Stomach Contents of Tiger Sharks, Galeocerdo, reported from the Pacific and Indian Oceans

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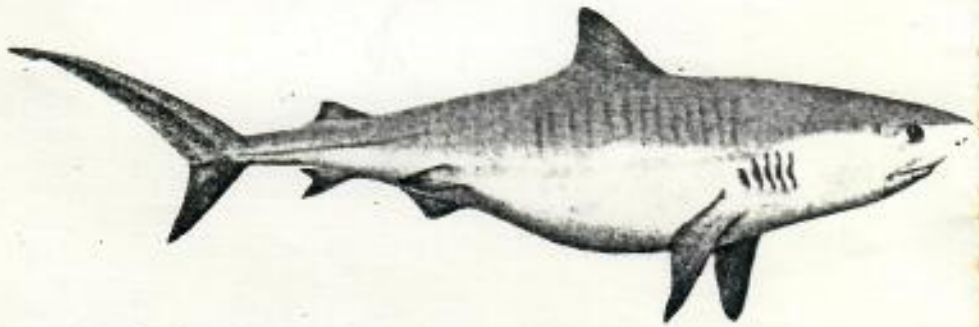
THIS is the third of a series of articles* dealing with the food and feeding habits of the tiger shark, *Galeocerdo*. The first dealt with the food of this shark in Gulf of Mexico waters at Key West, Florida, U.S.A. Here six of the seven specimens studied had been taken at or near Slaughterhouse Point on the southwest part of Key West Island. The food of the tigers here was quite miscellaneous and heterogeneous, but turtle scutes were found in the majority and in nearly all were mammalian remains—particularly the head of a cow in one stomach and of a horse in another, and in two stomachs three horses' hooves—two with leg bones.

In the second article are described the stomach contents of tiger sharks caught on the coast of North Carolina, U.S.A., and mainly in the Bight of Cape Lookout. The tigers, along with other sharks, various bony fishes and the large sea turtles, are summer migrants northward from Florida waters, and Cape Lookout is a natural fish trap for such migrants. Furthermore, in 1919-1923, the Ocean Leather Company maintained a fishery for sharks at Cape Lookout and a skinning and reduction plant at Morehead City, some 25 miles away. From this fishery most of my data came. Tigers were the most abundant sharks taken. Trapped in the Bight of Cape Lookout in large numbers, the tigers were further concentrated in the large nets of the shark fishermen, along with other sharks, various rays, porpoises and great sea turtles. Thus crowded together, the fierce tigers fed voraciously on their own species, on other sharks, on sea turtles and on porpoises. Thus was made pos-

* The first and second articles of this series are being published in America.



An Australian Tiger Shark, about 8½ feet long, showing the heavy build of the front half and the tiger-like stripes.

After Macdonald and Barron.

sible the feeding by the tigers on animals which—other than the slow and clumsy sea turtles and the fishes which go in schools—they could hardly have caught in the open ocean.

From the semi-tropical and warm temperate western North Atlantic, this story takes us to the greatest of the oceans, the Pacific, in which, according to H. W. Fowler,[1] *Galeocerdo* is found in all the "tropical and temperate seas to 70° or more from the equator". Over this vast area in the greatest ocean, *Galeocerdo* is found. Everywhere its food and feeding habits must in general be like those already described, but so far as this search has shown, the feeding has been recorded from but two regions—in the tropical eastern Pacific, and in Australian waters. To these widely separated parts of this great ocean, our studies will now take us.

Stomach Contents of Galeocerdo arcticus Taken in the Tropical Eastern Pacific.

Beebe and Tee-Van, in an expedition ranging from Cedros Island, Lower California (Lat. 28° N.), to the Galapagos Islands (almost under the equator), found the tiger shark (*G. arcticus*, syn. *tigrinus*) fairly common. They made dissections and notes on eleven specimens taken with the hook from the decks of vessels, and from these dissections, in the matter of concern for this article, they make the following statement:[2]

> FOOD: Almost any invertebrate or vertebrate of sufficient size may find a place in the diet of this shark. Our list is as follows: garbage (3 stomachs); octopus (400 mm.) [c. 16 in.]; *Heterodontus quoyi* (375 mm.) [c. 15 in.]; sting rays (7 in 3 stomachs, 4 of them *Urobatis halleri*); [of bony fishes, 4 specimens] *Gymnosarda alleterata* (400 mm.) [c. 16 in.] *Mycteroperca fordoni* (600 mm.) [c. 24 in.], *Diodon holacanthus* (200 mm.) [c. 8 in.], *Ogcocephalus* sp. (150 mm.) [c. 6 in.]; *Iguana iguana* (1-371 mm.) [c. 57 in.]; *Chelone midas* [turtle] full of eggs (700 mm.) [28 in.]; feathers (2 stomachs); 2 Clarion shearwaters, *Puffinus auricularis*; and a Galapagos sea-lion pup, *Otaria jubata*.

I submit that this list fully justifies the statement with which the authors begin their account of the food of the tiger shark. Further, it shows that the Pacific tigers have dietetic tastes similar to those of the tigers taken in the Atlantic.

And finally we now go to that last and far distant Pacific region from which there are most interesting data on the food intake of the tiger shark.

Stomach Contents of Galeocerdo cuvier (syn. rayneri), The Australian Tiger Shark.

As the illustration shows, the Australian tiger, like its western Atlantic relative, is heavily built, especially in the forward half of the body. The head is large, much wider than deep, and capable of swallowing large objects. These pass easily through a large gullet into a capacious stomach. As shown in the accompanying photograph, the teeth are sickle-shaped. These have the lower part coarsely, the upper finely serrate, and the oblique tips always point right and left to the angles of the jaws. With these teeth, the tiger shark makes a shearing cut in its prey. In size, the large Australian tigers tabulated by Whitley[3] run from 11 feet 8 inches to 13 feet 6 inches

The curious sickle-shaped teeth typical of the Tiger Shark. After Waite.

[1] Fishes of Oceania, *Mem. Bishop Mus.*, Vol. 10, 1928, p. 13.

[2] Fishes from the Tropical Eastern Pacific, Part 2, Sharks. *Zoologica, Sci. Contribs. N.Y. Zool. Soc.*, Vol. 26, Pt. 2, 1941, *Galeocerdo*, pp. 113-114, fig. 23.

[3] The Fishes of Australia: Part 1, Sharks, Sydney, 1940, p. 113.

Like "a sinister grey shadow", a Tiger Shark approaching its food.
Photo.—Otho Webb.

(the largest tiger on record from any ocean and for which, unfortunately, no weight is recorded[1]. The weight varies with the condition (probably with the stomach contents) of the shark from 710 lb. (12 feet) to 1395 lb. (13 feet 4 inches).

To turn now to the matter under study—the earliest indication of the feeding habits of the Australian tiger shark is from the pen of J. D. Ogilby.[1] He speaks of its size, fierceness and cunning, and then accounts for its abundance in Sydney Harbour in those days as follows:

> . . . the prevalence of these pests is undoubtedly due to the reprehensible system now in vogue [1888] of discharging the refuse of slaughterhouses and such like rubbish by means of lighters towed down the harbour, which, having been emptied of their load some distance outside the Heads, are immediately, while reeking with blood, brought back up the harbour and are followed by these keen-scented denizens of the ocean as naturally and as easily as hounds follow the trail of a fox.

Apart from some earlier references quoted by Whitley (see below), the oldest definite statement, found in this search, concerning the unexpected kind of food of the Australian tiger shark, is from D. G. Stead.[2] At a meeting of the Naturalists' Society of New South Wales, he stated ". . . that a large tiger had been caught off North Head [Sydney Harbour], the stomach of which contained a gannet and another sea-bird (possibly a gannet)". These must have been caught while floating on the surface of the water.

In the matter of the diversified food of the Australian tiger shark (or, perhaps better, the things swallowed by it), practically everything else known has been collected and published by my friend, G. P. Whitley, of the Australian Museum, Sydney, in various places, as called for by subjects, in his book on Australian Sharks (1940) previously referred to. Here follow these extensive and valuable data in the order of the pages on which they are found.

On his page 22, Whitley speaks of a tiger shark, 14 feet long, weighing 800 lb., which was caught off Bondi Beach (N.S.W.). "This tiger had been feeding on offal and matter from a nearby sewer outfall." Next (p. 34) Whitley records that a tiger captured and kept in an

Mouth of a Queensland Tiger Shark propped open to show the teeth. Note also the turtle-head bait still on the hook which caught the shark.
Photo.—Otho Webb.

[1] *Proc. Linn. Soc. N.S.W.*, Vol. 13, Pt. 2, 1888, *Galeocerda*, pp. 1768-1769.
[2] *The Australian Naturalist*, Vol. 9, 1931, p. 95.

many fish. The stomach also contained a dolphin's head, bitten clean off the body, and some spines of a porcupine fish. Apparently the humble porcupine fish is not infrequently eaten by sharks, though from some accounts, it is an unpleasant victim, as, when it is swallowed, it raises its numerous sharp spines and sticks in the shark's throat or stomach, or else chews its way to freedom with its parrot-like beak.

This story of the porcupine fish biting its way out through stomach and body wall of its captor has been often repeated over the years and over much of Oceania, but I think that it is only a "tale". My own experience in handling objects from the stomach of tiger sharks has taught me that frequent washings of the hands are necessary to prevent the intensely corrosive stomach fluids from decomposing the skin of the hands. One man has spoken of the tiger's stomach fluids as "burning like fire". My judgment is that the porcupine fish would be very shortly killed and its flesh, spines and bones presently decomposed by these very powerful juices. In this connection see Beebe and Tee-Van, above, who found a dead *Diodon* in the maw of one of their tiger sharks in the eastern tropical Pacific.

Mr. Max Nicholls, of Lord Howe Island, photographed a 12½ ft. tiger shark which was caught there on May 18, 1942, by Mr. Rowley Wilson. It contained one goat, one turtle, one big tomcat, three mutton birds, four big kingfish heads and two leg bones of bullock from the refuse of a freezing works, one dead shark about 6 ft. long, caught a few nights before and thrown back into the water, and a number of small fish."

A female tiger shark, 4 feet 9 inches long, caught near Fraser Island, Queensland, in March, 1943, was dissected by Mr. G. P. Whitley, who found fish (*Pomadasys*) and elasmobranch remains as well as pieces of cuttle bones in the stomach.

Stomach Contents of Galeocerdo in the Indian Ocean.

On the other side of Australia, Mr. Whitley performed autopsies on 25 Western Australian (Indian Ocean) tiger sharks in which were such varied objects as shags, turtles, sea snakes, various sharks and rays, an assortment of fishes (stonefish, tailor, leather-jackets, cod, whiting, snapper, toadoes, porcupine and boxfishes, eels and fish offal thrown overboard by fishermen), cuttlefish, squid and octopus, bailer shells (*Melo*) and a large whelk-like mollusc, crabs (*Portunus*), a sheepshank and rib, pieces of

[1] *Walkabout* Magazine, October, 1947, p. 36 and figure.

A large Tiger Shark at North-West Islet, Queensland.
Photo.—Embury Bros.

aquarium at Coogee "disgorged some pieces of shark and a number of bones and, strangest of all, a human arm almost unaffected by digestion". He kept this shark under observation and reports (p. 36) that "after having been in captivity for nearly a week, it vomited up . . . the bones of some non-mammal vertebrate and of a partly digested mutton bird". Next he states (p. 61) that:

> The scavenging Tiger Shark (*Galeocerdo rayneri*) is not finicky about its food. The stomach of a female caught in August, 1916, at Bondi, N.S.W., contained a full-grown Spaniel with the collar on, a porpoise's skull, remains of sea-birds, and a mass of more or less digested remains of fish, etc., including the spines of a porcupine fish. [This tiger shark was identified, and its stomach contents reported upon, by A. R. McCulloch, Sydney Sun newspaper, 15th August, 1916.]

Then with reference to tiger sharks in Queensland, Whitley (p. 61) quotes J. D. Ogilby[6] as follows:

> The most cunning and dangerous of all our sharks, lurking about wharves and similar places, where they pick up an easy living through the refuse thrown overboard from the vessels alongside, together with an occasional dog or other animal. When on board the "Endeavour" we were witnesses to a remarkable instance of gluttony and its fitting reward. While a brace of snapper was being hauled up, a large shark of this species was observed to be accompanying them from the bottom; instead, however, of tearing them from the hook, as is the usual practice in such cases, it contented itself with merely nosing them about, not even making any more vigorous protest when they were finally lifted intact out of the water.
>
> As it persisted in continuing this form of amusement with other captures, we threw out a shark hook nicely baited with fat pork, which it soon found. Even this tempting morsel it only nosed and mumbled for several minutes before taking it into its mouth so far as to enable us to effect its capture. When opened the secret of its extraordinary behaviour was revealed, for it was found to be full actually to the gullet with large leather-jackets (*Cantherines ayraudi*) of which it had already swallowed no less than 32, averaging fully fifteen inches apiece, all of which were perfectly fresh, unbitten, and undigested. This shark measured over 13 feet.

This intake of 480 inches (40 feet) of leather-jackets certainly constitutes a record. "Nowhere else in this search has it been found that a tiger shark has taken in a whole school of bony fish of such size and volume.

Concerning the eating of birds, Whitley (p. 62) adds to his earlier remarks that "judging from the stomach contents of a number of tiger sharks, they frequently swallow mutton-birds (petrels) which they must snatch from the surface of the water". Then he quotes Griffin[7] that in the stomach of a New Zealand tiger was found a blue penguin, also a very large crayfish and a coarse-haired dog the size of a collie.

More extraordinary than any of these, Whitley (p. 63) notes the exhibition before the Linnean Society of New South Wales in May, 1888, of a gold watch taken from the interior of a tiger shark in Port Jackson. And he further states that in December, 1930, a shark fisherman in Sydney Harbour ". . . caught a *Galeocerdo* which had swallowed a purse containing three shillings, a powder puff and a wrist watch". However, Whitley thought that these did not indicate tragedies, but were simply things dropped overboard and retrieved by the sharks.

And last of all of the extraordinary things swallowed by an Australian *Galeocerdo* is the following, noted by Whitley (p. 129). "A 12-foot tiger shark, caught off Sydney on 7 April, 1940, had swallowed the 7-foot tail of a thresher shark [*Alopias caudatus* — the whip-tailed Alopias], and part of the tail was protruding from the shark's mouth when it was caught". If only a photograph of this could have been taken.

Finally, Whitley on page 113, sums up as to the contents of the stomach of the Australian *Galeocerdo* as follows:

> The tiger shark is a scavenger, eating almost anything which may come its way. Such objects as bags, lumps of coal, dead dogs, etc., have been found in the stomach contents of sharks caught in our harbours.
>
> As an example of the varied nature of its menu may be detailed the stomach contents of a tiger shark caught some years ago at Bondi, N.S.W. This shark had eaten a full grown spaniel, several sea-birds, and

[6] *Mem. Qld. Mus.*, v, 1916, p. 79.

[7] *Trans. N. Zeal. Inst.*, lviii, 1927, p. 138.

seaweeds, and unidentifiable substances looking like pieces of bread, liver, and fat.

Otherwise the only published records of tiger sharks' food in the Indian Ocean are two accounts from India.[1]

I know of no paper dealing specifically with the food of *Galeocerdo* but the three on which I am at work. Of these one is based on my own dissections and observations of seven specimens of *G. tigrinus* at Key West and Tortugas, Florida. The second is from the writings of four men (two in collaboration) of *G. tigrinus* on the North Carolina coast. The third is the present article. Further, I know of no other paper bearing the specific title "The Food [or the Stomach Contents] of the Shark". So it has seemed well in these articles to bring together all the available data on the remarkable materials found in the stomach of *Galeocerdo*—of which it may be said that "All is grist that comes to its mill".

It is hoped that the publication of these reports on *Galeocerdo* may lead other observers, who have had the opportunity to study the stomach contents of this and other sharks, also to publish their observations under the name of the shark. Thus our knowledge of the food and feeding habits of sharks will in time be greatly extended.

Lastly, the inevitable question comes: "How does the tiger shark unload its stomach of the accumulation of indigestibles?" The answer is that these must come out as they went in—through the mouth. There is no other way. The shark relieves itself by the process of regurgitation as witnessed and recorded for three cases in the North Carolina, U.S.A., paper, and as recorded by Whitley on his page 34 (see this article, page 284).

[1] F. Day, *Fishes of India*, i, 1878, p. 718, and K. Chidambaram, *Journ. Bombay Nat. Hist. Soc.*, xlv, 1945, p. 247.

Mr. F. D. McCarthy, Curator of Anthropology at the Australian Museum, is gaining valuable experience as a member of the Australian-American Scientific Expedition at present in Arnhem Land. The expedition was on Groote Eylandt in the western part of the Gulf of Carpentaria from early April till about mid July, when it moved to Yirrkala in Arnhem Land. During the period spent on Groote Eylandt the wide range of Mr. McCarthy's activities included, apart from the collection of specimens, the recording of various craft techniques of the aborigines, recording of very numerous groups of cave paintings, examination of stone arrangements connected with totemism, excavation of Makassar graves, investigation of aboriginal bone-disposal caves and camp sites, study of genealogies of native families, study of the art of the people, observation of initiation ceremonies, and general observations on the physique and habits of the natives.

Mr. G. P. Whitley, Curator of Fishes, the Australian Museum, who has been seconded to the Division of Fisheries, Council for Scientific and Industrial Research for three months, left Sydney on 3rd September for New Guinea, where he will be acting as scientific officer associated with the fishery investigations being undertaken there.

The final lectures in the Museum's Popular Lecture Syllabus for 1948 will be:

October 7: "Spectacular Experiments in Zoology", A. N. Colefax, B.Sc.

October 28: "Some Aspects of Australian Fishery Research", H. Thompson, D.Sc.

These lectures will be delivered in the Museum's lecture theatre at 8 p.m. Admission is free.

1/24/77 George Balazs

Bishop Museum

by Donald E. Kauffman

CONTENTS

1950

Research Report 16

NOTES ON THE BIOLOGY OF THE TIGER SHARK *(Galeocerdo arcticus)* FROM PHILIPPINE WATERS

Fish and Wildlife Service USDI

Tiger sharks of the genus *Galeocerdo*, known to be distributed generally throughout the warm seas of the world, are notorious for their omnivorous feeding habits. Most literature to date has dealt with this phenomenon. In addition, some size records have been reported from a few localities, and Sarangdhar (1943) has discussed the breeding habits of this shark in Indian waters; he has also described the female reproductive organs during gestation. No doubt the lack of information concerning this genus has been due chiefly to the difficulty of securing sufficient specimens, as the capture of a tiger shark calls for special gear in any region where a commercial shark fishery does not exist.

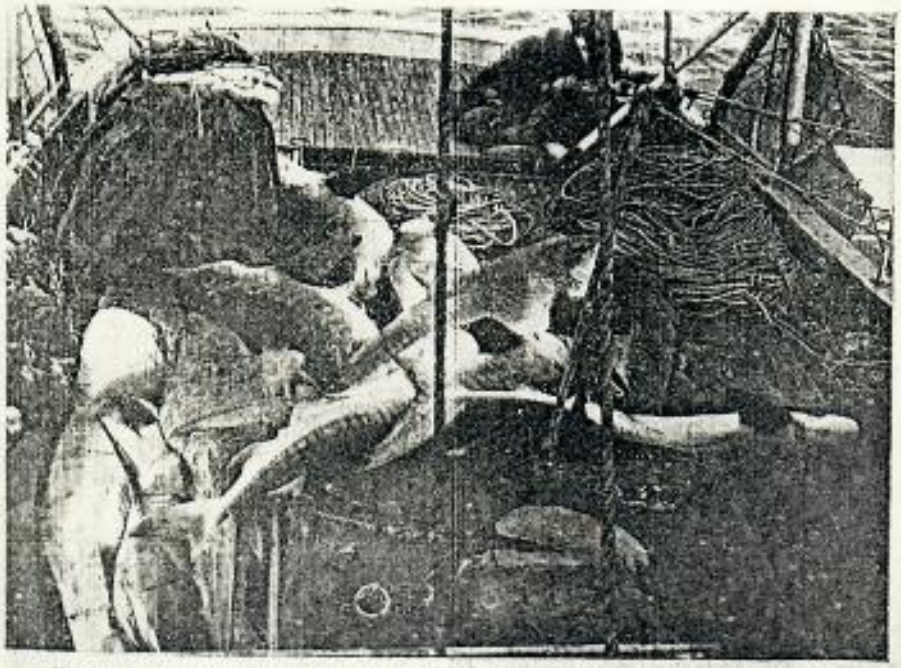


Figure 1.—A deckload of large tiger sharks from waters of the Sulu Archipelago.

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While carrying out exploratory shark fishing in the Philippines with the experimental fishing vessel *Theodore N. Gill* of the Philippine Fishery Program of the United States Fish and Wildlife Service[1] during April and May 1948, the writer collected data on 43 specimens of *Galeocerdo arcticus* (Faber). This is perhaps the greatest number of these large sharks ever collected or studied in so short a period. The data thus secured form the basis for the observations presented in this publication.

The author acknowledges the invaluable assistance of the following staff members of the Philippine Fishery Program: Herbert E. Warfel, in charge of the biological and oceanographical investigations; Augustin Umali, ichthyologists and the officers and crew of the motor ship *Theodore N. Gill*, whose efforts resulted in the capture and landing of the specimens upon which the data are based.

THE PHILIPPINE TIGER SHARK

Inasmuch as there is a tendency to reduce the genus *Galeocerdo* to a monotypic status, as Gudger (1949) indicated, and as it is doubtful if large sharks are well represented in collections, the following description of Philippine specimens, based on adults 293 to 373 centimeters in total length, is included for taxonomic reference:

Color.—The dorsal surfaces of the body and flanks are a uniform gray, with darker tiger-like markings beginning slightly ahead of the first dorsal and extending posteriorly onto the upper caudal lobe, where they appear as spots. The ventral surface of head and body is white. The lateral limit of the gray color on the head extends from the tip of the snout above the nostril, runs parallel to the angle of the upper jaw, passes slightly below the eye, thence under the lower origin of the gill slits, and joins the leading edge of the pectoral fin at its base. The pectoral and ventral fins are gray above and white below.

Body proportions.—Viewed from above, the head is widest where the massive jaws form their angle and it tapers very gradually to the broadly rounded snout. The snout is short and dorsoventrally compressed; its length is almost equal to that of the preoral. The horizontal diameter of the eye is 3.8–4.8 in snout length and 1.9 in distance from orbit to spiracle. The preoral length is 2.3–3.1 in mouth width across the angles. The upper labial furrow extends before the eye about the diameter of the latter; the lower furrow is nearly one-half the length of the upper.

A mid-level lateral keel, originating on each side midway between the two dorsal fins, extends slightly beyond the caudal origin; it is most pronounced on the peduncle. A conspicuous median dorsal ridge originates on the head slightly behind the eyes and extends to the first dorsal. It appears shortly behind

[1] A part of the Philippine Rehabilitation Program authorized by the Philippine Rehabilitation Act of 1946, Title 50 App., U. S. Code, 1789.

the base of the first dorsal and continues to within seven-eighths of the distance to the second dorsal, where it blends into a rather shallow furrow terminating at the base of the second dorsal fin.

The length of the caudal measured from the precaudal pit to the tip of the upper lobe is 3.9–4.5 in total length. The second dorsal base is 2.3 in first dorsal base; the anal base 1.2 in second dorsal base; and the vertical height of second dorsal is 1.5 in vertical height of anal. The teeth are $\frac{20\text{–}23}{22\text{–}24}$.

DISTRIBUTION AND METHODS OF CAPTURE

To determine whether a profitable shark fishery might be developed, experimental fishing was conducted in the waters of the SuluArchipelago, from the southwestern tip of the island of Mindanao southwesterly to British North Borneo. Here, during April and May 1948, tiger sharks were abundant. The sharks were taken in shallow waters near land masses where the depth was about 30 fathoms and the bottom often uneven from the coral present. They were captured on baited long-lines suspended from the surface to a depth of 8 to 12 fathoms. Stout manila hemp line and heavy hooks on chain leaders were required to hold the powerful creatures.

There is no established tiger shark fishery in these islands. If an accidental capture occurs, the inhabitants use the flesh as food, generally preparing it by drying.

RELATIONSHIP BETWEEN TOTAL LENGTH AND TOTAL WEIGHT

The measurements and weights of the tiger sharks were recorded within a few hours after capture. The total length included the distance from the snout to the caudal tip. The weight was taken on a hanging beam scale suspended from the single fall on the boom of the vessel. A rope sling was placed near each end of the animal and the loops hooked on the scale. The single fall was then raised by winch until the animal cleared the deck. Thus the shark remained suspended in a nearly horizontal position and the scale could be easily manipulated.

The weight-length relationship was calculated by fitting the actual weights and lengths by the method of least squares employing the equation $Y=aX^b$ (Ripley 1946), expressed as $\log Y=\log a+b \log X$. Log Y represents the logarithm of the total weight in pounds and log X the logarithm of the total length in centimeters.

Based on 21 specimens, the weight of the females was found to increase as the length to the 3.4 power. These specimens ranged from 153 to 350 centimeters (5.0 to 11.5 feet) in total length and from 40 to 630 pounds in weight. These calculations did not include pregnant females as their weight was affected by the increased liver weight and the developing embryos or pups.

The weight of the males, based on 19 specimens, increased as the length to the 3.3 power. The male specimens ranged in total length

from 211 to 367 centimeters (6.9 to 12.0 feet) and from 93 to 680 pounds in total weight. Maturity stages were not considered.

The results are shown graphically by the regression lines in figure 2. The data for the females are expressed by the formula log Y=

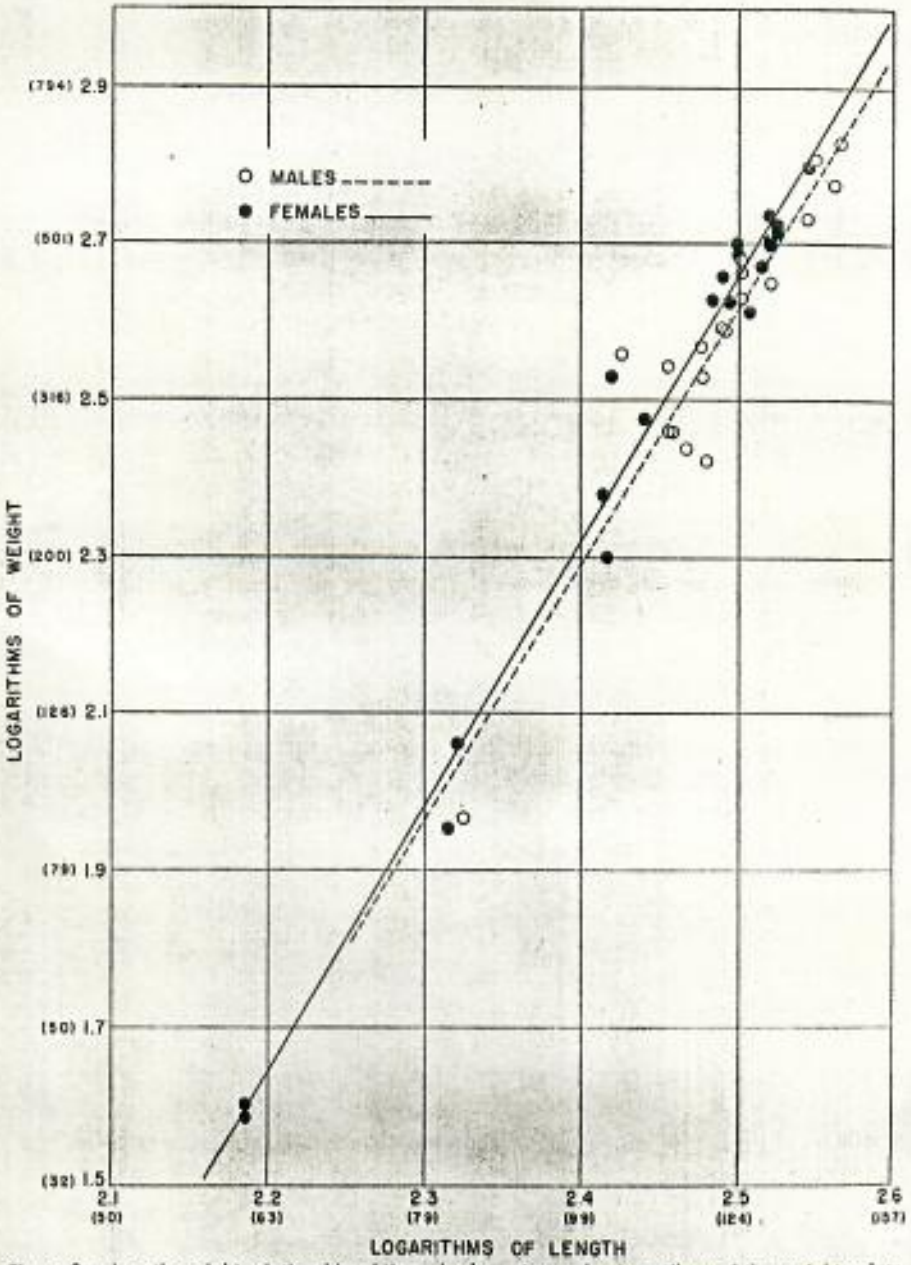

Figure 2.—Length-weight relationship of tiger sharks. Approximate antilogs of the weight values in pounds and of the length values in inches are included in parentheses for reference. The logarithms were originally in pounds and centimeters.

$-5.73351+3.35609 \log X$; for the males by the formula $\log Y = -5.5054+3.25007 \log X$.

LIVER WEIGHT AND TOTAL BODY-WEIGHT RELATIONSHIP

The large tiger shark possesses a comparatively large liver in relation to the total body weight. The average liver weight—both sexes combined—expressed in percentage of total body weight for 30 sharks weighing more than 100 pounds, was 21 percent. Sharks of both sexes under 100 pounds in total body weight had a liver weight of only 6 percent.

In general, it was found that the liver weight of both sexes increased with the total body weight until a body weight of 240 pounds in females and 300 pounds in males was reached, when the maximum liver weight was achieved. This average held for females weighing up to 1,085 pounds and males to 680 pounds. No specimens larger than these were taken.

As only three pregnant females were encountered, the data are inadequate to show conclusively the effects of pregnancy on liver weight. The female with eggs developing in the uteri showed the highest percentage of liver weight to body weight (26 percent); whereas the two females with well-developed pups showed a decrease in liver weight to 20 and 21 percent, which was usual for females greater than 100 pounds in total body weight. These variations in percentage liver weights may indicate that at the onset and in the early stages of pregnancy the liver weight reaches its maximum weight and gradually falls as the gestation period advances. Figure 3 presents graphi-

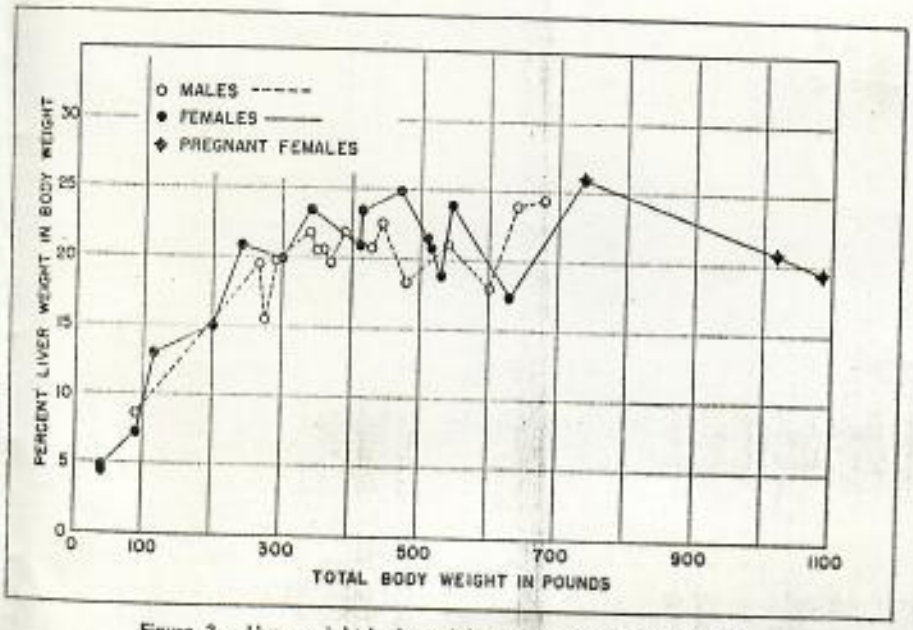

Figure 3.—Liver weight-body weight relationship of tiger sharks.

cally the liver weight-body weight relationship. The data are given in table 1.

SEXUAL MATURITY

A female shark was considered mature if large eggs were present in the ovaries or if the uteri contained fertilized eggs or embryos in any stage of development. The immature females had relatively small, flap-like ovaries composed principally of innumerable small ova of varied sizes.

Table 1.—Length, weight, weight of livers, and percentage relationship of tiger sharks captured during April and May 1948 in the waters of the Sulu Archipelago, Philippines

Sex	Total length in centimeters	Total length in feet	Total weight in pounds	Liver weight in pounds	Percentage liver weight in body weight	Sex	Total length in centimeters	Total length in feet	Total weight in pounds	Liver weight in pounds	Percentage liver weight in body weight
Female	153	5.02	40	2.2	5.5	Female	373	12.24	[1] 1,085	212.0	19.5
Do	153	5.02	40	1.9	4.8	Do	380	12.47	[1] 1,050	212.0	20.2
Do	206	6.76	90	6.7	7.5	Male	211	6.92	93	8.1	8.6
Do	210	6.89	115	15.0	13.0	Do	266	8.73	300	74.0	20.6
Do	250	8.20	240	50.0	20.8	Do	285	9.35	290	.....	.....
Do	261	8.56	200	30.0	15.0	Do	285	9.35	350	72.0	20.6
Do	262	8.60	340	80.0	23.5	Do	286	9.38	290	57.0	19.7
Do	272	8.92	300	60.0	20.0	Do	283	9.61	275	42.3	15.4
Do	305	10.00	425	.....	.....	Do	299	9.81	370	73.0	19.7
Do	310	10.17	453	.....	.....	Do	300	9.84	340	74.0	21.8
Do	312	10.24	415	97.0	23.4	Do	302	9.91	265	51.5	19.4
Do	314	10.30	485	.....	.....	Do	308	10.10	395	.....	.....
Do	315	10.33	485	.....	.....	Do	310	10.17	390	85.0	21.8
Do	321	10.53	412	86.0	20.9	Do	318	10.43	480	88.0	18.3
Do	327	10.73	470	117.0	24.9	Do	318	10.43	480	.....	.....
Do	330	10.83	500	.....	.....	Do	318	10.43	430	90.0	20.9
Do	330	10.83	545	130.0	23.9	Do	332	10.89	445	101.0	22.5
Do	330	10.83	510	110.0	21.6	Do	350	11.48	540	114.0	21.1
Do	334	10.96	530	100.0	18.9	Do	353	11.58	640	153.0	23.9
Do	335	10.99	518	107.0	20.7	Do	365	11.97	930	108.0	18.0
Do	350	11.48	630	113.0	17.9	Do	367	12.04	680	165.0	24.3
Do	360	11.81	[1] 760	160.0	25.7						

[1] Pregnant.

The three female tiger sharks captured which were considered mature were pregnant and greater than 350 centimeters (11.5 feet) in total length. The remaining 21 females had small ovaries with numerous small eggs and were considered immature. On this basis it can be assumed that the female tiger shark in the Philippines reaches a length of about 350 centimeters (11.5 feet) at the time of first maturity. In Indian waters specimens 10 to 13 feet in length were found containing young (Sarangdhar, 1943).

The most positive criterion of sexual maturity in the males was the release of milt from the gonoduct when pressure was applied. However, in the majority of the specimens the enlarged testes were indicative of a mature male. The lack of sufficient range in sizes, particularly in the smaller specimens, made it impossible to determine the size of the males upon attaining first maturity. All those greater than 266 centimeters (8.73 feet) in total length were considered mature, and two of these contained milt.

FECUNDITY

The two females that bore pups were the heaviest sharks collected; one contained 41 young and the other 53. The latter also had one large undeveloped egg and one small embryo (12 cm.) in its uterine compartments. The egg showed no sign of development. A third female was 360 centimeters (11.8 feet) in length, weighed 740 pounds, and had 62 fertilized eggs (4–5 cm. diameter) in the uteri. Male pups were recognizable by the presence of the intromittent organ, figure 4. They were larger than the females and were predominant in both broods. Following are the data on the two groups:

Adult female, 373 cm. (12.2 ft.) total length; total weight, 1,085 pounds:

Data on group of 53 pups:	*Males*	*Females*
Size range [1]	257–348 mm. (10–13 inches).	226–334 mm. (8–13 inches).
Average total length.	291.6 mm.	282.4 mm.
Sex ratio	51.9 percent	48.1 percent

Adult female, 380 cm. (12.5 ft.) total length; total weight, 1,020 pounds:

Data on group of 41 pups:	*Males*	*Females*
Size range [2]	555–686 mm. (22–27 inches).	535–660 mm. (21–27 inches).
Average total length.	660.6 mm.	681.8 mm.
Sex ratio	51.2 percent	48.8 percent

[1] Measurements made after pups had been preserved in formalin for a few weeks.
[2] Measurements made shortly after pups were removed from the uteri.

The pups with their array of varied dark spots and bars against a light background differ pronouncedly in coloration from the parent (fig. 5). The only portion of the young that has the gray coloration so typical of the adult is the top of the head and the area directly above the gill slits. The middorsal ridge was emphasized from behind the first dorsal to the caudal by a solid wide line of dark pigment. The yolk sac and cord together stretched about half the total length of the body and the amount of thick, oily yolk material remaining varied from less than 50 to approximately 100 cubic centimeters, depending upon the size of the embryo.

FOOD HABITS

Three recent papers by Gudger (1948a, 1948b, 1949) summarize the knowledge to date of the food and feeding habits of the tiger shark in various areas of the Pacific, Indian, and Atlantic Oceans. Supplementary information is given here for the Philippine waters where this shark was found to be a scavenger with an unselective appetite. The present observations are based on the examination of 43 specimens, 21 of which had empty stomachs, either normally or by extruding the contents before being brought aboard the vessel. In many cases the everted esophagus was evident.

The hawksbill turtle, *Eretmochelys imbricata*,[3] was the common turtle found in the stomachs examined and the predominant source of food. From one stomach a ten-pound specimen was recovered intact, its only wound being a slight

[3] According to Taylor (1921, pp. 180–182). However, Stejneger and Barbour (1939, p. 169) call the hawksbill turtle from the Indian and Pacific Oceans *Eretmochelys squamata*, and reserve the name *E. imbricata* for the hawksbill turtle from American seas. Seale (1911, p. 291) refers the hawksbill turtle to *Chelone imbricata*.

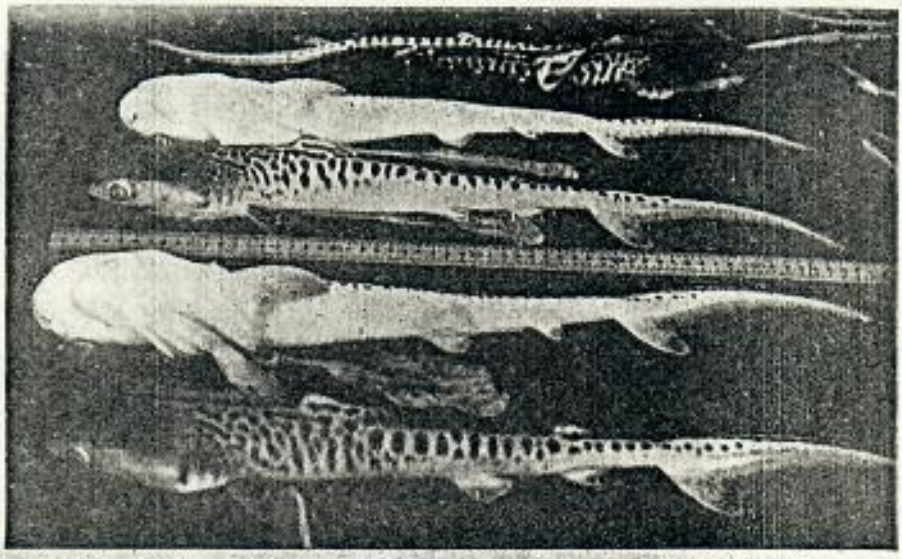

Figure 4.—Pups from a 12.5-foot female tiger shark. Note prominent markings, yolk sac, and point of attachment of the yolk sac cord. The claspers are visible on the male in the foreground.

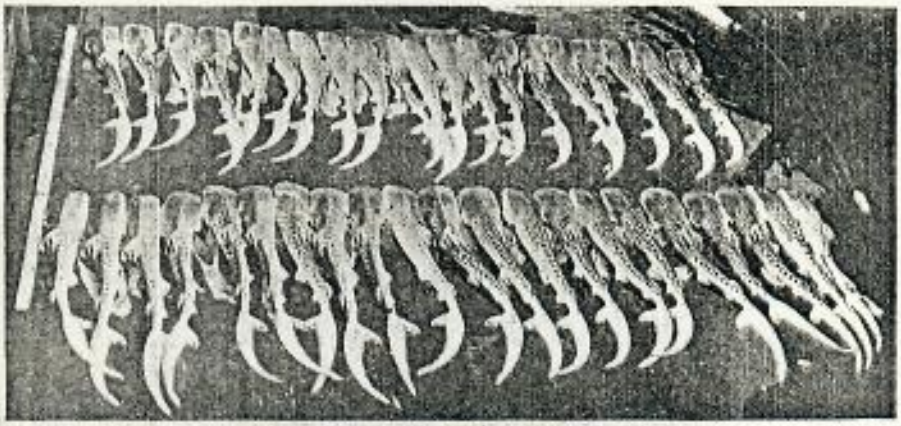

Figure 5.—Forty-one young tiger sharks on the deck of the fishing vessel. These were removed from a 12.5-foot female that weighed 1,020 pounds.

gash in the neck. Parts of the green turtle, *Chelonia mydas*,[3] were infrequent, appearing on only two occasions. In several stomachs all that remained to indicate turtle remains was a handful of fibrous intervertebral disks. In these cases the contents were classed as hawksbill since this species was identified most frequently.

The diversity of items in the tiger shark's diet and the frequency of their occurrence as revealed in the examination of the contents of 22

[3] According to Seale (1911, p. 202). Stejneger and Barbour (1939, p. 168) reserve the name *Chelonia mydas* for the green turtle of the Atlantic Ocean and Gulf of Mexico, and call the Pacific species *Chelonia agassizii*. Taylor (1921, p. 184), based on description of specimens from the Philippines, assigns the species the name *Chelonia japonica*.

stomachs are shown in the following tabulation:

Item:	Frequency of occurrence
Hawksbill turtle (*Nretmochelys imbricata*)	11
Unidentified fish remains	4
Hardtails (*Megalaspis cordyla*)	2
Green turtle (*Chelonia mydas*)	2
Squid	2
Crab	2
Feathers (origin unknown)	2
Sea snakes	2
Trigger fish (Monacanthidae)	1
Gurnard (Dactylopteridae)	1
Parrot Fish (Scaridae)	1
Shark flesh and liver	1
Eel	1
Black cat (*Felis domestica*)	1
Horse leg bone	1

The occurrence of the horse leg bone in one shark stomach may be explained by the fact that enroute to the fishing area horse meat was prepared for bait, and the bones thrown overboard. Possibly the shark had been following the vessel and remained long enough after swallowing the bone to take a baited hook.

During the fishing operations experiments were carried out to test the food preference of the species with horse meat, carabao meat, shark flesh, and fish flesh. However, no preference was found, and the shark appeared to take whatever bait was encountered first. From the standpoint of the bait most suitable for fishing, horse or carabao meat stayed on the hook the longest and could be used more than once if kept refrigerated between operations. Fish-flesh bait was most easily lost without a catch.

As the Sulu Archipelago is an area of scattered small villages inhabitated by primitive people and is off the route of large cargo and passenger vessels, the shark's main source of food must come from the indigenous fishes and reptiles. This explains the absence in the stomachs of the refuse material commonly found in sharks in other localities where great amounts of debris are available. This, as well as the fact that the sharks often remained on the hooks for as many as twelve hours between setting the gear and hauling—giving ample time for the completion of the digestive processes—may account for the large number of empty stomachs found. Not to be overlooked as another cause of empty stomachs is the possibility that the struggling shark had disgorged its stomach contents.

The viciousness of this shark toward members of its own species was twice demonstrated in the course of the study. The first occurred when a rather small specimen was hauled aboard with its entire belly and viscera torn away. Later many chunks of shark liver were found in a large female caught on the same gear. Also, as this large shark was struggling alongside the vessel, the author saw her disgorge nearly a dozen large chunks of meat that quite evidently were torn from the belly of the smaller shark. No doubt, while the smaller shark was struggling on a hook the female attacked it, ate her fill, and not satisfied, took a baited hook. The second instance of cannibalism occurred some days later when a baited hook was brought aboard with only the remnant of a jaw remaining. The teeth provided

positive identification of the jaw as that of a tiger shark and their size indicated a small specimen. Thus it appears that the large tiger sharks will attack smaller ones if the opportunity exists. This may explain why so few small specimens were captured, as they may avoid an area where larger individuals are abundant.

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GUIDE TO THE CLASSIFICATION OF FISHING GEAR IN THE PHILIPPINES

RESEARCH REPORT 17

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