THE TUNAS AND THEIR FISHERIES

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Explanatory Note

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THE TUNAS AND THEIR FISHERIES

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ERRATA

Page	Line	Correction
4	1	for "Katsuwonids" read "katsuwonids"
10	18, 19, 20	for "coeca" and "coecum" read "caeca" and "caecum"
20	47	for "figure 10" read "table 10"
26	11	for "12 + 35 = 37" read "12 + 25 = 37"
26	23	for "9 + 18 - 27" read "9 + 18 = 27"
26	25	for "haemal" read "hemal"
30	39	for "blakish" read "blackish"
32	12	for "pectiral" read "pectoral"
45	29	for "rise" read "rises"
58	39	for "roughtly" read "roughly"
60	11	for "*akakahiki*" read "*akakajiki*"
67	2	for "*shutome*" read "*shūtome*"
68	1	for "6 + 10 = 26" read "16 + 10 = 26"
89	17	for "it" read "its"
93	14	"(22) should be "(21)" and all subsequent footnotes are numbered one too high.
105	18	eliminate "limited"
112	10	for "spearfishing" read "spearfish"

FOREWORD

The position which the tuna fishery had come to hold among the fisheries of Japan was a rather important one, but now after the defeat that importance has increased markedly in comparison with the past.

The tuna fisheries that are carried on in Japan are of several kinds, but among them the most important, whether from the point of view of the scale of the enterprise or from that of the catch, is probably the longline fishery. In this book the author has recorded all that has been learned hitherto, mainly from the biological point of view, about the tunas, which are the resource that supports this tuna longline fishery. Accordingly, ecological and general material has been presented for the most part, and matters of fishing techniques and the characteristics of various fishing grounds have hardly been touched upon. I have the intention of attempting to treat these in another work.

The title refers to the tunas, but in this book the spearfishes are given equal weight. The reason for this is that the spearfishes are sometimes referred to as "spearfish-tuna" and are treated in the same way as the tunas. This, however, is not the only reason; the chief reasons are that the spearfishes are second in importance to the tunas in the catch of the tuna longlines, and that in their habits they have a great many points in common with the tunas. In this sense one would also have to discuss the sharks; however, there is still a great deal that remains to be understood about the sharks and so we must, unfortunately, omit such a discussion.

The order of the work is to take up the biological aspects first and to treat separately the morphology, ecology, and systematics of the tunas and the spearfishes, and then to discuss the fisheries for both together. However, as noted above, the fisheries are treated only in a general way.

Not a little of the material has been lost, and the data which I obtained in Taiwan in recent years I was forced to leave behind when I returned to Japan, so I regret very much that many parts of the book are abstract in treatment.

February 28, 1947 The Author

I. TUNAS*

A. General

a. External form

The tunas spoken of here are the fishes of the family Thunnidae. The Thunnidae, along with the Scombridae, the Cybiidae, and the Katsuwonidae are representative of the mackerel-like fishes or Scombriformes. Scholars sometimes lump these four families together into one to which they give the name Scombridae.

In general they are large fishes with stout bodies showing a roughly round shape in cross-section. The mouth is at the end of the snout and the jaws cannot be extended. Generally the lower jaw protrudes slightly beyond the upper. Inside both jaws there is a single row of curved sharp conical teeth, and there are also villiform teeth on the vomer, the palatines, and the pterygoid bones. On the palatines there are many calcareous plates covered with villiform teeth, making the palate feel rough to the touch. This is very different from the fishes of the family Katsuwonidae, which have smooth palatines. The eye is of a moderate size and is located on a line joining the tip of the snout and the middle of the caudal peduncle. The head, depending on the species, is 1/3 to 1/4 of the body length, the proportion changing more or less depending on age. The length of the head is usually somewhat greater than the body height. The profile of the belly is slightly rounder than that of the back, and the greatest body depth is roughly at the center of the first dorsal. The vent is located at or slightly to the rear of the center of the body without the head. The caudal portion of the body slopes sharply to the caudal peduncle, which is markedly compressed dorsoventrally and has a pair of conspicuous keels on both sides.

The skin is well developed and thick and its connective tissue is in several layers. Its fibers are arranged obliquely to the longitudinal axis of the body and each layer is laid down roughly at right angles to the next. Consequently, when this skin is made into tanned leather, it has the quality of not stretching in the direction in which these fibers are arranged, but of stretching obliquely.

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*Translator's note: In his discussion of the anatomy of the tunas the author has supplied English equivalents for most of the anatomical terms employed. The author's terminology has been followed in the translation without any effort to check on the accuracy or suitability of the names given to bones and other anatomical features.

The scales are developed all over the body with the exception of the head. On the head there are long narrow scales on the pre-opercle. The development of the corselet is generally not as clear as in the Katsuwonidae. Around the base of the first dorsal fin and above the origin of the pectoral fins there are large scales of somewhat modified form.

The lateral line is clear and forms a wide V-shaped bend above the base of the pectoral fins, while its posterior part is fairly straight. It is simple in form and does not give rise to any branches or loops.

The dorsal fin is divided into the first and second dorsal fins. The rays of the first dorsal are all spines, while the second dorsal has soft rays set thickly and strongly together. Posterior to it there are 8 - 9 finlets. At the base of the first dorsal there is a dermal groove within which the greater part of the fin can be folded away. The pectoral fins are generally large, and their shape is distinctive in the different species. The ventral fins have 1 spine and 5 soft rays and are of ordinary size. The anal fin is made up of soft rays and its form is roughly similar to that of the second dorsal. Posterior to the anal, just as posterior to the second dorsal, there are finlets, but their number is usually one less than that of the dorsal ones. The caudal fin is large and strong and is shaped like the crescent moon. Its rays are extremely stiff and both the upper and lower lobes are of roughly the same shape. The angle formed by their longest rays is greater than a right angle.

The color on the back is generally black with an indigo tinge, somewhat lighter in some species, and the coloration changes markedly after death. The color of the back changes with excitement, and when the fish is caught it sometimes takes on more or less of a purplish sheen. The color of the back becomes progressively paler toward the belly and does not extend below the middle part of the sides. The belly is generally white and, depending on the direction of the light rays, in many cases has clearly discernible diagonal lines alternating with round or oblong spots. These markings are particularly conspicuous in juvenile specimens. The pectorals, second dorsal, and caudal fin generally approximate the coloring of the back, and in some species a development of yellow coloration can be seen on the second dorsal, the anal, and the finlets. The ventral fins are generally pale gray or colorless.

b. Internal morphology

i. Skeleton

The skeletons of the fishes of this family differ rather markedly from those of the fishes of the families Katsuwonidae and Cybiidae, but they show a close relationship to the

Katsuwonids. When we compare them, a course of development leading from the Scombridae through the Cybiidae to the Thunnidae is clearly apparent.

In the Scombridae the skeleton is generally frail and weakly articulated, while in the Thunnidae the skeleton is strong and the articulations are solid.

The skull is roughly pyramidal in shape and is pointed anteriorly. There are five conspicuous projections at the rear. Among these the occipital crest in the center is particularly conspicuous. Lateral to it are a pair of temporal crests. Lateral to these are the pterotic crests, and there are deep grooves between these projections. Looking at the form of the skull as a whole, its length is markedly less than in the Scombridae and Cybiidae and it is only a little longer than it is wide. The breadth of the skull is far greater than its depth.

There is one ethmoid bone located anteriorly and in the middle. Above it is the frontal bone, and to the side and rear are the prefrontals. Below are the vomer and the parasphenoid. On the left and right there are a pair of hornshaped projections, the ventral surfaces of which articulate with the maxillary. The prefrontal forms the anterior wall of the eye-socket, and in the center of it there is a foramen for the passage of the olfactory nerve. There is one vomer at the farthest anterior edge of the skull. Its anterior part is thickened and on the ventral surface of the center of the thick portion there are villiform teeth.

There is a pair of large frontal bones. They are fused together on the center line and form a bridge above the eye-sockets. Their anterior portions are flat, thin, and narrow, but the posterior portions are broad and are bent somewhat ventrally. The anterior portions cover the dorsal surface of the prefrontals completely and extend onto the posterior part of the ethmoid. The posterior part articulates with or is fused to the supraoccipital, the parietals, the sphenotic, the pterotic, and the alisphenoids. The posterior edges of the frontals are not fused together over the alisphenoids and form a conspicuous foramen.

The alisphenoids are paired bones which form the anterior part of the floor of the brain case. The left and right bones are not perfectly fused together, but form a large opening. The anterior parts of these bones connect with the frontals, the posterior parts with the prootic and basisphenotic, and the lateral portions with the sphenotic. On their dorsal sides they are in contact with the supraoccipital.

The parasphenoid is a long narrow bone which forms the greater part of the ventral side of the skull. Except for its anterior end and posterior portion it is almost free of contact with other bones. Its anterior end connects with the vomer, the frontals, and the basisphenotic. Near its posterior end two short wing-like projections extend laterally and connect with the prootic.

The supraoccipital is a somewhat longitudinally extended unpaired bone. Its anterior edge connects with the occipital, and laterally it contacts the parietals and epiotic. Posteriorly it gradually decreases in width and rests on the central suture line of the epiotic. This bone shows taxonomic characteristics. In this family the fishes generally have the projections of the supraoccipital well developed.

The parietals are a pair of flat bones anterior to the supraoccipital. Their anterior portion is surrounded by the occipital, laterally it is connected with the sphenotic and dorsally with the pterotic. Posteriorly they are in contact with the epiotic. The dorsal surface of this bone has one longitudinal projection which forms part of the temporal projection.

The sphenotic forms part of the lateral wall of the optic lobe. The lateral portion of this bone forms part of the articulating surface for the anterior end of the hyomandibular.

The basisphenotic is the smallest of the bones of the skull. It is an unpaired, Y-shaped bone located between the prootic and the alisphenoid. A vertical projection on its center line is flattened laterally and connects with the parasphenoid, dividing the opening of the myodome in two.

The epiotics are on both sides of the posterior part of the supraoccipital anterior to the exoccipital. The posterior portions of these bones are joined in almost a straight line. These bones have projections which join with the temporal projections. On the inner surface of the brain case the epiotics are joined with the supraoccipital, the prootic, and the exoccipital.

The pterotic is a rather thin, somewhat elongated bone which forms the posterior lateral side of the skull. The anterior part of this bone is the pterotic process. On the ventral surface there is a large articulating surface for the hyomandibular.

The prootics are bones which can be seen only from the ventral side of the skull. In form they are rather large and extremely irregular. The right and left bones are attached right on the center line of the ventral surface of the brain case, and they are firmly fused to the various bones that form the brain case, but they are not enclosed by the supraoccipital and the parietals. They have thin vertical and horizontal processes, the vertical ones being high and twisted.

The exoccipital corresponds to the neural spine of the vertebrae. It surrounds the foramen magnum and protects the anterior end of the spinal cord. It can be seen from both the dorsal and ventral surfaces of the skull. This bone is surrounded by the epiotic, opisthotic, prootic, and basioccipital, and is also slightly in contact with the pterotic and the supraoccipital.

The opisthotic forms the posterior portion of the brain chamber. It is visible both from the ventral and from the dorsal sides, and is external to the exoccipital. Its anterior portion and outer sides are in contact with the prootic and pterotic bones.

The basioccipital is a bone directly under the floor of the foramen magnum. It has a concave occipital condyle on its posterior portion. It joins dorsally with the exoccipital, anteriorly with the prootic, and ventrally with the parasphenoid.

The nasal is a somewhat elongated bone, flat in form. Its posterior portion is fixed to the anterior edge of the frontal, and posteriorly it rests on the palatine.

The preorbital is an elongated flat bone beneath the eye. It has an articulating surface for articulating with the process on the ventrolateral side of the prefrontal. The dorsal edge of this bone is rather thick, but the ventral edge is extraordinarily thin. It protects the lower surface of the eye.

The suborbitals are thin flat bones arranged in a circle posterior to the eye. They are inconspicuous bones which are not greatly differentiated from the scales of the cheek.

The premaxillary is a long curved bone with a greatly thickened anterior end. The posterior portion, however, is flattened and narrow and is without any marked peculiarities such as grooves and so forth.

The maxillary is also a long narrow curved bone. Its anterior tip is thick and has a concavity. It rests on the premaxillary.

The palatines are on the outer sides of the vomer and are fused to the anterior end of the maxillary. Palatine teeth are developed on them. The pterygoid is a T-shaped bone which is joined by its small horizontal axis to the palatine. The posterior end broadens and joins to the inner surface of the metapterygoid and the quadrate. The mesopterygoid is a flat thin bone which is joined to the palatine and the pterygoid. Its inner edge rests on the parasphenoid. There is a band of villiform teeth on this bone.

The hyomandibular is a strong bone. Its upper portion is broad and its lower part is somewhat rod-shaped. The anterior and superior parts have two articulating processes which articulate with the palatine /?/. Posteriorly there is another process which articulates with the opercle.

The metapterygoid is broad; its dorsal edge is bifurcate and embraces the rod-shaped portion of the hyomandibular. The quadrate is flat and roughly triangular in form. At its anterior corner it has a marked saddle-shaped portion for articulation with the lower jaw. Its lower side has a shallow groove to receive the anteroventral portion of the preopercle. The symplectic is a small bone. Its anterior portion is sword-shaped and fits into the lower part of the quadrate, but the posterior portion is more or less flat. The lower edge is thick and is connected by cartilage to the lower end of the hyomandibular.

The articular is a stout bone which, together with the dentary, forms the lower jaw. It has three processes projecting anteriorly. The upper and lower processes are small with gradually tapering tips. The middle process is large and its tip is embraced by the dentary. Posteriorly it has a large concave articulating surface which articulates with the quadrate. The small angular bone is firmly attached to the posterior inferior portion of this bone.

The dentaries form the tip of the lower jaw, the right and left bones articulating at the tip. The posterior part is large and bifurcate, embracing the middle process of the articular. On the dorsal surface of this bone, that is the portion which is opposed to the upper jaw, there is a single row of sharp teeth which are curved inward.

Of the various bones which make up the gill cover, the opercle is a flat bone roughly square in shape. Its anterior angle has an articulating cavity for the hyomandibular. The subopercle presents a rather triangular form. Its upper edge is covered by the opercle, its anterior edge by the interopercle, and its posterior edge is free. The interopercle is oval in shape; its lower edge is slightly serrate and forms the lower edge of the gill cover. This bone is joined to the posterior end of the hyoid arch by a ligament. In the tuna (black tuna) its posterior edge is convex but in the other species it is fairly straight. The preopercle is a large curved bone, the vertical edge of which fits into a groove in the hyomandibular while its horizontal edge is joined to the pterygoid and quadrate.

Of the various bones that make up the hyoid arch, the glossohyal is a single small bone which is buried in the tongue. It is roughly spatulate in shape and its upper and lower edges are almost straight. The hypohyal is posterior to the glossohyal and the right and left bones are fused together. This bone is made up of two pieces, an upper and a lower. The upper is narrow and the lower is broad, covering a good deal of the upper one. The ceratohyal is one long flat bone with a broad posterior tip. Its upper edge is concave and there is a long process on the lower anterior edge. This bone and the epihyal are joined by fine serrate indentations and projections. The four most anterior of the branchiostegal rays are supported on this bone. The epihyal is a flat triangular bone located posterior to the ceratohyal to which it is bound by fine dentate processes. This bone supports the remaining three branchiostegal rays. The interhyal is a small triangular bone which joins the hyoid arch to the hyomandibular and the symplectic by means of cartilage. The urohyal is a flattened elongated bone which increases in width posteriorly. Its anterior end is joined to the hypohyal, while its posterior end is free but has a surface for the attachment of the muscles of the isthmus or the throat. There are seven branchial bars, flattened, slender, curved bones which become broader, longer, and more curved posteriorly.

Of the various bones that make up the branchial arches, the basibranchials are made up of three bones joined together in a straight line. The first bone is joined to the ceratohyal, the second is short with an oblique groove on each side, supporting the first gill arch. The third bone is the longest and near its anterior end there is an oblique groove like that of the second bone. It supports the second gill arch. The hypobranchial is a short bone attached to the sides of the second and third basibranchials. The ceratobranchials are extremely long, roughly equal in length, and have a groove on their lower surface. The epibranchials are short and much curved. The upper and lower pharyngeals are generally narrow bones.

The pectoral girdle or shoulder girdle is made up of a group of so-called membrane bones. Its upper part is attached to the skull; it cuts off the anterior part of the abdominal cavity and at the same time supports the pelvic fins. Among these bones, the posttemporal is a well-developed bifurcate bone. Its dorsal limb is flat and is supported on the epiotic, while its ventral branch articulates with the central node of the opisthotic. The supraclavicle is a small oval bone with its anterior end more or less pointed. Its lower edge is thickened. The anterior part of this bone joins the posterior projection of the posttemporal and the main part of it rests on the broad portion of the clavicle. The clavicle is a large curved bone. Its dorsal end is broad and its ventral end is thin and pointed. The main body of the bone is made up of two wing-shaped parts, an inner and an outer, which meet at roughly a right angle. The lower part of the outer wing-shaped process is not very greatly developed. The hypercoracoid is a small flat bone, the upper inner surface of which articulates with the clavicle, and there is a round hole in the center of it. The hypocoracoid is located below and in contact with the hypercoracoid and the anterior angle of its dorsal portion joins the clavicle. The inferior projection is broad and uniformly thin. The postclavicle is made up of two bones, the anterior and superior of which is lamellar and rather kidney-shaped. The posterio-inferior one is broad anteriorly and somewhat lamellar with sharp projections. Posteriorly there is a long sword-shaped process. This process is usually remarkably large.

The pelvic girdle is a pair of bones that support the ventral fins. These bones are buried in the abdominal wall. The right and left bones are joined together and are composed of an anterior external portion, an anterior internal portion, and a gladiate process. The juncture between the right and left bones involves the anterior internal portions and the gladiate portions.

The vertebrae number is 39 in this family of fishes. Of these 18 are abdominal vertebrae and 21 are caudal vertebrae, so the formula is $18 + 21 = 39$. All of the vertebrae are firmly articulated with each other, and except for the most posterior, that is the two directly anterior to the caudal fin, they can hardly move to the left or right. As noted above, there is not too great a difference between the numbers of the abdominal and caudal vertebrae, but the hemal spines are also well developed on the abdominal vertebrae so it is rather easy to mistake them for caudal vertebrae. It will be noted also that the hemal spines of the anterior abdominal vertebrae are curved forward. The form and structure of the vertebrae differ markedly depending on their position. These differences are most marked at the anterior and posterior ends and are inconspicuous in the central part of the spinal column. Four pairs of processes are well developed, but the anterior neural process is particularly so. Some of the abdominal vertebrae also have lateral processes. The first vertebra is very short and is firmly joined with a serrate suture to the posterior part of the skull in such a way that many scholars have overlooked it.

The ribs are developed on vertebrae posterior to the second one; they are broad and compressed.

ii. Viscera

The air bladder is generally well developed, but it is lacking in the *koshinaga* (*Neothunnus rarus*). The air bladder of the albacore is slender and extends the whole length of the body cavity with a swollen portion at the anterior tip on the dorsal side on the center line of the body. In the tuna (black tuna) the bladder is broad and triangular in shape with its anterior edge forming a straight line. The bladder in the big-eyed tuna is slender and extends the whole length of the body cavity. It has two swellings at its anterior tip. In the yellowfin it is simply a slender sac protected by thick connective tissue.

The mouth is large and the oral cavity is gray or black. There is no boundary between the oral cavity and the throat. The esophagus is rather long with thick muscular walls and it is clearly marked off from the stomach.

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*Figure 1.--Dissection of a tuna (abridged from Kishinouye 1. kidney, 2. intermuscular bones, 3. lower branch of subcutaneous blood vessel, 4. upper branch of subcutaneous blood vessel, 5. liver, 6. pyloric caeca, 7. air bladder, 8. stomach, 9. spleen, 10. cloaca, 11. anus.

Figure 2.--Outward appearance of livers Left to right: black tuna, big-eyed tuna, yellowfin

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The stomach is extraordinarily long and is conical in shape, reaching to above the anus. The pyloric orifice opens near the cardiac orifice on the left side of the stomach. The walls are thick and tough with conspicuous longitudinal folds, 30 - 40 in number. Pyloric coeca are well developed. Although the individual coeca are small, together they form a large mass. Each coecum does not open individually into the duodenum, but they open into 5 - 10 ducts of unequal length which connect with the duodenum. The intestine is slender and fairly long and has three bends. The small intestine and the rectum are both of roughly the same size.

The liver is brown and covers the anterior part of the ventral side of the stomach. It is divided into three lobes of approximately equal size, and in the /black/ tuna the surface has many small veins set closely together. Irregular branch lobes may be seen. In the big-eyed tuna a small number of short venules appear only around the margins, and in the yellowfin no venules appear.

The gall bladder is a conspicuously elongated sac which runs along the intestine on the inner side of the left lobe of the liver. Its color is generally greenish. The spleen is elongated in form and somewhat flattened, and it is closely attached to the vicinity of the boundary between the duodenum and the small intestine.

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*Translator's note: The figures in this paper, except for a few graphs, have been omitted as they were too poorly reproduced to copy. The captions have, however, been retained to mark the locations of the figures in the original text.

There are four gills and the pseudobranchiae are well developed. The gill filaments are set closely together and their length is roughly equal to the upper limb of the first gill arch. The gill-rakers are well developed. The gill cleft is extremely large; the gill membranes of the left and right sides are separate from each other and also from the isthmus.

The heart is generally large in comparison with other fish, and a large amount of blood and a large number of blood vessels are characteristic of these fishes.

The kidneys are concentrated in the pectoral region. This is especially marked in the case of the black tuna and the albacore. In the other species these organs are slender and extend along the dorsal surface of the body cavity.

The urinary bladder is generally small, but in some species it may be conspicuously developed.

The gonads are paired and lie on the dorsal surface of the body cavity. The ovaries when ripe are very long and also quite thick. The testes are generally slender and irregular in shape.

c. Ecology

i. Outline of habits

The fishes of this family are generally large and migrate through the open sea forming great schools. The majority of them are fishes of tropical seas, but, depending on the season, when the environment becomes suitable they migrate into the waters of fairly high latitudes. They generally occur in the deep layers during the daytime, but they characteristically come to the surface at night. This habit is common to fishes in general and is not limited to the fishes of this family. It is thought that the reason for it is related to the vertical movement of plankton and the corresponding vertical movement of small animals.

These fishes often swim in the surface layer during and directly after the spawning season, but it is said that at such times they are extraordinarily active and difficult to catch. It is known that they have the characteristic of frequently leaping on the surface of the water, it being said that the big-eyed tuna in particular has the strange habit of leaping at dawn.

Generally they migrate ceaselessly in the open sea, but at times they become "shoal fish" and remain for a period in the vicinity of hidden reefs or elevations of the ocean floor.

When their movements are restricted by their being placed in a confined space or caught in a net or on a hook, their resistance is very weak and they die in a short time. Ordinarily just before they die they are seen to go into violent convulsions.

They are fearful of nets and so forth, and they will not, until danger threatens, try to get out of nets which have such large meshes that they could easily pass through them. For this reason even though the meshes may be very large in the leads of trap nets, they are able to cut off the movements of the fish and direct them into the trap.

According to Dr. Kishinouye, in their migrations the males first appear most abundantly, then the females gradually increase in numbers, and finally the females become most numerous.

ii. Food habits

The tunas are carnivorous and are generally voracious. As fish which swim in the open seas, they have in general the feeding habits of plankton-feeders. In many cases they feed on planktonic crustaceans, argonauts, and the small fish which accompany floating logs, and such things as jellyfish are also found from time to time in the stomach contents. In the overall picture squids are the most numerous, but in the last analysis it is probably correct to consider that they feed on whatever animals are most abundant and easiest to catch in the waters in which they occur. Consequently, even assuming that they have taste in foods and that they select what they eat, it is hard to believe that these characteristics are very pronounced.

When it comes to large tuna, there are cases where they have eaten mackerel and frigate mackerel up to 40 cm. in length, and judging from their position in the stomach it is thought that they are swallowed head first. An examination of fish which have been eaten in this fashion commonly shows scars from bites on the trunk, and therefore it is thought that the tuna first bites from the side and gives a fatal wound after which it swallows its prey.

In general they eat live food, but they are not limited to such food, and in the case of bait used on hooks they will take dead or even salted fish. When they are moving on the surface of the water they will even bite on artificial lures. When they take the bait they are said to attack it at extremely high speed and then to dive deep turning obliquely to the rear. If we consider the manner in which the fish actually move when they are hooked on longlines, the spearfishes and sharks for the most part attempt to escape horizontally and in their struggles they tangle the branch lines, but the tunas generally try to escape in a vertical direction and thus rarely tangle the lines. They are extraordinarily strong, and it is not unusual for a large black tuna to drag a glass ball float 30 cm. in diameter deep down into the water, sometimes so far that it is burst by the water pressure.

According to Dr. Kishinouye, the tunas do not seek food on the bottom of the ocean, but it appears that one cannot make an absolute statement to that effect. As a concrete example, the author has seen dead leaves and gravel among the stomach contents of several yellowfin. Since these yellowfin were taken in the vicinity of Halmahera I. and Sangi I., it may be thought that there is a possibility that these fish seek food on the bottom near small islands and reefs. Of course, it is hard to believe that these dead leaves and gravel were eaten by the yellowfin as food, so it should probably be considered that they were swallowed along with some animals from the bottom.

Figure 3.--Juvenile [black] tuna (after Gamahara)

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iii. Spawning and growth

The facts that are known concerning the spawning of the fishes of the family Thunnidae are extremely few, only a certain amount of information being available in regard to the black tuna and the yellowfin.

The spawning season of the black tuna which migrate into Japanese waters is thought to be about June to July, and it is believed that they spawn in the offshore waters of the Pacific. Dr. Kishinouye says "in June and July the gonads become extraordinarily large and the fish congregate at the surface, frequently showing their dorsal fins above the water. This phenomenon is seen in the northern coastal waters of Japan on both the Pacific and Japan Sea sides. These ripe fish are mixed in with immature fish. I have not yet seen any completely ripe gonads, but in August the gonads are already spent. For these reasons it is thought that the black tuna spawn in the offshore waters. In late summer and early autumn small juvenile fish appear off southern Kyūshū and central Honshū, however, tuna with ripe gonads are unknown from these waters. Ripe adult fish are seen farther north, but it is hard to believe that these juvenile fish have migrated down from the north." Kawana (1935) has also reported spawning in the Japan Sea.

At the time when Dr. Kishinouye voiced the above views, the southern limit of the distribution of the black tuna was thought to be in the waters adjacent to Tanegashima. In 1935 it was ascertained that the black tuna also occurs in the waters of Formosa and the Philippines.

The schools which migrate into Formosan and Philippine waters are markedly larger than those which appear in southern Kyūshū in the winter, and it is believed that they belong to a different age group. The spawning season in this area is thought to be about 2 months earlier than that in Japan or from the middle of April to the middle of May. The author has obtained completely ripened ovaries from northwest of Lingayen Gulf in the middle of May. Many well-ripened ovaries and testes have also been collected from northeast of Luzon in May.

Since the time when Dr. Kishinouye made the above-quoted remarks it has been completely unknown whether or not the black tuna spawns in the waters of the Formosan and Philippine areas. In recent years migration of black tuna into the waters adjacent to Tanegashima has almost ceased, but there appears to have been little change in the occurrence of juvenile fish in late summer and early fall. If it is assumed that there have always been in the past migrations into the Formosan and Luzon areas, and that spawning has taken place there, Dr. Kishinouye's doubts, as quoted above, can probably be easily resolved.

Dr. Kishinouye felt some doubt concerning the proposition that in the waters adjacent to Japan the juvenile fish appear to the south of the waters in which spawning takes place, and wrote that he found it hard to believe that the juvenile fish migrated down from the north. If, however, it is assumed that these fish also spawn in the Formosan and Philippine areas, considering the pattern of the ocean currents there is nothing at all strange in the appearance of the juvenile fish off southern Kyūshū.

As will be explained later in the section on the spawning habits of the spearfishes, the spawning of these fishes extends over an extraordinarily long period, and is carried on over a wide area of ocean, it is believed. We say that it extends over a long period of time, but this applies to the organized schools in general and does not mean that the spawning of one individual lasts over a long period. As Dr. Kishinouye has also explained, the schools are made up of individuals having their gonads in various stages of ripeness, and it is thought that they carry on their reproductive activities successively beginning with the ripest. Spawning habits of this sort are peculiar to these fishes, and are considered to have an important significance in determining the character of the stock and the fishery.

The ova in ripe black tuna ovaries are 0.85 mm. in diameter. The eggs as a whole are clear and almost colorless with one oil globule of a rather deep yellow color. Around the oil globule there can be seen a pale yellow nimbus. The ova are perfect spheres, no structures being visible on the vitelline membrane. The figure differs depending on the size of the fish, but in an individual of 270 - 300 kg. the number of ova ripened at one time is 1,000,000.

Nothing at all is known as yet of the form of the larvae just after hatching, nor of the course of development that they follow. In late summer fish of about 250 mm. body length and 20 gr. weight can be taken on pole and line. Such fish are called imoshibi in Miyazaki Prefecture, kakinotane in Kanagawa, and abuko or bintsu in the Mie Prefecture area. On fish of this size 10 - 15 pale stripes can be seen on the sides. These transverse bars are divided into two on the belly, and they gradually fade out as they approach the midline of the belly. By winter they are already about 400 mm. in length, by the following spring they are 600 mm., and by summer they have grown to about 2 - 3 kg. In Formosa around February fish about 400 mm. in length are taken only very rarely, and the larval stages are almost never seen. At this stage they often form schools together with frigate mackerel, and their food is mainly planktonic crustaceans.

As noted above, the growth of the black tuna is extraordinarily rapid.

No concrete data have as yet been obtained concerning the spawning habits of the albacore, the big-eyed tuna, and N. rarus.

For the yellowfin too, no exact information has been obtained other than the hypothesis that they probably spawn in the warm seas of the south. In recent years in Formosa the author has collected a large number of eggs from ripe ovaries. The season has been around March - May. The yellowfin taken in the South China Sea at about that time generally have well ripened gonads, and from this circumstance it is thought that in these waters the spawning season of the yellowfin is around March - May. In the series of enclosed seas composed of the Celebes Sea, the Banda Sea, and the Flores Sea, it appears that spawning also occurs, with the seasons apparently overlapping somewhat.

The form of the eggs is absolutely the same as that of the eggs of the black tuna, and it is difficult to distinguish them by their outer appearance.

From April to June the so-called kimeji [small yellowfin] appear in large numbers off the east coast of Formosa where they are taken in trap nets. They are about 500 mm. long. Such fish are also taken in the Okinawa area about the same time.

iv. Distribution and migration

As has already been stated, the fishes of this family are widely distributed in the open seas, and they generally inhabit warm waters. Many species have been reported from all of the oceans of the world, and it is thought that among them there are quite a few which are the same species under different names. As a result of recent studies it is thought by some that the species in Japanese waters are the same as those which occur in the Indian Ocean and the Atlantic.

The albacore shows an extraordinarily broad range, occurring throughout all of the warm waters of the Pacific and Indian oceans. It is a markedly pelagic species and has not yet been reported from the Japan Sea. Nor is it plentiful in the South China, Sulu, Celebes, and Flores seas, a series of waters having the characteristics of enclosed basins. The northern limit of their distribution in Japanese waters is in the vicinity of 43° N. Around late autumn they gradually migrate to the southwest, and in the winter they are plentiful between 30° and 34° N., the fishery being active in the waters of the Izu Is., the Kinan Sea Area, and off Tosa. The most notable of the fishing grounds is that east of Nojimazaki in the area centered around 30° N. and east of 150° E. In spring the albacore begin their migration to the north, and it is said that this migration follows that of the black tuna and precedes that of the skipjack.

Among the various sea areas of the south, in the South China Sea the fish appear around February - March, but their distribution is mostly limited to the vicinity of the Bashi Strait. Almost nothing is known as yet of their distribution and migrations in such areas as the Sulu, Celebes, and Flores seas. In the former Japanese mandated area, that is the equatorial central Pacific, the albacore taken on the yellowfin longlines are about 1 percent of the total catch (tunas and spearfishes only).

The black tuna is the most common tuna in the waters adjacent to Japan. During the winter they are taken scattered generally over the area in the vicinity of 30° N. As a fishing ground the vicinity of Tanegashima has been noted in the past, but lately it has become almost impossible to find the fish there. In the past they began to appear sporadically around Tanegashima about December and the schools gradually became denser as the days passed, the peak season in these waters lasting until about February. Thereafter the fish gradually moved north with the Kuroshio, a part of them going along the Tsushima Current into the Japan Sea, traveling for the most part through the coastal waters of Japan. When the power of the warm currents was great, the fish sometimes passed through the coastal waters of Hokkaido and reached the western shores of Karafuto.

The tuna which move north along the Pacific side pass through the waters off Sanriku by summer and reach Hokkaido and the Kuriles. During this northward migration their route lies very close to land and they are taken abundantly in traps. It is also said that they generally swim close to the surface. They remain in the Hokkaido area until autumn, and then with the falling temperatures they turn southward. It is thought that at this time they take a route farther offshore and swim at somewhat greater depths.

There are schools which are believed to make a migration completely different from this. These are the schools which appear in the Formosan and Philippines regions. The reasons for thinking them a different population are their aforementioned markedly greater size, their having a markedly later season for migration, and the difference in spawning season.

In the schools which appear in the waters adjacent to Luzon and Formosa the fish are generally of large size, those taken at the beginning of the season being almost all over 300 kg. As time passes they gradually become smaller in size, but even at the end of the season fish of less than 150 kg. are extremely rare. However, according to Dr. Kishinouye's observations on the tuna taken in the vicinity of Tanegashima, a fish as large as 150 kg. would be considered to be on the big side. The fishing season in the Luzon and Formosan waters has in recent years gradually been becoming earlier. The fish appear in the northern part of the South China Sea in the middle of February in early years and ordinarily in the middle of March. The schools suddenly become densely concentrated both on the east and west in an area centered around the Bashi Strait, and in April and May the fishing season is at its height. In other words, the season is more than two months later than in the Tanegashima waters. In June when fishing in the South China Sea area is coming to an end, the fishing grounds shift into the area of the Kuroshio. Then there are no longer any concentrated fishing grounds, but catches are made scattered over a broad area, showing that the schools are moving north.

The above two strains, considering the size of the fish that compose them, are thought to be clearly two different age groups. Since, however, it appears that the schools which appear in the south also move north along the Kuroshio, it would be hard to say definitely that there are no fish from the south among the large tuna that are taken in the Hokkaido area in the summer and fall. Up to now the relationship between these two strains has been completely unknown. This is particularly the case now that there is no method of making a comparison, since in recent years it has got so that the schools do not appear in the vicinity of Tanegashima at all.

There are no reports at all yet from the central Pacific, particularly from the Ogasawara area. If it is assumed, for example, that the schools which are in the Hokkaido area during the summer and autumn move south and appear in the Bashi Strait region, it may be thought that there is a possibility that their route touches the region of the Ogasawaras. The need for a thorough survey of this area is keenly felt.

This species is also known from Hawaiian waters. An extremely similar species is also known from the Pacific coast of America, and there is another similar species in the southern hemisphere. It is thought by some scholars that these species and the one in the Atlantic are all the same species. In any case, there is a necessity for a thorough study of the question of whether or not these are after all the same identical species. Assuming that they are all the same -- which may well be believed to be the case -- unless their inter-relationships are thoroughly studied it will be impossible to give a theoretical explanation of the decline of the stock in the waters adjacent to Japan.

The big-eyed tuna has much stronger pelagic characteristics than the black tuna, and no proof has been given of its being distributed in the Japan Sea. The northern limit of its distribution is 43° N. It is broadly and generally distributed in the waters to the south, but its density is roughly uniform with no great differences.

The other tunas differ in their distribution mainly with regard to latitude, however, it is an interesting fact that not much change with latitude in the distribution of the big-eyed tuna can be perceived; there appears to be a tendency for their occurrence to be mainly related to the longitude (figure 4).

In figure 4 the range from 120° - 180° E. has been cut into sections of 5° of latitude and the longitude has been marked off at every 2°. Then the catch rate for each division of 5° of latitude by 2° of longitude has been calculated from the records of investigations carried on there. There is no great difference in the curve with regard to the latitude, but there is clearly a slope from east to west. In other words, the catch rate gradually increases toward the heart of the Pacific.

The yellowfin is the representative tuna of the tropical sea areas. It also occurs in enclosed sea areas and is known from the Japan Sea, although it is rare there. The northern limit of its distribution in the western Pacific is around 35° N., rarely reaching to 40° N., however, it is rather exceptional for it to reach this far north, and it is almost without significance as an object of the longline fishery. Its possession of a certain amount of significance in the longline catch varies with the season, but at the farthest it extends to the vicinity of 30° N.

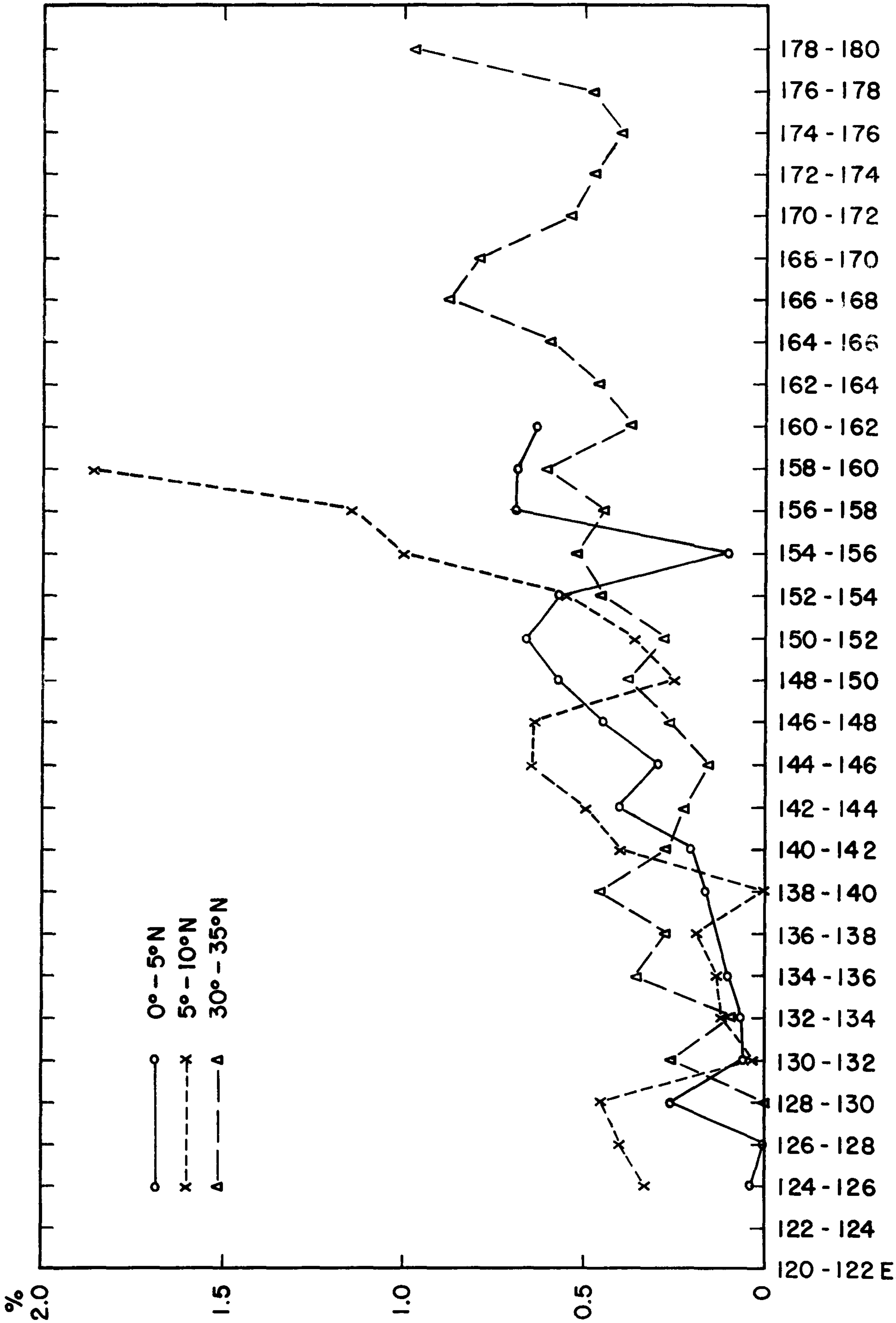

FIG. 4 BIG-EYED CATCH RATES

When they migrate north in the summer these fish sometimes enter the coastal waters, and they generally swim in the surface layer. When they are young they sometimes form mixed schools with skipjack, and sometimes school separately by themselves.

In the general view, the densest occurrence of the yellowfin is in the area of the Equatorial Countercurrent, and its north-south extension is comparatively narrow. In the Indian Ocean area, too, its densest distribution is in the vicinity of the Equator. Among the fish of the open seas in these low latitudes small individuals generally predominate, and it appears that those of around 30 - 35 kg. are most numerous. The fish which occur in subtropical sea areas and in enclosed waters are generally larger in size, with an apparent tendency for individuals of around 40 - 50 kg. to predominate. It is impossible under present conditions to state definitely whether or not such a phenomenon is conclusively established. If such were the case, it would be very interesting and would have an important significance ecologically.

In the case of the skipjack also, a roughly similar phenomenon is seen in that those which migrate widely in the open sea are said to be generally schools of young fish, while among those that occur in subtropical waters and enclosed sea areas mature fish are said to predominate for the most part.

Figure 5 shows the distribution of yellowfin with respect to latitude. In the figure the area from 140° E. to 150° E. is divided every 2° and the catch rate is calculated for each 10° of longitude and 2° of latitude on the basis of data from fishing ground surveys.

As the figure shows very clearly, the catch rates of the yellowfin tuna have a south to north slope. As it moves northward from the Equator the catch rate drops rapidly and reaches a low point in the vicinity of 10° - 12° N.

Around 20° N. a low peak appears, and northward from this point the catch rate gradually becomes lower. This figure shows the range from 140° E. to 150° E., but if the range of 120° - 160° E. is divided every 10° and the same sort of catch rate curve is drawn, the trend of the curves coincides perfectly, although there is some difference in the catch rates. In other words, the distribution of yellowfin tuna in the western Pacific does not show any great variation with longitude, that is in an east-west direction, but may be said to be related mainly to the latitude with north-south variation.

As noted above, the distribution of yellowfin is extremely dense in the vicinity of the Equator. However, as will be shown in a later chapter, the distribution varies a good deal seasonally and they are not distributed at all uniformly throughout the year. (See figure 10).

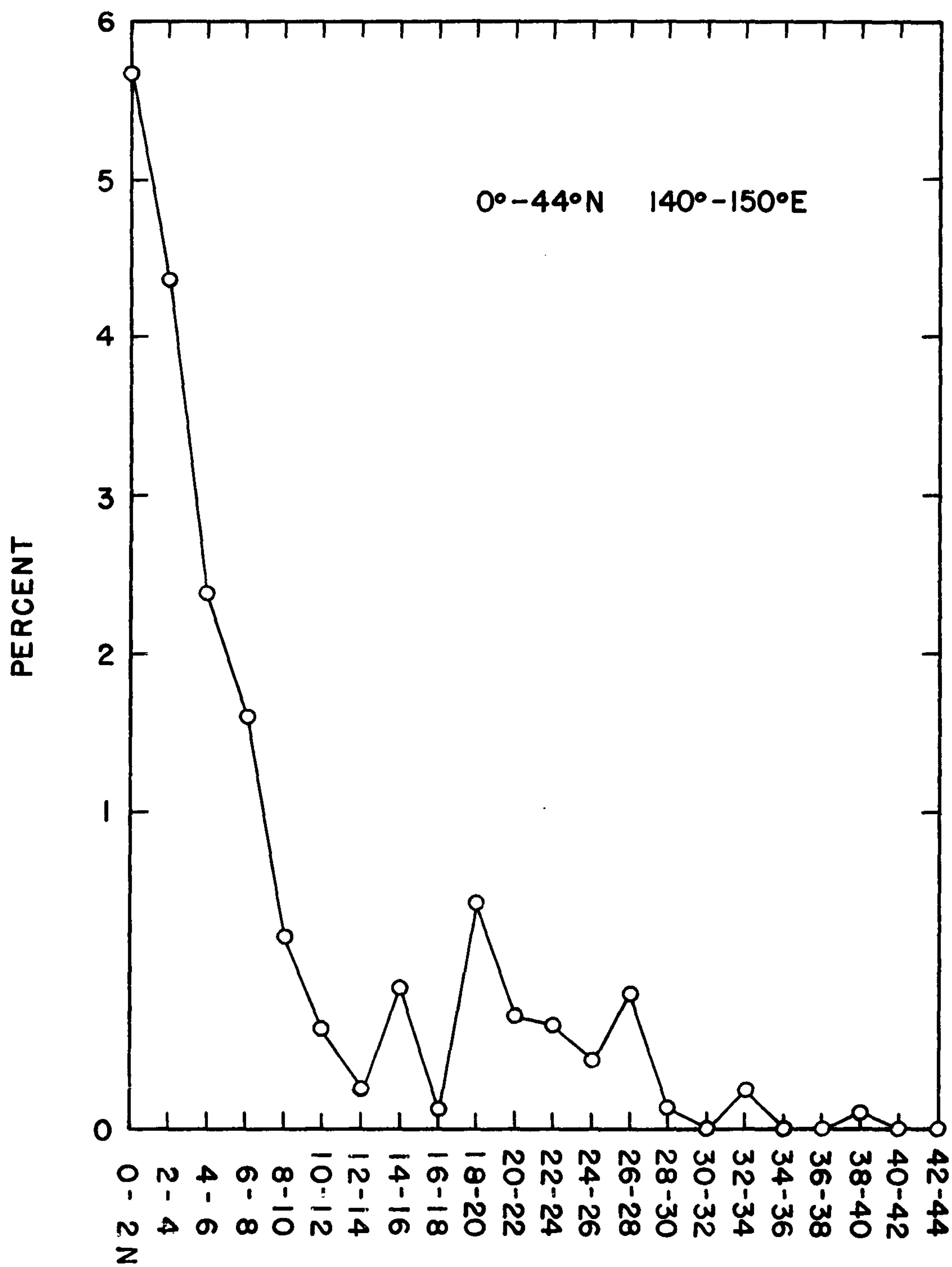

FIG. 5 YELLOWFIN FISHING BY LATITUDE

Even within the Equatorial Countercurrent the density of distribution varies with the season as has already been stated and as will be set forth in a later chapter. When the variations in the density of distribution in the northern and southern hemispheres are compared by means of the catch rates, there appears to be an increase in density in the summer in both hemispheres, but unfortunately because of the paucity of data from the southern hemisphere it is not possible to make a thorough examination of the correlation. For the northern hemisphere there are insufficient data on the situation in the vicinity of the Equator during the summer and so the picture is not very clear, but on the curve shown in figure 5 the peak which appears in the vicinity of 20^{o} N. is extraordinarily clear and a tendency can be detected for it to move about 5^{o} to the north.

Of course no conclusion can be drawn in any case because of the insufficiency of the data, but if the above circumstances are considered in conjunction with each other, it may be thought that the schools seem to carry out a great north-south movement centered around the Equator with the change of the seasons. If this were established as a fact, it would probably give rise to the conclusion that the yellowfin are a single stock. However, before that conclusion can be drawn there is a need for detailed and large-scale studies and surveys. Considered within the scope of the data actually available now, it is thought that even assuming that the stock itself is single, there must be a number of different age groups in different areas following differing routes of migration.

Dr. Kishinouye had the following to say of the scombroids:

> "Generally speaking of scombroid fishes, large and old are caught at the beginning of the season, while at the end of the season only young and small ones are caught.
>
> Generally the male fish come first, in the middle of the fishing season the number of both sexes is nearly equal, and at the end of the season the female fish predominate."

If these two quotations are combined, they must mean that the large, mature fish which are taken at the beginning of the season are males, the medium-sized ones that are taken in the middle of the season are equally divided between males and females, and the small ones taken at the end of the season are females.

Such phenomena may have an extremely important significance both to the study of the ecology of these fish and to the actual operation of the fisheries. The author has investigated a similar phenomenon in the spearfishes of the waters adjacent to Formosa. The results, interestingly enough, are completely opposite to the case of the scombroids, as will be shown later.

As regards similar problems with the yellowfin tuna, the author has only a little material and so cannot set forth any concrete opinion, but table 1 cites an example. In those fish which are of sizes to the left of the dividing line in the table, the sex ratio is close to 1 : 1, while in the larger ones there is a marked predominance of males. This condition corresponds to that cited by Dr. Kishinouye for the early part of the fishing.

Table 1. Sex ratios and size differences by sex

(yellowfin, June-September 1937, East Philippine Sea)

Weight (kg)	4/7	7/10	10/13	13/16	16/19	19/22	22/25	25/28	28/31	31/34	34/37	37/40	40/43	43/46	46/49	49/52	52/55	55/up	**Total**
Females	0	0	8	6	4	3	2	4	6	12	16 (61)	22	14	12	6	2	2	0	119 (58)
Males	0	1	8	2	4	4	5	3	8	10	18 (63)	30	35	42	26	17	12	2	227 (164)

Note: Figures in parentheses are the totals on each side of the vertical rule.

The distribution of N. rarus is not yet well understood, but in Japanese waters it is known only from southern Kyushu to the Nansei Shoto region. Of all the species of tuna, this one seems to have the greatest preference for the coastal water areas, and it apparently is seen commonly in the vicinity of tropical islands.

Figure 6 shows the distribution with respect to latitude of all of the tunas except the black tuna and N. rarus. The curves of the catch rates in the range of 140° - 150° east longitude have been drawn in the same way as in the preceding figures.

As is clear from the figure, the yellowfin plays a controlling role in the total catch up to the vicinity of 10° N. From about 10° - 24° N. the spearfishes determine the overall catch rates, and farther north the albacore has the greatest significance. The big-eyed tuna are somewhat more numerous to the south, but there is no great difference and they are thought to be distributed uniformly.

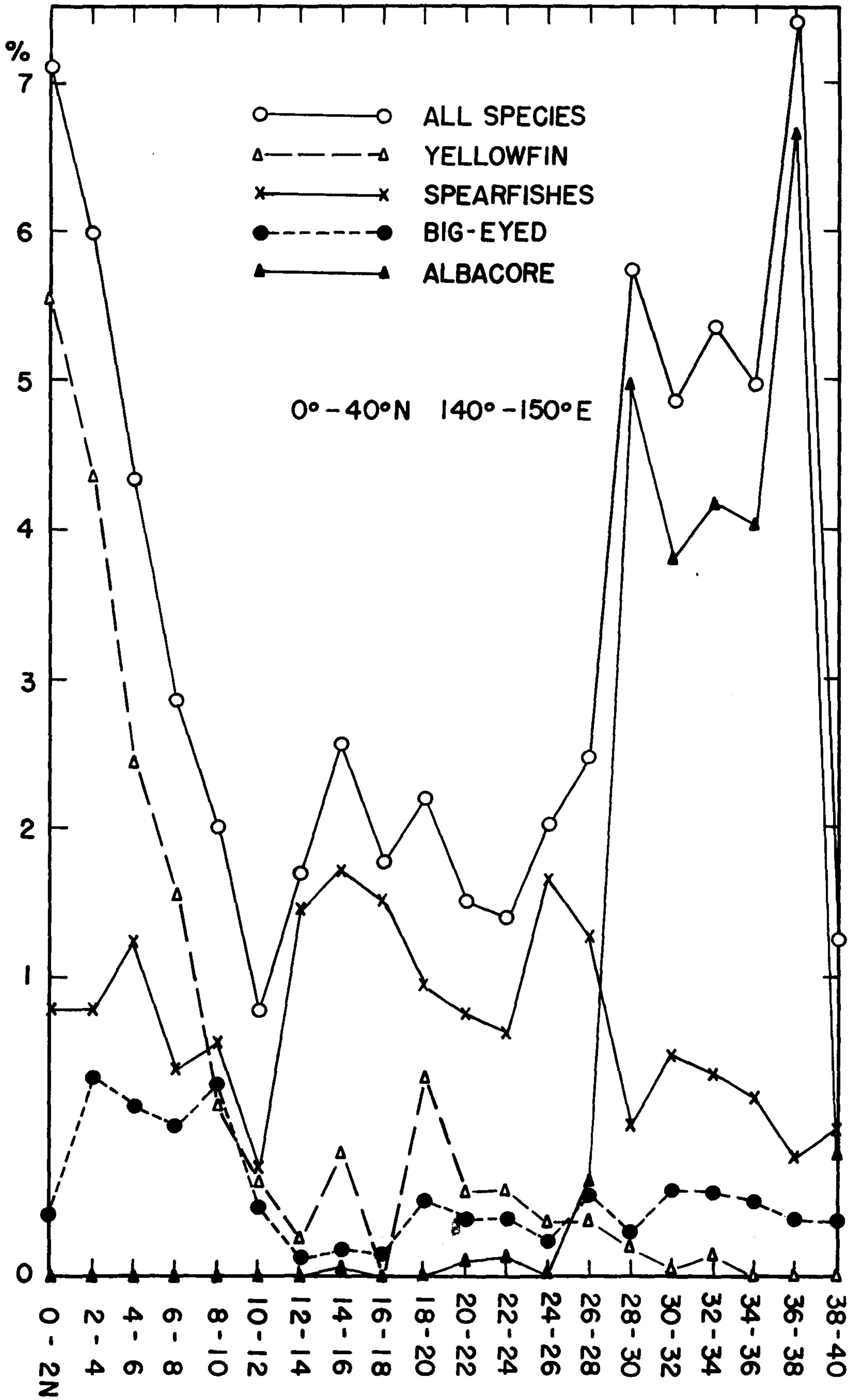

FIG. 6 FISHING AND LATITUDE

The question of the level at which the fish swim, that is the vertical distribution, is treated in a later chapter, but it differs with the species. Furthermore, for the same species it varies with the season and the area. It is thought that the factors controlling vertical distribution are probably temperature and the strength of the light rays, however, when it comes to the point of which of these factors is the most significant, it appears that this also differs with the area and no generally conclusive statement can be made.

Dr. Kishinouye has given a diagram of the vertical distribution of the tunas in Japanese waters, the essentials of which are as follows. The basis for these figures is not indicated, but probably they were calculated from the construction of the longlines used by fishermen.

albacore 0 - 80 meters
black tuna 0 - 58 meters
big-eyed tuna 0 - 58 meters
yellowfin tuna 0 - 57 meters

B. Taxonomy

The number of kinds of tuna that occur throughout the whole world is very large, but it is thought that among them there are quite a few which are the same species under different names. The following five species are the ones which occur in Japanese waters. Not a few scholars take the view that the majority of these are cosmopolitan species and that they are identical with the species of the Atlantic region. The author himself supports this view, with the proviso that there should be ample comparative study.

There is a detailed study by Dr. Kishinouye of the five species which occur in Japanese waters. He combined the families Thunnidae and Katsuwonidae to form the Order Plecostei, separating them from the Order Teleostei. The basis of his theory was the presence of a cutaneous vascular system in these fishes and the location of the so-called chiai [dark muscle tissue] close to the vertebral column. However, Dr. Takahashi (1924) pointed out the presence of cutaneous vascular systems in many other teleosts and proved that there was no reason for establishing the Plecostei.

At present the Plecostei is not adopted in the scientific world, but Dr. Kishinouye's studies of the scombroids have lost none of their value.

The taxonomy in this book is based on Kishinouye's with reference to the theories of other scholars.

Key to the Japanese genera

a. The cutaneous blood vessel passes through the myotome of the fifth vertebra. There are groups of small blood vessels on the surface of the liver .... a'

b. The subcutaneous blood vessel passes through the myotome of the seventh vertebra. There are no clusters of small blood vessels on the surface of the liver .... b'

a' Pectorals short, roughly equal to the head length, tips not reaching to beneath the anterior edge of the base of the second dorsal. Second dorsal and anal low. The number of gill-rakers is generally 12 ⨍ 35 = 37.... Thunnus

b'' Pectorals remarkably long, ribbon-like in shape, reaching to the anterior dorsal and anal finlets. The second dorsal and anal are of moderate height. Gill-rakers are 9 ⨍ 18 = 27 .... Germo

b' The posterior cardinal vein does not join with the Cuvierian duct. There are clusters of small blood vessels on the inner surface of the liver. The pectorals are long, reaching about to the posterior edge of the second dorsal base. The second dorsal and the anal are of moderate height. The dorsal and anal finlets are tinged with yellow but not bright. In most cases the gill-rakers are 9 ⨍ 18 - 27 .... Parathunnus

b'' The posterior cardinal vein and the Cuvierian duct join. There are plexuses of small blood vessels in the haemal canal. The gill-rakers are 6 -9 ⨍ 17-21 = 23 - 30 .. Neothunnus

Thunnus South 1845

The body is a long ellipse in outline and is very plump. The caudal peduncle is remarkably slender. The head is almost conical, and the mouth is large. In both jaws there is a single row of small conical teeth, and on the vomer and palatines there are minute villiform teeth and areas of sandpaper-like teeth. There are scales, and the corselet is indistinct. The pectorals are remarkably short. The gill-rakers in most cases are 12 ⨍ 25 = 37. There is only the following single species in Japanese waters.

Figure 7.--Thunnus orientalis.

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1. Thunnus orientalis (Schlegel)

This fish has the names maguro, kuromaguro, ōmaguro, kuroshibi, and gotōshibi, while the young specimens are called meji, yokowa, and kakinotane.

The first dorsal has 13 - 15 spines, the second dorsal has 14 soft rays and 8 - 9 finlets, the anal has 13 - 15 rays and 7 - 8 finlets, and the gill-raker count is 12-13 ≠ 24-26. The number of scales in one longitudinal row is about 230.

The body is stout, the posterior portion tapering rapidly toward the caudal peduncle. The body length is 3.2 - 3.5 times the head length and 3.2 - 4.3 times the body depth. The length of the head is 5 - 8 times the diameter of the eye, 3.2 - 3.7 times the distance between the eyes, and 3 - 6 times the snout length.

The pectorals are short and do not reach to below the anterior end of the second dorsal. They gradually taper to sharp points posteriorly. The height of the second dorsal is greater than that of the first and the two dorsal fins are not separated from each other. The anal fin is of approximately the same length as the second dorsal. The lateral line has a peculiar curve above the bases of the pectorals.

The air bladder is triangular with the posterior end pointed. The anterior edge is straight, broad, and thick. It is broad and extends completely across the width of the body cavity, but it is short and barely extends a little more than half the length of the body cavity.

The dorsal surface of the body is almost black, the anterior portion being particularly dark. Posteriorly it gradually becomes gray with a silvery sheen. The ventral surfaces are gray with a large number of colorless alternating lines and rows of spots arranged transversely across the body. The first dorsal is gray, and the tip of the second dorsal is tinged with yellow. The dorsal finlets are yellow. The anal and its finlets are silvery white, the pectorals are black, and the ventrals are gray.

The flesh is dark red in color and comparatively firm and it is prized in the winter for its flavor. In the summer after spawning the quality is lower and the price drops.

These fish grow to a very large size, and there are records of specimens 3 meters long and weighing 375 kilograms.

This is the most common species in Japanese waters, where it is taken both in the Pacific and in the Japan Sea. Early in the winter a number of them are taken in the vicinity of 30°N. west of the Bōsō Peninsula, but this is not a fishery which makes this species its special object. The fishery for this species begins around December in the waters adjacent to Tanegashima, with Aburatsu as a base. The fishing in this region is most active around February, and in March the schools begin to move slowly north. In midsummer they migrate from the waters off Sanriku to the coastal waters of Hokkaidō and reach the vicinity of 46° N. Nothing has been reported as yet concerning their distributions and migrations in the regions of the Ogasawara Islands and the former South Seas Government-General. From Formosan waters to the eastern and western coasts of Luzon they appear in the latter part of March, and from April to May the density of the schools is great. It appears that in late May and early June the schools in this region move into the area of the Kuroshio and go rapidly northward, disappearing from this region. The spawning season of the schools in the waters adjacent to Japan is thought to be around July, but in the Formosa region the schools spawn in April - May.

Looking at the migrational pattern in the Japanese coastal waters, the migrations of the albacore and the spearfishes follow that of this species, and when these fishes appear, the tuna season is drawing close to its end. In their northward migration the schools approach close to the coast and generally swim in the surface layer. In the autumn when the water temperature begins to fall they turn southward again, but at this time they swim offshore in rather deep layers.

They are voracious by nature, and feed on planktonic crustaceans, squid, and small fish such as sardines, mackerel, and frigate mackerel.

These fish are also said to occur in the Hawaii and California regions, inhabiting a wide range of water temperatures of $5^{\circ} - 28^{\circ}$. The most favorable temperatures in Japanese waters are thought to be $10^{\circ} - 15^{\circ}$ C.

This species is thought by scholars to be the same as the Atlantic *T. thynnus* (Linnaeus) and this name is applied to it. It may very well be the same species, but the author thinks that the decision requires a thorough comparative study with specimens from the Atlantic.

Germo Jordan 1888

The pectoral fins are very long, far exceeding the head length and reaching to at least the second dorsal finlet. They are ribbon-like rather than sickle-shaped in form. The length of the second dorsal and the anal is moderate. The gill-raker count in the majority of cases is $9 + 18 = 27$. One species of this genus occurs in Japanese waters.

Figure 8.--*Thunnus germo*.

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2. *Germo germo* (Lacèpéde)

This fish has the common names *binnaga*, *bincho*, *hirenaga*, *tombo* (or *tomboshibi*).

First dorsal with 14 spines, second dorsal with 14 rays, 8 dorsal finlets, anal with 14 rays, 8 anal finlets, gill-rakers $9 + 18 - 19$. Number of scales in one longitudinal row about 210.

The body length is 3.1 - 3.2 times the head length, and 3.5 - 3.7 times the body depth. The head length is 6.5 - 6.6 times the diameter of the eye, and 3 times the length of the snout.

The body is spindle-shaped and rather long, the head and eye are comparatively large, the caudal portion is short, the caudal peduncle tapers sharply, the scales are rather large, and the corselet is indistinct. The mouth is large, the posterior end of the maxillary reaching to a point directly beneath the anterior edge of the eye. There is one row of small conical teeth in each jaw, and there are areas of villiform teeth on the vomer, palatines, and pterygoid and on the tongue. The pectoral fins are ribbon-shaped and very long, reaching to beneath the dorsal finlets. The height of the second dorsal is equal to or slightly less than that of the first dorsal. The anal is of roughly the same shape and size as the second dorsal.

The dorsal surface of the body cavity is remarkably curved so that the cavity itself is narrow. The part of the liver that connects the various lobes is narrow, and there are many lobules on the edges of the lateral lobes. The anterior edge of the air bladder is rounded and its walls are rather thin. It is narrow but long, and extends the whole length of the body cavity.

The flesh is pink and soft and is tasteless when eaten raw so it has always been cheap in Japan, and the fishermen have called it "bait-stealer." However, in America it is called "Sea-chicken" and is prized for its flavor when canned in oil.

The dorsal surfaces of the body are dark blue, the part near the caudal fin having a green lustre. The belly is silvery white.

The fish is small for a tuna, individuals of 1 meter in length and about 25 kg. in weight being considered large.

The range of distribution is very broad, covering the warm waters of the whole Pacific and Indian oceans, and extending to the vicinity of 43° N. in Japanese waters. The water temperature in the waters which they inhabit ranges 10° - 28° C., and 10° - 25° C. is considered to be the range of favorable temperatures. They have strongly pelagic characteristics, hardly occurring at all in the Japan Sea and being scarce in the enclosed sea areas of the south. In winter they are plentiful in the vicinity of 30° - 35° N., giving rise to the well-known fishing grounds east of Nojimasaki and those of the Kinan Sea Area and the waters off Tosa.

According to some scholars this is the same species as the so-called albacore or germon of the Atlantic and they give it the scientific name G. alalunga (Gmelin). This view is probably correct.

Parathunnus Kishinouye 1923

The cutaneous blood vessel passes through the myotome of the seventh vertebra. There are no clusters of small blood vessels on the surface of the liver, and the posterior cardinal vein is not joined to the Cuvierian duct. The pectorals are long, reaching to the second dorsal, and the second dorsal and the anal are of moderate height. The head is large, and in most cases the number of gill-rakers is 9 + 18 = 27. One species occurs in Japanese waters.

3. *Parathunnus mebachi* (Kishinouye)

In Japanese *mebachi*, *daruma*, *darumashibi*, *mebuto*, and simply *bachi*.

First dorsal with 14 - 15 spines, second dorsal with 13 rays and 9 finlets. Anal with 13 rays and 9 finlets. Gill-rakers 8 - 10 + 18. Number of scales in one longitudinal row about 190.

The body length is a little more than 3 times the head length and 3.3 - 3.5 times the body depth. The length of the head is 6 times the diameter of the eye and 3 - 3.5 times the length of the snout.

Figure 9.--*Parathunnus mebachi*.

The body is remarkably stout with a short caudal region tapering abruptly to the caudal peduncle. The head and eyes are large. The dorsal profile is markedly curved, and the ventral outline is even more so. The anus is located about midway between the tip of the snout and the tip of the caudal fin. The scales are large, particularly those of the corselet. The lateral line forms a gently undulating curve above the base of the pectorals. The pectorals are long and taper gradually to their tips. In a fish of about 1 meter length the tips of the pectorals reach to beneath the first dorsal finlet, and if this line is extended vertically it will pass through the center of the base of the anal fin. In old fish these fins are shorter and they hardly extend beyond a point below the origin of the second dorsal. The second dorsal and the anal are of moderate size, comparatively narrow, and more or less falcate. They are of roughly the same size and shape and their height slightly exceeds that of the first dorsal. The posterior part of the first dorsal is generally convex.

The air bladder is well developed, and has two projections on its anterior edge. The kidneys are prolonged posteriorly. The intestine is the longest among the tunas, and its third loop is close to its first loop. In the liver each lobe is thick and triangular.

The dorsal surfaces are gray or blakish, while the sides and belly are silvery white. The dorsal fins are gray with their edges and tips only slightly tinged with yellow. The finlets are more or less yellow in color. The dorsal sides of the pectorals are black and their ventral sides are gray. Their tips are at times touched with yellow. The ventral fins are gray with yellow tips, the anal fin is white and its tip is yellow. The anal finlets are grayish white with their edges more or less tinged with yellow.

The flesh is pink and rather soft, and is considered to be rather inferior eating as raw fish. This fish is thought to occur at the deepest levels of any of the tunas. It is believed that the vertical distribution differs markedly as between night and day, the fish coming into shallower layers at night. The range of water temperatures in which they occur is thought to be 13° - 28° C., and they extend somewhat farther south than the black tuna and the albacore, while the northern limit of their distribution is supposed to be in the vicinity of 40° N. As they are an offshore species they do not occur in the Japan Sea, and in the southern seas they are scarce in enclosed sea areas and more numerous in the open ocean.

They attain a length of about 1.5 m. and a weight of 80 kg., and are the next largest species in size to the black tuna.

Neothunnus Kishinouye, 1923

The cutaneous blood vessel passes through the myotome of the seventh vertebra. The posterior cardinal vein joins the right Cuvierian duct. There are plexuses of small blood vessels in the haemal canal. Clusters of small blood vessels are completely absent from the surface of the liver. The vertebrae of the caudal region are elongated, and consequently even when viewed from outside the caudal region is long. The pectoral fins are long and reach to a point beneath the posterior edge of the first dorsal or even farther posteriorly. All of the finlets are yellow. Some individuals have air bladders and some lack them.

Jordan and Hubbs in 1924 separated from the species of this genus those which do not have air bladders and set up the new genus Kishinoella.

There are thought to be two or three species occurring in Japanese waters, but there has not been sufficient study of them as yet.

Key to the species:

(1) An air bladder is present. Number of gill-rakers 9 + 12 = 30. Pectorals long with their tips extending past the posterior edge of the first dorsal base. In mature fish the second dorsal and anal are remarkably long .... macropterus

(2) No air bladder. Number of gill-rakers 6 + 17 = 23. Pectorals short, their tips reaching to the vicinity of a point beneath the posterior edge of the first dorsal base .... rarus

4. *Neothunnus macropterus* (Temminck & Schlegel)

In Japanese *kihada*, *gesunaga*, *itoshibi*, *shibi*, and *kinhire*. Young individuals are generally called *kimeji*.

First dorsal with 12 - 13 spines, second dorsal with 14 rays and 9 finlets. Anal with 14 - 15 rays and 8 - 9 finlets. Number of scales in one longitudinal row approximately 270.

The body length is 3.5 - 4 times the head length, and about 4 times the body depth. The length of the head is about 7 times the diameter of the eye and about 3 times the length of the snout.

Figure 10.--*Neothunnus macropterus*.

The body is fusiform and long, the head is small, and the caudal region is long. The scales are minute. The pectiral fins are long with their tips extending posterior to a point below the origin of the second dorsal. In old specimens the second dorsal and the anal are greatly developed and somewhat threadlike, and they reach to the caudal peduncle or even farther back.

The air bladder is well developed, and has the form of a slender sac. The kidneys are elongated posteriorly and the ureters join below the thirteenth vertebra.

The dorsal surfaces are almost black with more or less of an indigo cast, the sides of the body are pale gray, and the belly is white, although in young specimens there are colorless oblique lines on the belly. The second dorsal and the anal are touched with yellow, and the finlets are completely yellow. The first dorsal fin is yellowish gray. The pectorals are black, but at times both they and the ventrals have some yellow color.

The flesh is a clear pink, firm, and delicious when eaten raw.

This species is widely distributed, extending generally over the Pacific and Indian oceans. In Japanese waters the northern limit of its distribution is in the neighborhood of 35° N., but it occasionally reaches 40° N. It is extremely rare in the Japan Sea. If the black tuna be taken as representative of the tunas in the waters adjacent to Japan, the yellowfin can be said to be the representative tuna of tropical waters. This species is the most important catch of the longline fishery in tropic seas, and although there is some variation with season and area, in general it comprises 80 - 90 percent of the total catch (exclusive of sharks). They are particularly numerous in the Equatorial Countercurrent, but they are also plentiful in enclosed sea areas. It appears that they spawn gradually over a wide area of the ocean. They spawn from March to May in the South China Sea area. They are said to prefer the highest temperatures of all of the tunas and for this reason they occur at shallow depths in Japanese waters, but in the warm seas of the south it appears that they are generally most numerous at about the 100-meter level and that they occur at even greater depths.

These fish attain a length of about 2,000 mm. and a body weight of about 70 kg.

5. Neothunnus rarus (Kishinouye)

In Japanese called koshinaga, bintsuke, hashibi, shiroshibi, and in Formosa seibanmaguro.

Figure 11.--Neothunnus rarus.

First dorsal with 13 spines, second dorsal with 14 rays and 8 - 9 finlets. Anal with 14 rays and 8 finlets. Number of scales in one longitudinal row about 220. Gill-rakers 5 - 6 + 15 - 17.

Body length 3.5 - 4 times the head length, about 4 times the body depth. Head length about 6 times the diameter of the eye, and 3 - 3.5 times the length of the snout.

The body is fusiform and deep with a long caudal portion. The head and the eyes are comparatively small and the snout is short. The scales are minute. The pectorals are short, their tips reaching to the vicinity of a point below the posterior edge of the base of the first dorsal fin. The second dorsal and the anal are not produced and are only slightly longer than the first dorsal. The ventrals are well developed.

In general they closely resemble immature yellowfin, but the gill-rakers are fewer and there is no air bladder. The coloration, too, is in general the same as that of the yellowfin, but a peculiar characteristic is that the finlets are yellow with gray edges.

The flesh is of an extraordinarily pale pink color and is somewhat soft. When eaten raw the flavor is said to be inferior to that of the yellowfin, but during the summer it is very delicious.

This is the smallest among the tunas, and individuals 700 mm. in length and about 7 - 8 kg. in weight are rather rare.

The species is distributed in Japanese waters from southern Kyūshū to southern Korea; it is seen commonly in the south and for the most part it occurs in the coastal waters.

Besides this species, Jordan and Evermann have reported Kishinoella zaccares from Hawaii. In this species the gill-rakers are more numerous than in rarus. In the waters of Formosa, too, there very rarely appear specimens with a gill-raker count of 8 - 9 + 18 - 20, but not enough study has been done to determine whether or not it is a different species.

II. SPEARFISHES

A. General

a. External form

The spearfishes are the fishes belonging to the two families Istiophoridae and Xiphiidae.

These fishes are generally large with elongated bodies. The fishes of the family Istiophoridae are more or less markedly flattened laterally, but the Xiphiidae show almost no lateral flattening. The caudal peduncle does not exhibit the marked abrupt taper of the tunas, and the keels on the peduncle are two pairs in the Istiophoridae and one pair in the Xiphiidae. The most remarkable characteristic of these fishes is the possession of a long projecting rostrum shaped like a spear or like a double-edged sword. This projecting rostrum is formed mostly by the premaxillary and in the Istiophoridae it is almost solid, but in the Xiphiidae the center is hollow with occasional membrane-like structures like the joints in a bamboo. The lower jaw also projects somewhat and its tip is sharp. In the Istiophoridae there are file-like teeth on both the upper and lower jaws, but no such teeth are developed in the Xiphiidae. The comparative lengths of the jaws differ in the various species, the ratio being 1.28 to 2.21 in the Istiophoridae, with the short-nosed spearfish having the smallest value and the black marlin the largest. In the Xiphiidae the difference is great, amounting to 4.5. The Istiophoridae have slender bony scales on the opercles and covering the whole body, where they are buried in the skin, but the Xiphiidae have no scales, there being only a section of the ventral surface of the pectoral region which feels rough to the touch. A lateral line is present in the Istiophoridae but is lacking in the Xiphiidae. The dorsal and anal fins each have two separate bases, although in juvenile fish they form a single base. The pectorals are located low on the body and are well developed. The ventral fins in the Istiophoridae have degenerated into filiform appendages composed of three rays firmly joined together, and in the Xiphiidae there is no visible vestige of the ventral fins. There are dermal grooves along the bases of the first and second dorsal fins, and the greater portion of these fins can be folded away into them. There is also a rather conspicuous groove along the center line of the belly from the base of the ventral fins to the neighborhood of the anus, and the ventral fins can be accommodated therein. The caudal fin is large, and both of its lobes are narrow and widely separated. If the lengths of the two lobes are compared, the lower is slightly longer than the upper. There are four gills on each side and there is an opening posterior to the fourth. The gill-rakers are not developed. The left and right branchiostegal membranes are joined in the Istiophoridae, but in the Xiphiidae they are separate and are both free from the isthmus. There are seven branchiostegal rays.

b. Internal morphology

Figure 12.--Diagrams of the structure of the rostra. a. Wahoo, b. Sailfish, c. Broadbill swordfish, d. Xiphiorhynchus, 1. premaxillary, 2. articular (ethmoid?), 3. nasal, 4. frontal, 5. maxillary.

Figure 13.--Cranium of black tuna.

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i. Osteology

In the general view, the skeletons of these fishes differ markedly from those of the Scombriformes, which they are supposed to be most closely related to, and furthermore the differences between the Istiophoridae and the Xiphiidae are also conspicuous.

If we compare the skulls with those of the Scombriformes, the frontals and prefrontals are notably wider. This form has probably arisen in order to support the long projecting upper jaw. The right and left frontal bones are closely joined together except at their most anterior parts. Their dorsal surfaces are generally rather smooth without any conspicuous projections. The juncture of the frontals and the supraoccipitals has a rounded projection on its dorsal surface forming roughly a hemispherical shape. There is absolutely no narrow occipital crest developed in the supraoccipital. Another marked peculiarity is the conspicuous projection directed posteriorly from the epiotic and the pterotic. In the istiophorid fishes the nasal bones are broad and are broadly joined to the frontal bones. Anteriorly they are joined to the premaxillaries. In the Xiphiidae the nasal bones are very small and are not directly concerned in the form of the upper jaw, as they are in the istiophorids. The upper jaw is principally formed from the premaxillaries and is almost solid with filamentous structures like the septa in bamboo. The maxillaries are roughly rod-shaped and extend about one-half the total length of the upper jaw, or less. The above-described form of the upper jaw applies to the istiophorids, but in the Xiphiidae the upper jaw is hollow with occasional membrane-like partitions like septa. Thus the upper jaw is made up of four bones.

Regan(1) describes these as one pair of premaxillaries and one pair of nasals, but as has been shown, the nasal bones in the broadbill swordfish are very small and so this must be thought a misconception. The determination of the homology of these four sets of bones must wait upon future studies. The lower jaw is made up of the articular and dentary bones. The dentary bones are stout in the Istiophoridae, but in the Xiphiidae they are rather weak with their anterior parts gradually tapered. In the Istiophoridae the predentary is at the tip of the lower jaw, and the dentaries are partly joined to each other and partly joined to the predentaries. In the Xiphiidae there are no predentaries. On the palatines the istiophorids have fine setiform teeth, but the xiphiids have no teeth on these bones. A number of differences can also be seen between the two families in the form of the various bones of the opercle. There are no gill-rakers on the gill arches. In the general view, the joining and articulation of the bones of the skull are weaker in the Xiphiidae.

Figure 14.--Structure of vertebrae. a. Sailfish, b. Broadbill, c. Short-nosed spearfish.

Figure 15.--Articulation of vertebrae (short-nosed spearfish).

The individual vertebrae in the Istiophoridae are long and the central portion of the ventral side is markedly constricted. The neural and hemal spines generally form thin and broad flat plates. On the two most anterior vertebrae, however, the neural spines are more or less spine-shaped. These lamellate neural spines are surrounded by the neural processes of the following vertebrae so that they are firmly stuck together. The neural processes have been modified into broad lamellar bodies projecting far forward. Their anterior edges extend almost to the middle of the preceding vertebrae. The hemal spines on the first two vertebrae are narrower than the neural spines of the same vertebrae, but on the more posterior ones they are of roughly the same shape and size. The hemal processes are narrower than the neural processes and are somewhat rod-shaped. They project far forward and encompass the hemal processes of the vertebrae immediately preceding them. The relative length and height of the neural and hemal spines differ considerably from one species to another. The neural canal and the hemal canal are both quite large. There are no transverse processes and the ribs are without heads [?]. The vertebral count is 24 for the whole family, but some are shown by the formula 12 + 12 = 24 and others by the formula 11 + 13 = 24. The former is the type

(1) Regan, C. T. Ann. Mag. Nat. Hist., London, Vol. 3, No. 13, pp. 73.

found in the subfamily Tetrapturinae and the latter is found in the subfamily Marlinae. The form of the vertebrae in the Xiphiidae differs greatly from that in the Istiophoridae. In the middle caudal vertebrae the centrum is somewhat elongated, but in the majority of them there is little difference between the length and height. Neither the neural spines nor the hemal spines are thin flat plates, but rather flattened, fairly broad spines in form. The neural processes are not produced anteriorly, but are directed obliquely upward to support the neural spine of the preceding vertebra. The hemal process is much less conspicuous than the neural process. The transverse processes are well developed, and the ribs are articulated to them. The vertebral count is $16 + 10 = 26$, two more than in the Istiophoridae.

The anterior part of the posttemporal bone, which is bifurcated in the Thunnidae, has three prongs in the Istiophoridae. Its posterior edge is generally rounded, but its form is not the same in all species. There is also an additional triangular projection which points obliquely to the rear. The supraclavicle is generally spatulate, with its upper end irregular in shape and tapering gradually to a point, its lower end rounded, and its middle portion somewhat constricted. The anterior margin of the clavicle in <u>Marlina marlina</u> and <u>Kajikia mitsukurii</u> is slightly concave above and slightly convex below, but on the whole roughly straight in outline. In the other fishes of the Istiophoridae the middle portion has a large concavity. The surface for the articulation of the hypercoracoid with the actinotis present differences as between species, being broad and horizontal and somewhat twisted anteroposteriorly in the white marlin, and narrow, obliquely slanted, and not twisted in the other species. Differences between species can also be detected in the breadth and form of the shoulder girdle as a whole. The differences between the two families are conspicuous.

The pelvic girdle is well developed in the Istiophoridae and presents a somewhat palmate form. In the white marlin the left and right sides are joined together and are hard to separate, but in the other species the space between the two sides is broad and they are easily separated. The ventral fins are composed of three rays, the first of which is a very short spine, while the other two are long, all of them being closely joined to each other. In the Xiphiidae both the pelvic girdle and the ventral fins are completely lacking.

A number of the interspinuous bones anterior to the first dorsal and the first anal fins are joined to each other, but in the more posterior ones the space between adjacent bones gradually increases. Marked differences between species can be seen in the anteriormost interspinous bones of the first dorsal. The interspinous bones of the second dorsal and the second anal are somewhat similar, being firmly joined to each other, and the last bone having a long portion projecting posteriorly. Some differences between species can be detected with regard to their height and length.

ii. Viscera

The mouth cavity is large, and the tongue is slender and toothless. In the fishes of the family Istiophoridae the body cavity is long, extending even posterior to the anus and reaching the vicinity of the origin of the first anal fin. The anus is in an advanced position about the length of the base of the first anal fin away from the origin of that fin. The esophagus is rather long and its walls are thick. The stomach is long and conical with its posterior tip extending to roughly above the anus. Its walls are tough, with many folds on the inner walls. The intestine opens near the cardiac orifice. The intestine is slender and its outer wall is smooth with no corrugations. Near the posterior end of the duodenal portion are the pyloric caeca completely surrounding the intestine. This part of the intestine is somewhat swollen. Posterior to this point it runs straight until the approximate middle of the body cavity, where there is a loop. The portion of the intestine posterior to the loop is joined to the anterior portion and runs anteriorly as far as the posterior end of the pyloric caeca. It curves gently around the posterior edge of the caeca and thence runs straight to the anus.

The total length of the intestine is remarkably short in relation to the body length, being only about half as long. The liver is small and covers part of the stomach and the pyloric caeca. The caeca are numerous and each one does not open directly into the intestine, but they are connected to the intestine by a number of dendriform tubes. The gall bladder is long and slender and is separate from the liver. The spleen is large and conspicuous. The form of these various viscera is very similar to that of the Thunnidae.

The gonads are generally symmetrically paired, but in the short-nosed marlin they are unsymmetrical and have a peculiar form, being Y-shaped with the right side short and joined to the left gonad by its posterior end. The point where they join is approximately above the anus and there is a short oviduct. The left gonad is long and its posterior end extends posterior to the anus.

The kidneys are rather long, and the end of the ureter is expanded forming what may be called a urinary bladder.

The air bladder is very peculiar, being many-chambered like a mass of bubbles, and covering nearly all of the dorsal surface of the body cavity. These small chambers are arranged more or less symmetrically in pairs on the right and left and are enclosed in thin membranes. In general they do not form layers, but in the white marlin they do make up 2 - 3 layers and the membranes surrounding these are tough. A point to be noted is that these bubble-like air chambers appear even beyond the body cavity in the caudal region. That is, there are many small air chambers arranged in rows between the muscles at the origins of the first and second anal fins. This sort of structure is completely lacking in the Scombriformes and the broadbill swordfish, and it is a conspicuous characteristic of the istiophorids.

The viscera of the Xiphiidae are similar to those of the Istiophoridae, but they differ in such points as having a longer intestine with many small corrugations on its surface and of uneven diameter, having the total mass of the pyloric caeca remarkably small, having the air bladder single-chambered, and in having no air chambers beyond the body cavity in the caudal region.

c. Ecology

i. Outline of habits

The spearfishes are large fishes which migrate widely in the open sea. Basically they are animals of the tropical seas, but in certain seasons they also appear in the waters of higher latitudes. They generally occur in the shallow layers and sometimes swim with a portion of the caudal and dorsal fins showing above the surface of the water. They are also known occasionally to leap into the air. The broadbill is fierce and is said to attack whales upon occasion. At such times it is thought to use its sword-shaped snout as a weapon. Such characteristics are not known in the case of the fishes of the family Istiophoridae, but it is generally believed that these fishes use their beaks as weapons in fighting and in attacking the animals upon when they feed. This, however, is probably something which has been imagined by people after seeing the form of the fish for it is thought that in actuality they do not use their beaks to catch their prey. The reason for this is that when the stomach contents of these fishes are examined, they bear the scars of bites, but wounds inflicted by stabbing have not yet been found. The fishes of the family Istiophoridae have file-like teeth on both jaws, but if the objectives were to catch their food by stabbing it should be most advantageous to have their weapon as sharp as possible. It cannot be believed that there would be any need for teeth which would increase the resistance. Even though the beak may be used as a weapon against large enemies, it cannot in the least be thought that it is used to capture food. It is also said that they occasionally attack fishing boats, but there is a great deal of doubt as to whether these fish make such attacks deliberately. Nor is the rostrum essential to the existence of these fishes for specimens are seen in which it has been broken off to various degrees. In these cases the broken part is already healed showing the passage of a certain amount of time after the damage was done. Sometimes as a result of such injury the upper jaw is made even shorter than the lower jaw. A consideration of such damage suffered under natural conditions makes it possible to believe that the spear is used as a weapon against large enemies.

In general these fishes migrate widely in the open seas, but they do not form dense schools like the tunas and skipjacks and the individuals are usually dispersed at rather wide intervals. The marlins sometimes swim along the surface in a line of two or more individuals, and this sort of formation is seen with particular frequency in the spawning season.

When caught on a hook or harpooned the tunas for the most part try to escape in a vertical direction by diving deep, but these fishes first make several repeated leaps into the air and then swim wildly in broad circles near the surface.

In general they do not come into the coastal water areas very much, although certain species sometimes do. The sailfish is an example of this. They also sometimes become resident on shoal areas. In some species there are differences in size between the males and females, and there also seem to be differences in the migrational patterns of the sexes.

ii. Food habits

These fishes are also carnivorous and their food resembles that of the tunas. Since they lack gill-rakers it may be thought that they cannot pick up very small feed, but in the open sea they sometimes feed on small fishes and crustaceans just as the yellowfin do. Rather large fishes such as skipjack and mackerel are frequently found in their stomachs, but as previously noted they show no signs of stab wounds and commonly have the marks of bites on their bodies. When the position of these large food items in the stomach is considered, it can be clearly judged that they were swallowed head first. In view of the fact that their food differs depending on the area in which they were taken, and with the season within the same area, it cannot be thought, just as was the case with the tunas, that they have any particular taste in food, and it should probably be considered that they feed on whatever is most abundant in the area, or on what is most easily sighted or caught.

They feed chiefly on live food, but like the tunas they will also take dead bait and can be caught even on salted fish. Since they are often taken on trolling lines with artificial lures, it may be that in such cases the motion of the bait exercises a kind of attraction. Of course the significance of the shape and coloring of the artificial lures that are used should not be forgotten.

A remarkable difference from the feeding habits of the tunas is that these fishes do not seek food on the bottom. Considering the construction of their jaws, it is very natural that they cannot feed on demersal organisms. It is certain that they do not feed on the bottom, but it appears that the broadbill goes rather deep, and in northern waters they eat cod, Sebastodes, and myctophids. The istiophorids in southern waters also sometimes eat deepsea fishes. Naturally the vertical distribution differs markedly with sea conditions, but there is danger in judging from the food of the fish. For example, even though they may feed on such deepsea fish as the myctophids, it is more reasonable in view of the difference between the depths at which these fishes occur during the night and during the day to think that the marlins catch and eat them during the night when they come up into the shallow levels than that they dive deep to catch them.

iii. Spawning and growth

The life history of these fishes is almost completely unknown. It is thought that, like the tunas, they spawn gradually over a broad area of the sea.

Figure 16.--a. Ripe egg of black marlin (X30), b. Ovarian egg of short-nosed spearfish (X30), c. Ripe egg of sailfish (X30), d. Ripe egg of tuna (X23).

Figure 17.--Upper left - juveniles of Atlantic Ocean sailfish: 1. Total length 9 mm., 2. Total length 14 mm., 3. Total length 60 mm. Upper right - larval sailfish: 1, 2. Total length ≒ 6 mm. Middle - juvenile broadbill, lower: a. Larval sailfish (body length ≒ 3 mm.), b. Juvenile sailfish (body length ≒ 12 mm.), c. Juvenile sailfish (body length ≒ 140 mm.)

The facts that are known concerning the spawning of the short-nosed spearfish are briefly as follows. The spawning habits of this species in other sea areas is as yet unknown, but in the waters adjacent to Formosa it spawns around November to December. The area in which it spawns is centered 150 miles offshore in the Pacific and the fish are almost never seen within 30 miles of the coast. At the season mentioned, fish with ripe eggs and those with unripe eggs are taken together, showing that spawning extends over a long period of time. Eggs from a fish in the act of spawning, when treated with milt, have a diameter of about 1 mm. Unfertilized mature ovarian eggs have a diameter of 0.8 - 0.85 mm., which does not differ much from the size of the eggs of other species. In eggs at this stage of ripeness there are two oil globules, but it is thought that later these form a single globule. Surrounding the oil globules there is an indefinite pale yellow nimbus, but there are no structures on the vitelline membrane and the egg as a whole is clear and almost colorless. Nothing at all is known as yet about the larvae and their development.

With regard to the sailfish there is a comparatively large[2] amount of data. The juveniles of the sailfish of the Atlantic have been known for a long time. The areas and seasons in which the author has collected ripe eggs and larvae in the Southwest Pacific are as follows:

Month and Year	Area	Ripe Eggs	Larvae (length in mm.)
12 - 31	Banda Sea	+	---
18 - 31 [? Sic] 4 - 7	Formosan waters	+	---
7 - 35	E. of Formosa	+	140
8 - 35	Off Hongkong		200 - 260
7 - 39	Hainan waters	+	3 - 6
5 - 40	NE of Luzon	+	7 - 12
8 - 41	Nhatrang		700 - 750

In addition to these, Uchida[3] has reported a juvenile of about 7 mm. body length from Satsunan waters.

Spawning is carried on with a male and a female paired or with two or three males chasing a single female, and this act can be seen often during the spawning season. The ripe ovarian eggs are about 0.85 mm. in diameter and they have a single oil globule. Around the oil globule there is a pale yellow indefinite nimbus. There are no structures on the vitelline membrane and the egg as a whole is almost colorless and clear.

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(2) Gunther, A., 1880. An Introduction to the Study of Fishes. London.

(3) Uchida, Keitarō. 1937. On the Flotation Mechanisms Seen in the Larval Stages of Fishes, Science 7. Iwanami.

In larvae of about 3 mm. body length, which are thought to have just hatched out, the snout protrudes hardly at all, the mouth is large, and there are large, sharp teeth in both jaws. There is a serrated projection on the upper edge of the eye socket. This projection adjoins a huge spine on the upper end of the posterior edge of the preopercle. At the lower end of the posterior edge of the preopercle there is a spine even larger than the one at the upper end. Except for the eyeball hardly any pigment is developed on the body.

In individuals of 5 - 7 mm. the serrate portion above the eye has degenerated somewhat, but the upper and lower spines on the preopercle are still conspicuous. The snout projects somewhat, the mouth is large, and the teeth in both jaws are still prominent. Heavy dark purple pigment has developed on the head and body, but none appears on the caudal region. Particularly large chromatophores can be seen on the dorsal surface of the head over the brain, and a number of large round chromatophores also appear along both sides of the base of the dorsal fin.

In specimens of about 12 mm. the snout is already markedly elongated and the lower jaw also projects. Sharp, canine-like teeth are closely set in both jaws, the tip of the upper jaw having three particularly large canine teeth, the middle one of which is hooked somewhat upward. The bony portion of the upper rim of the eye socket with its serrated edge has degenerated markedly, and the upper and lower spines of the preopercle have diminished in relative length. The dorsal fin has greatly developed and its rays are clearly discernible. The other fins have also developed remarkably. Both the dorsal and the anal fins have a single base. The unpigmented portion of the caudal region has become restricted to the farthest posterior part, remaining only on the caudal peduncle. The large chromatophores which appeared on the dorsal surface of the head above the brain and at the base of the dorsal fin have disappeared. On the part of the dorsal fin having the longest rays large, round, deep black chromatophores appear forming spots.

Of the larger sizes of fish none have been collected as yet up to a length of about 140 mm. Specimens of this length are in general like mature fish in form, and the projections and spines which are seen in the juvenile stages have completely disappeared. Marked differences from mature fish are the extraordinary length of the snout, the fact that the dorsal and anal fins each have a single base, the nearly semicircular form of the edge of the dorsal fin without the concavity which appears in the anterior portion in the adult, and the fact that the markings and spots on the lateral line and the first dorsal are unclear and barely apparent.

In fish of a body length of about 260 mm. almost no differences in form from specimens of around 140 mm. can be perceived. The dorsal and anal fins are still single-based, but the rays which are to form the anterior portions of the second dorsal and the second anal are developing and those which are to make up the posterior extremities of the first dorsal and the first anal are becoming shorter so that the tendency toward the separation of each set of fins into two bases is becoming clear.

When it comes to larger specimens, I have seen one of about 700 mm. body length taken in a coastal gillnet in the Annam area, but I had no opportunity to make a thorough examination of it.

Fish of around 140 - 260 mm. body length have a marked positive phototropism and they are frequently collected with fishing lights.

I have no data at all as yet on the spawning habits of Kajikia formosana.

The spawning of Kajikia mitsukurii in Formosan waters seems to be at its peak from April to May, and in the fish taken at that season the gonads are generally well developed, ripe ova being seen frequently. At this season in Formosan waters this species is comparatively scarce in the Pacific coast waters and more abundant in the South China Sea. Consequently it is thought that spawning is carried on mainly in the South China Sea. In form the ripe ova are almost the same as those of the sailfish, and it is impossible to distinguish them merely by seeing the eggs. No data have been obtained as yet concerning the larval and juvenile forms. It is known that this species also spawns near the Ogasawara Is. in the Central Pacific around May-June.

The spawning of the black marlin occurs from April to August in the waters east of Luzon and Formosa, and eggs from ripe ovaries have been collected. There is not as yet, however, any material on the larval and juvenile stages. The form of the ripe ova is just like that of the sailfish and K. mitsukurii.

No concrete data have yet been obtained regarding the spawning habits of the white marlin, but for reasons given below it is presumed that their spawning season in Formosan waters is probably around August - October.

The number of eggs in the ovaries of one spearfish varies depending on the species and the size of the individual, however, it appears to amount to from 1 million to 1,200,000. This figure is obtained from the total weight of the ovaries and the number of eggs contained in 1 gram, and is thus an extremely rough estimate. Such questions as what proportion of these eggs hatch, what percentage reach full maturity, and what is their rate of development remain to be investigated.

The spawning season of the broadbill swordfish in Japanese waters is thought to be around August-September. Its development is known to include marked changes in form. Nakamura[4] has reported the collection in the spring of 1933 near Ominato, Chiba Prefecture, of two specimens measuring 660 and 860 mm. in total length. The 660 mm. individual in form had the outline of a mature fish, but both the dorsal and anal fins were single, the former with 2 spines and 42 rays and the latter with 1 spine and 15 rays. The mature fish have no teeth, but larval fish at this stage have setiform teeth. There are keels on the caudal peduncle, but they are not as conspicuous as in the adult. There are hard scales forming rows on the sides of the body, and the dorsal surfaces are deep indigo in color, the sides paler, and the belly is white. The yellow bands on the fins and body pictured by Lütken on a 37 mm. larva have already faded out and cannot be seen. In the 860 mm. specimen the lower jaw has become rather short. The dorsal and anal fins both are still single, but in the dorsal the fifth to the sixth rays from the posterior end have become shortened, and in the anal fin the fifth to the seventh rays from the posterior end have become buried in the muscles, clearly indicating a tendency toward separation into two fins.

iv. Distribution and migrations

These fishes are present at all times in tropical seas. In the coastal waters of Japan they begin to migrate gradually north as the water temperature rise in the spring. The season of the northward migration is somewhat later than that of the black tuna and about the same time as that of the albacore.

The short-nosed spearfish is very pelagic in nature, and it hardly ever comes into coastal waters nor is it seen in enclosed seas. Its distribution in the waters adjacent to Japan is in general south of Sagami Wan. Many of these fish spawn in the waters east of Formosa in an area centered about 150 miles offshore from October to December. When the Shōnan Maru[5] conducted a survey in the central part of the East Philippine Sea (10° N. - 15° N.) in July, 1937, not one fish was taken, and only one was caught in the southern part of that sea (3° N. - 10° N.) in August. In the survey made by the

[4] Nakamura, Hidenari. 1935-36. Larval Stages of Shorefishes Appearing in the Vicinity of Ōminato (Parts 12, 14). Yōshokukai Shi 5. pp. 191-195; 6. pp. 133-139.

[5] Originally the Taiwan Government-General's research vessel.

Takao Maru[6] in September 1940, in the center of the same sea area (10° N. - 15° N.) eight fish were taken. A tabular comparison of the catches of these two survey vessels is as follows:

Table 2

Comparison of Catches (central part of East Philippines Sea)

Vessel	Yellowfin		Big-eyed		Black Marlin		Striped Marlin		Sailfish		Short-nosed	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Shonan	54	47.6	3	2.4	57	50.0	0	0	0	0	0	0
Takao	24	48.0	0	0	12	24.0	2	4.0	4	8.0	8	16.0

Note: % indicates the composition of the catch.

A look at the above table shows that there is no great difference in the proportion of yellowfin, but the black marlin decrease markedly and the short-nosed spearfish show a conspicuous increase. Considered seasonally, such a difference in the catch occurs in a matter of about 2 months. Since the surveys were made in different years, it is hard to make any definite statement, but it is thought that the variations shown in the table accompany the change of season. If this fact is taken together with the above-described distribution in the waters east of Formosa, it can be thought that the distribution of this species in these sea areas gradually becomes denser from September on.

The sailfish is of extraordinarily wide occurrence and comes into the coastal waters so far as to be taken in traps. In Japanese waters they are numerous south of Kishū, and the northern limit of their distribution is off Northeastern Japan. They are commonly seen in the Ryūkyū and Formosa areas, being especially abundant in summer. The season of dense distribution coincides with the spawning season for this species in these waters.

K. formosana appears to have approximately the same distribution and migrations as the short-nosed spearfish, but the details are not yet known. From a consideration of certain data it appears that this species appears in the waters east of Formosa somewhat later than the short-nosed spearfish.

The striped marlin is also extremely widely distributed, occurring in all of the tropical waters of the Pacific and in

(6) Originally the research vessel of Takao-shu [Formosa].

the Indian Ocean. It is said that the northern limit of its distribution in Japanese waters is in the vicinity of 42° N. Attempts have been made to gather various data, but since in Japan the striped marlin, the black marlin, and the white marlin are seldom carefully distinguished and all three species are in many cases reported together as striped marlin or simply as marlin, the distribution and migratory pattern of each species is not very clear. In Japanese waters the area extending from southwest of Kyūshū to the Tsushima Strait, the Kinan Sea Area, and waters off the Izu and Boso peninsulas, and the coastal waters of the Izu and Ogasawara islands are noted as fishing grounds for the spearfishes. Farther south these fish are taken throughout the year.

The waters east of Formosa and the South China Sea are areas in which the spearfishes are very abundant. From prewar statistics it appears that there was no great difference between the number of fish taken in Formosa and the total catch from all of Japan proper.

The fishing season in the seas east of Formosa is the season of the northeast monsoon, that is, from October to April. The fishing grounds are generally within 30 miles of the coast, and as one goes farther out to sea the density of distribution decreases. The fishing carried on in these waters is chiefly the harpoon fishery. The longline fishery is also prosecuted vigorously in this area, but its main objective is numerous species of shark. In the catch from the harpoon fishery the white marlin is very numerous at the beginning of the season, while the striped marlin increases during the middle part of the season, and the black marlin gradually become more numerous toward the end of the season. If we calculate only the proportions of tunas and spearfishes in the longline catch, the tunas make up 60 - 65 percent and the spearfishes 35 - 40 percent of the whole. Such a high ratio of spearfishes is not seen anywhere else north of the central part of the East Philippine Sea except at certain seasons.

The pattern of distribution and migration in the South China Sea area seems to differ considerably from that of the Kuroshio region. The main fishing season is still the northeast monsoon and the white marlin generally predominates in the early part of the season, but the catch also includes a considerable number of black marlin, which are extremely rare in the Kuroshio at this time. The composition of the spearfish catch from the middle of the season on does not differ greatly from that of the Kuroshio area. Quite a few fish are taken after the season has ended in the Kuroshio, and from July to September white marlin occur in considerable abundance in the northwestern part of this sea area. Considered generally, the schools are most abundant at the beginning of the season in the southeastern portion of the area, that is, in the waters adjacent to the Sulu Sea, while in the middle of the season they are dispersed all over the area. Usually in March and April dense schools of white and striped marlin move from south to north in the waters off Annam.

The fishing grounds in the East Philippine Sea have been opened up in recent years and it has not yet been possible to acquire full data on them. The fishing season in this sea area tends to be during the season of southwest winds. The results of the investigations of the Shōnan Maru in 1937 were as shown in the following table:

Table 3

Fishing Conditions in the East Philippine Sea
(Shōnan Maru, June-September, 1937)

Area(1)	Yellowfin		Big-eyed		White Marlin		Black Marlin		Striped Marlin		Sailfish		Short-nosed	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Northern	19	1.7	0	0.0	1	0.1	57	5.1	0	0.0	3	3.0	0	0.0
Central	54	3.5	3	0.2	0	0.0	57	3.7	0	0.0	0	0.0	0	0.0
Southern	286	9.4	14	0.4	2	0.1	59	1.9	1	0.0	7	0.2	1	0.0

Note: % indicates the number of fish taken per 100 hooks.

(1) Northern area - 15° - 20° N.
123° - 125° E. number of hooks 1,120
Period of survey June 25-29, July 24-25

Central area - 10° - 15° N.
125° - 129° E. number of hooks 1,560
Period of survey July 12-23

Southern area - 3° - 10° N.
127° - 131° E. number of hooks 3,040
Period of survey August 15-31, September 1-8.

As is clear from table 3, at this season in the East Philippine Sea the distribution of spearfishes other than the black marlin is extremely sparse. The division of this sea area made in the table (see the footnote) is based on the fact that the northern part is the place of origin of the Kuroshio and the currents clearly point north, the central part in general is an area in which the Equatorial Current impinges upon the Philippine Islands and the currents have no definitely fixed direction, and in most of the southern part the currents run mainly eastward, showing that it is within the Equatorial Countercurrent. Thus oceanographic conditions appear to be different in each of these three parts of the sea area.

From the fishing situation as it appears in table 3 it is clear that as one goes south the density of occurrence of the black marlin gradually decreases, however, it must be taken into account that there is a break of more than 2 months between the beginning and end of the investigation.

In data from investigations in the area formerly under the jurisdiction of the South Seas Government-General, which continues to the eastward of this sea area, the species were not sufficiently differentiated, and consequently it is difficult to make a full comparison with the material in table 3. Data from the adjacent Celebes Sea area to the west are also inadequate in this respect. If, however, we consider both the distributional and migrational pattern in the waters east of Formosa, as described above, and the situation in the East Philippine Sea, the migrations of the spearfishes in the Kuroshio current area, which is thought to be most deeply related to our coastal waters, are probably in general as follows:

(1) At the beginning of the northeast monsoon the white marlin appear in the central part of the Kuroshio east of Formosa. They gradually begin to move northward, and around April they become scarce in these waters.

(2) At about the same time as the white marlin, but farther offshore than the central part of the Kuroshio Current area east of Formosa, the short-nosed spearfish occurs in considerable concentration.

(3) The striped marlin appears in the central part of the Kuroshio current area somewhat later than the white marlin, and about April their occurrence becomes sparse.

(4) At about the same time as the striped marlin, the little marlin /Kajikia formosana/ appears in the waters where the short-nosed spearfish occurred.

(5) The black marlin's appearance follows the striped marlin. It begins to increase in numbers beginning around February. The period of its appearance is very long, and the density of its occurrence apparently begins to decline from

September on. It is further thought that the density of its distribution is greater in the Equatorial Current and the Kuroshio and less in the Equatorial Countercurrent.

(6) The sailfish occurs in its greatest density in several months before and after June. It comes far into the coastal waters.

The broadbill swordfish occurs in higher latitudes than the marlins, and at some seasons is fairly numerous in the Northeast and off Hokkaido and the southern Kuriles. It is also widely distributed in tropical waters, but in these areas its commercial significance is not as great as that of the marlins.

The question of depth of occurrence, that is, vertical distribution, will be discussed along with that of the tunas in the chapter on fisheries.

When we examine the marlin which are taken in the area in which the Kuroshio originates and in the South China Sea area, we find that there is generally a marked difference in their sex ratio at different seasons. For example, in the case of the black marlin, there is from October to about April an overwhelming majority of females and males are few. Beginning in April the males gradually increase in numbers and in July and August the opposite situation obtains with an overwhelming majority of males. With the striped marlin this phenomenon appears somewhat earlier than with the black marlin, and in the case of the white marlin it appears about 3 months later. It seems that the sex ratio of the sailfish is about even and does not change greatly throughout the year, but adequate data have not yet been collected for this species and for the short-nosed spearfish and the little marlin. It will be necessary to inquire whether this phenomenon results from differences in the season of migration of the sexes or whether it is caused by differences in feeding habits which bring about a differential representation in the catch.

The fishery based at Takao operates with longlines, but the fisheries of Suo and Keelung are mainly harpoon fisheries and do not use bait. The changes in sex ratios in the catch of both of these fisheries show a tendency toward almost complete agreement. Furthermore, during the height of their spawning seasons in the waters adjacent to Formosa the sex ratios of the sailfish, short-nosed spearfish, striped marlin, and black marlin show values approximating 1 to 1. The sex ratios also generally average about 1 to 1 in the course of a year. Considered in this way, it can hardly be thought that there is any sexual difference in food habits. Accordingly it is thought that in the waters adjacent to Formosa, at least, the sexes differ in the season of their migrations. Whether such a phenomenon can be seen throughout the whole sea area in which these fishes occur and migrate is not yet known, but it is certain that it bears a close relationship to their spawning.

Then there is the deeply interesting fact that the fish differ in size by sexes.(7) In general in the Tetrapturinae the sexual difference in size is not conspicuous, but in the Marlinae it is extremely so. This fact was noted along with the sex ratio in the course of the investigations carried on by the Shonan Maru in the East Philippines Sea in 1937. The results of this study are shown in table 4.

Table 4

Sex Ratio and Body Weights of Black Marlin
(Shōnan Maru, East Philippines Sea, June - September, 1927)

Body Weight (kg)	20 / 30	30 / 40	40 / 50	50 / 60	60 / 70	70 / 80	80 / 90	90 / 100	100 / 110	110 / 120	120 / 130	130 / 140	140 / 150	150 / 160	160 / 170	170 /	Total	%
Male	8	17	57	39	21	9	1	0	0	0	0	0	0	0	0	0	150	91
Female	0	2	0	0	0	1	2	2	2	1	1	1	0	1	1	1	15	9

As the table shows, the males were all under 90 kg. and the majority of them were between 40 and 60 kg. There were few females, but the majority of them were over 90 kg. For a number of years thereafter the sex ratios and size differences of the fish landed at Takao and Suo were studied with the following general results(8):

a. For the black marlin the largest male was about 110 kg. and there were none larger than that. Most of them were between 40 and 60 kg. Hardly any were taken under 20 kg. The females ranged from 20 kg. to a maximum of 500 kg., but the greatest number were between 100 and 120 kg. Consequently, if a frequency curve is drawn according to size, the mode for the males will appear between 40 and 60 kg. and above and below this point the

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(7) As has already been described in the section on the tunas, the sexes are known to differ in size among the tunas also, but it is interesting that in the spearfishes this difference is exactly opposite.

(8) Nakamura, Hiroshi. (1945) Studies on the Istiophoridae of Formosan Waters, 7, Sexual Differences in Size of Fish. Proc. Formosan Nat. Hist. Soc., Vol. 35, Aug.

curve will fall off sharply. For the females the peak will appear between 100 and 120 kg., above and below which point the frequency will gradually decline in a gentle curve.

b. In the white marlin the males reached a maximum weight of about 120 kg., and there were almost none over this weight. The most numerous size group was from 40 to 60 kg. The females ranged from 20 to a maximum of 560 kg., but they were most numerous between 100 and 140 kg. A curve of size frequencies shows the same general form as in the case of the black marlin. Almost no fish of either sex weighing less than 20 kg. were caught.

c. In the other species size differences between the sexes are inconspicuous. Data are also meager, and the size of the fish, which even in the striped marlin rarely exceeds 100 kg., is still smaller in the other species, so in a comparison using 10 kg. as the unit it is believed that no difference in size between the sexes would appear.

Since, as explained above, the sex ratios vary with the season, and the sexes differ in size, it is only natural that there should be seasonal variation in the size of fish that are taken. An attempt has been made to clarify this using the individual weight data from all of the fish of each species landed at Takao and Suo. The data cover the years 1942 and 1943.

The facts which were made clear as a result were briefly as follows[9]:

a. In the black marlin the average body-weight gradually increases from January to April and reaches its peak in the latter month. The average for January is slightly over 90 kg., while that for April is about 120 kg. After May there is a rapid decline, and the minimum of about 65 kg. is reached in August. In September the average weight begins to increase rapidly, and in October it is almost equal to the January figure. In November it is around 80 kg., and in December it again nearly equals January's mark. The greatest number and weight of fish, however, are taken in July.

b. In the case of the white marlin, too, the curve follows the same trend as that of the black marlin, but the periods in which the maximum and minimum sizes appear are about 3 months later than for the black marlin.

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(9) Nakamura, Hiroshi. 1945. Studies on the Istiophoridae of Formosan Waters, 8, Seasonal Differences in the Size of Fish. Proc. Formosan Nat. Hist. Soc., Vol. 35, Oct., Dec.

c. In the other species this sort of change is not conspicuous.

As stated previously, in the black marlin the greatest number of males weigh 40 - 60 kg., while among the females those of 100 - 120 kg. are most numerous. Considered very summarily, the fish can be divided into those under 60 kg., which can be taken to be almost entirely males, and those over 100 kg., which can be thought to be almost exclusively females, and the proportions of these two size groups in the total number of fish caught can be taken as an estimate of the ratio in which the sexes appear. If we try drawing curves of the frequency of occurrence of males and females in each month, we find as a natural result that these curves intersect each other twice, in May-June and in August-September. In effect, the frequency curve of the females agrees generally with the curve of monthly average weights described above, while the males are nearly the reverse. The period from the time when the frequency curve for the females reaches its peak in April to the time of its lowest point in August is in general the spawning season in Formosan waters, and the intersection of the two curves in May-June is at the height of the spawning season. This can be said to be a deeply interesting phenomenon.

The spawning season of the white marlin is completely unknown. It is merely presumed from some data on gonads obtained in the Hainan Island area that July to August is probably the spawning season in those waters. If the curves for the frequency of occurrence of males and females are drawn, based on the same assumptions that were made in the case of the black marlin, the curves show approximately the same trend as those for the black marlin. However, the maxima, minima, and points of intersection of these curves are all about 3 months later than those of the black marlin. Consequently, although the spawning season, as deduced from the condition of the gonads, has not yet been concretely and completely proven, its probability has been remarkably enhanced.

B. Species

Jordan and Evermann[10] have reported the spearfishes or Xiphiiformes of the world under 2 families, 4 genera, and 32 species. It is, however, questionable whether so many species actually exist, and it is believed that the opinion which was expressed with regard to the tunas may be applied in the same terms to these fishes.

[10] Jordan and Evermann. 1926. Occ. Papers California Acad. Sci. XII.

Temminck and Schlegel[11], Jordan and Snyder[12], and Dr. Tanaka[13], have reported on the species from Japanese waters. The present writer[14], has reported two families, four genera, and six species from Formosan waters, and in recent years has classified the spearfishes of the western Pacific in two subfamilies, five genera, and six species[15]. The two subfamilies, 3 of the 5 genera, and 2 of the 6 species are new. Accordingly, if the broadbill swordfish is added, the species occurring in the western Pacific are seven.

Such characteristics of the Istiophoridae as elongated bony scales, the so-called reticulated gills, and the absence of gill-rakers are shared with the Scombriformes, so it is thought that they are derived from this latter group. Furthermore, since in form they resemble the juvenile stages of the broadbill swordfish, they are believed to be probably an intermediate form between the Xiphiidae and the Scombridae. It is not, however, possible from a morphological comparison simply to affirm this evolutionary relationship. And viewed geologically the fossils of the mackerels, spearfishes, and swordfishes appear parallel to one another so that the above-mentioned relationship is not proved from this angle either.

Key to the Families

a. Elongated bony scales present. Snout short, nearly round in cross section. Teeth present in both jaws. Ventral fins present; two pairs of keels on the caudal peduncle. Dorsal fins close together .... Istiophoridae

b. No scales. Snout long, both upper and lower members gladiate. Teeth present in juveniles but absent in mature specimens. No ventral fins; dorsal fins widely separated. Single pair of large keels on caudal peduncle .... Xiphiidae

Family Istiophoridae

Body long, trunk laterally compressed, caudal portion gradually becoming cylindrical. Covered with elongated bony scales almost buried in the skin. Upper jaw projecting in the form of a spear; predentary bone at tip of lower jaw. Rasp-like teeth are present in both jaws. In mature fish the dorsal and anal fins are each divided into two

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(11) Temminck and Schlegel. 1850. Pisces. Siebold's Fauna Japonica.

(12) Jordan, D.S. and J.O. Snyder. 1901. Jour. Coll. Sci. Imp. Univ. Tōkyō, 15.

(13) Tanaka's Fishes of Japan, Vol. I. 2nd Ed. p. 324.

(14) Nakamura, Hiroshi. Taiwan Suishi Hōkoku No. 10. 1938.

(15) Nakamura, Hiroshi. Studies of the Istiophoridae of Formosan Waters. Sci. Rpts. Taihoku Imp. Univ. (unpublished).

parts, but in juveniles they are both single. The pectorals are placed low on the body. The ventrals are made up of 3 rays, but they are fused together and appear externally to be a single ray. There are two keels on each side of the caudal peduncle, and the lobes of the caudal fin are narrow and widely bifurcate. A lateral line is present, but while it is clear in some specimens it is extraordinarily obscure in others. Some individuals have a single lateral line, while in others it is complex in form. There are 24 vertebrae, which can be described by the formula 12 + 12 in some individuals and by 11 + 13 in others. The ribs are well developed, but they are headless [?] and there are no supracostals. The air bladder is a mass of numerous small spongy chambers. There are similar air chambers in the muscles of the belly between the anal fins. The family is divided into two subfamilies.

Key to the Subfamilies

1. The vertebrae are 12 + 12 = 24. The body is slender with the height of the first dorsal exceeding the depth of the body. The anterior portion of the first dorsal has a concave outline. The lateral line is single and clearly discernible. The ventral fins are generally well developed .... Subfamily Tetrapturinae

2. Vertebral formula 11 + 13 = 24. Body stout, height of first dorsal less than body depth; height of the fin decreases sharply posterior to the 4th or 5th ray. Lateral line obscure, may be single or complex. Ventral fins generally short ....Subfamily Marlinae

Subfamily Tetrapturinae

Body slender, trunk markedly compressed laterally. The first dorsal, at its highest portion, exceeds the body depth, and its anterior portion is concave in outline. The lateral line is single and clearly discernible. The ventral fins are generally long. There may or may not be transverse rows of spots on the sides of the body. Vertebral formula 12 + 12 = 24.

Key to the Genera

1. Snout short, no transverse bands on the sides of the body. .... Genus Tetrapturus

2. Snout long, transverse bands on sides............ see 3

3. 3-1. Dorsal fin remarkably high, its central portion far exceeding the body depth. Body remarkably slender .... Genus Istiophorus

3-2. Dorsal fin height only slightly greater than the body depth, less than body depth in the central portion of the fin. Body rather stout .... Genus Kajikia

Genus Tetrapturus Rafinesque, 1810

The smallest in size among the fishes of this family. The body is long and slender and markedly compressed laterally. The snout is short. The posterior rays of the dorsal fin are high and the pectoral fins are short. Jordan and Evermann record six species in this genus, of which five occur in the Indo-Pacific region. Among them are included some which clearly belong to other genera. One species occurs in Japanese waters.

1. Tetrapturus angustirostris Tanaka

In Japanese fūraikajiki, sammakajiki, or sugiyama.

Figure 18.--Short-nosed spearfish.

The first dorsal fin has 49 to 53 rays, of which the first three are spines. Eleven to 13 of the rays immediately following the first three have branched tips, and the remaining 35 to 37 rays are spines. The second dorsal has 6 soft rays, and the first anal has 2 spines and 12 soft rays. The second anal fin is composed of 7 to 12 rays. The vertebral count is $12 + 12 = 24$.

Body length is about 7 times the greatest body depth, and about 8 times the depth of the body at the insertion of the first anal fin. The body length is about 6.3 times the length of the snout. The snout length is 1.4 times the head length. The head length, excepting the snout, is about 3.3 times the diameter of the eye. The greatest body depth is 3.8 times the depth of the caudal peduncle. The ratio of upper jaw to lower jaw length is 1.3 (This is a comparison of the distance from the posterior edge of the maxillary to the tips of both jaws.)

This species is the smallest of the spearfishes. The trunk is conspicuously compressed laterally. The upper jaw is short. Toward the caudal peduncle the body gradually becomes cylindrical in cross section, and on each side of the caudal peduncle there are two keels. The scales are bony and slender, and their posterior ends are sharply pointed and buried in the skin. The lateral line, which is clearly evident, follows a somewhat wavy course above the pectoral fin. Posterior to the tip of the pectoral fin it runs in a straight line slightly above the median line of the side of the fish.

The first dorsal fin is well developed with delicate rays. Just posterior to the anterior end of the fin, which is its highest portion, the length of the fin rays decreases rather suddenly, but thereafter, in the central portion of the fin, the height of the fin rays increases gradually. At the posterior end of the fin, the height of the rays again decreases gradually. Consequently, the profile of the first dorsal fin is concave in its anterior portion and arcuate in its posterior portion. The pectoral fins are remarkably short, their length being about 0.8 times the body depth. The ventral fins are conspicuously longer than the pectoral fins. The first anal fin is well developed. The falciform second dorsal and anal fins are located diametrically opposite each other and are of approximately the same shape and size. The caudal fin is large and strong, its upper and lower lobes being narrow in width but broadly forked.

There are rasp-like teeth on both the upper and lower jaws and a patch of slender brush-like teeth on the palatine. The cranium is somewhat longer and narrower than in other species. The vertebrae are long and both the haemal and neural spines are roughly rhomboid in shape. The gonads are Y-shaped, with the left side longer than the right. The right gonad joins the left above the vent.

The dorsal surface is steel blue and the belly is silvery-white. The boundary between these two colored areas is a rather distinct, finely serrated line which runs straight along the side of the body somewhat above its median line.

This species occurs from Sagami Wan south. It is extremely pelagic by nature, and hardly ever enters coastal sea areas or enclosed waters. It is rather abundant from October through December in the waters east of Formosa, at which time and place it spawns.

This species attains a length of 1,500 millimeters and a weight of 20 kilograms.

This fish has been reported as a new species by Professor Tanaka, however, morphologically it is extremely close to *T. belone* of the Atlantic and *T. brevirostris* of the Indian Ocean. It is thought that these probably are all the same species, but at present it is impossible to confirm this.

Genus *Istiophorus* Lacepède, 1802

Body long and slender, markedly compressed laterally; the height of the first dorsal fin much greater than the body depth. The ventral fins are long and their rays are incompletely fused together.

Figure 19.--Sailfish

Nine species have been reported for this genus, of which five occur in the Indo-Pacific region. The following single species occurs in Japanese waters.

2. Istiophorus orientalis (Temminck & Schlegel)

In Japanese bashōkajiki, nōrage, hauo, baren, oba, sugiyama.

The first dorsal fin has 44 to 47 rays. The first 3 are spines, the following 9 have branched tips, and the remaining posterior rays are again unbranched spines. The second dorsal fin has 67 soft rays. The first anal fin has 2 spines and 11 soft rays, and the second anal fin has 6 soft rays. The vertebral count is 12 + 12 = 24.

The body length is 3.2 times the head length, 6.3 times the greatest body depth, and 7.8 times the body depth at the insertion of the first anal fin. The head length is 1.4 times the snout length, and 7.5 times the interorbital space. The length of the snout is 3 times the length of the head excluding the snout. The head length without the snout is 3.7 times the diameter of the eye. The distance from the eye to the insertion of the first dorsal fin is 3.8 times the diameter of the eye. The greatest body depth is 4.6 times the depth of the caudal peduncle. The length ratio of the upper and lower jaws is 2.2.

The body is long and slender, greatly compressed laterally, with the caudal portion gradually becoming cylindrical. There are keels on each side of the caudal peduncle. The upper jaw is more than twice the length of the lower jaw, and there are rasp-like teeth on both jaws. The scales are bony and slender, and almost completely buried in the skin. The lateral line is simple and clearly visible.

The first dorsal fin is remarkably developed, its height being far greater than the body depth. The height of the third spine of this fin is 1.3 times the body depth. The following 8 or 9 fin rays gradually decrease in height, but thereafter the fin rays again increase in height until the 14th or 15th ray, where a maximum height of over twice the body depth is attained. Posterior to this point the height of the fin decreases rather rapidly. Consequently, the outline of the first dorsal fin is indented anteriorly and arched posteriorly. The pectoral fins are rather short, being 0.8 to 0.9 times the greatest body depth. The ventral fins are well developed, their tips reaching to the vent. Their rays are incompletely fused together, and consist of 1 spine and 2 soft rays. The first anal fin is well developed, but is not falciform in outline. The second dorsal and the second anal fins are roughtly symmetrical, being almost the same shape and size. The caudal fin is large and strong. Its upper and lower lobes are narrow, but the angle between them is great.

Palatine teeth are poorly developed. The cranium is rather long. The vertebrae are long and the anterior edges of the neural and haemal spines are somewhat arched in outline. In general, the neural spines of the ventral vertebrae are small, and consequently the space between spines is great.

The dorsal surface is dark blue with a violet cast. When the fish is excited, violet patches appear. The belly of the fish is of a brownish-grey color, and on the sides of the fish there are seventeen vertical stripes composed of cobalt spots. Scattered over the dorsal fin are black spots the size of soy beans. All of the fins are dark blue, the caudal fin sometimes having a brownish cast. In life the body is covered with a thick brown slime. The flesh is reddish in color.

This species occurs from the northeastern coast of Japan south, and is comparatively abundant in the Kinan Sea Area. These fish spawn in Formosan waters from April to August. Compared to other spearfishes, this species shows a conspicuous tendency to enter coastal water areas.

This species attains a body length of 2,000 millimeters and a weight of 60 kilograms.

The main points of difference between this species and I. gladius, reported from the Indian Ocean area, are the presence in gladius of a number of short, thick spines between the two dorsal fins, which are absent in this species, and the smaller number of black spots on the dorsal fin in gladius. In juvenile fishes of this family, the dorsal and anal fins are single, separating into two fins as the fish develops. Consequently, it is thought possible that at some stages of development, there may be some fin rays remaining at the posterior end of the first dorsal fin. Among the species recorded by Jordan and Evermann there are some which are clearly juveniles, and it is entirely possible that the number of species actually in existence is less than the number reported by them.

Genus Kajikia Nakamura, 1946*

The body is elongate and rather stout. The height of the first dorsal fin is slightly greater than the body depth and the longest rays form two steps at the extreme anterior end of the fin. The profile of the anterior portion of the dorsal fin is indistinctly concave. The body is covered with slender, bony scales. The ventral fins are either equal to or slightly shorter than the pectoral fins. There are on the side of the body, 10 or more vertical stripes formed of cobalt spots. Two species occur in Japanese waters.

Hitherto, this genus and the subfamily Marlinae have both been placed in the genus Makaira, Lacépède, 1803. The original description of Makaira is however, extremely incomplete. The species of this genus differ morphologically from Makaira in many points, and therefore it has seemed proper to set up this genus as a separate group.

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* Taihoku Imperial University, Memoirs of the Science Department (unpublished).

Key to the Species

(1) Size large, central portion of first dorsal fin much less than half body depth. Pectoral fins long, roughly equal to or slightly greater than body depth ......mitsukurii

(2) Size small, length of rays in central portion of first dorsal fin greater than half the body depth. Pectoral fin short, less than body depth .... formosana

3. Kajikia mitsukurii (Jordan and Snyder)

Figure 20.--Striped marlin.

In Japanese kajiki, makajiki, nairagi, nairanbo, nairage, akakahiki, or aka.

The first dorsal fin has 37 to 43 rays, of which the 3 most anterior are spines. The succeeding 12 to 15 rays have branched tips, and the remaining 22 to 25 posterior rays are spiny. The first anal fin has 2 spines and 12 to 25 soft rays. The second dorsal fin has 6 soft rays, and the second anal fin has 6 soft rays. The ventral fins have 1 spine and 2 soft rays. The vertebral count is 12 ⁄ 12 = 24.

The body length is 5 to 5.5 times the greatest body depth, about ? times the body depth at the first anal fin, and 2.6 times the head length. The head length is 1.5 times the snout length and about 6 times the distance between the eye sockets. The length of the snout is about 4 times the length of the head excluding the snout. The head length excluding the snout is about 4 times the diameter of the eye. The distance between the eye and the insertion of the first dorsal fin is 4 times the diameter of the eye. The greatest body depth is roughly 5 times the depth at the caudal peduncle. The ratio of length of upper jaw to lower jaw is 1.8 to 1.9.

The body is long and slender, with the trunk conspicuously compressed laterally, the caudal portion gradually assuming a cylindrical form. There are two keels on each side of the caudal peduncle. Body depth is the greatest among the species of this subfamily, and in external form this species rather closely resembles the fishes of the subfamily Marlinae. The body is covered with bony, slender scales which are buried in the skin. The lateral line is single, and it is not clearly visible. The lower jaw is rather long, the difference in length between the upper and lower jaws being slight.

The first dorsal fin is well developed, the length of its longest rays being somewhat greater than the body depth. The highest portion of the fin is divided into two parts, the profile of the intervening portion of the fin being more or less concave. The profile of that portion of the fin immediately posterior to its longest rays decreases in height rapidly and is more or less sickle-shaped, while the more posterior portion decreases in height gradually. The pectoral fins are well developed, their length being 1.1 times the body depth. The ventral fins are short, their length never exceeding that of the pectoral fins. The first anal fin is also well-developed, but its posterior rays are generally short. The second dorsal fin and the second anal fin are roughly the same shape and size and are located directly opposite each other. Both lobes of the caudal fin are narrow, and the angle between them is great.

Both jaws have rasp-like teeth, but the development of the palatine teeth is poor and they cover only a small area. The gill filaments are long and slender. The centra of the vertebrae are long, and the neural spines are also long. The neural spines of the abdominal vertebrae generally have their anterior and posterior edges somewhat rounded; their posterior tips are sharply pointed, and they are somewhat foliate in shape.

The dorsal surface is dark purple in color, and the belly is silvery-white. There are more than 10 clear, vertical cobalt stripes on the sides of the body. The first dorsal fin is of a bright cobalt color, and there are sometimes numerous dark blue spots on the lower part of its highest portion. The other fins are generally a dark blue in color. The flesh is of the so-called "spearfish-color", and is delicious when eaten raw.

This species is broadly distributed south of the northeast coast region of Honshū. In the area in which the Kuroshio originates, this species is next to the white marlin in terms of numbers. The peak of the spawning season for this species in Formosan waters is May.

These fish attain a body length of 3,000 millimeters and a weight of 100 kilograms, however, ordinarily fish of 40 to 60 kilograms are most common.

4. Kajikia formosana Nakamura

In Japanese kokajiki.

Closely resembles K. mitsukurii in form. In this species, however, the pectoral fins are shorter and the rays posterior to the middle part of the first dorsal fin are longer. The length of the pectoral fins is roughly 0.85 times the body depth. The rays of the middle part of the first dorsal fin are somewhat longer than 1/2 the body depth. Consequently, the profile of the first dorsal fin somewhat resembles that of Tetrapturus angustirostris.

A species very closely resembling this one has been reported from the Hawaiian area by Jordan and Evermann. They assigned this species to the genus Tetrapturus on the basis of the form of the first dorsal fin and the pectoral fins, and gave it the name T. ectenes or the slender spearfish. It is thought that these two species are probably one and the same, however, they appear to differ in a number of characters and therefore, pending future investigation, they are here recorded as separate species. Furthermore, it is thought that Jordan and Evermann's assignment of the species to the genus Tetrapturus should obviously be corrected.

Subfamily Marlinae

The body is elongated but conspicuously stout, and the body depth is generally great. The greatest height of the first dorsal fin is less than the body depth, and the height of the fin gradually decreases posteriorly. The ventral fins are shorter than the pectoral fins. Vertical stripes may or may not be present on the sides of the body. The vertebral count is $11 + 13 = 24$.

The species of this subfamily show marked differences in size by sex, the males generally being smaller than the females. Furthermore, the sexes differ with regard to the season at which they migrate into various areas, and consequently, the sizes of fish which are taken at different seasons vary remarkably. Hitherto, the species of this subfamily have been lumped together with those of Kajikia in the genus Makaira, but because of their marked morphological differences, they have been separated and set up as a new subfamily.

Key to the Genera

1. The pectoral fin forms a right angle with the side of the body, and cannot be folded against the body without breaking the joint. No vertical stripes on the side of the body. A simple lateral line. The air bladder is foam-like, with several layers of small chambers, the whole enclosed within a thick membrane .... Genus Marlina

2. The pectoral fins can be readily folded back against the side of the body. Vertical stripes are present on the sides of the body. The lateral line is complex. The small chambers of the air bladder are generally arranged in a single layer, and the membrane which covers its outside is not particularly well developed .... Genus Eumakaira

Genus Marlina Nakamura

The pectoral fins form roughly a right angle with the sides of the body, and cannot be folded back against the sides of the body without destroying their joints. The construction of the air bladder is peculiar, being a bubble-like mass of small chambers arranged in several layers, the outside of the whole mass being enclosed in a thick membrane. The lateral line is single. There are no vertical stripes on the sides of the body. The following single species occurs in Japanese waters.

5. Marlina marlina (Jordan and Hill)

In Japanese shirokawa, shiromazaara, genba, katahari, or shirokajiki.

Figure 21.--White marlin.

First dorsal fin has 36 to 40 rays, of which the first three are spines, the following 10 to 12 have branched tips, and the remaining posterior rays are again spines. The second dorsal fin has 7 soft rays. The first anal fin has 2 spines and 10 to 11 soft rays. The second anal fin has 7 soft rays. The ventral fins have 1 spine and 2 soft rays. The vertebral count is 11 + 13 = 24.

The body length is about 2.8 times the head length, 4.5 times the greatest body depth, and about 6 times the body depth at the first anal insertion. Head length is 1.5 times snout length, and 5.8 times the space between the eye sockets. The length of the snout is 2.3 times the head length excluding the snout. The head length excepting the snout is 4.3 times the diameter of the eye. The distance between the eye and the insertion of the first dorsal fin is 4.3 times the eye diameter. The greatest body depth is 6.1 times the depth of the caudal peduncle. The ratio of the length of upper to lower jaw is 1.9.

The body is elongated. It is rather conspicuously compressed laterally, the body depth is great, and the projection of the dorsal profile at the anterior end of the first dorsal fin is conspicuous, for which reason it is sometimes called katahari (broad-shoulder). The caudal region gradually becomes cylindrical in form, and there are two keels on each side of the caudal peduncle. The snout is rather short and somewhat compressed dorso-ventrally. The body is covered with slender bony scales which are buried in the skin. The lateral line, which is simple, is extremely difficult to see, but it is present.

The highest portion of the first dorsal fin is at its fifth ray, but it is far less than the body depth, the body depth being roughly 1.6 times the height of the first dorsal fin. Posterior to the sixth ray the dorsal fin gradually decreases in height, and the rays posterior to its central part are extremely low. The pectoral fins are well developed, falcately curved, forming a right angle with the side of the body. They cannot be folded back against the sides of the body without breaking their joints. Their length is roughly equal to the body depth. Because of this peculiarity, this species is called in Formosan Chinese the "Standing Wing Spearfish." The ventral fins are remarkably small. The first anal fin is well developed. The second dorsal and anal fins are roughly of the same shape and equal size, and are located symmetrically with respect to one another. Both the upper and the lower lobes of the caudal fin are narrow and they are broadly forked.

The teeth in both jaws are rasp-like, and the palatine teeth are vestigial. The branchiostegals are rather broad, particularly the most posterior, which are triangular in shape. The pectoral girdle is broad, and the surface for articulation with the projection of the coracoid is twisted into a nearly horizontal position. The centra of the vertebrae are rather short and thick, and both the neural and haemal spines are remarkably long, being arranged more or less in echelon. The neural spines of the abdominal vertebrae are broad and their anterior edges are curved, but they do not differ conspicuously in form from those of the caudal vertebrae.

The dorsal surface is steel-blue with a blackish cast, and the belly is white. In life there is a steely-blue slime, but the overall coloration is close to a milky-white. There are no vertical stripes on the sides of the body. The first dorsal fin and the first anal fin are a beautiful cobalt color, but when exposed to the air for a long time, they become dark blue. In many cases, there are a number of round dark blue spots on the highest portion of the first dorsal fin. The other fins are all dark blue in color. The flesh is of the so-called "spearfish color", and is delicious when eaten raw. Fish taken in Japanese waters during the winter are said to be somewhat inferior in flavor.

This species occurs widely throughout the warm seas of the Pacific and Indian Oceans and the northern limit of its distribution in Japanese waters is said to be off the Sanriku region (Northeastern Honshū). This fish attains a body length of 3,500 millimeters and a weight of 570 kilograms.

Because the structure of the pectoral fins and the form of the air bladder differ completely from all other species, this species has been placed in a new genus. Jordan and Hill have recorded no comments on the peculiar form of the pectoral fins, but in the photograph of their type specimen this peculiarity is clearly apparent.

Genus Eumakaira Nakamura

The pectoral fins can be readily folded back against the sides of the body. The body is remarkably stout and the degree of lateral compression is slight. The lateral line is complex in form, dividing near its anterior extremity, joining again approximately below the 10th ray of the first dorsal fin, dividing again, joining at a point below the 15th to 17th dorsal rays, thereafter dividing again, and joining again below the 30th to 33rd dorsal rays. Posterior to this point the line runs straight, but it is extremely obscure. The following single species occurs in Japanese waters.

6. *Eumakaira nigra* Nakamura

In Japanese *Kurokajiki* or *kurokawa*.

Figure 22.--Black marlin.

The first dorsal fin has 40 to 46 rays, the first 3 of them spines, the following 14 to 16 rays with branched tips, and the remaining posterior rays spinous. The second dorsal fin has 7 soft rays. The first anal fin has 2 spines and 14 soft rays. The second anal fin has 7 soft rays. The ventral fins have 1 spine and 2 soft rays. The vertebral count is $11 + 13 = 24$.

Body length is 2.8 times the head length, 4.6 times the greatest body depth, and 5.7 times the body depth at the insertion of the first anal fin. The head length is about 1.5 times the snout length and about 5.7 times the interorbital space. The snout length is 2.5 times the length of the head excluding the snout. The length of the head excluding the snout is about 4 times the diameter of the eye. The distance between the eye and the insertion of the first dorsal fin is 4.2 times the diameter of the eye. The greatest body depth is 5.9 times the depth of the caudal peduncle. The ratio of length of upper to lower jaw is 2.2

The body is elongated. The body depth is great, the degree of lateral compression is slight, and the caudal region is almost cylindrical in shape. The body depth at the insertion of the first dorsal fin is comparatively greater than in other species. There are two keels on each side of the caudal peduncle. As the upper jaw is rather long and the lower jaw is short, the head tapers sharply to a point. The gill membranes are short. The body is covered with bony, slender scales buried in the skin. The lateral line is extremely obscure, and of the complex form described under the characteristics of the genus. The longest ray of the first dorsal fin is the 5th. Its height is conspicuously less than the body depth, the body depth being 1.5 times the height of the first dorsal fin. Posterior to its 6th ray, the first dorsal fin gradually decreases in height, and its posterior rays are extremely short. The pectoral fins are well developed, hardly at all falcate, and their length is roughly equal to the body depth. The ventral fins are poorly developed and shorter than the pectoral fins. The first anal fin is rather well developed. The second dorsal fin and the first anal fin are almost the same shape and size, and are located approximately opposite each other. Both lobes of the caudal fin are narrow, and the angle formed by them is great.

Both jaws have rasp-like teeth, but the palatine teeth are vestigial. The branchiostegals are rather short. The vertebrae are rather short, and the neural and haemal spines are conspicuously elongated, their anterior margins being rounded and their posterior margins somewhat concave with the posterior point sharp. The neural spines of the abdominal vertebrae are arranged roughly in echelon.

The dorsal surfaces are dark purplish-blue, while the ventral surfaces are rather brownish, but the overall color is blackish. The scales come off more easily than in other species, and where they are removed the coloration of the fish is brown. The first dorsal and first anal fins are cobalt in color, but when exposed for a long time to the air, they become dark blue. In extremely rare cases, there are a number of dark blue round spots on the highest portion of the first dorsal fin. All of the other fins are dark blue in color. There are a number of vertical stripes of cobalt color on the sides of the body. The flesh is of the so-called "spearfish color", and in early spring the fat content is high and the flesh is particularly delicious.

This species is widely distributed in the warm seas of the Pacific and Indian Oceans, and appears to be generally abundant in the Equatorial Current and the Kuroshio. The peak of its spawning season in Formosan waters is in June.

This species is second in size to the white marlin, Marlina marlina, and attains a body length of 3,000 millimeters and a weight of 500 kilograms.

The author has previously reported this species as Makaira mazara (Jordan and Snyder), but in the original description of M. mazara there is no mention made of the peculiar form of lateral line which is found in this species. Furthermore, the photograph of Jordan and Evermann's type of M. mazara clearly differs from E. nigra as described here, and is either identical with or extremely close to Kajikia mitsukurii. The new genus has been established and this fish has been reported as a new species on the basis of these facts.

Family Xiphiidae

The body is elongate, but there is hardly any lateral compression. There is one large keel on each side of the caudal peduncle. The scales disappear in the adult fish, but the skin in the pectoral region is coarse and has somewhat the feel of shark skin. Teeth are present in juvenile specimens, but these too disappear in the adult fish. The dorsal and the anal fins are both single, continuous fins in juvenile fish, however, in adult fish each is divided into two fins separated by a large space. There is no trace of ventral fins. The snout is long, with the form of a two-edged sword, and there is no predentary bone at the tip of the lower jaw.

There is one genus (Xiphias Linnaeus, 1758) containing one species. It is of cosmopolitan distribution in the tropical and temperate seas of the whole world, and occasionally appears in waters of rather high latitudes.

7. Xiphias gladius Linnaeus

In Japanese tsun, kajikitōshi, shutome, or mekajiki

Figure 23.--Broadbill swordfish

The first dorsal fin has 38 to 40 rays, the 3 most anterior being spines, the following 9 rays with branched tips, and the remaining posterior rays are all spines. The second dorsal fin has 4 soft rays. The first anal has 2 spines and 7 soft rays. The second anal fin has 4 soft rays.

Body length is 1.8 times the head length, 5.2 times greatest body depth, about 6 times the depth of the body at the insertion of the first dorsal fin, and 1.4 times the head length excluding the snout. The head length excluding the snout is 3.7 times the eye diameter. The interorbital space is about twice the eye diameter and the distance between the eye and the insertion of the first dorsal fin is about 3.4 times the eye diameter. The greatest body depth is 7 to 7.5 times the depth of the caudal peduncle, and 1.3 times the length of the pectoral fins. The length ratio of the upper to the lower jaw is about 3.8.

The body is elongated, but there is hardly any lateral compression. The profile of the dorsal surface anterior to the insertion of the first dorsal fin does not project as conspicuously as in the fishes of the family Istiophoridae. There is one large keel on each side of the caudal peduncle. For this reason, when the caudal peduncle is viewed from above, it appears conspicuously flattened. In the juvenile stages the fish has bony scales which disappear in adult specimens, however, the skin in the pectoral region is coarse and has the feel of shark skin.

The height of the first dorsal fin is roughly equal to the greatest body depth. Posterior to the fifth dorsal ray, the height of the fin decreases rapidly, and from about the vicinity of the 20th ray posteriorly, the fin rays hardly project above the surface of the body. The second dorsal fin is well separated from the first dorsal fin, and is composed of 4 small, soft rays. The pectoral fins are placed low and are rather short, being 0.8 times the greatest body depth. Ventral fins are non-existent. The first anal fin is of moderate size. The second anal fin and the second dorsal fin are roughly the same shape and size. Both the upper and lower lobes of the caudal fins are narrow and broadly forked, however, the angle formed by them is smaller than in the case of the Istiophoridae.

The upper jaw is remarkably long, being more than 7/10 the length of the remainder of the body. It has the form of a two-edged sword blade, and is hollow with occasional septa. The lower jaw is short and rather slender, and there is no predentary bone. The vertebral count is 6 $\neq$ 10 = 26. The neural and haemal spines have the form of spines rather than of flat plates. Both the neural and haemal projections are narrow and their length does not exceed that required to support the immediately preceding neural and haemal spines. The form of the vertebrae is conspicuously different from that of the fishes of the family Istiophoridae.

The dorsal surfaces are dark blue with a brownish cast. The ventral surfaces are white and rather yellowish. All of the fins are dark blue in color. The flesh is a pale pink.

This species is widely distributed throughout the warm seas of the world.

III. FISHERY

Among the fisheries which have the tunas and spearfishes as their object, net fishing with gill nets and encircling nets and hook and line fishing with trolling lines, poles and lines, and longlines are carried on. Another special type of fishing which is carried on is that using the harpoon. Each of these types of fishery has its special characteristics, and each has an important significance in one area or another. Among them, however, the longline fishery can be considered the most important, both in terms of the scale on which it is prosecuted and its widespread character.

A description of the gear and methods employed in each of these fisheries is not the objective of the author in the present book, so it will be omitted, and the discussion will be limited to a description of the characteristics and various problems of the longline fishery as representative of the tuna fisheries.

a. Characteristics

When a general comparison is made between the so-called surface fisheries, which have the tunas and bonitos as their object, and the bottom fisheries, it is apparent that there are a number of marked differences between the two, although they are spoken of inclusively as the deep sea fisheries.

In the first place, they differ as to the type of enterprise which operates in them; hitherto the surface fisheries have been chiefly prosecuted by individual entrepreneurs with comparatively small capital, while the bottom fisheries have been carried on almost entirely by corporations with large capital.

The second point of difference is in fishing gear and methods. In the surface fisheries hook and line gear is of primary importance, while net fishing is the principal method employed in the bottom fisheries.

There are probably various other differences which might be cited, but, if we consider the origin of these differences, they are, after all, based on the characteristics of the resource which each of these fisheries has as its object. The essential characteristics of the resource are, in the final analysis, ascribable to the environment, that is, to differences in the character of the waters and the adaptability of the fishes.

First of all let us add some considerations relating to the first point of difference, that is, the difference in the type of enterprise.

The surface fishes are possessed of great mobility and migrate widely in the oceans. Various explanations of the causes and courses of these migrations are put forward, but, because of the presence of numerous elements of difficulty in the study of these phenomena, knowledge which might contribute directly and appropriately to the operation of the fishery is as yet almost totally lacking. For this reason it is difficult to forecast the results of fishing without actually going to the fishing grounds and operating there. In the case of the bottom fisheries such forecasts can already be made with some accuracy. In other words, the surface fisheries can be said to be inferior to the bottom fisheries in stability or susceptibility of planning. This low degree of operational planability and the low catch efficiency described below have probably been the most important causes operating to curb the desires of capitalists to invest in these fisheries in the past. Besides these reasons, the surface fisheries do not require a great deal of material as compared with the bottom fisheries, and so it is comparatively easy to enter such a fishery with small capital. This has probably been a powerful cause for the prevalence of individual enterprise in the fishery.

In recent years tuna longline fishing grounds, principally for yellowfin, have been developed in tropical waters, the planability and stability of the fishery have been greatly increased, and the advance of big capital into this field has been brought about. This is the so-called mothership-type tuna fishery.

The initiation and development of the mothership-type tuna fishery before the second World War cannot, however, be fairly ascribed simply to the above-mentioned improved planability and stabilization of this fishery. It is an undeniable fact that it reflected the economic conditions which obtained in Japan at that time. That is, the strengthening of controls on the use of materials employed in the fishery, particularly fuel, made single vessel operations remarkably difficult, and mothership-type tuna fishing was devised as a measure for overcoming these circumstances.

Whatever the causes may have been, the fact remains that the change over from single vessel to mothership-type operation was a great stride forward in the tuna longline fishery. And it may prove to have been an essential stage in the path of development of this fishery.

So considered, the tuna longline fishery, compared to the bottom fisheries, can be thought to be in its youth or in a primitive stage of development. If this view is correct, it must mean, on the other hand, that the tuna longline fishery has many unexploited fields which will be greatly developed in the future.

If we look at conditions since the war, we see that the tuna longline fishery, through the establishment of a number of large and small so-called "new" fishing companies, and especially through the advance into this fishery of the Nichiro Fishing Company, which was prominent for many years in the fisheries in northern waters, has become quite suddenly the bright star of the Japanese fishing industry. This situation does not, however, necessarily represent an essential stage in the development of this fishery. It is, rather, in large measure something made unavoidable by the restrictions of various kinds under which Japanese fisheries have been placed during the Occupation, and it also partakes to a large extent of the nature of an emergency measure taken in the face of the great general overturn in the Japanese economy. Accordingly, one cannot, unfortunately, deny the impression that at bottom it still retains an element of instability.

As to the second point, the differences in fishing gear and methods, they may, after all, be ascribed to the marked differences of environment and habits of the fishes sought.

In the open sea, where the depth of the water attains to several thousand meters, there is absolutely no place for the establishment of a trawl fishery. Seines and gill nets, too, require many conditions for their use, and they cannot be operated at just any time or any place. Therefore under present conditions, except in sea areas which offer certain particular characteristics, the establishment of net fisheries for tuna cannot be considered. This is, however, a view based on present conditions, and in case in the future a method is devised for causing fish to concentrate within a small area by means of special kinds of light rays, sound waves, or the like, the establishment of a net fishery will become by no means impossible.

Stated in an extremely general sense, net fisheries are a great deal more efficient than hook and line fisheries. The obviousness of this is witnessed by the common saying "Net -- rich man; line -- beggar." For example, according to prewar statistics, the catch per ton of fuel oil consumed was 5 - 6 tons in the trawl fishery and around 2 - 3 tons in the tuna longline fishery. This high catching efficiency, considered only from the point of view of the entrepreneur, is advantageous and desirable, but looked at from the broad standpoint of overall production, it would be hard to say that it is always necessarily advantageous or desirable. The more efficient the fishing method becomes, the greater is the danger of its effectiveness surpassing the reproductive potential of the fish. In other words, there arises a danger of a decline in the resource itself. Such a tendency toward a decline in the resource was already rather clearly apparent in the trawl fishery before the war, and measures to protect the resource, such as limitations on the number of vessels and the establishment of prohibited areas, were being devised. The marked decline in the bottom fish resources of Japanese coastal waters since the war is a good example of this phenomenon.

Table 5

Comparison of Catches in the Trawl Fishery
(Statistics from Ministry of Agric. and Forestry)

Year	Catch (kan)*	Index
1926	12,149.207	73
1930	16,638.505	100
1931	15,720.414	94
1932	15,146.358	91
1933	13,427.134	80
1934	13,787.940	80
1935	14,257.940	81
1936	13,886.917	80
1937	13,380.415	80
1938	10,072.302	60
1939	9,709.846	58
1940	9,002.069	54

* 1 kan equals 8.27 lbs.

Note: The sudden decline from 1938 on was due to the Sino-Japanese war.

As has been shown, the longline fishery is the main part of the tuna fishery. If we consider the catch by nets as a solid body, the catch by longline is, by comparison, a line, or rather, a dotted line. In recent years the tuna longline fishery has come to be prosecuted on a remarkably large scale, with large vessels in some cases operating as much as 300 - 350 baskets of gear at a time. Since the length of the main line in one basket is about 300 meters, the total length of the gear comes to about 90 kilometers. This is done on the chance that some part of the line will encounter a school of fish, but the gear itself remains, as before, a dotted line. Furthermore, in this fishery the catch is limited to fish which have already grown to quite a large size. Knowledge concerning the larval and juvenile forms of the tunas is extremely poor, and hardly anything is known about their ecology. Consequently they are not the object of a fishery at all. Even if their ecology were made clearly known, it cannot be thought that a fishery would grow up which would make the larval and juvenile fish its objective. After all, it is possible to think of fishing as a sort of thinning out of a crop. In actuality, up to the present the tunas seem to show absolutely no evidence of overfishing. The yearly variations in the catch are thought to be caused mainly by changes in oceanographic conditions. We know of absolutely no data that would show that cessation of fishing had any effect upon the population of these fishes.

In order to afford a contrast with table 5, some tuna catch statistics are given in table 6.

Table 6

Comparison of Tuna Catches, Including Spearfishes
(Statistics of the Ministry of Agriculture and Forestry)

Year	Catch (kan)	Index
1926	12,247.074	100
1930	12,234.290	100
1931	17,766.043	145
1932	16,398.100	134
1933	17,253.381	141
1934	16,015.738	131
1935	18,787.228	154
1936	20,642.541	168
1937	16,927.320	138
1938	15,743.556	129
1939	23,285.086	190
1940	23,389.231	191

If this table is compared with table 5, it will be noted that the variations in the amount of the catch from year to year are great. In spite, however, of these marked variations, there is clearly a general tendency for the catch to increase gradually. It is to be regretted that the number of vessels engaged in the fishery is not accurately known, but if the assumption is made that the boats working in the skipjack fishery all engage in the tuna fishery during the winter, we get approximately the following situation.

Table 7

Number of vessels engaged in the tuna fishery
(Compiled by the Oceanic Fisheries Association,
based on conditions in the Japanese fishery)

Year	Number of Vessels	Tonnage
1932	98.2	95.8
1933	88.3	95.9
1934	86.6	113.3
1935	100.0	116.7
1936	114.8	131.8

Notes: (1) These are index figures with 1931 as 100.
(2) The number of vessels in 1938 was about 1,100.

Comparing tables 6 and 7 it seems that the rate of increase of the number of vessels employed and the rate of increase of the catch roughly parallel each other. If this is really the case, this fact must be said to be of extreme importance. For it means that although the number of vessels operating has increased, the boats themselves have increased in size, and the fishing grounds have in consequence been extended, the annual catch per boat cannot be perceived to have changed very much from what it was before the war. At this stage it cannot yet be thought that the catch is surpassing the natural increase of the tunas. In other words, not only can it be said that there is no indication of overfishing, but the inference can be drawn that this fishery, which has been thought to be lacking in planability, is, in the overall view, susceptible of planning to some degree.

Let us add a few considerations anent the third problem, that of the distribution, even or uneven, of fishing grounds and fishing seasons.

In the bottom fisheries and the coastal fisheries the fishing grounds are subject to geographical limitations, and these limitations are absolute. In these fisheries, both because of the distribution of the fishes which are their object and because of the fishing techniques employed, the fishing grounds are almost entirely restricted to the so-called continental shelf. Consequently the sea areas suitable as fishing grounds are really only a very small part of the sea as a whole, and they are unevenly distributed.

In the case of the tuna fisheries the restrictions imposed by the depth of the sea are, in general, exactly the opposite of those imposed in the case of the bottom fisheries. Generally stated, the sea areas in which tuna are found are centered on the Equator, from which they extend 40° - 45° north and south. Accordingly, all of the sea areas within this range have some direct relation, leaving aside the question of quantity, to the tuna fishery. In Japanese waters one or another species is found throughout the year in the area south of 35° north latitude. Farther to the north excellent fishing grounds are found from autumn to early winter. Thus the fishing grounds of the tuna fisheries, compared to those of other fisheries, have a remarkable evenness of distribution.

Of course it is a great deal more advantageous that fishing grounds be extensive and evenly distributed than that they be restricted in extent and spotty in occurrence. However, the sole fact that they are extensively and evenly distributed does not necessarily mean that they are superior fishing grounds. The density of distribution of the fishes which are sought, and the difficulty or ease of operation are important factors.

The factors which determine the density of distribution of fishes are extraordinarily complex and not easily learned, but they probably boil down finally to the productive potential of the sea area. In other words, they may be thought to be directly related to solar energy and the distribution of nutrient salts within the area.

It is a known fact that, for various reasons, the amounts of nutrient salts present in coastal waters and in the seas of high latitudes are great, while in the open sea of low latitudes they are scanty. Consequently, it is said that the productive potential per unit of sea water in the seas of the low latitudes is much less than it is in the high latitudes and in coastal areas, and the fish population is therefore smaller.

The facts set forth above provide extremely disadvantageous conditions for the tuna fishery, which has as its fishing grounds the open seas of the low latitudes. The most advantageous situation from the point of view of convenience in catching fish is to have the greatest possible number of fish concentrated within the smallest possible area. From this point of view the fishing grounds of the bottom fisheries and the coastal fisheries offer much better conditions than do the tuna grounds.

If, however, we advance a step further in our thinking, we see that because they do offer such excellent conditions, these fishing grounds have been exploited early, the fisheries carried on in them have been developed to a remarkably high degree, and they have either already reached the peak of their development or are close to it. Consequently the question of how best to regulate the catch and the maintenance and propagation of the resource has become an important and pressing problem; various positive and negative measures for the maintenance of the resource -- such as limits on the size of fish to be taken, limitations on fishing seasons and grounds and the number of vessels engaged, and the establishment of facilities for the propagation and protection of the resource -- have become extremely vital matters.

The yellowfin grounds centered on the Equator, the spearfish grounds covering all of the subtropical seas, and the albacore grounds centered at 30° - 40° north latitude all are subject to restrictions of latitude and all present shifts due to seasonal changes, but they are indeed extensive. Because the fishing methods employ mainly the hook and line, and because of the spawning habits described below, it is thought that the propagation of the resource is suitably regulated under natural conditions. At any rate, under the conditions obtaining up to the present it is hard to discern any signs of a decline in the resource due to overfishing, and the yearly fluctuations in the catch may be considered to be mainly controlled by changes in the environment.

The foregoing refers to the universality of distribution of the fishing grounds in a horizontal sense, but it is also necessary to take account of the distribution in depth. In tropical sea areas, where the sea water is highly transparent, solar energy can reach to great depths and the sphere within which marine life can exist is thereby enlarged. It appears that in the tropic seas the range within which the tunas can live extends to far greater depths than has been thought hitherto. For example, there are data which show that the yellowfin is present in some abundance at depths as great as 160 meters. (See table 9).

It has already been said that, if we compare the productive potential per unit of sea water, the cold seas and coastal waters show markedly higher values than the tropic seas. And it has been noted that there is a theory that the density of distribution of fishes in tropical waters is consequently low. If, however, the range of occurrence is compared, that of the tunas is much more extensive than that of the fishes of northern seas or of demersal and coast-dwelling species. Thus if a comparison is made of the absolute quantity of the resource, it may be wondered which will be the greater, the so-called pelagic fishes such as the tuna, or the demersal and coastal fishes?

Within the limits of present knowledge there is absolutely no way to arrive at an answer to this question, however, if we take into account the various factors set forth above, it is impossible to conclude that the tuna resource, in terms of its absolute quantity, is necessarily inferior to the demersal and coastal fishes. The schools which migrate into Japanese waters(15) probably represent no more than one branch of the tuna resource of the Indian and

(15) There are people who think that all of the tuna and bonito at least once in their lives migrate into Japanese waters. The author is of the opinion expressed above.

Pacific oceans. And the amount of fish that is actually taken[16] can be thought to be only a part of that branch. It is probably impossible to grasp the absolute quantity of the resource, and even if it were possible to do so, the magnitude of this quantity and such things as the difficulty or ease of capturing the fish and the possibility of loss in the operation of the fishery remain quite separate problems. The discussion has strayed from the question of the universality of distribution of the fishing grounds, but in any case there is no basis upon which to gainsay the fact that the tuna grounds have such universality to a much greater extent than do the bottom-fishing grounds and the coastal fishing grounds.

I will now present some opinions on the matter which may be thought to have deep relationship to the foregoing, that is, the way in which the tuna resource is propagated, or in other words, the spawning of the tunas.

As has already been set forth in the sections on spawning and growth, it is thought that the spawning of these fishes takes place throughout an extremely wide area and over a long period of time. This type of spawning habit is not limited to the tunas, but is thought to be generally shared by all the pelagic fishes of warm seas. To cite an example, in the case of the milkfish Chanos chanos the larvae appear throughout the year in the waters of the Java area, but the periods of greatest abundance are said to be May and November. The larvae of the same species appear in Phillipine and Formosan waters from April to October, with the period of greatest abundance extending from June to August. It is not clear whether or not these larvae are produced by the spawning of schools belonging to separate independent stocks, but as far as the period of greatest spawning activity is concerned, at any rate, the northern and southern hemispheres present quite different situations.

With regard to the tunas and spearfishes we do not yet have as reliable data as in the case of the milkfish, however, if we assemble and consider certain data, it appears that the same sort of phenomenon can be discerned. A tendency can be detected for the spawning season to differ somewhat and for different year-classes to appear in different sea areas. However, as their interrelationships are completely unknown, no conclusions can be drawn as to whether they belong to the same or different stocks. Furthermore, with regard to the temporal differences, it cannot be hastily determined whether it is a case of different schools spawning at different seasons, or whether it arises through the same school's spawning while on the move. In any case, it is a fact that spawning

(16) Morisaburo Tauchi (1940) has given the following catch rates for tuna migrating into Japanese waters: yellowfin, 29%; black tuna, 55% when young/meji/ and 10% when mature/maguro/; albacore 18%.

continues over a very long period of time and throughout very extensive spawning grounds. There are hardly any data from the southern hemisphere, so the situation there is not clear, but there may be thought to be a possibility that, if we consider the northern and southern hemispheres together, spawning may be taking place somewhere throughout the whole year.

In the general view, the higher the latitude of the sea area, the shorter and more clearly delimited is the spawning season of the fishes dwelling there. There also seems to be a tendency for the spawning grounds to be more sharply defined. It goes without saying that such phenomena are almost entirely controlled by temperature. In short, fishes of the cold seas have a short spawning season and their spawning grounds are, comparatively speaking, limited to particular areas. In other words, the propagation of the resource is carried on within a restricted sea area during a short period of time.

The best conditions for fertilization are that the greatest possible number of ripe males and females should congregate at the same time within the smallest possible area. The results of their reproductive activity will be the production of a great number of larvae in a short period of time. Unless the largest possible number of these larvae attain maturity, the basic objective of reproduction will not be realized. For this growth the most essential and important condition is probably the presence of abundant food. It goes without saying that the ultimate food, not only of larvae but of all fishes, is plankton.

The production of plankton in cold seas is regulated by the temperature, and an explosive proliferation of plankton takes place once a year. In temperate seas there are two such proliferations, in the spring and autumn, but the flowering is far less conspicuous than it is in colder waters. When we come to tropical waters it is even less marked than it is in the temperate zone, and a particular season of plankton abundance can hardly be detected.

If the spawning habits discussed above and the conditions of plankton production in various sea areas are compared, it can be seen that in each case the spawning habits are such as to provide most adequately for the maintenance of the species.

The fact that the tunas spawning in the warm seas, where seasonal quantitative changes in the plankton are slight and its quantitative distribution is even and sparse, spawn throughout broad sea areas and long periods of time can be thought, from the ecological point of view, to be extremely reasonable. If, like the fishes of cold seas, the tunas spawned great numbers of eggs in a very short period of time in a limited area, the larvae which hatched out would quickly starve and it would be difficult to realize the objective of maintaining the species.

The spawning habits of the tunas are generally as outlined above. The life of the immature fish is almost completely unknown, but when they have attained a certain size they form large schools and begin to migrate. The tuna fisheries are based on the utilization of this habit.

Considering the whole extent of the seas in which they are distributed, the population per unit of area is no doubt small in comparison with that of other fishery resources, but the population within the scope of schools that are formed is by no means small. The reason for the markedly unstable character of the tuna fisheries in comparison with the coastal and bottom fisheries is not that the absolute quantity of the resource is inferior to that of the demersal fishes. The problem is that the organization and form of the schools and the factors controlling their migration, congregation, and dispersal are extremely difficult of investigation, and consequently our knowledge concerning them is extraordinarily poor.

A look at present conditions in the tuna fisheries reveals that the more progressive among the operators engaged in these fisheries are gradually coming to raise their voices more and more in demands for scientific backing. But at present the only application of scientific methods is merely the measuring of surface water temperatures in order to locate fishing grounds, and not one step has been taken in advance of a condition where operations are still based on the experience and judgment of the fisherman.

b. The problem of fishing gear

The structure of longlines is not standardized, but has changed from period to period and varies according to the species fished for. There are also local peculiarities, constructions which are thought to be best suited to conditions in various sea areas. Furthermore, within the same region individuals construct their lines differently, each fisherman using the type of gear which he thinks most suitable on the basis of his personal experience and study.

The factors which should determine the structure of the lines are:

i. Catch efficiency
ii. Simplicity and ease of operation
iii. Strength
iv. Expense of construction

It is not thought that factors iii and iv offer any great difficulties, but i and ii, particularly i, involve some rather important problems.

It need hardly be said that the most effective way to bring operating efficiency to its highest level is to select for operations the areas in which the tuna are present in the greatest concentrations. This, in other words, means the selection of good fishing grounds. This is the field which has received the most attention hitherto, and it is hardly an exaggeration to say that fishery investigations and fishing ground surveys have almost been limited to this one objective.

However, the problem under discussion here is not that of the methods to be followed in selecting a fishing ground, but that of the construction of the most efficient gear for a given ground. This sort of problem, in spite of its importance, generally receives little attention in comparison with the interest shown in the matter of scouting for fishing grounds. There is almost no scientific basis worth mentioning for the consideration of such problems as the length of branch lines and float lines, that is, the depth at which the hooks should fish, the number of branch lines, and so forth. The construction of the lines is determined simply by experience, or by imitation of others, or according to the materials available.

It hardly need be said that errors in the selection of fishing grounds can have a lethal effect on the fishery; but even though there are no such errors, if the fishing gear is unsuitable, the results of the fishing will naturally be inferior. As an example, the results obtained by the Hakuyō Maru[17] on training cruises in various southern sea areas are cited in the following table.

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(17) Former training vessel of the Ministry of Agriculture and Forestry's Fisheries Institute.

Table 7

Fishing Results of Different Branch Lines (Hakuyō Maru)

Year and Month	Area	Short Branches		Long Branches		Notes
		Fish	%	Fish	%	
1930, Dec.	Coastal waters of Nicobar Islands	28	27	76	73	Fish particularly numerous on short branches 3 times, on long 4 times.
1931, Jan.	Coastal waters of Sumatra and Java	32	29	81	71	
1933, Jan.	Coastal waters of New Guinea	13	23	43	77	Numerous on short branches 1 time, on long 2 times, unknown 10 times.

Notes: (1) Short branches 5 ken [30 ft.] 4 lines

(2) Long branches 16.5 ken [99 ft.] 2 lines

(3) Float lines 15 ken [90 ft.]

(4) As the number of short branches is twice as great as the number of long branches, it must be halved when calculating the catch per 100 hooks.

It appears from table 7 that the long branch lines were much more efficient than the short ones. In all of the various sea areas fished the results were approximately the same, with the catch rate of the long branches being about 6 times that of the short branches. From these results it is judged that the efficiency of the short branches is markedly inferior to that of the long ones. This evidences the fact that the suitability or unsuitability of the construction of the gear has a very great effect on the catch rate.

It may be inferred that the depth at which the catch rate is highest, or in other words, the level where the tunas are most densely distributed or where the light and temperature conditions of the environment make it easiest to catch them, differs according to the sea area and the season. The necessity of clarifying this situation is incontrovertibly shown in table 8. For the purpose of ascertaining the level at which the fish are swimming, the gear in general use (including that used by the Hakuyō Maru) can hardly be said to be suitable. As the following figure shows [Figure 24 Plan of tuna longline], it is hard to tell accurately where the hooks are, although their approximate position can be known. As the positions of a and b in the figure change, the position of c will necessarily undergo various changes. In order to do away with this defect, the Shōnan Maru employed gear in which there was a float attached to each branch line to investigate the level at which tuna were caught. The results are given in table 8.

Surveying the results set forth in table 8, a - c, one can detect a tendency for the catch rates for tuna in waters east of Formosa to increase with increasing depth, at least down to 100 meters. The spearfishes are caught in greatest numbers at somewhat shallower depths, 50 - 60 meters, while the catch rates for sharks are highest at even shallower levels.

Table 8

Fishing Situation at Different Depths

a). East of Formosa, Nov. - Dec., 1935 (Shōnan Maru)

Depth	Number of Hooks	Yellowfin		Big-eyed		Striped Marlin		Sailfish		Short-nosed		Sharks	
		Fish	%	Fish	%	Fish	%	Fish	%	Fish	%	Fish	%
35	1,758	8	0.5	0	0.0	1	0.0	1	0.0	0	0.0	35	2.0
56	879	6	0.7	1	0.1	9	1.0	0	0.0	0	0.0	9	1.0
86	1,758	15	0.9	3	0.2	9	0.5	0	0.0	0	0.1	10	0.6

b). East of Formosa, Nov. - Dec. 1936 (Shōnan Maru)

Depth	Number of Hooks	Yellowfin Fish	%	Big-eyed Fish	%	Striped Marlin Fish	%	Sailfish Fish	%	Short-nosed Fish	%	Sharks Fish	%
60	2,160	22	1.0	5	0.2	18	0.8	4	0.2	16	0.7	42	1.9
80	2,160	28	1.3	5	0.2	5	0.2	1	0.0	5	0.2	9	0.4
100	2,160	32	1.5	2	0.1	5	0.2	0	0.0	5	0.2	1	0.0

Notes: (1) % indicates catch per 100 hooks.
(2) In addition, 2 albacore were taken at 100 meters.

c). East of Formosa, Dec. 1936 - Feb. 1937 (Shichisei Maru)

Depth	Number of Hooks	Yellowfin Fish	%	Big-eyed Fish	%	Striped Marlin Fish	%	Sailfish Fish	%	Short-nosed Fish	%	Sharks Fish	%
48	1,552	1	0.1	9	0.5	5	0.3	14	0.9	6	0.4	43	2.8
58	1,504	12	0.8	8	0.5	13	0.9	5	0.3	4	0.3	30	2.0
68	1,504	7	0.5	8	0.5	8	0.5	8	0.5	5	0.3	29	1.9
78	1,504	12	0.8	7	0.5	7	0.5	6	0.4	4	0.3	30	2.0

Note: % indicates catch per 100 hooks.

When we compare the results of the Shōnan Maru and the Shichisei Maru, a rather conspicuous difference between them appears, but this probably results from a difference in the areas surveyed. The Shichisei Maru[18] worked mainly north of 24° N.[19] whereas the Shōnan Maru operated between 20° and 24°. Hitherto it has been said that among the tunas the big-eyed tuna inhabits the greatest depths, but the foregoing table tends to contradict this thesis.

The following figures are data from the Celebes Sea area.

Table 9

Fishing Situation at Various Depths

a. Celebes Sea, Dec. 1936 - Feb. 1937 (Shōnan Maru)

Depth	45	68	91	129
Catch Rate	4.2	1.7	2.1	5.9

Note: Catch rates are totals for spearfishes and tunas.

b. Celebes Sea, Feb. 1933 (Shōnan Maru)

Depth	23	90	113	136	160
Catch Rate	3.9	7.3	4.7	5.1	6.0

Note: Catch rate same as in (a).

c. Celebes Sea, Aug.-Sept. 1934 (Shōnan Maru)

Depth	Tunas		Spearfishes	
	Fish	%	Fish	%
45	65	6.3	26	2.5
76	182	8.8	36	1.7
106	205	9.9	20	0.9

d. Celebes Sea, Aug. 1934 (Shōnan Maru)

Depth	Tunas		Spearfishes	
	Fish	%	Fish	%
45	9	2.5	11	3.1
76	53	7.6	28	3.9
106	47	6.5	11	0.6

Note: % in a - d indicates catch per 100 hooks.

(18) Former fisheries research vessel of Taihoku Province, Formosa.
(19) Where there are many shoals and islets.

If we combine the data appearing in table 9, a - d, we see that in the Celebes Sea the depth at which tuna are taken in the greatest numbers is about 100 meters. The spearfishes are shown to be in general most numerous at shallower levels. This situation seems to agree in the main with that encountered in the area east of Formosa. The tunas are lumped together and nothing is known of the catch of each species, but it is certain that most of them were yellowfin. According to part d of table 9, in the Celebes Sea there was a catch rate for yellowfin of as much as 6% even on branch lines extending as deep as 160 meters. This fact shows that there is a possibility that, at least in tropical waters, the vertical distribution of yellowfin goes far deeper than has been believed hitherto. At the same time this gives an important indication for the consideration of the tuna fishery resources of the tropics.

Table d alone differs somewhat from a - c, with the maximum catch rates for both tunas and spearfishes on the 76-meter branches. This is thought to be principally caused by differences in oceanographic conditions. The Celebes Sea is homogeneous in character and clearly stratified, but oceanographic conditions in the East Celebes Sea are extraordinarily confused and the curves of vertical distribution of water temperatures show several remarkable rises and falls between 60-70 meters and 200 meters. In the Celebes Sea area the water temperatures at 100 meters are in the range of about 24° - 26° C., while at the 160-meter level they are within the range of 18° - 22° C.

In addition to the above, there are also some data from the East Philippine Sea, the northern part of the South China Sea, and, farther south, from the Banda Sea, the Flores Sea, and the vicinity of Sunda Strait, but in general they show the same tendencies that appear in tables 8 and 9. Accordingly, it is considered that the construction of longlines for yellowfin tuna in southern waters should be planned so that the hooks will hang at about the 100-meter level in order to maximize the catch rate.

With regard to fishing grounds in Japanese waters some data have been reported by the Chiba Prefecture Fisheries Experiment Station and others, but on the whole the data are scanty and cannot be considered accurate enough for the planning of fishing gear, so they are omitted here.

From a consideration of the data presented above it is clear that in order to make the operation of a tuna longline fishery profitable, it is not enough simply to find out the horizontal distribution and paths of migration of the fish. Unless a firm grasp is had of both the horizontal and vertical distribution, the former in order to avoid errors in the selection of fishing grounds, and the latter in order to plan the most suitable construction of gear for the area fished, it can hardly be said that enough has been done. In actual operations the fishermen are by no means unconcerned with these problems. They do adjust the float-lines in various ways, however, this is not based on any reliable theoretical foundation, but is merely a sort of probing.

Assuming that the lengths of the branch lines and the float lines have been settled, the next problem is their number. The number of branches is generally considered in relation to their length and that of the main line. Increasing the number of branch lines is advantageous in that it means a like increase in the number of hooks employed in each operation. However, the interval between branch lines naturally has to be determined by considerations of convenience in handling the gear. Furthermore, for reasons of economy one hank of line is cut into four or five pieces in such a way that none of it will be wasted. The number of branch lines is also related to the weight of the gear as a whole, and so to the problem of the so-called "stretch" of the line. When the branch lines are few, it gives rise to a tendency for the line to stretch and the danger of the line's breaking increases. If the branch lines are many, the whole gear becomes heavy and hard to handle, and also occasions arise where a large number of fish are taken on one part of the line which consequently breaks or simply sinks.

When various factors of this sort are taken into consideration, determining the construction of the lines is very difficult. Among the gear in use at present, except for albacore lines, most of the lines have either five or six branches. This type of gear is the result of many years of experience in the light of the various conditions set forth in the foregoing. Therefore, it may well be that this construction is the best possible, but there is as yet no scientific evidence that this is the case. The longline construction most suitable for each sea area should be established upon a scientific basis through the consideration of oceanographic conditions, ease of operation, and economic problems connected with materials and bait.

c. The problem of bait

In the case of the skipjack fishery, bait is a very great problem, in some instances a limiting factor on the development of the fishery. As everyone knows, this is because live bait is an absolute requirement. In the case of the tuna longline fishery the bait does not have to be alive. Frozen, iced, or in some cases even salted bait may be used. This fact may be considered an extraordinarily strong point of this fishery.

Of course fresh bait is preferable and is superior as bait. This superiority may, of course, lie to some extent in the fact that tuna bite better on fresh bait, but of even greater importance is the fact that such bait "keeps" well. This means that the bait does not fall off the hook easily. According to the results

106	205	9.9	20	0.9

obtained by many research vessels in surveys in southern waters, there is little difference in the catch rates achieved in a given area whether iced, frozen, or salted bait is used. Furthermore, on the whole little difference can be detected whether the bait employed was saury, sardine, herring, or squid.

As has already been stated in the section on food habits, there is room for doubt as to whether the tunas and spearfishes select things which they particularly like to feed on. When we actually examine the contents of their stomachs, it appears that they feed on whatever is most plentiful in the area they inhabit, or whatever is comparatively easy to catch, or whatever strikes their eye most easily. Of course more thorough studies of the food habits of the tunas are necessary, and our conclusions must be verified experimentally, but it is thought that in selecting baits to be used the emphasis should be on their ability to catch the eye of the tuna and their keeping qualities on the hook. Such matters as ease of procurement and cheapness of price go without saying.

Whether or not the above reflections are correct or not is a question to be settled by future researches. If they are correct, the fact will have a rather important significance in the operation of this fishery. Unfortunately, however, there have been few connected, organized studies in this field, and the problem of bait is almost entirely left to the future.

d. Fishing grounds and fishing seasons

Almost all of the researches and surveys which have been carried on hitherto with regard to the tuna fisheries have had as their main object the extension of present fishing grounds and the discovery of superior new grounds, and not a few of them have produced results worthy of note.

After engines began to be installed in fishing vessels in the latter years of the Meiji Era, line-hauling machines were imported and the efficiency of operation increased epochally, while at the same time larger and larger vessels came to be built and the fishing grounds were extended year by year. Particularly in the period of approximately 10 years from early Showa Era (about 1930) to the beginning of the Pacific War the rapidity with which the fishing grounds were expanded was astonishing. During this period the training vessels of the Fisheries Institute of the Ministry of Agriculture and Forestry and many research vessels surveyed tuna longline grounds from the Maldives in the Indian Ocean on the west, eastward to the vicinity of 170° west longitude, and from 15° south latitude to 45° north latitude. As a result of these surveys and the unflagging endeavors of the fishermen, there were opened up the albacore grounds extending east from Cape Nojima to the Midway area and the fishing grounds, principally for yellowfin, in the former Japanese South Seas mandate; fishing boats from Japan Proper, based chiefly at Misaki in Kanagawa Prefecture, and vessels based in the outlying areas were busily engaged in fishing in these grounds. Elsewhere vessels based in Formosa were active in the South China Sea, the Sulu Sea, the Celebes Sea, and the East Philippines Sea. It gradually became known that, in addition to the grounds under exploitation, yellowfin, big-eyed tuna, and the spearfishes were densely distributed in various other southern sea areas.

In order that a given sea area may be considered a tuna fishing ground, it is not enough that there merely be biological evidence of the presence of tuna there. It need hardly be said that in order to have significance as a fishing ground actual operations must be carried on in the area and the results must be a catch at least sufficient to pay expenses. The expenses of operating a fishing enterprise may in general be thought to be proportional to the number of days spent per voyage. The more distant the fishing ground, the higher the expenses mount; as the number of days required to go and come between the base and the grounds increases, the number of days on which actual fishing is possible decreases. It follows that the farther the fishing ground, the higher the catch rate must be in order to pay expenses. Since the capabilities of fishing boats are limited, unlimited extension of the fishing grounds is naturally impossible under the present system of single-vessel operations.

The fishing season, needless to say, is the season or period during which fishing is carried on within a given sea area. Since fishing seasons are mainly controlled by seasonal changes in oceanographic conditions, they are generally the same from year to year.

The tuna longline fishery in Japan is operated as a complement to the skipjack fishery, so, in general, the fishing season is almost limited to the winter. Actually in most cases it is a matter of vessels which engage in the skipjack fishery from spring to autumn turning to the tuna longline fishery during the winter. This does not, however, indicate that the tuna are most densely distributed during the winter; it should be considered chiefly as a phenomenon controlled by the distribution and migration of the skipjack. Except for albacore and the big-eyed tuna, the distribution of the tunas and the spearfishes in the North Pacific, in general, is denser in the summer than in winter. As a consequence, one can see a tendency in recent years toward a gradual increase in the number of vessels operating the year round in the tuna longline fishery.

Both the fishing grounds and the fishing seasons are determined by the distributional and migrational patterns of the tunas. Therefore, if it were possible to know accurately in advance the times, positions, and routes of these migrations, it should be possible for the tuna longline fishery to become stabilized to a high degree. However, the factors which control these migrations are chiefly changes in oceanographic conditions.

So stated it appears quite simple and clear that if we investigate oceanographic conditions, it will naturally become possible to foreknow the migrations of the tunas. The actual problem cannot, however, be solved so simply. One reason is that oceanographical observations on the large scale necessary in order to gain a thorough grasp of oceanographic changes in the sea areas inhabited by the tunas cannot be so easily carried out. Even supposing that such observations could be made, there are in addition to such physical factors as temperature and salinity of the sea water other complexly intertwined and as yet unknown factors involved in the mutual relationships of the tunas with other living organisms, so that it can hardly be expected that we can easily gain a foreknowledge of the causes and paths of their migrations. At any rate, within the scope of our present knowledge it is not, unfortunately, possible to find a method by which these migrations can be accurately foretold.

i. Fishing grounds of the low latitudes and of the high latitudes.

Because the tunas are in general so-called warm water species, they do not like very low temperatures. The species differ in this respect, but each has limits on the temperature range within which it can exist and the fish are continually on the move seeking favorable waters. In sea areas which are bounded by zones of limiting temperature, as for example in the fishing grounds of the Hokkaidō area or at the advance point of the gradual northward migration of the schools which begins in the spring, the schools are continually being restrained by limiting temperatures and their progress is a series of alternate advances and retreats. In fishing grounds where such factors operate, the relationship between oceanographic conditions and fishing conditions is very apparent and observations of the water temperature contribute immediately to the fishery as an effective indicator for the location of fishing grounds. Also in many cases the fishing season is clearly defined, and when the season unsuitable for the habitation of tuna comes around, they disappear and the fishery likewise comes to a complete end.

In the warm seas of the low latitudes the water temperature, salinity, and so forth always offer favorable conditions for the habitation of the tunas, and, in fact, it is known that most of the species are at all times present there. It follows that the fishing grounds and fishing seasons are exceedingly generalized. However, even in the low latitudes the density of distribution is not always the same, but shows rather marked changes both as between different seasons and as between different areas. In this area the year is divided roughly into two seasons, that of prevailing southwesterly winds from April to September and that in which northeasterly winds prevail from

October to March[20]. A comparison of the changes in fishing conditions which occur in these two seasons is shown in table 10. The figures used in the table are based on data collected by a large number of research vessels over many years, data from commercial fishing vessels not being used at all.

Table 10

Fishing Situation by Seasons

Area	Southwest Trades		Northeast Trades	
	Hooks	Catch rate	Hooks	Catch rate
E. Philippine Sea 0°-20° N., 120°-130° E.	7,800	7.93	2,394	0.67
South Sea Govt.-General 0°-10° N., 130°-160° E.	152,563	6.34	491,703	4.50
Celebes	10,493	8.86	146,663	4.06
N. Guinea, Solomons	10,500	4.39	11,292	4.04

Note: (1) The catch rate is the number of fish caught per 100 hooks fished.

(2) The southwest trades blow from April to September, the northeast from October to March.

(3) The catch is the total of tunas and spearfishes, but does not include sharks.

Looking over the material presented in table 10, it appears that on the whole the catch rates during the southwest monsoon exceed those of the northeast monsoon. It must be noted, however, that the figures given in this table are a summary of data from a rather extensive area, and that the number of units of fishing gear employed at different seasons varies markedly. Just as a trend, though, it does appear that the fishing is better during the season of southwesterlies than during that of northeasterly winds. This tendency seems particularly conspicuous in the East Philippine Sea and the Celebes Sea.

(20) There is a time differential of about 1 month between the shift in the seasonal winds and the changes in oceanographic conditions, the changes in sea conditions lagging behind the change in the winds.

If it were possible to get data from surveys evenly distributed throughout the year in a comparatively limited area, the seasonal variations in fishing conditions would become much clearer. Unfortunately, however, data of this sort are almost completely lacking. Only from the area of 0° - 5° N., 150° - 160° E. do we have data which to some extent fulfill these requirements. Fishing conditions for yellowfin, big-eyed tuna, and spearfishes in this area in each month of the year are shown graphically in figure 25 A, B, and C. The number of experimental operations and the number of hooks fished are shown in table 11.

Figure 25A shows that the yellowfin fishing is extremely slack in January and February. In March the catch rate rises sharply, but it drops again somewhat in April. No conclusions can be drawn as to the situation in June as there are no data at all, however, judging by the trend of the curve, it would appear that the catch rate reaches it maximum in about that month. From July to December there is no great change in the catch rate which remains between 4 and 5 percent.

For the big-eyed tuna (figure 25B) the catch rate is at its lowest in March and reaches its peak a half year later in September.

Figure 25C shows the spearfish (chiefly black marlin) catch conditions. As the graph shows, the catch rate is lowest in March and highest in August, but the variation is not as marked as in the case of the big-eyed tuna.

Table 11

Number of Times Fished and Number of Hooks Fished by Months [0°-5° N., 150°-160° E.]

Month	Jan.	Feb.	Mar.	Apr.	May	June	July
Trials	15	20	12	14	16	0	18
Hooks	24,081	24,964	12,495	18,110	26,028	0	31,540

Month	Aug.	Sept.	Oct.	Nov.	Dec.
Trials	4	6	13	37	21
Hooks	7,126	10,225	19,915	46,967	27,519

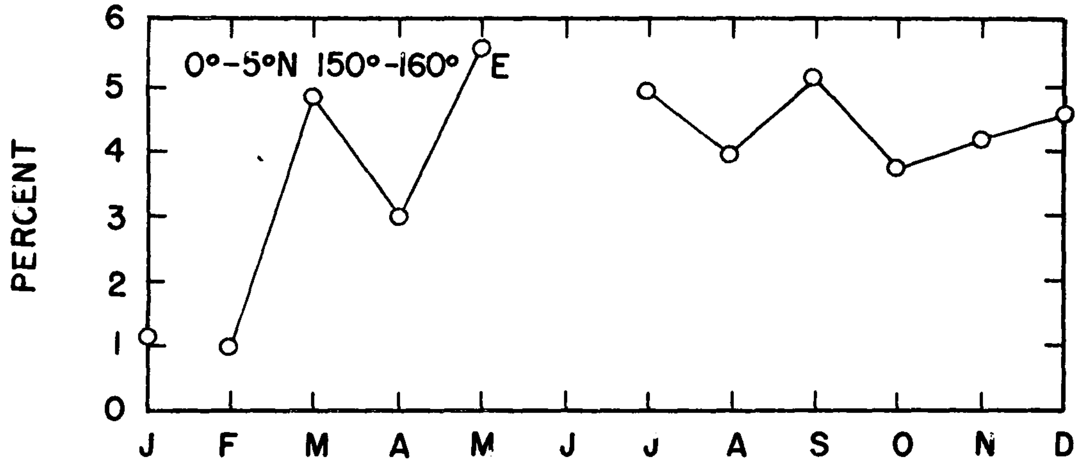

FIG. 25a FISHING CONDITIONS BY MONTHS (YELLOWFIN)

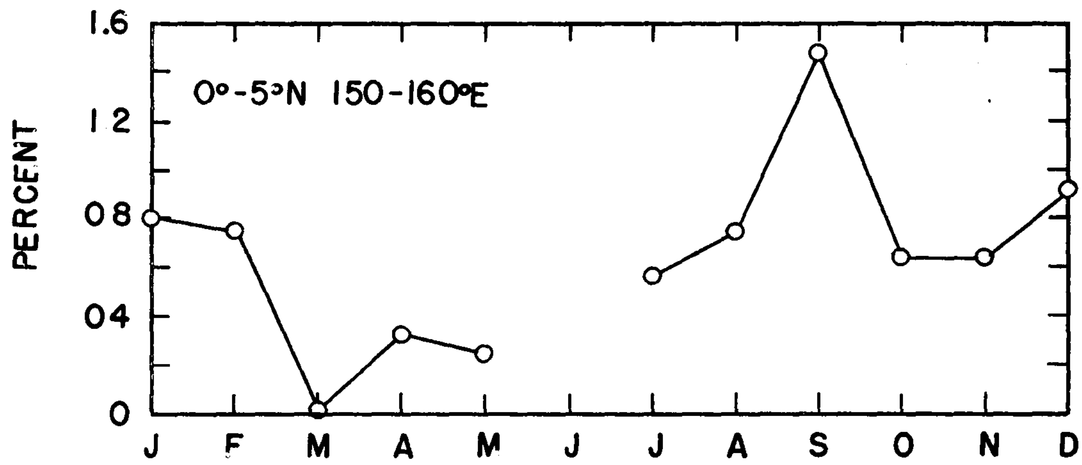

FIG. 25b FISHING CONDITIONS BY MONTHS (BIG-EYED)

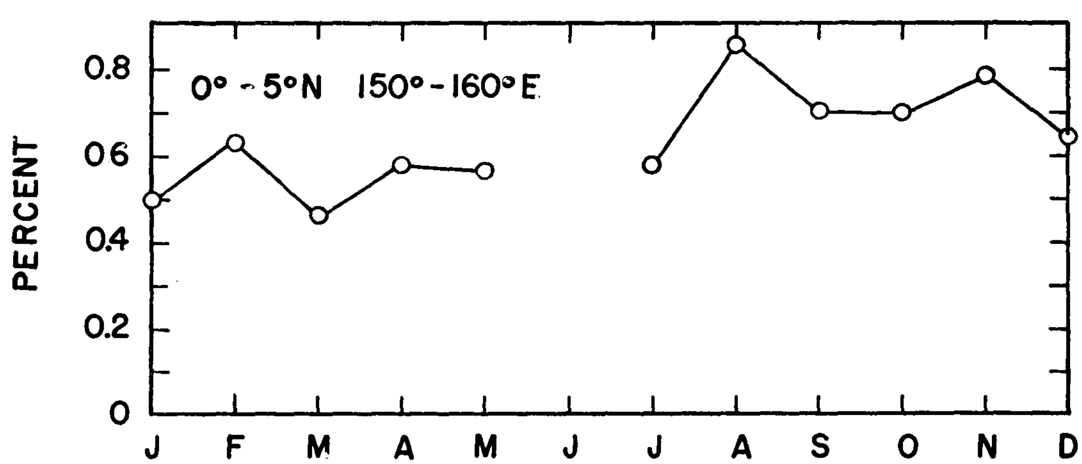

FIG. 25c FISHING CONDITIONS BY MONTHS (SPEARFISHES)

The season at which these changes in the catch rates occur may be earlier or later depending on the species, but in all cases the period between the minimum and the maximum is about a half a year. It is thought that this fact is worthy of attention. It may be considered that even in the seas of the low latitudes, where conditions are always favorable for the tunas, there are great annual movements of the schools.

When it comes to such questions as whether these migrations cross the Equator into the southern hemisphere, whether they extend far eastward to the coasts of the American continent, or whether they pass Malaysia and form a link with the Indian Ocean region, there are no data at all which might clarify these problems and there is under present conditions no way of tackling them. Furthermore, it is not possible to explain the relations of these migrations to the movements of the schools in the fishing grounds of high latitudes such as those of Japanese waters because what data we have only cover certain seasons and certain areas.

Figure 26 shows the changes in the fishing situation throughout the year in the waters of the Izu and Ogasawara island groups. According to the graph, the yellowfin catch rate gradually increases from April to July, drops in August and September, and rises sharply in November. The accepted explanation is that the July peak consists of ascending fish, while the November peak represents returning (or descending) fish. If this is compared with figure 25A, the peak which appears in the season of ascending fish is about 1 month later than the maximum in the low latitudes. The peak representing the descending fish is not distinguishable in the south. As the following table shows, the degree of reliability of these data is much inferior to that of the data presented in table 11.

Table 12

Number of Times Fished and Number of Hooks Fished in Each Month

Month	Jan.	Feb.	Mar.	Apr.	May	June	July
Trials	15	50	32	3	21	22	7
Hooks	15,954	37,896	29,234	1,448	15,486	13,959	3,632

Month	Aug.	Sept.	Oct.	Nov.	Dec.
Trials	3	4	5	4	7
Hooks	600	4,140	4,140	780	1,452

Note: Area surveyed -- 25°-30° N., 140° -150° E.

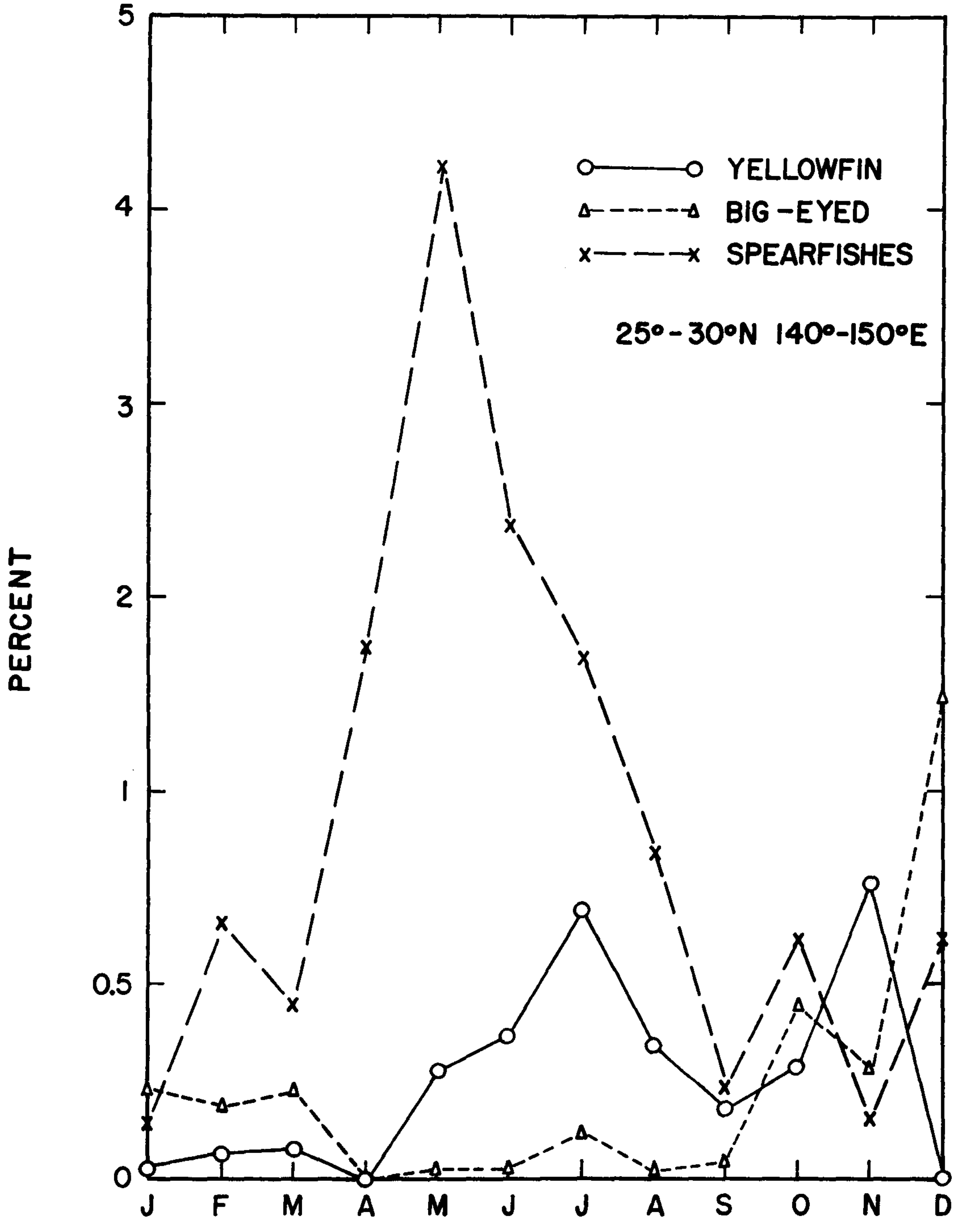

FIG. 26 FISHING CONDITIONS BY MONTHS

The catch rate for big-eyed tuna gradually declines from January to April, rises to a low peak in July, and is at its highest for the year from October to December. If this is compared to figure 25B, it seems that the maximum and minimum appear about 1 to 3 months later.

In the case of the spearfishes, there is an extremely conspicuous peak in May. In this area the catch in April and May is usually mainly striped marlin, while from June to August the black marlin are on the increase. Since, however, the records are not clearly defined by species, it is difficult to elucidate the catch situation for each species.

The foregoing deals with movements of the schools extending over long periods of time. The data obtained by the Haruna Maru[22] on fishing conditions off the Indian Ocean coast of Sumatra near the Equator are presented in the following figure.

Table 13

Fishing Conditions in the Coastal Waters of Sumatra near the Equator (Haruna Maru, 1932)

Date	Position	Size of Yellowfin (kg)	Catch Rate	Date	Position	Size of Yellowfin (kg)	Catch Rate
1932 Dec. 14	1°-2°N 96°-97°E	18.61	2.12	Dec. 26	1°-2°N 96°-97°E	22.55	5.76
" 15	"	35.29	24.09	" 27	"	34.69	10.00
" 16	"	34.96	14.00	" 28	0°-1°N 97°-98°E	34.43	13.46
" 17	"	37.95	14.55	" 29	0°-1°S 97°-98°E	31.84	2.92
" 18	"	36.02	10.83	" 30	"	32.33	27.01
" 19	"	39.85	17.88	" 31	"	35.07	12.36
" 20	"	35.86	17.83	1933 Jan. 1	"	27.29	5.07
" 21	"	37.63	21.88	" 2	"	16.12	7.11
" 22	"	35.11	13.61	" 3	0°-1°N 96°-97°E	32.21	3.06
" 23	"	16.84	2.99	" 4	"	34.17	9.38
" 24	"	30.41	17.36	" 5	"	35.90	9.86
" 25	"	37.43	22.15	" 6	"	37.06	5.63

Notes: (1) The catch rates represent the number of yellowfin and big-eyed tuna per 100 hooks.

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[22] The Haruna Maru (1,537 tons) was converted for use as an experimental tuna cannery ship, and operated in 1932 and 1933, chiefly in the Indian Ocean area.

(2) Underlined figures represent occasions when the fish were particularly small.

(3) "Size of yellowfin" is the average of the yellowfin in the day's catch.

According to table 13, at this season in this area yellowfin of 30 to 40 kilograms predominate, with fish of around 35 kilograms being most numerous. In spite of the fact that the area surveyed was only 120 miles from east to west and 180 miles from north to south, it appears that from time to time fish of remarkably small size were taken, and on the days when such fish were taken the catch rate took a sudden drop. On the whole, one can detect a tendency for the fish taken to become somewhat smaller and for the catch rate to gradually become lower with the passage of time. In order to make the data of table 13 easier to visualize, they are presented graphically in figure 27.

Whether or not the phenomena described in the foregoing are due merely to chance cannot be ascertained because there are no other data with which to make a comparison. According to Dr. Kishinouye, the black tuna taken at the beginning of the fishing season are large, and with the passage of time they gradually become smaller. No clear explanation can be given of the significance of the fact that among the schools of fish of about 35 kilograms weight, which are thought to be all of about the same age group, there suddenly appear from time to time fish of markedly smaller sizes, but it is thought that they may represent fragments of a number of schools which successively passed through this sea area.

The validity of the above remarks is open to doubt, but at any rate the phenomena described in the foregoing probably give some hint as to the movements of the schools in this area.

It is said that if you go to the seas of the low latitudes, you can catch yellowfin at any time, but the data presented above show that the fishing conditions are by no means always the same. In other words, even in these latitudes a fishing season can be discerned, however, this fishing season differs in some respects from that of the high latitudes. In waters which seasonal changes place outside the limits of distribution of tuna, there is no catch at all except during the fishing season, while in the low latitudes the change is expressed simply in terms of an increase or a decrease in the catch rate.

As was shown in table 3, the value and significance of the fishing grounds vary remarkably from one area to another. Some remarks on this sort of variation are to be set forth in the following section, but it shows that even in waters of the

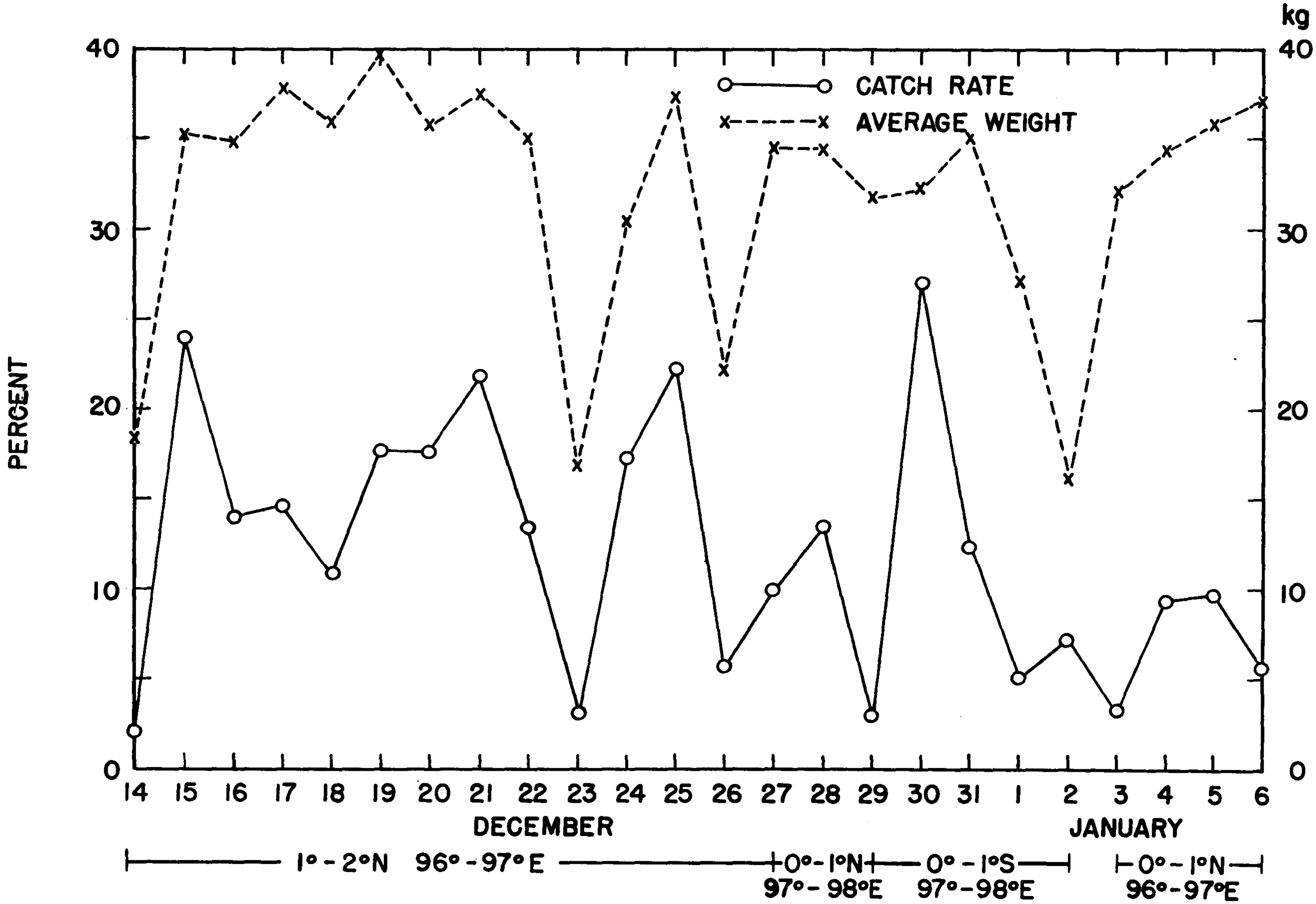

FIG. 27 AVERAGE WEIGHT AND CATCH RATE FOR YELLOWFIN (DEC 14, 32 JAN 6, 33)

low latitudes the distribution of the tunas is by no means everywhere equal. Unless one has as much knowledge as can possibly be obtained concerning the regional variations in fishing seasons and fishing grounds, as set forth above, venturing forth to fish in distant waters is fraught with the danger of unforeseeable losses.

In connection with the fact that in Japan the main season for tuna longlining is the winter, Kimura[23] has put forward the explanation that "the fishing season is the season of convection currents in the ocean, that is, the winter, when convection currents are set up in the sea water and the temperatures at the 50-100 meter level become roughly the same as the surface temperatures."[24]

Much of the data cited above, however, show rather that the density of distribution increases in the summer, and the season of migration appears to be different for each species. It follows that there is great doubt as to whether or not a sweeping explanation like the foregoing can be applied generally without modifications. The fact that the fishing season tends to be in the winter may probably, more simply considered, be ascribed to its relationship to the skipjack fishery.

ii. Ocean currents and fishing grounds

The ocean currents each have their different physical characteristics, and they have the greatest effect on changes in the oceanographic conditions in the sea areas which belong to their systems. They therefore naturally bear a very important relationship to the fishing seasons and fishing grounds of the tuna fishery.

The tuna grounds of Japanese waters are for the most part under the direct control of the Kuroshio. Furthermore, the grounds north of the Bōsō Peninsula are directly affected by the Oyashio in its reciprocal relationship with the Kuroshio. This has already been set forth in outline in the section on "Distribution and Migration."

Even in cases where there impinge upon each other two currents which, unlike those that, like the Oyashio, have completely negative characteristics as regards the distribution of

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(23) Kimura, Kinosuke. 1942. Tuna and spearfish fishing conditions. Lectures on Fisheries Technology.

(24) The albacore and the big-eyed tuna are the main species whose catch increases in the winter.

the tunas, have characteristics that make it possible for tuna to inhabit their waters, and which, in fact, do afford a habitat for tuna, it is sometimes seen that when one crosses the boundary between the two currents, the distribution of the tuna is remarkably different. In other words, there are cases where the boundary between two currents marks a conspicuous difference in the value and significance of the waters as fishing grounds. This phenomenon has already been treated to some extent in the section on "Distribution and Migrations", but it will be further gone into in this section.

The following table shows a comparison, based on data from surveys in the former Japanese mandated South Sea islands (0° - 10° N., 130° - 160° E.), of the fishing conditions north and south of the line of 5° N., leaving out all consideration of longitude, year, or season. The data employed are all from reports of research vessels, no results of commercial fishing operations being included.

Table 14

Fishing Conditions by Areas
(former South Seas Mandate)

Area	Trials	Hooks Fished	Yellowfin		Big-eyed		Spearfishes		Total
			Fish	Catch Rate	Fish	Catch Rate	Fish	Catch Rate	Catch Rate
1°-5° N.	356	468,572	18,063	3.85	2,077	0.44	2,996	0.64	4.93
5°-10° N.	332	315,267	4,845	1.57	1,192	0.38	1,760	0.56	2.51

Note: In addition to the above a small amount of albacore was taken.

The reason for dividing this area along the line of 5° N. is as follows:

In this area there are two conspicuous ocean currents. One is the North Equatorial Current, which runs west, the other is the Equatorial Countercurrent, which runs east. The boundary between these two currents varies in different years, in different areas, and at different seasons. Furthermore, this boundary is not a straight line, but lies generally within a range of 5°-8°N. For our purposes it would be desirable to draw a sharp delimitation by means of a current boundary, but as an actual problem this is impossible. Therefore, if the line of 5° N. is used, the region to the south of it will at least be completely within the Equatorial Countercurrent. To the north a portion of the Countercurrent will also be included, but the greater part of the area will be within the influence of the North Equatorial Current.

Fishing conditions in the two regions delimited on this basis are, as table 14 shows, conspicuously different. As is clear from the table, the catch rates for big-eyed tuna and spearfishes hardly differ at all, but the catch rate for yellowfin in the northern area is less than half what it is in the southern, and on the whole the catch rates north of the line are remarkably low. This means that if the two areas are compared as fishing grounds, the northern is far inferior to the southern.

As there are very few data on which to base a judgment as to whether the fish in the two areas are of different age groups or whether it is simply a case of the same groups having a different density of distribution in the two areas, this point is unknown.

A consideration of data obtained in the Indian Ocean region reveals some phenomena of extraordinarily deep interest. The data from this region are limited to the period from November to February, so the year-round situation is completely unknown, but some discussion is possible of the relationship between the ocean currents and the distribution of the tuna during the season of northerly winds.

The following table gives the data from the Indian Ocean region arranged generally in order from north to south without regard to the year of the survey.

Table 15.--Fishing Conditions by Areas (Indian Ocean region)

Date	Area	Hooks	Yellowfin		Big-eyed		Spearfishes		Average Yellowfin Weight	Notes
			Fish	Catch Rate	Fish	Catch Rate	Fish	Catch Rate		
1930 I	6°- 18°N 92°- 94°E	2,944	168	5.61	6	0.20	3	1.00	42	Hakuyō M.
" XII	6°- 9°N 93°- 97°E	3,498	168	4.80	0	0.00	7	2.00	37	"
1931 I	6°- 7°N 93°- 94°E	600	36	6.00	1	0.17	1	0.17	46	"
1932 I	6°- 7°N 93°- 94°E	1,779	335	18.92	3	0.16	11	0.63	36	"
1933 I	6°- 7°N 92°- 94°E	8,480	472	5.57	33	0.39	48	0.57	40	Haruna M.
1934 II	5°- 6°N 94°- 95°E	12,032	1,258	10.45	47	0.39	128	1.06	45	Hakuyō M.
1931 I	0°- 6°N 95°- 97°E	900	37	4.11	0	0.00	7	2.78	26	Haruna M.
1932 XI	Near Equator	7,800	341	4.37	65	0.83	31	2.40	35	"
1932 XII	0°- 3°N 96°- 98°E	12,152	616	5.07	88	0.72	59	0.49	33	"
1932 XII	1°S- 2°N 96°- 98°E	27,528	3,497	12.71	412	1.50	114	0.41	33	"
1933 I	1°S- 5°N 9?8- 98°E (?)	12,800	815	6.37	102	0.80	90	0.70	32	"
1933 I	3°- 6°N 94°- 96°E	17,272	1,626	9.41	104	0.60	204	1.18	33	"
1933 II	5°- 6°N 94°- 95°E	4,320	474	10.93	48	11.1	56	1.27	33	"
1933 XII	2°- 7°S 98°-105°E	11,808	427	3.62	75	0.63	76	2.64	49	"
1934 I	5°- 6°S 103°-105°E	16,8 0 (?)	1,304	7.80	213	1.32	100	0.60	50	"
1934 I	1°S- 6°N 94°- 98°E	22,080	1,840	8.33	162	0.73	182	0.82	43	"
*	Java	9,620	290	3.02	63	0.65	61	0.53	48-50	"
**	Lesser Sundas	48,274	4,032	8.35	161	0.33	322	0.66	48-50	"

Notes: * Total of Hakuyō Maru, Jan. 1931, and Haruna Maru, Dec. 1932.

** Total of Hakuyō Maru, Haruna Maru, Kiyō Maru, and Zuihō Maru, 1933-1940.

(?) Typographical error in original.

The facts which may be gathered from the foregoing table can be listed as follows:

1. The fishing gradually improves from November on, and is very good in January and February.

2. In the area between the Equator and about 6° N. the schools appear to be dense, and there is little variation in fishing conditions.

3. Variations in the fishing conditions appear to be somewhat more marked south of the Equator.

4. The fishing is conspicuously poor in the coastal waters of Java.

5. Fishing north of 6° N. is inferior to the fishing south of that latitude.

6. Fishing is good around November in the coastal waters of the Lesser Sunda archipelago.

7. Big-eyed tuna are most abundant around December and gradually decrease thereafter.

8. The spearfishes seem to be most abundant around February, somewhat later than the big-eyed tuna.

9. In the coastal waters of the Lesser Sundas the yellowfin are large.

10. From the average size of the yellowfin, the catch rates, and the composition of the catch it is thought that there are boundaries near 6° N., near the Equator, in the vicinity of Sunda Strait, and in the vicinity of Lombok Strait, and that the schools which occur on each side of these boundaries are different.

It has been said that the size of yellowfin differs by regions, and if this is represented graphically for the sake of clarity, we get figure 28. This graph is based on surveys made between the west coast of Sumatra and the Nicobar Islands, and the average weight of the yellowfin taken in each survey has been plotted for each degree of latitude.

Figure 29 shows the currents in this region during the season of northerly winds.

Figure 29.--Chart of currents in the northeastern Indian Ocean (Jan.-March).

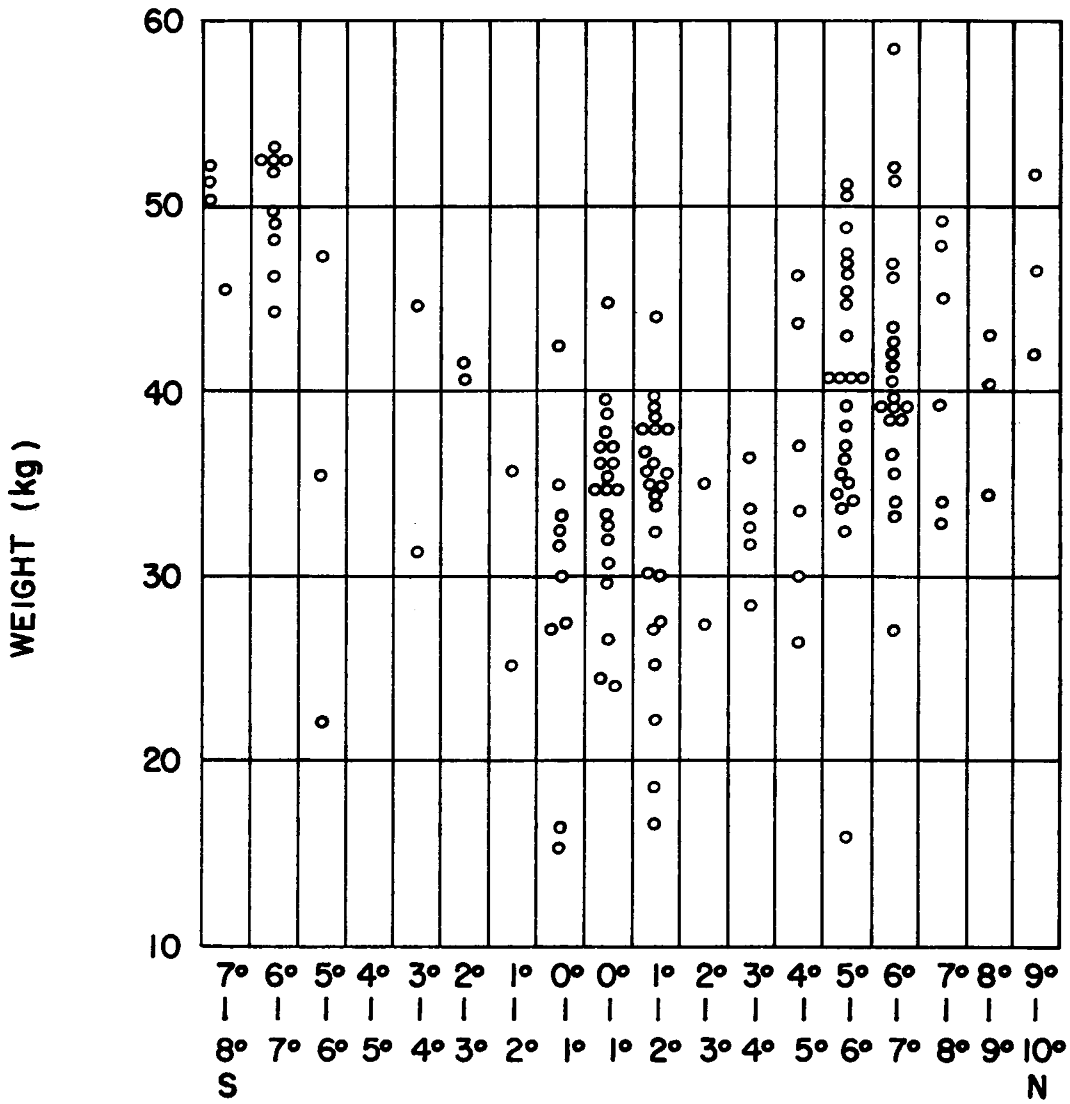

FIG. 28 AVERAGE YELLOWFIN WEIGHT BY AREA

The boundaries between currents on this chart and the boundaries of fish distribution which appear in figure 28 coincide almost perfectly. Figure 28 shows that in the range of 5° - 6° north and south of the Equator the majority of the yellowfin have an average weight of 30 - 40 kilograms, followed by those of 20 - 30 kilograms. Fish of 10 - 20 kilograms are few, and there are none over 50 kilograms. North of 5° N. fish of 30 - 40 kilograms and those of 40 - 50 kilograms are about equal in numbers, and some fish weighing more than 50 kilograms also appear. South of 5° S. averages of 30 - 40 kilograms hardly appear at all, the majority being within the ranges of 40 - 50 and 50 - 60 kilograms. These relationships are presented in tabular form in table 16.

Table 16

Average Weights of Yellowfin Taken by Area (Sumatran waters)

Area	0-10 kg.		20-30 kg.		30-40 kg.		40-50 kg.		50-60 kg.	
	Trials	%	Trials	%	Trials	%	Trials	%	Trials	%
5°N-5°S	4	5.4	15	20.3	6	62.2	9	12.1	0	0.0
5°-10°N	1	1.8	1	1.8	24	42.1	25	43.8	6	10.5
5°-8°S	0	0.0	1	5.9	1	5.9	7	41.2	8	47.0

Notes: (1) The number of trials is the number of fishing experiments in which the average weight fell within the particular weight category.

(2) % is the percentage which (1) was of all fishing experiments within the area.

As was stated at the beginning of this section, it is very natural that there should be a close relationship between the ocean currents and the distribution of the tunas, and there hardly seems to be any need for stating it anew. Nevertheless, it must be said that the sort of facts that appear in table 3, tables 14-16, and figure 28 provide very important indications for the consideration of fishing grounds. Furthermore, it is thought that these facts indicate, not only that the density of distribution of the tunas differs in different current systems, but that in different currents, even though they may be adjacent to each other, there occur different kinds of fish and different age groups.

It cannot be denied that in past surveys of tuna grounds this point of view has been neglected. In the future, investigations in this field must be greatly emphasized, both in order to gain knowledge of the tuna stocks and to maintain and improve the stability of the fishery. In the warm seas, particularly, where the water temperatures are always within the range habitable by the tunas, water temperature, especially surface water temperature, has very little significance and value as an indicator of the distribution and fishing potentialities of tuna. For this reason it is considered necessary that close attention be always given to changes in the position and strength of the currents.

iii. Topography and fishing grounds

Where there are shoals and sea mounts in the ocean, tuna grounds often develop in their vicinity. Examples in Japanese waters are the Kinan Reefs south of Shionomisaki, the Kōhō Bank, named for the Kōchi Prefecture research vessel Kōhō Maru, and many others in the vicinity of the Okinawa, Izu, and Ogasawara archipelagoes.

In places with this sort of topography one sees the phenomenon of so-called resident schools (setsuki), and because the schools remain in the locality, fishing continues good over long periods of time or at all times. The following explanation is given for this phenomenon.

In such places the sea water is stirred up and the water from the lower levels, rich in nutrient salts, is pushed up to the surface. As a result the growth of plankton is stimulated and fish are attracted. Or a sort of vortical current may be formed which will concentrate the small animals upon which fish feed, and therefore food will be always abundant.

It is thought that the foregoing is quite a reasonable explanation of the phenomenon of resident schools in the vicinity of banks, but there is some room for doubt as to whether or not it exhausts the subject. Problems of this sort require further study in the ecology of fishes. Whatever the theoretical basis may be, however, it is a fact that in seas having this sort of topography there are tuna grounds of a permanent and stable character.

Until recent years the notion that tuna longline grounds were restricted to waters of this sort was strongly prevalent, and there was a tendency for large numbers of boats to congregate to fish in limited areas. Furthermore, exploration for new fishing grounds was largely a matter of searching for such banks.

Waters where islands occur in the migratory paths of the tunas are also notable for their tuna fishing grounds. There is probably no need to cite examples or to explain the reasons.

In recent years, however, when the tuna longline fishery has developed with rapid strides and the fishing grounds have been expanded, it has become evident that fishing grounds are not confined to areas having the sort of topography described above. For example, the waters 100 - 200 miles east of the Philippines, which are among the deepest in the world, possess excellent fishing grounds at certain seasons. Likewise the albacore grounds east of Cape Nojima and the yellowfin grounds near the Equator are located right out in the middle of the open sea, and it is difficult to see how they may be related to the configuration of the sea bottom or the position of land masses.

This situation seems extremely natural, if we take into account the migratory character of the tunas. If we only had the requisite knowledge of the seasons and routes of their migrations, we could tell directly when the fishing would be good and which areas could be developed as fishing grounds, without any reference to the topography.

In short, such topographically defined fishing grounds are an extremely limited part of the total potential tuna longlining grounds. On the other hand, the fishing grounds which lie along the paths of migration are highly mobile and extremely generalized in character. This is not to say that the fishing grounds possessed of the type of topography described above have little significance and value. The point is that each type of ground has its particular characteristics.

iv. Relationship to other marine life.

In a broad sense, all of the marine animals living within the range inhabited by the tunas are related to them in some way, and by extension bear some relationship to the fishery. It must not, however, be thought that a great problem, such as these relationships present, can be studied thoroughly in any short period of time. Furthermore, considering it as an actual problem, the knowledge which we have been able to gain up to the present is really insignificant. We will consider here only two or three examples which are thought to have an especially direct connection with the tuna fishery.

The first example is that of the marine animals which are eaten by the tunas. It may be thought that, other oceanographical factors being equally favorable, an area where food organisms are abundant will have superior possibilities as a fishing ground over one where such organisms are scarce. The type of fishing ground described above, where resident schools are found on shoals, is evidence of this sort of superiority. Among the fishing grounds in Japanese home waters, the black tuna grounds off Tanegashima and in Hokkaidō waters may be considered, from one point of view, to have exactly this same sort of significance.

The migrations, fishing grounds, and fishing seasons of the tunas and the skipjack in Japanese waters have in the past been studied and actually explained mostly on the basis of oceanographical factors. The policy and purport of such studies rest on the idea that the various biological phenomena in the seas are, in the last analysis, based on and directly or indirectly controlled by the physical character of their waters. There is no room for doubt as to the rationality of this view. Studies of this sort might be called the method of direct attack.

Let us now, however, just consider as a factor in the fishing season and fishing conditions of the black tuna, the water temperature, which has hitherto been the factor most emphasized and most widely utilized. As far as is known at present, the range of water temperatures habitable by this species is very broad, extending from about 5° to 29°C. This is, of course, considering the whole range of the habitat of the black tuna, and cannot be applied to such limited areas as the waters off Tanegashima or off Hokkaidō. In such limited limited areas the extent of the fluctuations in oceanographic conditions is not that great, and also the adaptability of the black tuna is probably not such as to enable it to withstand sudden temperature changes of such a magnitude. They doubtless do, however, possess a certain degree of adaptability, and do not respond to temperature changes with the exactness of physical phenomena, as when water freezes at 0° C. and boils at 100° C.

As has already been stated, near the limits of the habitat the water temperature is a very potent indicator of the fishing conditions and the fishing seasons, but it cannot be said to be infallible. In the low latitudes, where the water temperatures are always within the habitable range, their significance and value as an indicator of fishing seasons and fishing conditions are markedly diminished. From the realistic point of view of the operation of a fishery, it would be a very fine thing if there were a more direct, effective, and simple indicator.

There is no doubt that the direct cause of the distribution and migrations of the tunas is related mainly to the distribution of their natural food. To cite again the example of the black tuna, it is recognized that the schools which during the winter are in the so-called Satsunan Sea Area begin a northward migration in the spring. The explanation given hitherto for this migration is that "as the water temperature rises in the Kuroshio, the northward movement begins, and by midsummer the fish reach the waters from Sanriku to Hokkaidō." The author himself has used similar expressions. Thorough notice should be taken, however, of the fact that this northward migration follows nearly the same track as the migration of the sardine in Japanese waters.

Around January and February the sardine form great schools in the area centered around Tanegashima, where they spawn in large numbers, then gradually move northward along the Japan Sea and Pacific coasts of Japan, reaching the Hokkaidō area in the summer and autumn. This has been the standard pattern of their migrations in the past. In recent years the number of sardines on the Tanegashima spawning grounds has shown a rapid decline and the catch in Japanese coastal waters has also dropped sharply. At the same time the black tuna fishing in the Satsunan Sea Area has become very poor and has been almost abandoned.

Another example is that of the spearfish fishery in the waters east of Taiwan. This area is known as an excellent ground for these fishes during the northeast monsoon, and the success of the fishery is thought to be intimately related to the abundance of such fishes as the round herring, Decapterus, and mackerel, which migrate successively into the area. Of course the abundance of these fishes upon which the tunas feed is, after all, controlled by changes in oceanographic conditions. It goes without saying that all of these various problems are in the end bound up with the productive potential of the ocean, and they probably cannot be solved except by the method of direct attack referred to above. However, from the standpoint of the tuna fishery and its present problems, and leaving out of consideration these basic questions, it would be extremely useful if these food organisms could be directly utilized as an indicator of fishing conditions and fishing seasons. Of course, in order to do this it would be necessary to clarify further the mutual relationships between the tunas and these organisms. And even if it were possible to use such food organisms as indicators, if it turned out that their ecology was more complex and difficult of investigation than that of the tunas, they would in actuality be worthless. It is, after all, a question of convenience.

The second case is that of the relationship to the tuna fishery of fishes having ecological characteristics and habits resembling those of the tunas. As examples of species having such habits we can cite the skipjack, cybiids, Lampris regia, the dolphin, and many sharks. Among these fishes some have a fairly important significance in the catch of the tuna longline fishery. The sharks are significant in one respect as a part of the catch, and in another as pests which damage the fish hooked on the lines.

It is known that the migrations of some of these fishes precede those of the tunas, others occur at the same time, and still others follow them. It follows that, aside from their significance as a part of the catch or as harmful pests, referred to above, they may be thought to have potential value as actual indicators of fishing grounds and seasons. But, although there are known to be many fishes which have such a close relationship with the tuna fishery, our knowledge concerning these fishes is extremely poor and has not been brought to the point where it can make any real contribution to the operation of the fishery. It is believed that in order that this fishery may have a healthy development, there is a great necessity for surveys and studies which will consider all of these species together.

As has been previously stated, the distribution of the tunas is thought to differ markedly in different current systems. Not only does the catch rate change sharply when a current boundary is crossed, but in extreme cases the kinds of fish making up the catch also differ completely. The carrying on of detailed oceanographical observations by an operating fishing boat, considered as an actual problem, can hardly be thought feasible. At present almost all of the boats are taking surface water temperatures, however, in the warm seas of the south it is difficult to detect the differences between water systems accurately by observations of this sort.

Such evidences of "active waters" as an abundance of birds or flyingfish are serving some purpose as indicators of fishing grounds, but they can hardly be said to suffice. What is wanted is some kind of indicator by means of which a simple operation will make it possible to find easily the water systems in which tuna are abundantly present. Such an indicator would not necessarily have to be any of the fishes discussed in the foregoing. A physical factor would do, or plankton might well be used, as it is in the North Sea herring fishery.

In the foregoing we have presented the outline of some of the basic factors related to the tuna fishery, but it is hard to think that each of them bears an individual relationship to the fishery. Rather are they probably mutually interrelated in a complex fashion. This sort of complexity is an essential characteristic of fishing, which has living organisms as its direct object, and it is the reason for the extraordinary difficulty of fishery investigations.

To sum up, the tuna longline fishery must be said to be one of the most primitive in character of all fisheries. We do not, however, mean to say that because of its primitive nature, the fishery itself has little prospect of future development. In view of the characteristics of the tuna resources, we should be led to quite the opposite conclusion.

For Japan, which through her defeat lost so many other important fisheries resources, this may turn out to be an essential resource. However, the fishery can never be satisfactory in its present form. It must be given a higher degree of planability and stability through a more thorough study of the essential nature of the resource.

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