sawfish and the guitarfish, are classified as true rays on the basis of gill position, certain differences in skeletal structure which seem to more nearly ally them to rays than to sharks, and a few other, possibly more obscure, characteristics.

Several species of rays that inhabit shallow water are provided with long, sharp spines on the base of their tails. These spines are capable of inflicting serious injuries on persons coming in contact with them. The seriousness of the wound resulting from a ray-spine puncture is apparently attributable to secretion of poison in at least a few instances, but is also due to the accumulated covering of dirt, slime, and bacteria that clings to the spine, to the configuration of the wound, and to the jagged nature of the cut. Owing to the deep-puncture character of the spine wound, conditions are optimal for gangrene.

Examination of the mouths and tooth structure of rays and skates provides ready explanation of how some of these creatures can feed upon hard-shelled crustaceans and mollusks. Unlike the teeth of most sharks, which are pointed, sharp, and fitted for tearing, the teeth of the typical rays and skates are blunt, platelike, or arranged like a pavement over the jaws and well-suited for crushing. Jaw musculature is correspondingly powerful.



A "typical" ray, the roughtail stingray, *Dasyatis centroura*. This specimen measured 62 inches across the fins and weighed 285 pounds. Such rays are taken frequently in trawl drags along the east coast of the United States.

Relation to Man

Rays have never been as important, commercially, as sharks; but small fisheries for rays are in existence in many parts of the world. The meat of the wings (pectoral fins) is said to be of excellent quality, but little marketing of ray meat is done in this country. Some of the larger skates and rays contain appreciable quantities of oil but with less vitamin-A content than sharks.

Danger from stingray wounds has been discussed. Stingrays are found most often along quiet, muddy shores. The spines of stingrays have provided primitive peoples with weapons, and even today, in some countries, there are laws prohibiting or limiting the possession of stingray spines.

CHIMAERAS

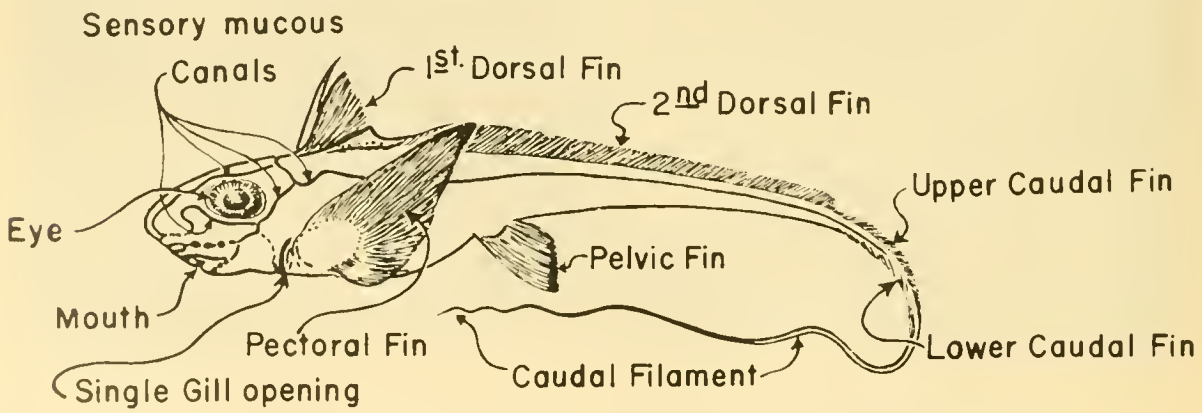
Numbers and General Distribution

Only about 2 dozen species of this group are recognized at the present time. This number will, perhaps, be added to as deep-water and midwater oceanic investigations become more comprehensive.

Chimaeras are worldwide in distribution and are found in almost all seas--tropic, subtropic, temperate, and boreal. In most instances, however, they appear to be limited to the cooler water masses. For that reason, in the tropic and subtropic seas, they are generally found in the deeper and therefore cooler depths or in cold upwellings. Chimaeras have been found from near the surface to depths of approximately 1,500 fathoms. Very probably they exist in deeper waters also.

Abundance

It is difficult to assess the abundance of the chimaeras because the group is so little known. Surely, compared with the bony fishes, they are infrequently observed or collected, but this may be, in part, a function of differences in distribution or reaction to collecting gear. The chimaeras apparently occur in a "patchy" distribution pattern, and when and where present, they often are relatively abundant. Much more work remains to be done before problems of chimaera distribution are completely resolved. In some parts of the world, the fishes are sufficiently abundant to form the basis for small fisheries. In the northwestern Atlantic (along the eastern coast of the United States), the group is known only from isolated specimens collected with small scientific gear. In the Gulf of Mexico, several specimens have been trawled on or beyond the edge of the Continental Shelf, and where they were taken at all, they appear to be found in aggregations. Off Puerto Rico, in the Caribbean, small aggregations also appear to be present.



A generalized chimaera illustrating terms used in description.

On the west coast of the country, there are a few shallow-water representatives of the group which are locally abundant.

Size

In contrast with the wide size ranges exhibited by sharks, skates, and rays, the chimaeras constitute a relatively uniform size group, with extremes placed just below 2 feet at maturity to a little over 6 feet.

Food and Feeding Habits

The chimaeras are carnivorous and therefore predacious, as are most members of the class Chondrichthyes. Chimaeras, however, are feeble swimmers and are selective in their feeding only to the extent that they feed upon animals with limited powers of escape--principally small fish and invertebrates. In the Orient, where they are fished with handlines, they apparently bite a wide variety of baits.

Anatomical Features

Two out of three families of chimaeras are characterized by oddly shaped prolongations of their snouts, whereas members of the third family possess gently rounded noses. These rostral characteristics have been responsible, in large, for the various common names applied to the group, including "goat fish", "elephant fish", "rabbit fish", and others. Chimaeras are also characterized by their large, weak fins, a large spine in front of the first dorsal fin, a groove along the back into which the spine and the first dorsal fin can be folded, and a straight, thin macrouridlike tail (hence the common name "ratfish" for both the bony-fish group Macrouridae and the chimaeras).

Chimaeras breathe by taking in water through their nasal apertures, passing it over the gills through respiratory channels (and removing part of the oxygen from it), and sending it out through the single openings on either side.

Chimaeras rest on the bottom at irregular intervals. When doing so, they are said to use the tips of the large pectoral and pelvic fins as "props" to support themselves off the softer substrates.

Relation to Man

In the Pacific Northwest of the United States, there is a minor fishery for chimaeroids; the liver oil has a small commercial value. In some other parts of the world, however, the fish are used on a large scale, owing to their greater availability, high oil content, and edible quality. The fish form the basis for an industrial oil fishery in some Scandinavian countries and a foodfish fishery in New Zealand as well as in China and some other parts of the Orient.

Chimaeras present little or no danger to humans, for despite their ability to bite rather viciously, they are usually either dead or dying when pulled from the water.

ANNOTATED LIST OF REFERENCES

The literature on sharks, skates, rays, and chimaeras is voluminous and composed of contributions from all major countries of the world. The list of references following can only provide a glimpse of the total. The reader may scan the bibliographies of the works consulted for further clues as to the nature and extent of literature.

Because zoology is a dynamic subject, zoological literature is constantly increasing in volume, and zoological concepts are constantly undergoing modification. Some of the most important current references are, therefore, found in journals rather than in textbooks.

GENERAL REFERENCE BOOKS

The following books should be regarded as basic references for the serious student of elasmobranchs:

BIGELOW, HENRY B., AND WILLIAM C. SCHROEDER.

1948. Sharks. *In* Fishes of the western North Atlantic. Sears Foundation Marine Research Memoir No. 1, pt. 1, p. 59-576.

1953. Sawfishes, guitarfishes, skates, rays, and chimaeroids. Fishes of the western North Atlantic. Sears Foundation Marine Research Memoir No. 1, pt. 2, xv 588.

These two companion volumes, although largely systematic in scope, summarize most of the information available at the time of printing on habits, food, size, abundance, reproduction, and distribution of the known chondrichthoid fishes in the western North Atlantic.

NORMAN, J. R., AND F. C. FRASER.

1938. Giant fishes, whales and dolphins. Putnam, London, xxii + 376 p.

A general and popularized account of the size, habits, and occurrence of the common large marine animals.

GENERAL REFERENCE PAPERS--NATURAL HISTORY

The following papers, although dealing primarily with particular sharks, or groups of sharks, are selected as general owing to the large amount of discussion of a more general nature that has been included in them:

OLSEN, A. M.

1954. The biology, migration, and growth rate of the school shark, *Galeorhinus australis* (Macleay) (Carcharhinidae) in southeastern Australian waters. Australian Journal of Marine and Freshwater Research, vol. 5, no. 3, p. 353-410.

RIPLEY, WILLIAM E.

1946. The biology of the soupfin *Galeorhinus zyopterus* and biochemical studies of the liver. The soupfin shark and the fishery. California Division of Fish and Game, Fisheries Bulletin 64, p. 6-37.

SPRINGER, STEWART.

1960. Natural history of the sandbar shark *Eulamia milberti*. U. S. Fish and Wildlife Service, Fishery Bulletin, vol. 61, no. 178, p. 1-38.

Discusses the natural history of a common shark of the coastal waters of the east coast of the United States, with many comments applicable to elasmobranchs in general.

STRASBURG, DONALD W.

1958. Distribution, abundance, and habits of pelagic sharks in the central Pacific Ocean. U. S. Fish

and Wildlife Service, Fishery Bulletin, vol. 58, no. 138, p. 335-361.

Discusses the natural history of 12 species of oceanic sharks on the basis of observations made in the course of longline tuna fishing cruises. The only paper of its sort dealing with shark populations of offshore waters.

TEMPLEMAN, WILFRED.
1944. The life-history of the spiny dogfish *(Squalus acanthias)* and the vitamin A values of dogfish liver oil. Newfoundland Department of Natural Resources Research Bulletin No. 15 (Fisheries) p. 1-102.

GUIDES TO THE CLASSIFICATION AND NAMING OF CHONDRICHTHOID FISHES

AMERICAN FISHERIES SOCIETY.
1960. A list of common and scientific names of fishes from the United States and Canada. 2d ed. American Fisheries Society, Special Publication No. 2, Ann Arbor, 102 p.

Lists the common and scientific names of the most common jawless, chondrichthoid, and teleostean fishes and indicates the general area of distribution of each.

REGIONAL KEYS AND GUIDES TO IDENTIFICATION

The following papers provide lists, keys, discussions, or guides to the identification of chondrichthoid fishes in the areas indicated in the titles. In most cases, the papers have an even wider range of applicability (in a geographical sense), as many elasmobranchs are far-ranging animals. Because the subject matter of these papers is described so aptly in the titles, no further annotation is given in this section.

BAUGHMAN, J. L., AND STEWART SPRINGER.
1950. Biological and economic notes on the sharks of the Gulf of Mexico, with especial reference to those of Texas, and with a key for their identification. American Midland Naturalist, vol. 44, no. 1, p. 96-152.

BEEBE, WILLIAM, AND JOHN TEE-VAN.
1941. Eastern Pacific Expeditions of the New York Zoological Society. XXV. Fishes from the tropical eastern Pacific. (From Cedros Island, Lower California, south to the Galapagos Islands and northern Peru). Pt. 2, Sharks. Zoologica, vol. 26, no. 2, p. 93-122.

BIGELOW, HENRY B., AND WILLIAM C. SCHROEDER.
1953. Fishes of the Gulf of Maine. U. S. Fish and Wildlife Service, Fishery Bulletin, vol. 53, no. 74, viii + 577 p.

CLEMENS, W. A., AND G. V. WILBY.
1946. Fishes of the Pacific coast of Canada. Fisheries Research Board of Canada, Bulletin No. 68, 368 p.

FOWLER, HENRY W.
1941. The fishes of the groups Elasmobranchii, Holocephali, Isospondyli and Ostarphysi obtained by the U. S. Bureau of Fisheries steamer "Albatross" in 1907 to 1910, chiefly in the Philippine Islands and adjacent seas. U. S. National Museum, Bulletin 100, vol. 13, x + 879 p.

HILDEBRAND, SAMUEL F., AND WILLIAM C. SCHROEDER.
1928. Fishes of Chesapeake Bay. Bulletin of the U. S. Bureau of Fisheries, vol. 43, pt. 1, p. 1-366.

JORDAN, DAVID STARR, AND HENRY W. FOWLER.
1903. A review of the elasmobranchiate fishes of Japan. Proceedings of the U. S. National Museum, vol. 26, no. 1324, p. 593-674.

RADCLIFFE, LEWIS.
1916. The sharks and rays of Beaufort, North Carolina. Bulletin of the U. S. Bureau of Fisheries, vol. 34, Doc. no. 882, p. 241-284.

ROEDEL, PHIL M., AND WILLIAM E. RIPLEY.
1950. California sharks and rays. California Division of Fish and Game, Fishery Bulletin 75, p. 1-184.

ROSENBLATT, RICHARD H., AND WAYNE J. BALDWIN.
1958. A review of the eastern Pacific sharks of the genus *Carcharhinus*, with a redescription of *C. malpaloensis* (Fowler) and California records of *C. remotus* (Duméril). California Fish and Game, vol. 44, no. 2, p. 137-159.

SCHULTZ, LEONARD P., EARL S. HERALD, ERNEST A. LACHNER, ARTHUR D. WELANDER, AND LOREN P. WOODS.
1953. Fishes of the Marshall and Marianas Islands. U. S. National Museum Bulletin 202 (vol. 1), p. 1-685.

SMITH, J. L. B.
1950. The sea fishes of southern Africa. Central News Agency, South Africa, xvii + 564 p.

TORTONESE, ENRICO.
1956. Fauna d'Italia. Vol. 2, Leptocardia, Ciclostomata, Selachii. Edizioni Calderini, Bologna, p. 1-332.

WHITLEY, G. P.
1940. The fishes of Australia. Part 1, The sharks rays, devilfish and other primitive fishes of Australia and New Zealand. Royal Zoological Society of New South Wales, Sydney, p. 1-280.

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DANIEL, J. FRANK.
1934. The elasmobranch fishes. University of California Press, Berkeley, 332 p.

Devoted exclusively to a discussion of the anatomy of sharks, skates, and rays.

HYMAN, LIBBIE H.
1942. Comparative vertebrate anatomy. 2d ed. University of Chicago Press, Chicago, 544 p.

NORMAN, J. R.
1949. A history of fishes. A. A. Wyn, Inc., New York, 463 p.

A generalized account of the anatomy and lives of the fishes.

ROMER, ALFRED SHERWOOD.
1949. The vertebrate body. W. B. Saunders Co., Philadelphia, viii + 643 p.

A standard textbook of comparative vertebrate anatomy. Contains a discussion of the anatomy of the dogshark.

PHYSIOLOGICAL REFERENCES

HEILBRUNN, L. V.
1952. An outline of general physiology. 3d ed. W. B. Saunders Co., Philadelphia, xiv + 818 p.

A technical treatise dealing largely with physiology at the cellular level. Chapter 29, "The Production of Electricity" and Chapter 30 "Bioluminescence" are recommended.

NICOL, J. A. COLIN.
1960. The biology of marine animals. Sir Isaac Pitman and Sons, Ltd., London, xii + 707 p.

A general reference on ecological physiology of marine animals including members of the class Chondrichthyes.

PROSSER, C. LADD (editor).
1950. Comparative animal physiology. W. B. Saunders Co., Philadelphia, x + 888 p.

A comprehensive text covering the animal kingdom. specific sections on nutrition, foods and feeding, excretion, metabolism, circulation, chemoreception, photoreception, muscle and electric organs, bioluminescence, nervous system and other subjects.

REFERENCES ON THE RELATION OF SHARKS TO MAN

COPPLESTON, V. M.
1958. Shark Attack! Angus and Robertson, Sydney, 266 p.

A general account of damage wrought by sharks and of their attacks on man.

GILBERT, P. W., L. P. SCHULTZ, AND STEWART SPRINGER.
1960. Shark attacks during 1959. Science, vol. 132, no. 3423 (August 5), p. 323-326.

LLANO, GEORGE A.
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TABLE 2.--Maximum length and widths of common species of sawfishes, guitarfishes, skates, rays and chimaeras

Species		Maximum length	Maximum width
Common name	Scientific name		
Smalltooth sawfish.....	*Pristis pectinatus*.....	18 feet	---
Largetooth sawfish.....	*Pristis perotteti*.....	22 feet	---
Atlantic guitarfish....	*Rhinobatos lentiginosus*....	3 feet	---
Shovelnose guitarfish..	*Rhinobatos productus*	4 feet	---
Lesser electric ray....	*Narcine brasiliensis*.....	1 foot 6 inches	---
Atlantic torpedo.....	*Torpedo nobiliana*.....	5 feet 11 inches	---
Big skate.....	*Raja binoculata*	6 to 8 feet	6 feet
Barndoor skate.....	*Raja laevis*	---	5 feet
Little skate.....	*Raja erinacea*.....	1 foot 9 inches	1 foot
Roughtail stingray.....	*Dasyatis centroura*	---	7 feet
Diamond stingray.....	*Dasyatis dipterurus*.....	6 feet	---
Atlantic stingray.....	*Dasyatis sabina*.....	2 feet 9 inches	1 foot 4 inches
Gulf dwarfskate.....	*Breviraja sinus-mexicanus.*	1 foot 2 inches	0 feet 7 inches
Spiny butterfly ray....	*Gymnura altavela*.....	4 feet 8 inches	6 feet 10 inches
Smooth butterfly ray...	*Gymnura micrura*.....	---	3 feet 6 inches
Spotted eagle ray.....	*Aetobatis narinari*.....	---	7 feet 7 inches
Bat stingray.....	*Myliobatis californicus*	---	4 feet
Atlantic manta.....	*Manta birostris*.....	17 feet	22 feet
Chimaera.....	*Hydrolagus affinus*.....	4 feet 1 inch	---
Ratfish.....	*Hydrolagus colliei*	3 feet 2 inches	---