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PREFACE

THE PRESENT AUTHORS have combined their five separate papers into one article of the Bulletin series for the convenience of workers in the field of speared fishes. They are indebted to the American Museum of Natural History, the University of Miami Marine Laboratory, and the University of Louisville for permitting this method of publication.

In the course of the last few years, interest in the genus *Makaira* has suddenly increased both here and in other parts of the world, resulting in closer cooperation between workers in the Istiophoridae, Makairidae, and Xiphiidae. With this has come a united effort to publish any observations as quickly as possible for the benefit of other workers. Owing to lack of growth series and of comparable material, no definite conclusions can yet be drawn from some of the published observations, but it is hoped that the observations themselves may contribute towards ultimate conclusions.

A large part of the material on which the articles are based was collected off Bimini, Bahama Islands, and worked on in the Lerner Marine Laboratory there. The authors wish to express their gratitude for the use of the facilities of this laboratory and for the help given them by the laboratory personnel, and also for the cooperation of the University of Miami Marine Laboratory.

Through the kindness of Mr. Victor Till and the generosity of the tournament anglers, a number of specimens used by the authors was provided by the catches of the Blue Marlin and the White Marlin Tournaments of the Bimini Marlin Tuna Club. The authors are also deeply indebted to Mr. Al Pflueger, of Miami, Florida, for help given them over many years, and to Mr. Joseph Reese of Fort Lauderdale for allowing them to examine specimens in his establishment and to him and his representative, Mr. Jones, for permission for the author and the artist of the second paper to work on his dock space in Ocean City, Maryland.

To innumerable anglers, boat captains, and officials who have cordially helped all the authors both here and abroad, we wish to express our great gratitude.

For help and facilities given over the years, Miss LaMonte wishes to thank Mr. and Mrs. Michael Lerner, Captain and Mrs. Russ Kline, Dr. and Mrs. Roy B. Dean, and the tournament committees of the International Light Tackle Tournaments. In Ocean City, Maryland, she wishes to acknowledge the help and hospitality of the two Ocean City angling clubs, and Captain and Mrs. Whaley and Captain Bunting, and, in Bimini, many courtesies shown her by Mr. Neville Stuart and Mr. Ronald McCann. She is also much indebted for photographic help to Mr. Don McCarthy and Mr. Frederic Maura of the Bahamas Development Board, Mr. Ludovico Ferraglio of the American Museum of Natural History, and Dr. Max Hecht of Queens College.

For the section on Histology of Marlin Skin (pp. 383–384) the author is most grateful to her colleague, Miss Priscilla Rasquin. As usual, Miss LaMonte is keenly appreciative of the cooperation of her artist, Miss Janet Roemhild, and also most grateful to Dr. Louis A. Krumholz for his assistance and advice on material for the second paper included herein.

Dr. Krumholz and Mr. deSylva wish to acknowledge with gratitude additional material and means for collecting furnished through the cooperation of Mr. George Collier, Mr. Gordon Ford, Mr. Robert Maytag, and Captain Eddie Moore of the yacht "Panda." They are also indebted to Dr. Gilbert Voss of the University of Miami Marine Laboratory for identifying the octopod *Ocythöe tuberculata*. Dr. Krumholz wishes to express his lasting gratitude to the Bahamians who helped in handling his specimens and particularly to Mr. Ernest Brennen for his assistance in making dissections.

The diagrammatic drawings for "Scales of the Atlantic Species of *Makaira*" were made by the author; the drawings for the text figures and plates for "Notes on the Alimentary, Excretory, and Reproductive Organs of Atlantic *Makaira*" are by Janet Roemhild. Unless otherwise acknowledged, dissections and preparations of material for these two papers were made by the author.

FRANCESCA R. LAMONTE

The American Museum of Natural History
October, 1957

CONTENTS

SCALES OF THE ATLANTIC SPECIES OF *MAKAIRA*

FRANCESCA R. LA MONTE
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Department of Fishes and Aquatic Biology
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MATERIAL EXAMINED

Makaira albida (Poey)

Field number 6: Inactive female, 39 pounds, Bimini, Bahamas, 1951
Field number 25: Male, 40 pounds, Bimini, Bahamas, 1953
Field number 27: Female, 114½ pounds, Ocean City, Maryland, 1953
Field number 32: Not sexed, 60 pounds, Ocean City, Maryland, 1953
Field number 4-56: Ripe male, 43½ pounds, Bimini, Bahamas, 1956
Field number 7-56: Male, approximately 50 pounds, Ocean City, Maryland, 1956
Field number 1-57: Not sexed, estimated weight 45–50 pounds, Bimini, Bahamas, 1957

Makaira ampla (Poey)

Field number 14: Female, 470 pounds, Bimini, Bahamas, 1950
Field number 2-56: Female near rupture of membrane, 552 pounds, Bimini, Bahamas, 1956
Field number 5-56: Ripe male, 209 pounds, Bimini, Bahamas, 1956
Field number 1-57: Not sexed, estimated weight 275 pounds, Bimini, Bahamas, 1957

Istiophorus americanus (Cuvier and Valenciennes)

A.M.N.H. No. 18961: Not sexed, standard length approximately 250 mm., Messina, Sicily, 1950
Unnumbered: Male, approximate weight 45 pounds, Miami, Florida, 1957

Xiphias gladius Linnaeus

A.M.N.H. No. 15355: Not sexed, 8 pounds, Cuba, 1940
A.M.N.H. No. 18960: Not sexed, standard length 271 mm., Messina, Sicily, 1949
A.M.N.H. No. 18962: Not sexed, standard length 393 mm., Messina, Sicily, 1949
A.M.N.H. No. 20321: Not sexed, standard length over 485 mm. (tip of sword missing), gift of Naples Aquarium, 1956
Unnumbered (at present mounted): Not sexed, not weighed, 4 feet in total length, 80 miles east of Newport, Rhode Island, 1937

Unidentified Juveniles

Field number Pflueger 1-1957: Standard length 1575 mm., fork length 1460 mm., 19 pounds, May 5, 1957, Marathon, Florida
Field number Pflueger 2-1957: Fork length 754 mm., total length approximately 38 inches (tip of spear broken); 2½ pounds, April 3 or 4, 1957, St. Georges, Bermuda
Field number Pflueger 3-1957: Fork length 1290 mm., 12 pounds, May 5, 1957, Marathon, Florida

LITERATURE

There is a fairly large literature on the genus *Makaira*, but it contains little on the subject of squamation and almost no detail.

Although several species of fossil fishes in this general group are known, the specimens have consisted almost entirely of rostra.

Canestrini (1861), Day (1878-1888), Desbrosses (1939), Gray (1838), Günther (1860), Lowe (1840), Philippi (1887), Tanaka (1913-1915), Whitley (1954), and others speak of the spiny or lanceolate scales of adult *Makaira* or of "subdermal scales of strange forms" or "spinules." More detailed descriptions of squamation follow.

Cuvier (1832) describes a fish "called Machaera," and says [translation]: ". . . like *Xiphias*, the istiophorids and the scombroids in general, it has long, straight scales on the cheeks. Those of the body are lanceolate, pointed, small, quite hard, and marked with longitudinal radii, their bases narrow and rounded. The lateral line, formed by rounded scales, is barely distinguishable. Beginning at the top of the gill opening, it runs parallel to the dorsal and on the upper third of the body up to a point on a vertical with the middle of the pectoral where it describes almost a right angle and descends . . . to just below the middle of the body depth, then runs in a straight line to the center of the caudal base."

In view of our present knowledge of the lateral-line patterns of the two Atlantic species, this fish would appear to be *M. albida*.

Both Atlantic species of *Makaira* were originally described by Poey (1858, 1860, 1861, pp. 239, 244). His only comment on the scales of *M. ampla* (his *Tetrapturus ampla*) is: "*La ligne latérale n'existe pas; les écailles sont plus fréquemment crochues. . . .* " Of *M. albida* (his *Tetrapturus albidus*) he writes: "*La ligne latérale se marque par un série de petits trous sur une bande continue; elle commence au haut de l'opercule, et après avoir traversé un court espace longitudinal, elle se courbe en sense opposé à la ligne du dos, et atteint le milieu du corps vers la pointe de la pectorale. . . . Les écailles du corps . . . sont osseuses, linéaires, il n'y en a pas sur la tête, sauf sur les joues. Celles de la ligne latérale ne sont pas percées; mais elles ont en dessus un canal qui, avec la peau, complète le tube qui s'ouvre à la surface extérieure. Toutes les écailles sont recouvertes par l'épiderme.*"

Hirasaka and Nakamura (1947) describe the scales of their Pacific genus *Eumakaira* and its type *E. nigra* as follows: "Skin covered with imbedded long tabloid osseous scales, which are rather deciduous than other form. Lateral line indistinct and highly complicated. . . . Body covered with osseous scales imbedded in skin. . . . Lateral line not very distinct, it branches in two under the 10th fin ray of the first dorsal, again united under the 17th ray, divided once more and united under the 23rd ray, then divided to unite under the 30th ray; finally they unite after bifurcation at certain unknown point. One indistinct line is recognised at the ventral side of the lateral line, between the second branching point and the 33rd ray of the dorsal fin. . . . This form was once identified with *T. mazara* of Jordan and Snyder. But after further investigation we found many unrecorded differences such as the peculiarity of lateral line system."

These authors had obviously noted the two kinds of scales, one surface and the other subcutaneous. The lateral line as described by them for their genus *Eumakaira* was, I assume, seen through skin held up to a strong light, unless the authors are describing the surface pattern possibly visible in juveniles (see below, p. 412). They speak of having had "premature individuals."

Ueyanagi (1957a, 1957b) refers to *Eumakaira nigra* Nakamura (a fish synonymized questionably by LaMonte with *M. mazara*) as the black marlin; to *M. marlina* (believed by LaMonte to be either *M. m. tahitiensis* Nichols and LaMonte or the as yet taxonomically unestablished "blue marlin" of the Pacific) as the white marlin, and to *M. mitsukurii* as the striped marlin. He lists the lateral line of *mitsukurii* and of *marlina* as "monotonous," but that of *E. nigra* as "complicate," and his figures would seem to indicate a reticulated or hexagonal pattern on the surface of a (young?) fish, similar to that of the lateral line of *M. ampla*.

De Buen (1950) describes the squamation of his species *M. perezi* (synonymized by LaMonte in 1955 with *M. ampla*). He says: "*Todo el cuerpo, a excepción del survo medio ventral, es desnudo, con piel gruesa finamente granulosa. Las escamas están totalmente embutidas, adquiriendo formas extraordinarias, algunas son simples estiletes, otras de larga base terminan en piene de dos a seis o más púas agudas. En ciertes escamas resta el recuerdo de la parte que estuvo embudita en la epidermis y la parte que fué libre.*

"*Bajo la piel tienden las escamas a formar series longitudinales en apretadas filas imbricadas. La mayoría son estrechas y largas, pocas, en series propias, son más anchas, con modesto realce transversal separador de las dos regiones de la antique escame hoy en degeneración.*"

Rivas (1956) noted the peculiar lateral-line pattern of *M. ampla* and writes of it: "Unlike other species of marlin, *Makaira ampla* does not possess a visible, simple lateral line running along the middle of the sides of the body. Instead, the lateral line is inconspicuous, complex and forms a reticulate pattern covering the sides of the body. It is faintly visible only when a patch of skin is removed and held up to the light. Both Atlantic and Pacific specimens were found to be similar in this character."

This statement is taxonomically confusing owing to the fact that Rivas believed the range of *M. ampla* to include the Pacific. I would expect to find the hexagonal-patterned lateral line in the black marlin of the Pacific, but this statement is based purely on a guess because of the obviously close relationship of this species to *M. ampla* of the Atlantic.

HISTOLOGY OF MARLIN SKIN

"In section, the integument of *M. ampla* is revealed as an extremely complicated structure. The material that was used for histological study was fresh when fixed in Bouin's fluid. It was decalcified in phloroglucin-nitric acid, sectioned at 8 microns, and stained with both Harris' hematoxylin and eosin, and Masson's trichrome stain. In spite of good fixation, some of the histological details are very difficult to interpret in as much as they are not comparable with any other familiar tissues.

"Grossly [in both *Makaira* species (F. LaM.); see pl. 76], the skin consists of a thin epithelial covering, beneath which is a wide band of collagenous tissue. Many melanophores, small blood vessels, and nerves are embedded in this layer of connective tissue. The epithelial sheet is broken at frequent intervals by small bony scales [pl. 76, fig. 1], and the surface is considerably modified in these areas. Immediately beneath the collagenous layer are the scale pockets containing very large scales [pl. 75, fig. 2]. The scales are serrated on their peripheral surfaces and are laminated along the longitudinal axis. As many as 12 to 18 layers of bone can be counted from the peripheral to the proximal surface. Both types of scales are provided with small lacunae in which blood vessels can be seen. Beneath the scale pockets lies a second and much wider band of extremely coarse collagenous tissue. Between this heavy layer and the body musculature lies a spongy layer of loose connective tissue containing many fat cells, nerves, and blood vessels.

"The puzzling aspect of this skin concerns the modification of the area about the small scales. A glandular-like structure is formed by small threads of collagenous fibers rising almost at right angles from the first collagenous layer at fairly definite intervals. These are joined by a thin collagenous layer over the top, forming a series of cuboidal pockets. The thin outside epithelium is usually lacking in these areas, but it is possible that this is an artifact and that the thin epithelium would be easily rubbed off with any handling. The pockets are filled with a curious substance which cannot be identified by the methods used.

"Part of the contents was undoubtedly fat, which was dissolved by the alcohol and xylol used in dehydrating the tissue. Another of the contents is free melanin granules. The rest of the material is a coarse granular precipitate which stains red with the ponceau of Masson's stain, and some unorganized, thread-like strands of protoplasm. There are no visible nuclei associated with these structures, so that whatever cells are responsible for this secretion are not at these sites which must, therefore, be only of the nature of reservoirs or storage spaces. These small reservoirs could easily rupture, and their contents are probably responsible for the oily nature of the marlin skin.

"The question is where this material originates. Near the base of the first collagenous layer are large lacunae, the contents of which have been considerably shrunken by the technical processes. What tissue remains appears to be in the centers of the lacunae, and perhaps some fatty tissue has been dissolved from between the centers and the walls. Capillaries and somewhat larger blood vessels are in the centers. Some loose fibrous material is present, as well as scattered nuclei, but cell boundaries cannot be determined. Some nerve fibers are also present. At various intervals a connection is made between these lacunae and the base of the reservoirs in the skin surface in the form of small narrow channels [pl. 76, fig. 2]. The channels are lined by cells of the fibroblast type, with long, spindle-shaped nuclei. Occasionally a channel ends immediately beneath one of the small peripheral scales. It seems possible that the secretion is elaborated in these lacunae and transferred through the channels to the reservoirs at the surface. Any slight pressure on the peripheral scales would also serve to free this secretion to the outside surface of the fish. Until histochemical determinations of various kinds are made on this tissue, no certain interpretations can be made."

PRISCILLA RASQUIN (1957)

SCALE STRUCTURE AND PATTERNS

As I have seen no definitely identified juveniles of *Makaira*, unless otherwise stated I am here dealing with the scales of the adult fish.

Owing to the peculiar modifications of *Makaira* scales, I have made little attempt to define markings as "circuli," "radii," or "annuli."

The external appearance, scale patterns, and lateral lines of *Makaira ampla* (Poey), the blue marlin, and *Makaira albida* (Poey), the white marlin, differ markedly, and the two species can be differentiated on this basis alone.

Hirasaka and Nakamura (1947) and Ueyanagi (1957a, p. 97) indicate that similar specific differences in squamation exist in the Pacific species of *Makaira*.

The fins of both Atlantic species are scaleless. An arthropod parasite, most commonly found on the ventral fins and belly, is frequently mistaken for scales.

The skin of *M. ampla* is tougher than that of *M. albida*, not transparent except in front of very strong light, and little elastic. In both species, the surface of the fish is thickly sprinkled with small round openings, some of which lie immediately beneath the spines of the surface scales. Both species have two distinct scale types, occurring in separate layers of integument. A large amount of oily exudate is present in both.

The surface scales are found on the outermost surface of the fish, completely separated from the subcutaneous scales. They are of the same general type as the surface scales of *Istiophorus* and the unkeeled surface scales of juvenile *Xiphias*. In *Makaira*, they consist of a fragile oval base, radially striated, in the center of which, perpendicular to the scale base, rises a minute, blunt, glassy, conical spine. These scales are tiny and are scattered thickly over the body of the adult (pl. 76, figs. 1, 3).

The armor of subcutaneous scales shows marked differences in the two Atlantic *Makaira*, especially in the scales of the lateral-line system. In general, the form of the subcutaneous scales in both species is lanceolate, and each scale consists of the usual bony outer and fibrous inner layer. Each scale is contained completely in a pocket of integument (pl. 75, figs. 2, 3; pl. 76, fig. 4).

SCALES OF *Makaira ampla*

The subcutaneous scales of *Makaira ampla* are outwardly indicated only by slightly raised impressions on the opaque surface skin. There is no external indication of the lateral-line system. (See pl. 75, fig. 1.)

Minute, glassy-spined, oval-based scales, strongly resembling placoid scales and with a pulp cavity often directly above one of the small openings mentioned below, are thickly scattered over the surface of the body, including the opercle and preopercle. In addition, the surface skin is riddled with minute round openings. The entire fish is noticeably oily.

The subcutaneous, unspecialized (non-lateral-line) scales lie in their own integument pockets entirely beneath and separated from the skin of the surface. They are, in general, lanceolate, but vary enormously in size and shape. There is an indication of pattern in arrangement, but only for very limited areas (text fig. 1). The overlap is irregular, complicated, and tight. The scales may be single- or multiple-spined.

Within the hexagons of the lateral-line

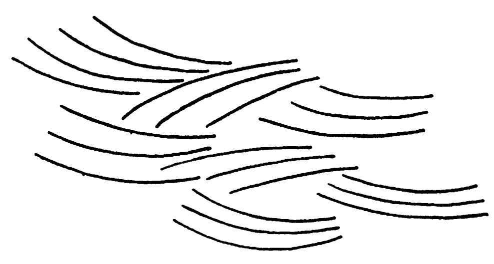

FIG. 1. Subcutaneous scale pattern visible on outer surface of *Makaira ampla*.

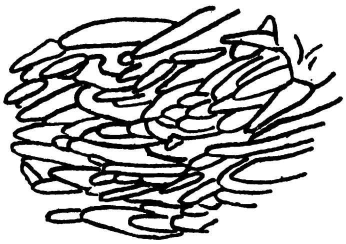

FIG. 2. Group of regenerative scales within lateral-line hexagon in *Makaira ampla.*

system, in addition to the normal scales, there are small groups of closely clustered, very small, very narrow scales, which appear to be regenerative (text fig. 2).

The most usual form of the unspecialized *M. ampla* scale is shown in text figure 3. It has a round or somewhat pointed basal end and a single- or multiple-spined apical end. In general, the scales are shaped like flattened thorns, very sharply pointed at the apices. The spines are usually uneven in length and width. The deep clefts between the spines are continued as grooves (radii ?) on the main portion of the scale. The base is without ridges or grooves except in the scales of the lateral-line system in which sculpturing is formed by the roofs of the canals. The multiple-spined scales appear to be made up of fused scalelets having a common base. The "fusion" is about midway towards the base of the scale, and the "scalelets" seem to be held together largely by the fibrous layer. The scale base is flat and, as are the outer lateral margins of the scale, very thin and almost completely transparent.

There is great variation not only in the number of spines, but in the sculpture or

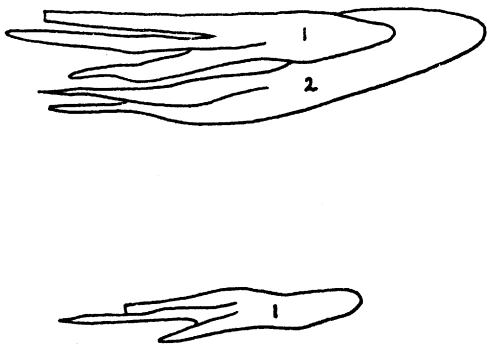

FIG. 3. Unspecialized overlapping scales of *Makaira ampla.*

what I here call "lines" (circuli?) on the scales. In general the pattern of lines is a series of diagonals beginning near the lower margin of the base and running from the lateral margin in and downward to the central groove from each side of the scale. These lines gradually straighten until, midway down the scale, they run down the spines straight to the apices. There is, however, unevenness and irregularity in such lining in individual scales, whether or not they are on the same part of the body.

TYPES OF UNSPECIALIZED (NON-LATERAL-LINE) SCALES

1. Single-spined, occasionally bifid, with fairly wide base rounded at its outer margin (fig. 3; fig. 5, scale x). On one such scale, 27 mm. long with a maximum width of 4 mm., and on a closely bifid scale of approximately the same length and a slightly wider base, no ridges or grooves could be seen on the main part of the base. The lines of the sides began diagonally from margin to groove high on the sides of the scale base, but did not extend to its free basal margin.

2. Single-spined, both apex and base pointed. Such a scale, 34 mm. long, was widest at the center where there was a bulge on each lateral margin and where the scale width measured 3 mm. Otherwise the two ends of this scale were distinguishable only by the direction of the oblique lines. There were no lines on the base.

3. Two-spined (fig. 3), or occasionally three-spined, with incomplete concentric lines (circuli?) the upper margin of which was on the lower rim of the scale base. The upper, closed, arched end of these circular lines was at the level of the bottom of the scale base and outlined the top of the space enclosed between the two main spines. Ultimately the lines ran straight to the apices of the spines. Occasionally such spines were found in which the concentric lines were on one side of the scale only.

4. Two-spined, with concentric lines on the scale base. In one of these, 25 mm. long, oval, closed concentric lines on the scale base extended to its free margin, the focus being on the center of the base. The lines left the oval towards the lower lateral margin of the base and began slanting inward and apically, towards an off-center sulcus which ran from the

anterior rim of the base to the point where the scale spines met. An occasional scale with sculpture of this type was found to have the lines farther to one side of the base than the other.

5. Three-spined, with concentric markings (circuli ?) on the sides, not on the base, of the scale. Some scales on a portion of the body, also containing single-spined and bifid scales, were three-spined, but the third spine was almost entirely indicated by grooves (radii?) on each side of it. The only free portion was the extreme tip, visible under magnification. The markings of the two sides were unlike. One side had concentric, but not closed, lines, their open end facing the apex. These lines began above the joining of the spines and gradually widened to run down the side of the scale. The other side of the scale showed the usual diagonal lines, straightening towards the apex.

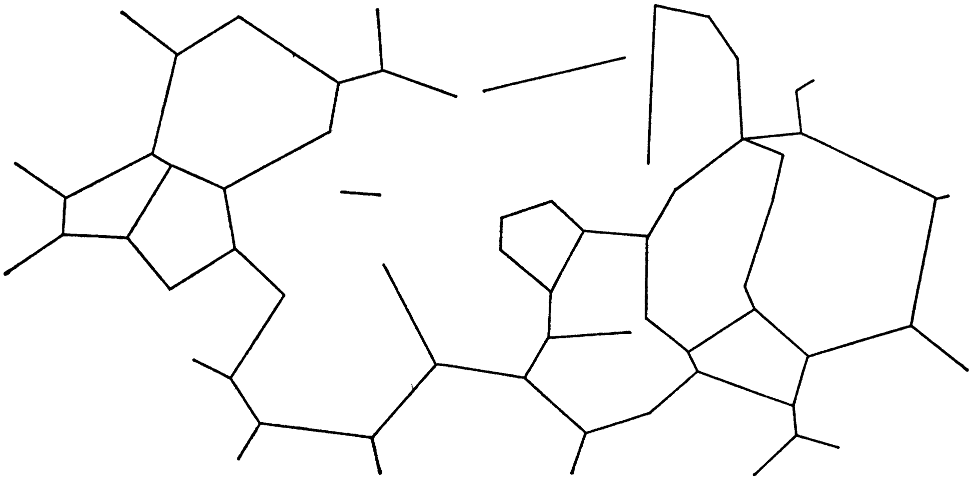

FIG. 4. Hexagonal lateral-line pattern of *Makaira ampla*.

LATERAL-LINE SYSTEM OF MAKAIRA AMPLA

In order to expose the lateral-line scales of *M. ampla* without disturbing possible connections between it and the exterior or surface skin of the fish, the flesh was scraped from the ventral surface of the scales, the outer skin of the fish remaining untouched. The pattern shown in plate 75, figure 2, is, therefore, seen from the ventral aspect of the scales.

The lateral-line scales of *Makaira ampla* form a series of uneven-sided, pentagons or hexagons, connected with one another and enclosing unspecialized scales of varying sizes and types (pl. 75, fig. 2; text fig. 4). All the scales, including those of the lateral line, are overlapped and tightly involved with one another, despite the fact that each rests in its own pocket of integument. The lateral line scales are farthest from the exterior of the fish. They are overlapped above by other lateral-line scales, but most of the topmost scale layer (nearest the exterior) is unspecialized. These layers, of course, consist not of the whole scale, but of the overlapping portion.

There are two types of lateral-line scales in this species. The more frequent of the two is larger and wider-based than the other (fig. 5, scales 2, 5; fig. 6). At corners of the hexagons or where one hexagon joins another, the scales are always of this type (figs. 5, 6). These scales are flattish, with multiple spines and a wide, flat, trilobed base. I was unable to find any trace of concentric markings on the bases. In one scale of this type, 28 mm. mm. long and 19 mm. from lateral lobe to lateral lobe of the base, lines ran up each spine and in and along the separating sulci, up to the canal opening nearest the apical end of the scale. Beyond these longitudinal and diagonal markings, I could find none. The scale base was thickly sprinkled with small, shallow pits which did not penetrate the scale. These pits extended as far towards the outer basal margin as the central opening of the horizontal canal. All scales of this type showed pitting.

On the base of the wide-based scale there is a branched, covered canal (fig. 6). This consists of one canal branch running lengthwise in a basal-apical direction. Halfway in its short length, it widens, and below this widened area is a three-lobed pocket. The canal then continues from the pocket towards the apical end, nearly reaching the division of the spines. This canal in turn branches to each side just below the side lobes of the scale base and extends to the tips of the lobes, opening just below their outer edges. Each of the branches has a smaller branch running at a slight angle, and towards, but not reaching, the outer margin of the scale base. An indication of this arrangement can be seen from both aspects of the scale, as the base is translucent.

I could find no direct connection of the lateral-line canals with the exterior of the fish. The canals that form the outlines of the hexagons are connected with one another, and a very fine bristle may be run through them from scale to scale (fig. 6). The canals in the fresh specimens of skin I examined were clogged with the oily matter which pervades the whole skin area of *M. ampla*, but by punching through the covered opening over the scale pocket in which the canals meet, it was possible to insert bristles into the canals and to get stain through, thus showing their course.

The less numerous, more narrow-based scales of the lateral-line system show the canals indistinctly, but the canal crossing the base from lateral lobe to lateral lobe can be distinguished on all of them, as well as at least a portion of the canal running perpendicular to it. The other branches were not vis-

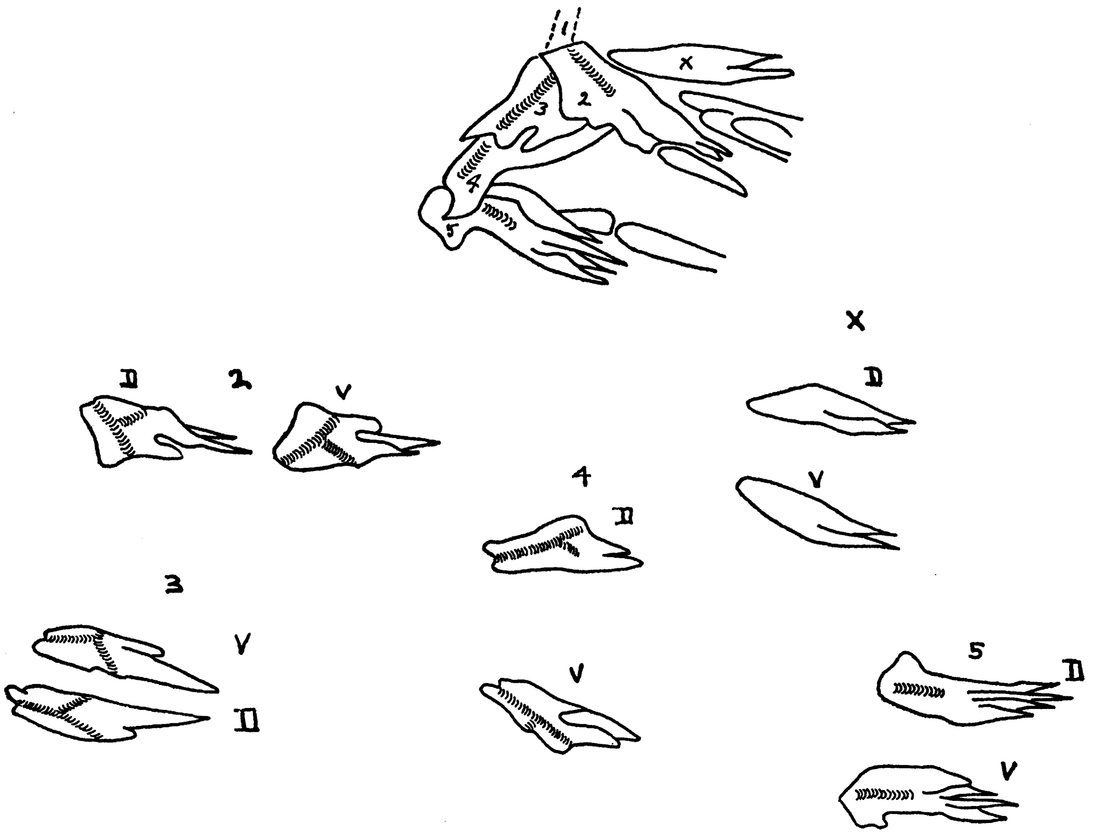

FIG. 5. Corner of lateral-line hexagon in *Makaira ampla.* Scales numbered 2–5 are types of lateral-line scales; scales marked x, an adjacent unspecialized scale. *Abbreviations:* d, dorsal aspect; v, ventral aspect.

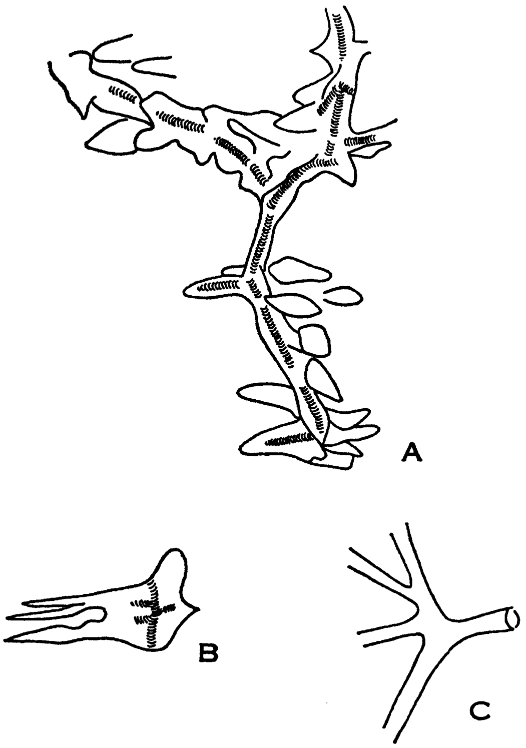

FIG. 6. A. Adjacent lateral-line hexagons in *Makaira ampla*, with connecting canals. B. Wide-based lateral-line scales. C. Canals.

ible. These scales usually follow the wide-based scales typical of the corners of the hexagons.

Figure 5 (scale 3) represents this narrow-based type of lateral-line scale. It usually has only two spines, on which are prominent ridges alternating with grooves. These run from the tips of the spines up to the margin of the basal lobes and are separated by the openings of the canal. They are also to be seen on the base as far as to slightly past the lateral canal opening nearest the apical end of the scale; also prominently on the sides; and, unevenly, on the raised portion of the scale covering the longitudinal canal and pocket. A group of shallow pits was found around the canal opening nearest the apex. There were no indications of concentric markings. One such scale measured 30 mm. long and 7.5 mm. across its base.

SCALES OF *Makaira albida*

Externally *Makaira albida* shows the same type of surface scale, with round, radially marked base and glassy perpendicular spines, as that found in *M. ampla* (pl. 76, fig. 3). The small round openings, sometimes directly under these scales, are also found in *M. albida*.

The subcutaneous scales in this species are very narrow and slightly flattened and thorn-like. They show so clearly externally that their apices appear to lie free on the surface of the fish, although in reality the entire scale is not only completely contained in its own pocket of very fibrous integument, but is also completely covered by the outer skin of the fish and entirely separated from it (pl. 76, figs. 3, 4).

The pattern of the unspecialized scales is regular, with only a few interpolated scales. The unspecialized scales are most frequently single-spined and of fairly uniform size (pl. 76, fig. 4). Their sculpture (text fig. 7) is like that of the "dermal scute" of *Istiophorus greyi* figured by Beebe (1941, text fig. 8). Concentric lines form a somewhat irregular circle, the top of which is on the basal margin of the scale; the bottom is somewhat wavy. As the lines run towards the lateral edges of the scale base, they develop a median dip, making them wavy. Gradually the closed concentric pattern is broken, and the markings slant increasingly from the margins of the scales downward towards the central sulcus. This sulcus also contains ridged lines. The sulcus is a little off-center throughout most of its length, making the length of the lines of each side of the scale differ. However, at some distance from the apex, the lines straighten, running to the tip of the spines. Where there are only two spines, the lines run down both as if on a single-spined scale. The lower outline of the main body of the scale between such points is lunate or deeply and narrowly notched.

The scales of *M. albida* do not usually overlap, but occasionally the apical tip of one is over the base of the next, or there may be a very slight lateral overlap. This lack of involvement may be the reason for the great elasticity, both longitudinal and transverse, of the skin of this fish.

The lateral line of *Makaira albida* is clearly visible on the external surface of the fish as a raised roughened line, some 4 mm.

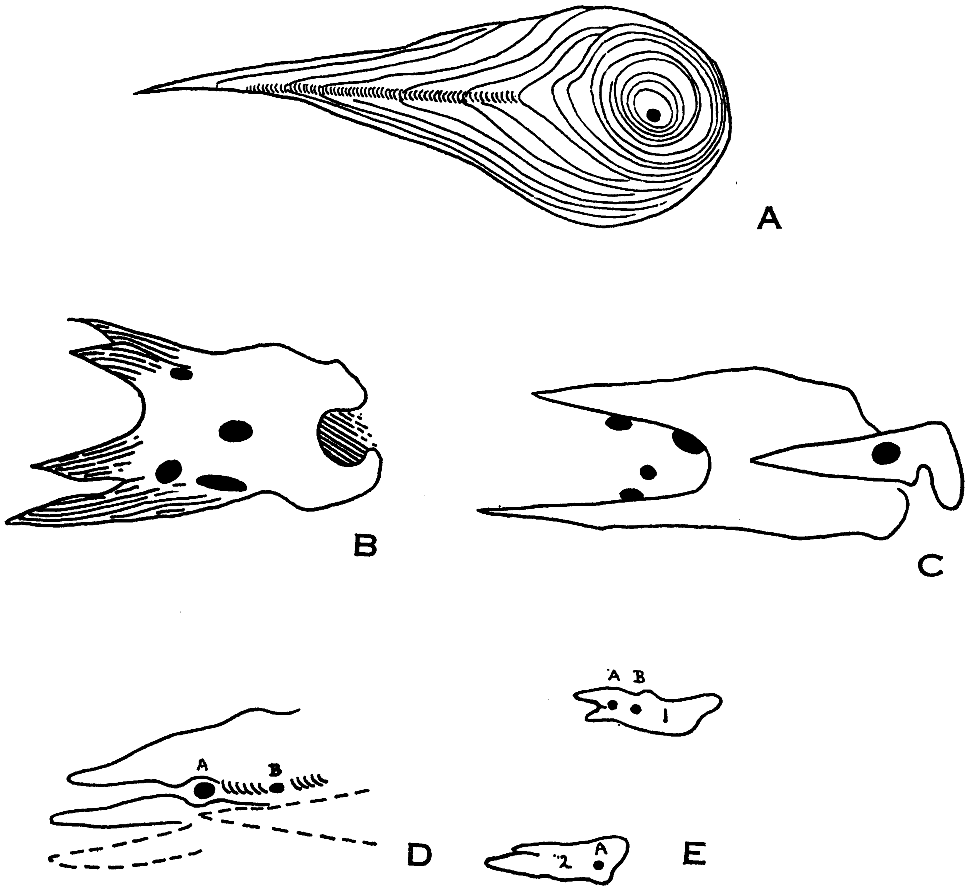

FIG. 7. *Makaira albida.* A. Sculpture and groove of unspecialized scale. B–E. Lateral-line scales and overlap, with vertical connection between canals. D. Overlapping scale in position. E. Overlapping scales separated; 1 lies over 2, with A connecting A.

wide, running from just beyond the origin of the peduncular keels to the shoulder, where it rises and then runs straight to the angle of the gill cover (pl. 75, fig. 3). The lateral-line scales (text fig. 7) are widely bifid, and their central portion is extremely fragile. Small, round, uncovered openings in the scales lead directly to similar openings in the thin surface skin and thus are in direct connection with the exterior. These skin openings are larger than the small round openings mentioned on page 384. The openings at the top of the scale also lead into the lateral-line canals on the individual scale, and one of them is directly above a similar opening on the lateral-line scale which it overlaps (fig. 7). These openings may appear to be on integument, but close examination, confirmed by staining, shows that they are on a thin, but integral, part of the scale. The short, not easily traced canals run into very large scale pockets. There are longitudinal sculpturings on the spines of the lateral-line scales, continued to a short distance on the sides of the scale base. There are no concentric markings on the bases.

Comparison of Scales of *Makaira* with Those of Juvenile *Xiphias* and Juvenile and Adult *Istiophorus*

The glassy-spined scales of juvenile *Xiphias* and *Istiophorus* have often been noted, but there is no full description of scales of anything identified as the young of either species of Atlantic *Makaira*, although it is probable that at least two of the specimens mentioned on page 392 are *Makaira*, very probably *M. albida.* It is unfortunate that deSylva's two specimens (p. 412) were not in condition to make such examination possible. Plate 81 of his specimens shows a reticulated pattern on the upper sides, very similar to the hexagonal pattern made by the lateral-line scales of *M. ampla*. Again Gehringer (1956) among his istiophorid specimens collected from the "Theodore N. Gill" in the Caribbean, found 15 specimens less than 10 mm. in length which he thinks may be either *Tetrapturus* or *Makaira*, probably the former. One of these (Gehringer, 1956, fig. 25, p. 153) shows a young fish with short jaws, the upper one of which is slightly, if at all, longer than the lower, a very high, blotched sail, and, beginning below the twelfth and ending below the thirty-third ray of the high dorsal, a reticulated patch which seems to be a skin pattern on the upper sides of the fish and which possibly indicates the subcutaneous lateral-line pattern of the adult *M. ampla*. It is much the same, only less of it, as that shown in the deSylva specimens. It is, of course, possible that *Tetrapturus* has this pattern, although if the "short-nosed Spearfish" listed by Japanese authors (Ueyanagi, 1957a) is *Tetrapturus*, it is unlikely, as Ueyanagi lists this fish as having a "monotonous" lateral line.

Arata (1954) describes the juvenile scales of a series of *Xiphias gladius* from 6.1 to 192.1 mm. long. He says in conclusion:

"The scales of the largest specimen are strong and cover the entire body, which leads us to a consideration of the size at which the scales are lost. Nakamura et al. (1951) discuss the scales at various sizes larger than 192.1 mm. At 252 mm. they found scales still existing but about half were smooth. They concluded that the scales are deciduous in some stage of growth. They discuss a 454 mm. specimen pointing out that the scales have degenerated conspicuously, being imbedded in the skin with their existence still traceable exteriorly. They mention a specimen of 580 mm. with the scales totally absent. LaMonte and Marcy (1941) report the skin of a four foot specimen 'thickly set with irregularly set overlapping somewhat triangular scales, each bearing a series of from three to ten small, transparent, sharp, recurved spines.' Lütken (1880) refers to scales on a specimen 27 inches long.

"From these conflicting views, it must be concluded that during post larval life the swordfish has scales present from about 9.0 mm. to some stage beyond four feet."

Nakamura *et alii* (1951) state that the lateral line, although indistinct, exists in the 454-mm. stage, starting from below the origin of the first dorsal fin, "making wavy curve of about 10 mm. and disappears backward."

In a specimen in the American Museum of Natural History, measuring at least 485 mm. (the end of the upper jaw is missing) in standard length, the scales are conspicuous and show no sign of embedding or degeneration or of being deciduous. They are easily discernible with the naked eye. In this specimen almost every part of the body except the fins is heavily scaled—the opercle, preopercle, top of head, top of sword, under part of lower jaw, and entire belly, as well as the sides. There are two types of these scales: the smaller, which has a flat base, and the larger, which is keeled. The smaller scales lie on the surface. In general, they have an oval flat base radially grooved and with a coarsely ctenoid margin. From the center of the scale rise the one or more small, sharp, glassy spines.

The larger, higher-keeled, tougher-spined scales form four rows. These scales are based not on the surface of the skin, but subcutaneously in a layer of very fibrous integument. The surface skin, covered with its small scales, covers the base of many of the keeled scales. The keeled scales consist of a base which is somewhat oval and rises in the middle to form a long, blunt keel, along the top ridge of which is a row of six strong conical spines. The first three of these spines are very conspicuous and of almost equal height; the last three are about half of the height of the others. At the apical end of the scale, lying flat, are two strong, wide, pointed spines; at the basal end there is an unevenly lobed wider portion. The lateral margins of the center of the scale are crenate. There are some concentric lines on the base of the keels and some indication of radial grooves.

The larger, higher-keeled scales mentioned above as having a subcutaneous origin, although their spines emerge on the surface, and as having two strong, wide, flat-pointed spines, may be analogous in this fish to the subcutaneous lanceolate scales of *Istiophorus* and *Makaira*, although they also resemble in general the placoid scale originating in the dermis, with its spines eventually breaking through the epidermis.

The outer (upper) row of scales on the belly of this juvenile *Xiphias* is heavily keeled and rises at the origin of the anal fin to run along the sides of the fish above the anal fin and thence slightly beyond the origin of the caudal keel.

The rows of scales on the belly between these outer rows are conspicuously spined, and most of them are very slightly keeled. There are three rows of heavily keeled scales on the sides of the fish. The first row begins about 10 mm. behind and somewhat above the upper angle of the gill cover, and at its origin is 10 mm. below the base of the dorsal fin. It gradually runs nearer and nearer the dorsal base until, at its end and the end of the dorsal base, they are about 2 mm. apart.

The second row begins approximately 35 mm. behind the origin of the top row, running at a distance of some 13 mm. from that row and ending below its end. The third row begins midway down the body from gill cover to caudal base, runs about 20 mm. below the row above it, and continues to the caudal base. The row marking the belly margin runs 13 mm. below the row above it, rises, as decribed, above the anal fin, and continues to a short distance below the origin of the caudal keel.

There is no sign of scales in the fully adult *Xiphias*. The skin is quite thickly sprinkled with small mucous (?) openings.

I have examined the scales of juvenile *Istiophorus* in the American Museum of Natural History collections and cannot improve upon their description by Beebe (1941). In describing the squamation of a specimen of *I. greyi* (Pacific sailfish), 84 mm. long, he says: "Staining and clearing reveal unsuspected scalation of remarkable complexity. Scales are found over the entire body and even a short distance out on the caudal rays. . . . The density of the scales on the body is such that the edges of the scales touch one another. They may be round, oval, ovate or almost diamond shaped. . . . A typical scale consists of two outer rings coarsely marked with wide-spaced radiating lines. Inside the second ring is a small clear area, and from the posterior rim of this . . . arises a long, slender, sharp spine. . . ."

Beebe's text figure 2 shows a clear drawing of such a scale. We may add that although staining and clearing increase the visibility of detail, these scales are clearly visible under ordinary magnification.

On page 221 of the same article, Beebe describes the scales of a "full grown male, of 2,616 mm. standard length, 2,946 total length (9′ 8″)." He continues: "Much of the skin of the adult sailfish is covered with a multitude of minute mucous openings, sometimes in parallel lines. Many of these are surrounded by a well ossified, but tissue-thin plate or scale, oval or rounded, and easily detached, if the central portion lies over a mucous opening it is perforated, doughnut-like" [Beebe calls these the "guard scales"]. . . . "Under high power, a typical, elongate oval guard scale is seen to have the surface covered with a mass of low, blunt tubercles, presenting a rough, crystalline appearance. The center is perforated with a large, oblong hole and around this are grouped eleven enlarged, thick, sharp spines or teeth. . . . These toothed scales seem to be placed more regularly and to protect openings larger and of different origin from the multitudinous small mucous vents.

"The second type of adult scale is a stiff scute, strongly ossified, irregularly abundant, sometimes completely buried in the epidermis."

Beebe illustrates the latter type in his text figure 8. He does not describe the lateral line as such.

The lateral-line scales of the adult sailfish (*I. americanus*) given to me by Al Pflueger closely resembled those of *M. albida* in shape, size, arrangement of canals and of pockets, and in the course of the lateral line along the body from caudal base to above the pectoral where it rose, continuing to the upper angle of the gill cover. The communicating canal openings were the same, only seemed to be more numerous, and the openings on the skin surface were the same and also, as in *M. albida*, larger than the more numerous small pores. The scales of the lateral line were bifid as in *M. albida*.

Both types of scales, surface and subcutaneous, were present in the Pflueger specimen, as stated by Beebe for the Pacific species. In the Pflueger specimen, scales of the surface type were found over the body and scatteringly on both opercle and preopercle, although many of them in these two areas had been rubbed off. The subcutaneous, unspecialized scales were delicate and sharply pointed. They overlapped very slightly or not at all. These scales were of two types: a single scale as shown in Beebe's figure 8, and a bifid scale in which there were concentric lines on the base. Below the base on these bifid scales was another group of markings, outlining the cleft between the two spines and thus making their closed peak back to back with the lower edge of the concentric lines of the scale base. The markings ran down both spines.

Scales of Unidentified Juveniles

Through the courtesy of the University of Miami Marine Laboratory and of Mr. Al Pflueger, in whose establishment the fish were, I had an opportunity of making a superficial examination of three fresh, apparently juvenile, speared fishes and of taking for further examination small pieces of skin from the mid-section, including a portion of the lateral line, of each fish.

In all three specimens, the lateral line was clearly visible on the surface. In none of them was there any trace of the reticulated surface pattern shown in the deSylva juveniles of 5 and $30\frac{1}{2}$ pounds, respectively (see below, p. 412). Lanceolate, subcutaneous scales were present in all three specimens, not only on the body but on the opercle and preopercle.

The internal organs, partially exposed by a mid-ventral and vertical lateral cut, showed no pronounced differences from those of *M. albida*. Specimen Pflueger 1-1957 had very small gonads, the longer about 5 inches, the other about $1\frac{1}{2}$ inches, with a diameter of 5 mm. The shorter gonad was very closely adherent to the other. The appearance and position of the gonads in the other two specimens were normal.

Specimen Pflueger 1-1957 was taken on May 5, 1957, off Marathon, Florida. Its standard length was 1575 mm.; its fork length, 1460 mm.; it weighed 19 pounds. Dr. C. Richard Robins of the University of Miami Marine Laboratory noted that the vent of this fish was 145 mm. from the origin of the first anal fin, a distance proportionally greater than in the adult of either species of Atlantic *Makaira*. In this fish, both surface and subcutaneous scales and those of the lateral lines were small and fragile, but like those of the adult *M. albida*.

Specimen Pflueger 2-1957 was taken either on April 3 or April 4, 1957, off St. Georges, Bermuda. Its fork length was 754 mm.; its total length, a maximum of 38 inches (the spear was broken); it weighed $2\frac{1}{2}$ pounds. On the outermost surface, on a small patch of outer integument left on the fish, were barely perceptible indications of glassy-spiked surface scales. The unspecialized subcutaneous scales were flat, very fragile, translucent cycloid scales, smooth-edged except for three rounded basal lobes (see fig. 8B). The scales overlapped very slightly and were regularly arranged. The scale was entirely occupied by closed concentric lines, the focus in the center of the scale. These scales were approximately circular and measured an average of 4 mm. in diameter. The lateral-line scales of this specimen were slightly longer than wide and distinctly three-spined (fig. 8A). A central canal opened in one small circular opening. On the base of the scale, interrupted by the canal, were concentric lines. On one side, above the cleavage of the two longer spines, were outlining markings (circuli?) which ultimately ran straight down to the apices of the spines. The other side of the scale was covered with wavy lines (ridges) splitting off from the concentric ones of the base.

The relationship of these scales to one another was that of the adult *M. albida* and

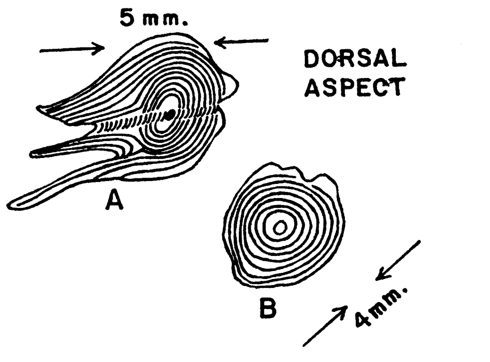

Fig. 8. Unspecialized and lateral-line scales of unidentified juvenile specimen Pflueger 2-1957. A. Lateral-line scale. B. Unspecialized scale.

showed no sign of the hexagonal pattern of *M. ampla*. Except for the trilobed base, however, one type of the unspecialized scales is, so far as I know, not present in *M. albida* and very closely resembles the scales shown in Ueyanagi (1957a, pl. 2, fig. D) for the young of Nakamura's *Eumakaira nigra*. Also present in our specimen were single-spined, unspecialized scales exactly like those figured by Ueyanagi for *E. nigra*. Ueyanagi (1957a) states, however, that the lateral-line pattern of *E. nigra* is "complicate" in contrast to the "monotonous" lateral-line pattern of all the other Pacific speared fishes listed by him, and his figures indicate that this pattern shows on the surface in the juveniles. This adds to the evidence that specimen Pflueger 2-1957 cannot be a juvenile *M. ampla*.

There is, of course, no possibility that this Pflueger specimen, which was collected in the Atlantic Ocean, is the Pacific fish *E. nigra*. Whether or not the genus *Eumakaira* is valid or a synonym of *Makaira* and whether or not *E. nigra* is a synonym of *M. mazara* (Jordan and Snyder) or a third, as yet scientifically unnamed, Pacific marlin also remain to be proved. There is evidence (Nichols and La-Monte, 1941) that the fish known as the black marlin (Pacific Ocean) is closely related to *M. ampla*, in which case it would seem normal for the same lateral-line pattern to be present in both the blue marlin and the black marlin. It is not present in the Pflueger specimen.

There is also the possibility that specimen Pflueger 2-1957 is a *Tetrapturus*. I unfortunately have no material for comparison, and know of no speared fish on record as having this type of unspecialized scale except our specimen, that figured by Ueyanagi (1957a), and a young "*Tetrapturus*" taken off Batavia and described by Van Campen (1908) as having a conspicuous lateral line and thin, overlapping scales which resembled normal scales.

In *Tetrapturus*, the position of the vent may be diagnostic, and Rafinesque (1810) mentions that in his *T. belone* the anus is in the middle of the body. Tanaka (1913–1915) also says of his *T. angustirostris* that the vent, in a specimen of some 6 feet 8 inches, is "a little closer to the tip of the ventral than to the insertion of the first anal." Tanaka also says that in his fish, the lateral line is complete and that there are "vermiculate maculations."

Further examination of the specimens will be made at the University of Miami Marine Laboratory, and it is hoped that vertebral counts or other features not possible to observe in my examination will put these three juveniles in the correct genera at least.

SUMMARY

Present in the adults of both species of Atlantic *Makaira* are two types of scales, one on the outermost surface, distinctly separated from the other, which is subcutaneous and entirely different in type. The lateral line of *M. albida* is uncomplicated and visible externally; that of *M. ampla* is not externally visible and its scales form a series of connecting hexagons. This hexagonal pattern is also described by Japanese authors as being unique among Pacific speared fishes for *Eumakaira nigra* Nakamura.

The identity of juvenile specimens, the sculptural markings of scales, and the histological details of the integument of the genus *Makaira* are difficult to interpret, as there is no familiar comparable material.

Adult and juvenile *Istiophorus* have both surface and subcutaneous scales and an nn-complicated, externally visible lateral line. Adult *Xiphias* is scaleless; its juveniles have two types of "surface" scales, one of which, however, seems to originate in a deeper layer of integument and in some ways resembles the subcutaneous lanceolate scales of the other two genera.

Juvenile specimens thought to be *Makaira* have both types of scales. Some of these showed a surface pattern (pl. 81, figs. 1, 2) resembling the hexagons of the lateral-line system of *M. ampla*. Others (specimens Pflueger 1-1957, 2-1957, and 3-1957) had uncomplicated lateral-line patterns, but specimen Pflueger 2-1957 revealed a type of unspecialized surface scale noted before only for *E. nigra* Nakamura. It is probable that this specimen is a juvenile *Tetrapturus*. I have no material for comparison.

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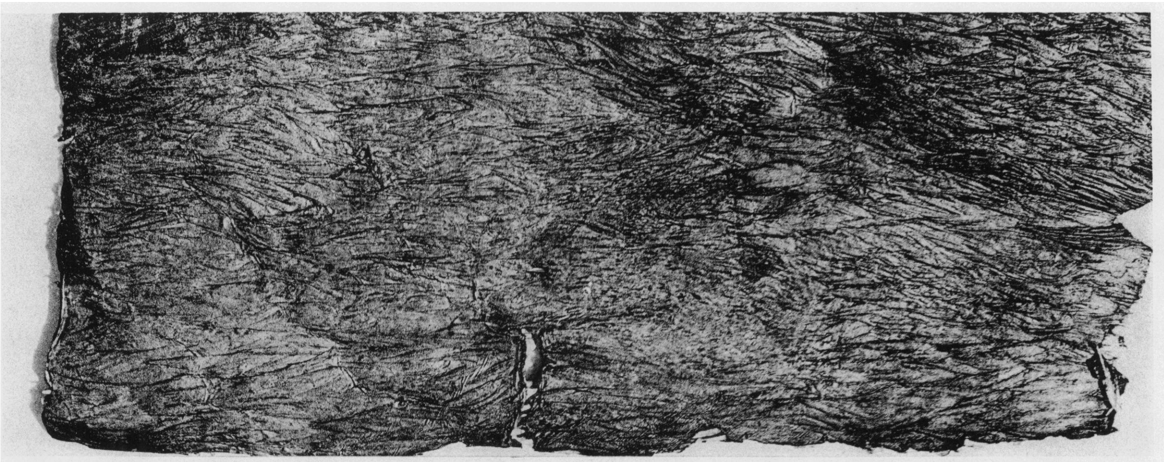

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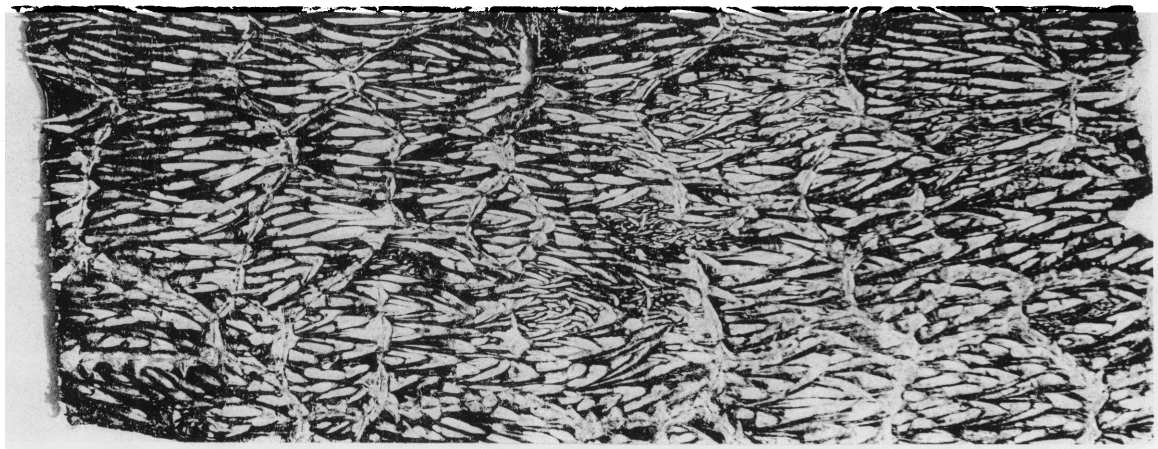

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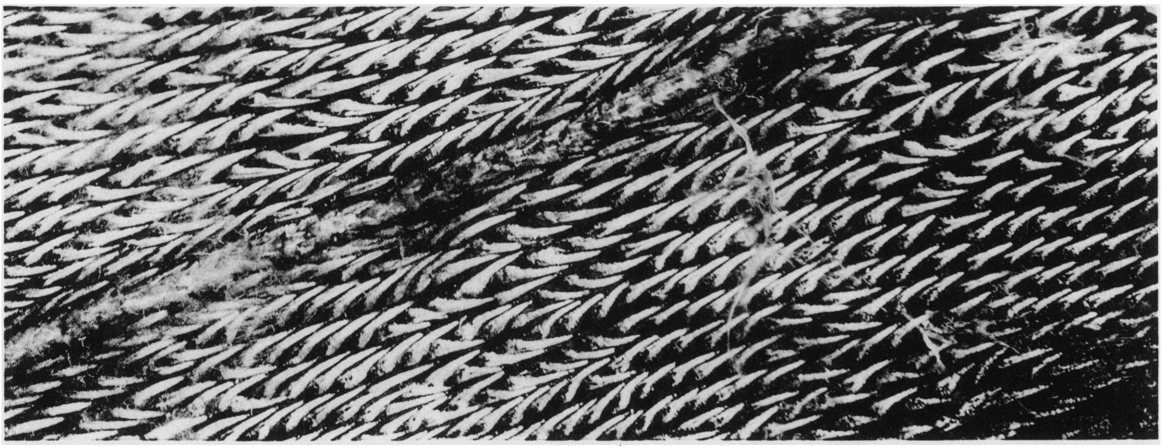
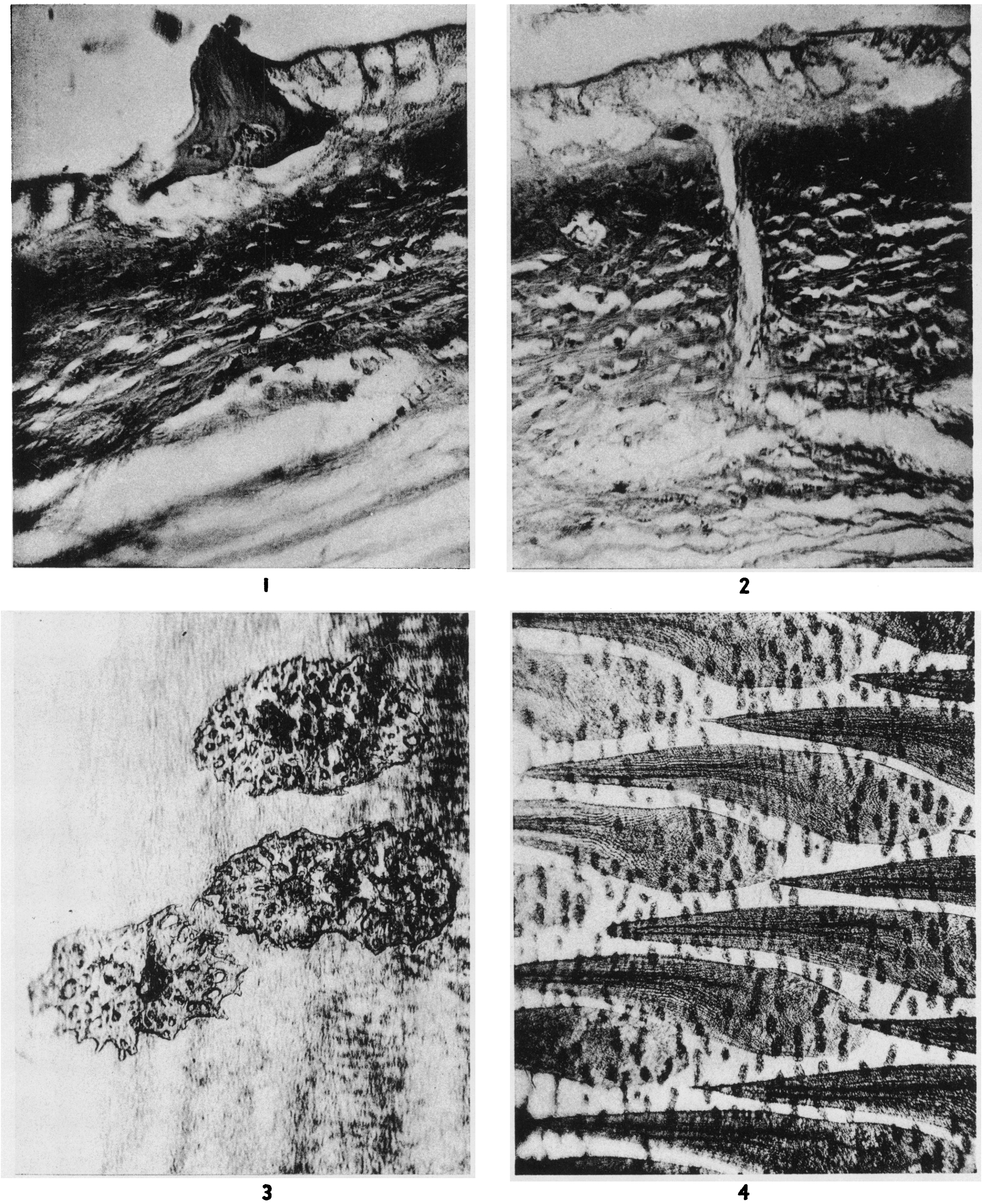


3

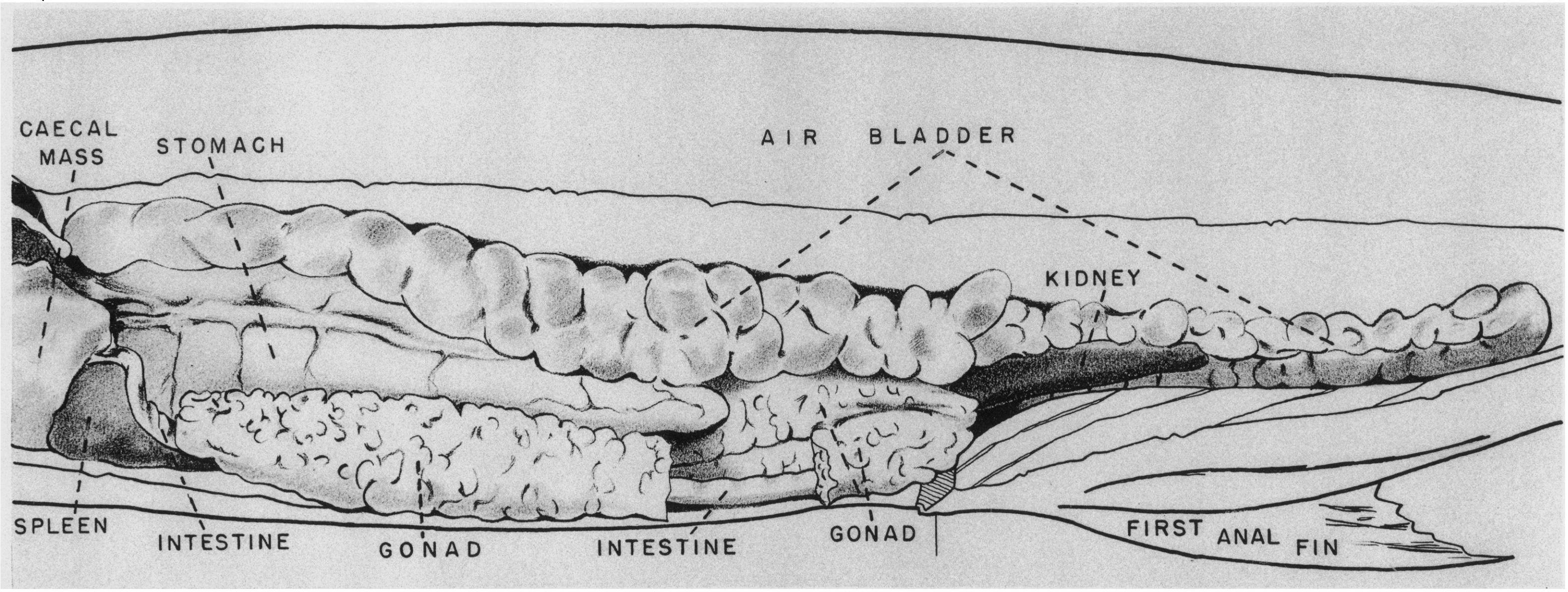
1. Outer surface of *Makaira ampla*
2. Ventral aspect of subcutaneous scales of *Makaira ampla*, showing lateral-line hexagons
3. Outer surface of *Makaira albida*, showing lateral line

All photographs by Frederic Maura, Bahamas Development Board



1. Surface scales and modification of peripheral layers of skin in *Makaira ampla*. × 360
2. Skin of *Makaira ampla*, showing channel connecting lacunae in dermis with surface. × 360
3. Surface scales of *Makaira albida*. × 80
4. Subcutaneous scales of *Makaira albida*. × 7

All photographs by Priscilla Rasquin, the American Museum of Natural History



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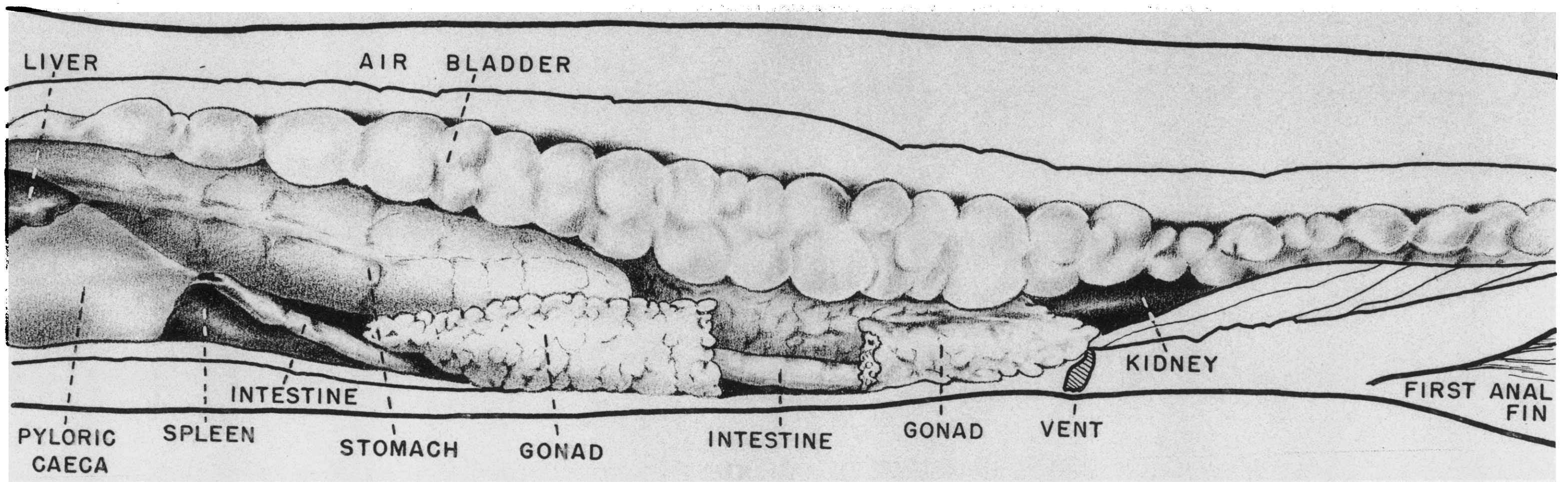
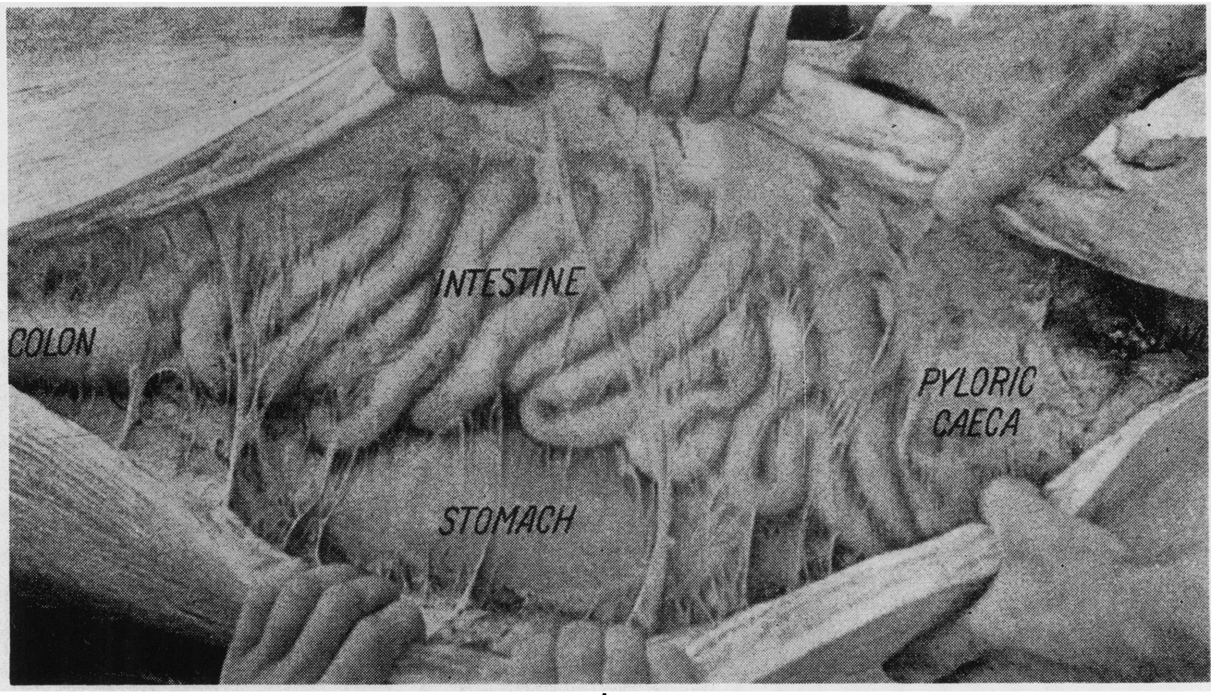


2

1. Semi-diagrammatic lateral view on single plane of *Makaira ampla*, showing relative positions of organs. Peritoneum removed to show kidney
2. Soft organs of *Istiophorus americanus* (Cuvier and Valenciennes)

Both drawings by Janet Roemhild



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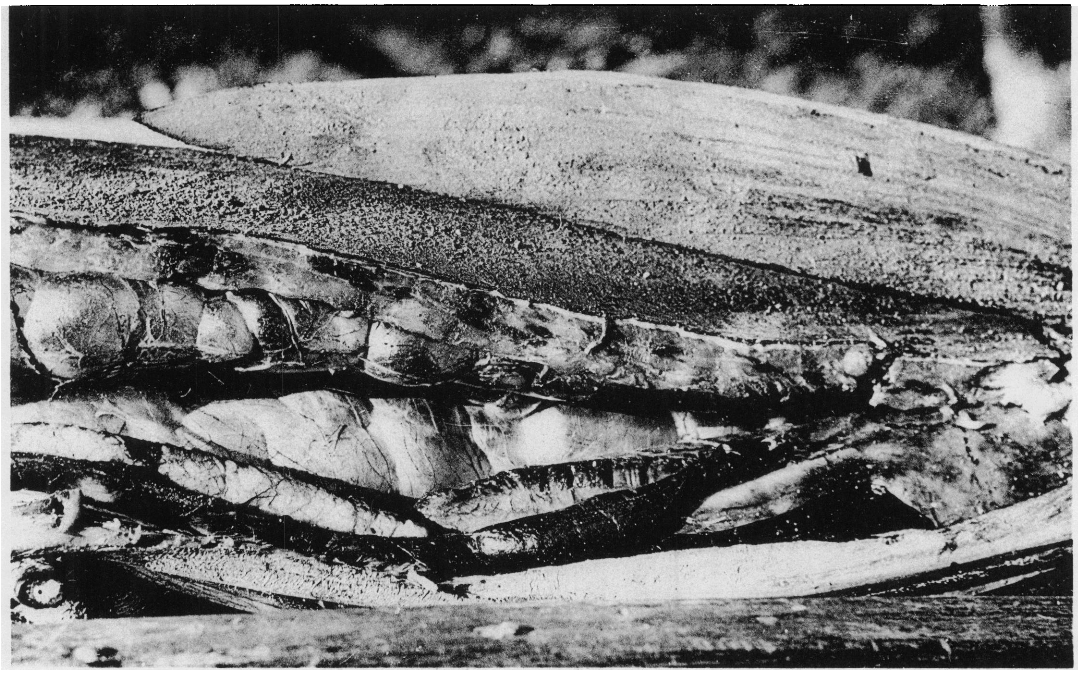

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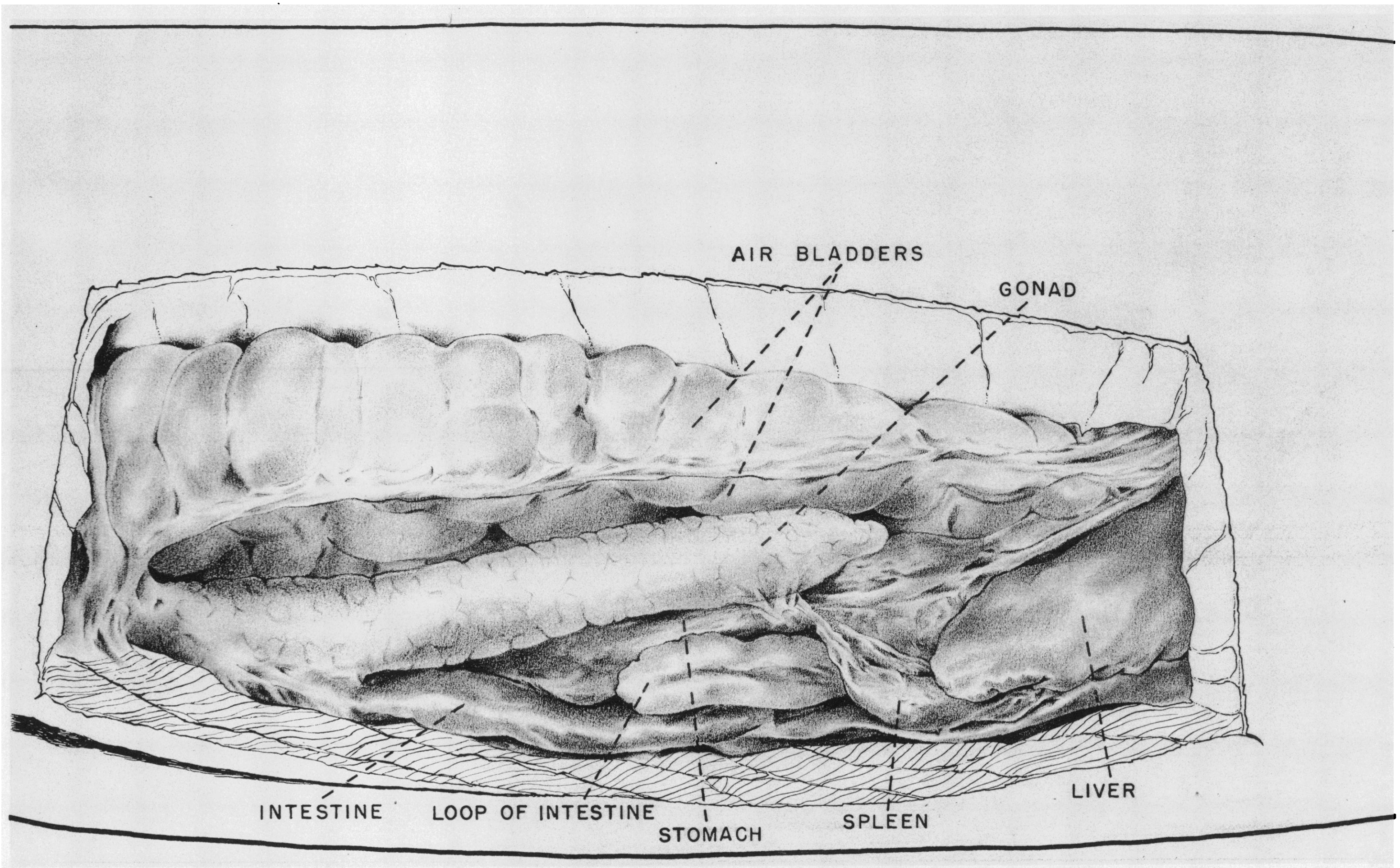
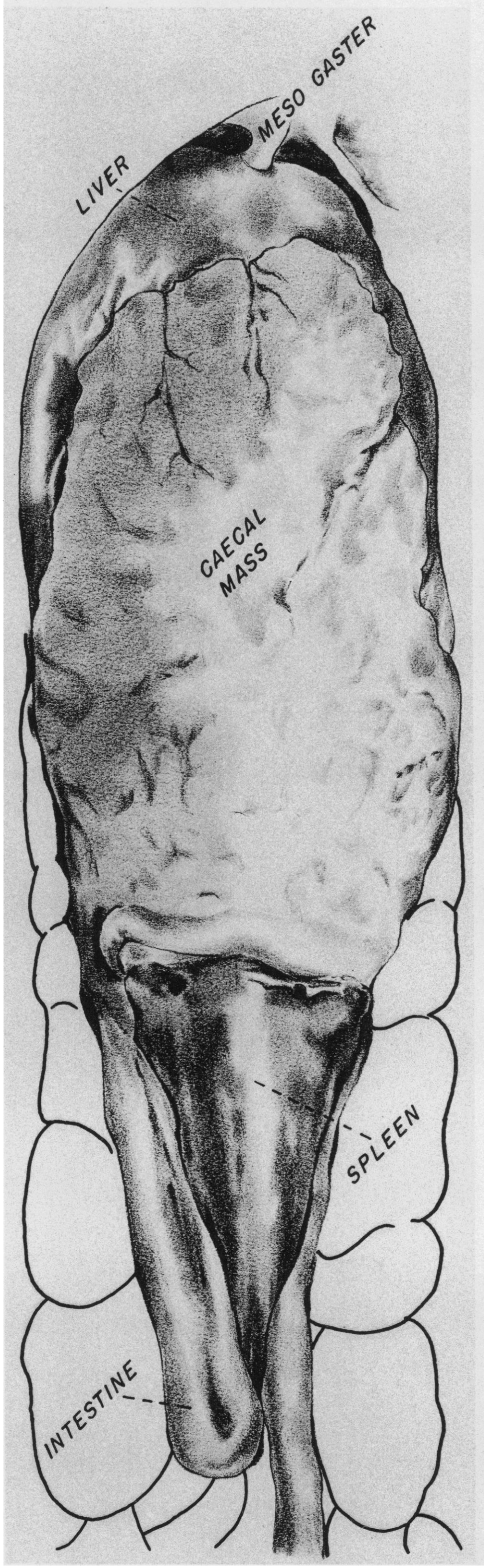
1. Soft organs of *Xiphias gladius* Linnaeus, taken off Louisburg, Nova Scotia. Dissection by H. C. Raven and F. LaMonte; photograph by L. Ferraglio

2. *Istiophorus greyi* Jordan and Hill, taken off Acapulco, Mexico. Photograph by Max Hecht

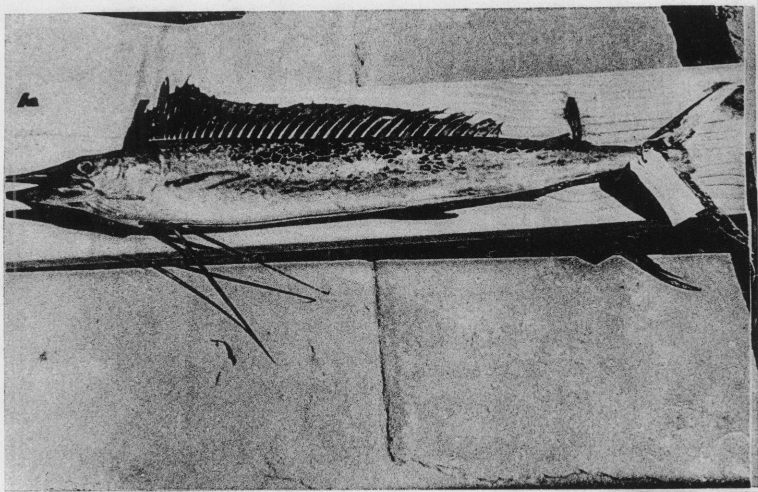


Makaira ampla. An area of 25 cm. from the origin of pectoral fin to 11 cm. anterior to the origin of the first anal fin. One gonad, pulled upward and reverted, lies over the stomach; the mesentery is still adherent at the free end. The spleen is doubled over on itself

Drawing by Janet Roemhild



Ventral aspect of *Makaira albida* from mesogaster to end of intestinal loop. Drawing by Janet Roemhild



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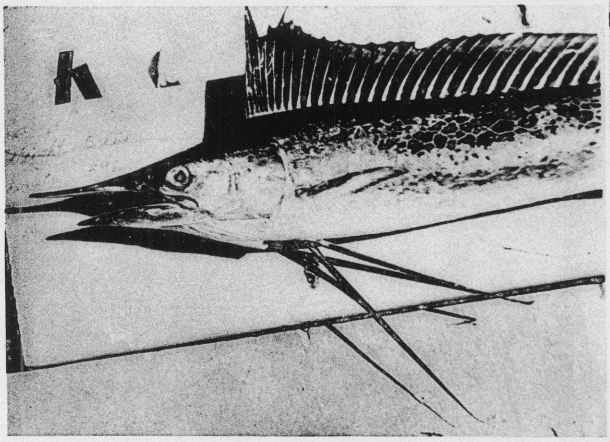

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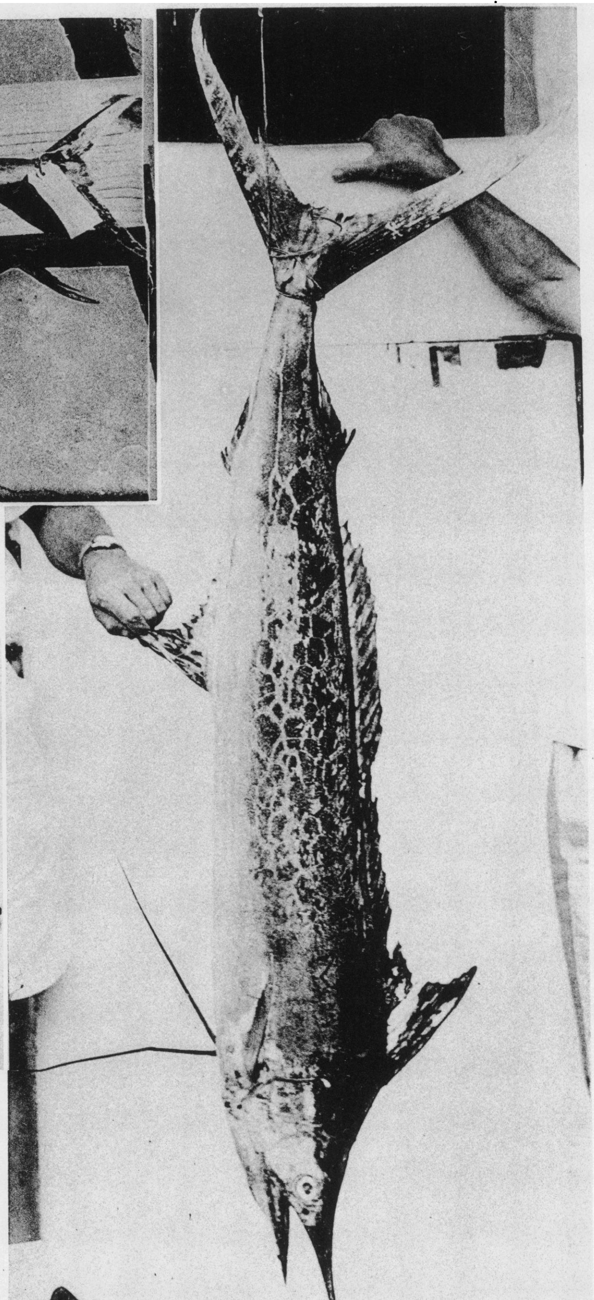

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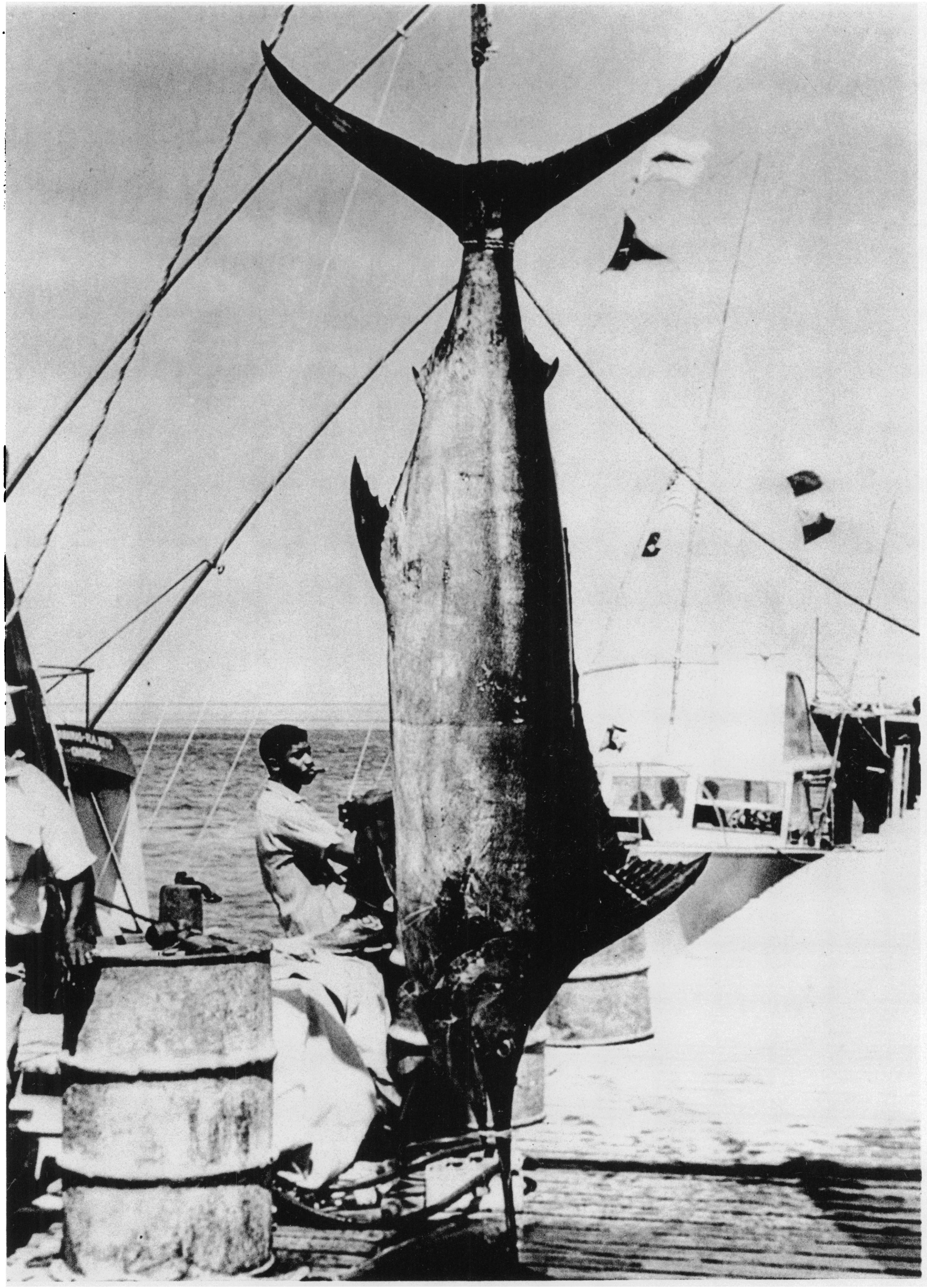
1, 2. Blue marlin caught off West End, Bahamas, December 26, 1955, by Capt. Roland Garnsey. Weight 5 pounds. Photograph by J. T. Reese

3. Blue marlin caught off Miami, Florida, May 8, 1956, by Capt. Lou Case. Weight 30½ pounds. Photograph by J. K. Howard



Blue marlin caught off Bimini, Bahamas, June, 1953. Weight 373 pounds
Photograph by Donald P. deSylva

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NOTES ON THE ALIMENTARY, EXCRETORY, AND REPRODUCTIVE ORGANS OF ATLANTIC *MAKAIRA*

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MATERIAL EXAMINED

Makaira albida (Poey)

Field number 4-56: Ripe male, 43½ pounds, over 2125 mm. in total length, caught July 10, 1956, Bimini, Bahamas, by Mrs. Victor Till, boat "Southern Comfort," Captain Shultz

Field number 6-56: Ripe male, approximately 50 pounds, caught August 13, 1956, Ocean City, Maryland, by William Ahtes, boat "Anne"

Field number 7-56: Male, approximately 50 pounds, caught August 14, 1956, Ocean City, Maryland, by Roger Hale, boat "Parker"

Field number 8-56: Not sexed, approximately 50 pounds, caught August 4, 1956, Ocean City, Maryland, by Christian Heurich, boat "Blue Runner"

Makaira ampla (Poey)

Field number 1-56: Inactive male, 506 pounds, total length 12 feet 3 inches, caught July 6, 1956, Bimini, Bahamas, by Luke Wilson, boat "Ouphe II," Captain Verity

Field number 2-56: Female near rupture of membrane, 552 pounds, total length 11 feet ½ inch, caught July 8, 1956, Bimini, Bahamas, by D. Hill, boat "Sandona," Captain Stuart

Field number 3-56: Ripe male, 140 pounds, about 2600 mm. in total length, caught July 10, 1956, Bimini, Bahamas, by Bob Bertha, boat "Stag," Captain Black

Field number 5-56: Ripe male, 209 pounds, caught July 11, 1956, Bimini, Bahamas, by Victor Till, boat "Sandona," Captain Stuart

Additional specimens, as follows, were examined:

Makaira ampla (Poey) and *Makaira albida* (Poey)

Males and females, Bimini, Bahamas, 1937

Makaira mitsukurii (Jordan and Snyder)

Caught at Cabo Blanco, Peru, and Tocopilla, Chile, May and June, 1940, by Helen and Michael Lerner, boats "Santa Luisita" and "Santa Teresita," Captains W. D. Hatch and Douglas Osborn

Makaira mitsukurii (Jordan and Snyder) and *Makaira mazara tahitiensis* (Nichols and LaMonte)

Caught at Acapulco, Mexico, 1948 and 1952

Istiophorus americanus (Cuvier and Valenciennes)

Caught in 1957 off Florida, presented to the American Museum by Mr. Al Pflueger

Istiophorus greyi Jordan and Hill

Caught at Acapulco, Mexico, 1948 and 1952

Xiphias gladius Linnaeus

A.M.N.H. No. 18960: Juveniles collected off Messina, Sicily, August 1949, by G. Arena

Inactive females caught in 1936 and 1938, Louisburg, Cape Breton, Nova Scotia, by Michael Lerner and by commercial fishermen

BODY FORM

The speared fishes as a group are fusiform, the greatest depth being at the shoulder. The deepest bodied are the swordfish, *Xiphias*, and the black marlin of the Pacific, *Makaira mazara* (Jordan and Snyder, 1901), and the possible subspecies of the latter, *M. m. tahitiensis* (Nichols and LaMonte, 1935). Least deep are the rare *Tetrapturus*, or spearfish, and the sailfish, *Istiophorus*. Of the two Atlantic species of *Makaira*, *M. albida* is the smaller and the more slender.

MOUTH REGION

Figure 9

The mouth gape in *Makaira* is wide; the cleft reaches well beyond the posterior margin of the eye. The inside of the mouth is whitish. There are small denticles on the palatines, and a patch in the vomerine region, which appears to be on the palatine

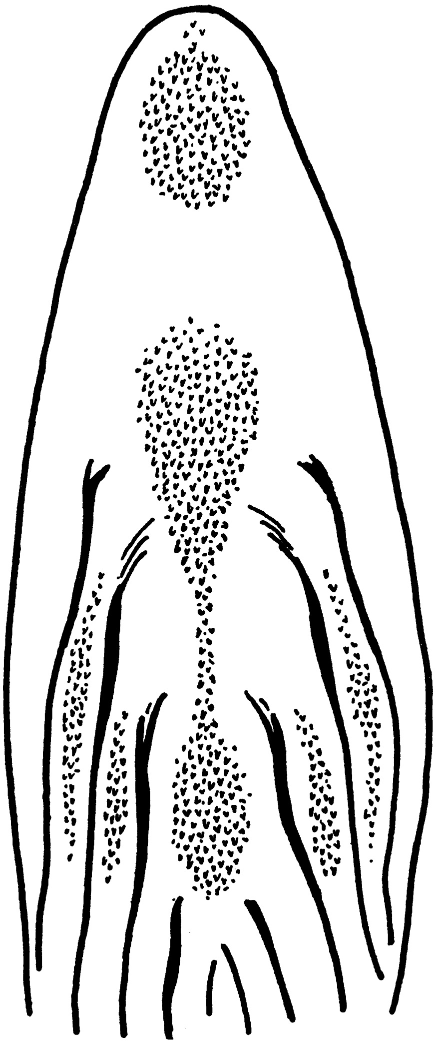

FIG. 9. Mouth of *Makaira albida*, showing tooth patches. Drawing by Janet Roemhild.

membrane. In *M. ampla*, there is a well-defined patch on the tongue, close behind its tip; in *M. albida*, the tongue denticles are fewer and more scattered. There are also small denticles on the margins of both jaws, running to within an inch or so of the tip, and smaller ones on the under sides. There are no teeth on the upper surface of the spear or the lower surface of the under jaw. There are patches of denticles on the pharyngeals (fig. 10).

GILLS

The wide, laminated gills are paired; each pair is connected from the base to within a short distance of the free margins, as if woven together. Gill-rakers are absent or vestigial. This gill structure is typical of the group.

BODY CAVITY

The body cavity in both species extends from the cardiac region to the end of the air bladder. Beyond the pectoral girdle, little or no protection for the soft organs is provided by bony structures, but a great deal is given, in *Makaira*, by the scales, the thick flesh and muscle layers, and the mesenteries.

FLESH

The flesh of *Makaira*, *Istiophorus* and *Xiphias* is usually white; in rare cases, pink.

The flesh of *Makaira* is oily and somewhat granular, that of *Istiophorus* is slightly oily and less firm than that of *Xiphias*, which is very solid and not oily.

SOFT ORGANS

The soft organs of the two Atlantic species of *Makaira* (pl. 77, fig. 1) and those of *Istiophorus* (pl. 77, fig. 2; pl. 78, fig. 2) are very similar in structure and arrangement in the body cavity. Those of *Xiphias* (pl. 78, fig. 1) are most markedly different in the unchambered air-bladder and many-coiled intestine (Raven and LaMonte, 1937).

AIR BLADDER

In *Makaira*, the physoclistic air bladder (pls. 77, 79) lies against the dorsal wall, its upper section partly behind the ribs. It runs from the cardiac region to a point on a vertical dropped to just before the origin of the second anal fin and is supported by a strong tendon. It consists of a double row of uneven-sized, bubble-like chambers enclosed in a common outer membrane, but separate from one another so that one chamber may be collapsed without the collapse of the others.

ALIMENTARY, EXCRETORY, AND REPRODUCTIVE ORGANS

A dorsoventral view of the soft organs would show them to lie as follows: in a superior position in the body, in a retro-peritoneal cavity and against the vertebrae, lie the kidneys (pl. 77, fig. 1; text figs. 10, 11, 12). The ureter runs through the peritoneum (text

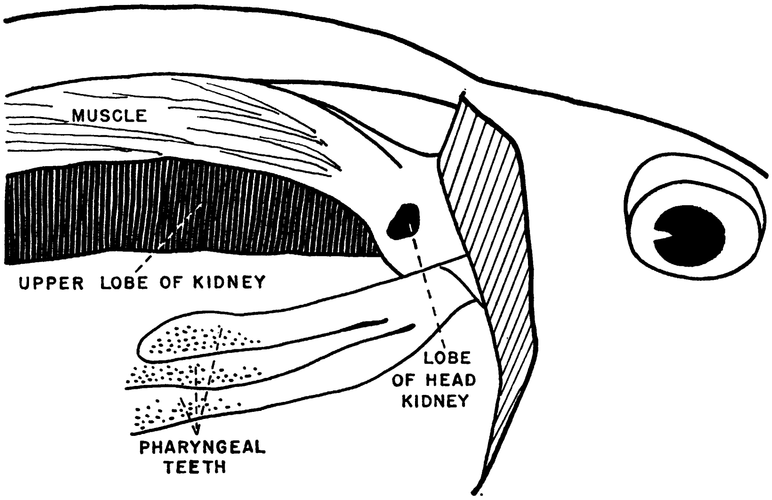

FIG. 10. Anterior part of kidney of *Makaira albida*, showing lobe of head kidney. Dissection by Francesca R. LaMonte. Drawing by Janet Roemhild.

fig. 12) to the groove containing the urinogenital and intestinal outlets. Next, separated from the kidneys by the peritoneum, is the long, chambered, air bladder (pl. 77, fig. 1; pl. 79), dorsad in the body and against the inside of the body wall. At the anterior end of the body, is the stomach (pl. 77, fig. 1), lying with its pyloric portion in the mid-section of the body and slightly to the left. Below the stomach, anteriorly, next to the heart, and lying median in the body, is the mass of pyloric caeca capped by the liver which is below and around it (pl. 80).

On the left side, ventrad in the body and touching the posterior end of the caecal mass (pl. 80) is the spleen. Adjacent to this is the

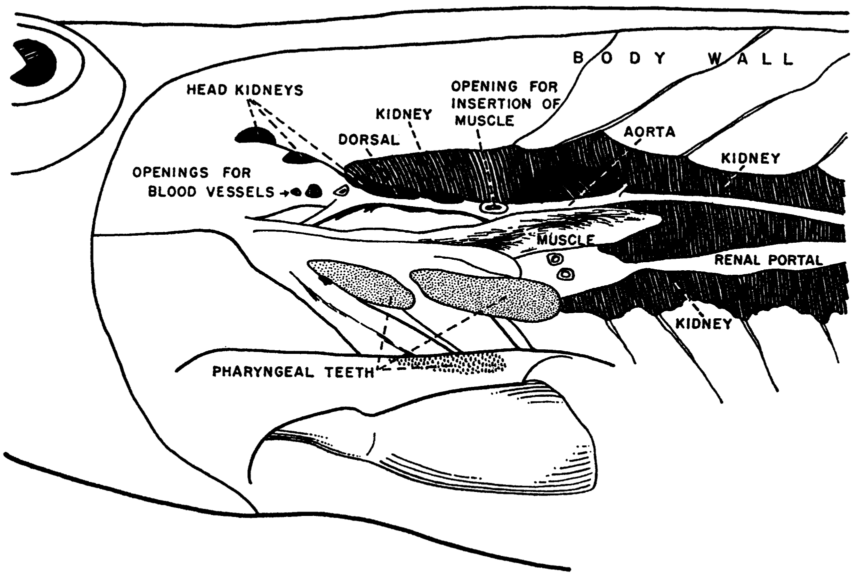

FIG. 11. Lateral-ventral view of kidneys and head kidneys of *Makaira ampla*. Distortion of other structures due to their necessary displacement. Pharyngeal supporting muscle has been cut. Dissection by Louis A. Krumholz and Francesca R. LaMonte. Drawing by Janet Roemhild.

intestine (pl. 77, fig. 1; pl. 80) which makes one coil upon itself and runs straight along the body wall to the vent which lies on the ventral body line in a groove of skin also containing the urinogenital opening. The gonads (pl. 77, fig. 1) lie on either side of the stomach.

Most of the cuts shown in the figures and plates were ventrolateral; the lateral cuts were made dorsoventrally just behind the pectoral girdle and just before the first anal fin in some cases; before the second anal fin in others. These two cuts were connected by a cut just above the ventral body line, and the flesh was retracted.

Seen in this view, before the kidneys are exposed, the chambered air bladder lies dorsad. Below it, directly behind the heart, is the lobed liver of typical color and texture and capping the large mass of pyloric caeca. Partially covered at its anterior end by the caecal mass and ventrolaterally by the spleen and a gonad is the stomach, its pyloric end almost or quite reaching the anal region. It is sac-like and capable of great distension.

The spleen, a discrete, obovate, red-black organ, lies ventrad in the body, directly touching the posterior end of the caecal mass. The intestine runs along the edge of the spleen and behind the adjacent gonad, and thence to the anus. There are three prominent, tough, bifurcate connections between the intestine and the caecal mass, wider proportionately in *M. ampla* than in *M. albida* (fig. 14).

Dorsad to the intestine and partially obcured by a gonad and surrounded by the caecal mass at one end is the long, green, tube-sac arrangement of the gall bladder.

The kidneys lie against the vertebral column, dorsad in the body. They are alike in both species, the lobes being of unequal length. They run from far forward in the body to a point approximately on a perpendicular dropped to the anterior end of the groove containing the urinogenital and intestinal outlets. The renal vein and dorsal aorta are conspicuous. Running forward from the kidneys in both species, and also in *Istiophorus* and *Xiphias*, is a black, very small, very narrow, trilobed, discrete organ, the head kidney (figs. 10, 11). This is lymphatic and high in melanin content. The main lobe of this organ, in a specimen of *M. ampla* weighing 140 pounds, was 42 mm. in length and about 5 mm. in diameter; anterior to this was an intermediate lobe 11 mm. in length and about 5 mm. in diameter. Four millimeters dorsolateral to the last lobe was the anterior lobe which measured about 13 by 10 mm. These lobes lie ventrolateral and ventromedial to a large tendon.

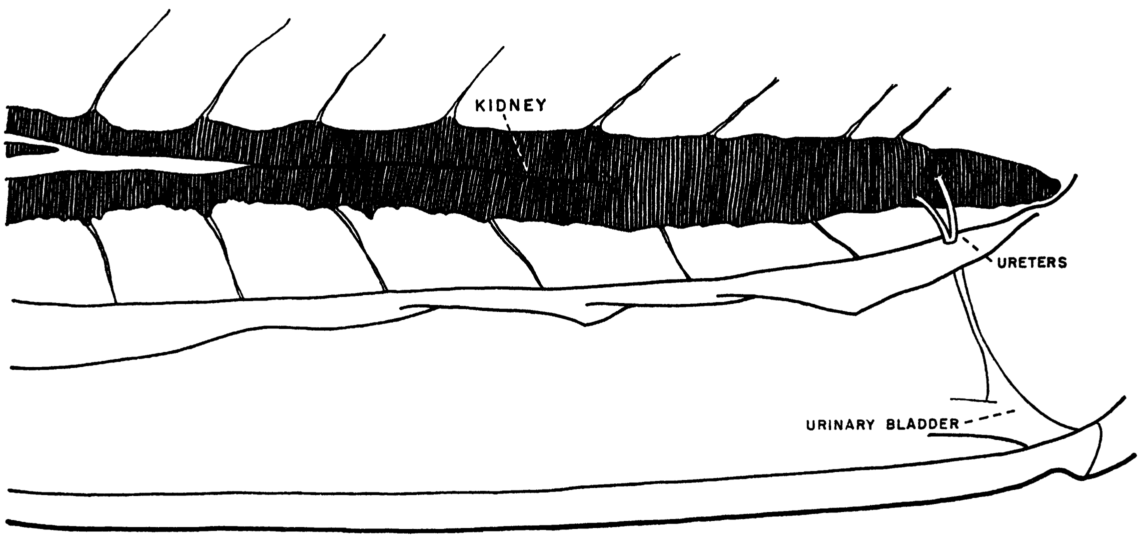

FIG. 12. Posterior end of kidneys shown in figure 11, also ureters and urinary bladder. Dissection by Francesca R. LaMonte. Drawing by Janet Roemhild.

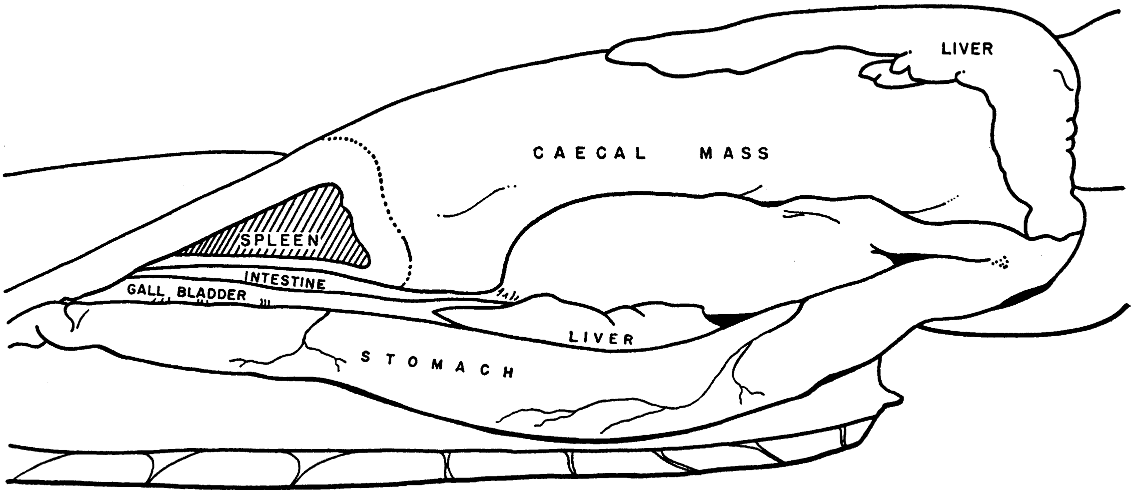

FIG. 13. Diagram of *Makaira albida*, showing ventral-lateral aspect, with caecal mass reflected to left. Approximately natural size. Dissection by Francesca R. LaMonte. Drawing by Janet Roemhild.

The ureters (fig. 12) exit as a short, bifurcated tube near the posterior end of the kidneys (in the above specimen, about 76 mm. from the posterior end).The ureter then runs as a single narrow tube to the point at which its slight expansion forms the urinary bladder, which discharges through the urinogenital opening lying anteriorly in the groove which also contains the anus.

The gonads (pl. 77, fig. 1; pl. 79), two sausage-shaped organs tapering at both ends, lie ventrad to each side of the stomach and are free until slightly before their discharge to the exterior. The muscle sheath that binds them at the vent end also connects them to the lower part of the intestine and is very strong. The gonads are usually unequal in length and often vary in shape. In the ripe female they may be very long and large; in the ripe male, particularly of *M. albida*, they are apt to be very small and narrow. The gonads in one male *M. albida* were about 280 mm. in length and 80 mm. in circumference and very flabby; in two others they were the same length, but about 170 mm. in circumference and very firm. In a male specimen weighing 39 pounds, they measured 7 inches in length and about 1½ inches in circumference. In one female *M. ampla*, weighing 505 pounds, the gonads were 575 mm. in length and 185 mm. in circumference and flabby. In this specimen it was noted that the urinogenital opening was about 3½ inches before the posterior tip of the gonad.

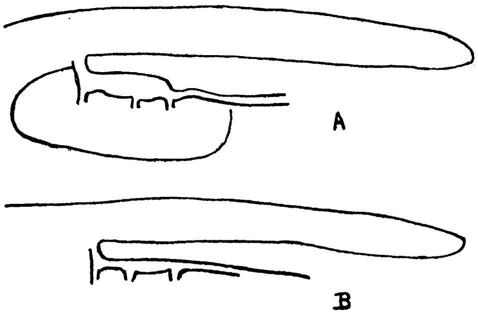

FIG. 14. Attachments of caecal mass and intestine. A. *Makaira ampla*. B. *M. albida*. From a sketch by Louis A. Krumholz.

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RELATIVE WEIGHTS OF SOME VISCERA IN THE ATLANTIC MARLINS[1]

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DURING THE FOUR-DAY PERIOD April 24–27, 1956, 42 white marlin, *Makaira albida* (Poey), and three blue marlin, *Makaira ampla* (Poey), were dissected, and the weights of some viscera were obtained. In some instances there were marked differences in the relative weights of similar organs between the two species. In addition, there were differences in the relative weights of similar organs between the sexes of the same species.

All fish were caught from the waters of the Florida Current.

Each fish was weighed as soon as it was brought onto the dock, and all dissections were performed while the specimens were still fresh. Each fish was dissected in the same manner: First an incision was made along the mid-ventral line anteriorly from the vent, through the median symphysis of the pectoral girdle, to the anterior gular region near the base of the gill arches. Then a dorsoventral cut was made just posterior to the pectoral girdle. When the two flaps of tissue formed by those two cuts were lifted, the abdominal viscera and the heart were exposed.

The viscera were excised and separated as follows:

The heart, together with the entire conus arteriosus and the entire sinus venosus.

The digestive tract which, in turn, was separated into three distinct parts as follows: the stomach, excised at the posterior end of the gullet and emptied of all food material; the intestine, from the point at which it left the stomach to the anus, and including all the rami which connected the intestine with the caecal mass and emptied of all food material; and the caecal mass.

The liver, the entire organ from which the supporting mesenteries had been removed.

The gall bladder, together with its contents and the bile duct. The gall bladder was weighed only when it contained bile.

The spleen, from which the connective tissue capsule had been removed.

The kidneys, from which all connective tissue and the large ducts had been removed.

The gonads, free from all mesenteries. None of the gonads of the fish taken during this study were ripe, but some of them appeared to be approaching that condition.

Each of the organs was weighed to the nearest gram on a triple-beam balance. All weights are recorded as wet weights. From these data the percentage of the total body weight made up by each organ was determined for each fish.

The average percentages, together with the minima and maxima, of the total body weight for each of the viscera of the white marlin and the blue marlin collected during this study are listed in table 1. No specimens of female blue marlin were available for study; all three specimens were males. Among the white marlin were 20 males and 22 females.

From these data it is obvious that the percentage of the total body weight contributed by a particular organ may or may not be similar for both species of Atlantic marlins. When the data for the male white marlin are compared with those of the male blue marlin in table 1, it is readily apparent that the average percentages of the total body weight, as well as the ranges established by the minima and the maxima, contributed by the heart, the stomach, the liver, the gall bladder, and the spleen are fairly similar for both species. On the other hand, there are marked dissimilarities between the two species in the average percentages, as well as between the ranges established by the minima and maxima, contributed by the caecal mass, the intestine, the kidneys, and the gonads. There, the maxima for the percentages contributed by the caecal mass, the intestine, and the kidneys in the blue marlin are below the minima contributed by the same organs in the white marlin. Although the maximum percentage of the total body weight contributed by the testes in the white marlin is greater than the minimum for the testes in the blue marlin, there was only

[1] Contribution No. 11 (new series), Department of Biology, University of Louisville, Kentucky.

one specimen among the white marlin in which the testes contributed a greater percentage to the total body weight than the minimal figure for the blue marlin. In other words, the testes of each of 19 of the white marlin contributed less than (0.750%) the minimal figure for the blue marlin (0.796%) to the total body weight. The single specimen of white marlin in which the testes contributed more than the minimal figure for the blue marlin was the largest male in the collection and weighed 80.25 pounds.

Here it must be kept in mind that the gonads of the fish used in this study were not ripe, although a few of them appeared to be approaching that condition. As the gonads of the fish approached spawning condition, there certainly would be a continued increase in their relative weight until spawning took place. As soon as spawning occurred there

TABLE 1

Minimum, Average, and Maximum Percentages of the Total Body Weight Made Up by Different Organs from White Marlin and Blue Marlin

(Figures in parentheses indicate the number of organs weighed.)

	White Marlin		Blue Marlin	
	Male	Female	All Fish	Male
Heart				
Minimum	0.140	0.132	0.132	0.147
Average	(20) 0.185	(22) 0.169	(42) 0.176	(3) 0.164
Maximum	0.216	0.213	0.213	0.183
Stomach				
Minimum	0.585	0.889	0.585	1.124
Average	(20) 1.240	(21) 1.172	(41) 1.205	(3) 1.255
Maximum	1.647	1.628	1.647	1.409
Caecal mass				
Minimum	1.370	1.463	1.370	0.984
Average	(20) 2.238	(21) 2.163	(41) 2.200	(3) 1.185
Maximum	2.904	3.284	3.284	1.357
Intestine				
Minimum	0.417	0.390	0.390	0.149
Average	(20) 0.748	(21) 0.619	(41) 0.677	(3) 0.206
Maximum	1.317	0.997	1.317	0.246
Liver				
Minimum	0.642	0.741	0.642	0.588
Average	(20) 0.822	(22) 1.308	(42) 1.077	(3) 0.711
Maximum	1.053	2.062	2.062	0.811
Gall bladder				
Minimum	0.045	0.037	0.037	0.040
Average	(13) 0.072	(17) 0.056	(30) 0.063	(2) 0.060
Maximum	0.099	0.086	0.099	0.081
Spleen				
Minimum	0.082	0.062	0.062	0.060
Average	(20) 0.115	(22) 0.105	(42) 0.110	(3) 0.092
Maximum	0.151	0.146	0.151	0.126
Kidney				
Minimum	0.648	0.542	0.542	0.536
Average	(20) 0.926	(22) 0.833	(42) 0.878	(2) 0.586
Maximum	1.339	1.245	1.339	0.617
Gonads				
Minimum	0.097	0.882	—	0.796
Average	(20) 0.422	(22) 4.556	—	1.426
Maximum	1.266	9.762	—	1.896

would be a sharp decrease in the percentage of the total body weight made up by the gonads. However, any such relative increase or decrease would apply to the blue marlin as well as to the white marlin. It may be that, if there is any marked difference in the relative weights of the testes of the white marlin and those of the blue marlin, it is a seasonal phenomenon which becomes less marked as the spawning season approaches.

In as much as the males of both species of Atlantic marlins were not ripe but did appear to be approaching the ripe condition, it may be assumed that neither species had spawned in the area that year. According to LaMonte (1955) very little is known of the spawning habits of either species of Atlantic marlin.

The differences in the percentages of the total body weight contributed by similar organs of the male and female white marlin are not so pronounced as those between the males of the two Atlantic species (table 1). The greatest differences are found in the average percentages contributed by the intestine, the liver, and the gonads.

It is well known that in most bony fishes the ovaries are relatively much heavier than the testes. The data summarized in table 1 indicate that the ovaries of the white marlin are relatively about 10 times as heavy as the testes. However, such a difference is only apparent and does not apply equally to individuals of different sizes. The data for the percentages of the total body weight contributed by each of the various organs for fish of different weight groups of each sex are listed in table 2. From these data it can readily be seen that there is a progressive increase in the relative weight of the gonads with the size of the fish. That increase applies to both sexes but is relatively much greater among the females. The percentage of the total body weight made up by the testes of the largest male white marlin is smaller than the average percentage made up by the ovaries of the three smallest females. However, as was pointed out above, the percentage of the total body weight made up by the ovaries of one female was considerably smaller than that of the testes of the largest male. The female from which those ovaries were taken was the second smallest one in the collection and weighed 50.25 pounds.

The percentage of the total body weight made up by the intestine of the white marlin decreases as the weight of the fish increases (table 2). This decrease in relative weight of the intestine with the increasing size of the fish applies to both sexes, and the data in table 1 indicate that the average relative weight of the intestine of the female is slightly heavier than that of the male. That difference is apparently the result of the presence of a relatively large number of the smaller males

TABLE 2

Average Percentages of Total Body Weight Made Up by Different Organs of Male and Female White Marlin Arranged in Progressively Increasing Weight Groups of 10 Pounds Each

	Males							Females				
Weight (pounds)	20–29	30–39	40–49	50–59	60–69	70–79	80–89	50–59	60–69	70–79	80–89	90–99
Number of fish	2	5	3	6	2	1	1	3	7	5	6	1
Heart	0.182	0.182	0.200	0.193	0.167	0.140	0.179	0.163	0.173	0.168	0.169	0.161
Stomach	1.644	1.442	1.015	1.213	1.128	0.585	1.115	1.160	1.132	1.176	1.194	1.229
Caecal mass	2.677	2.411	2.228	2.042	2.244	1.588	2.323	2.320	1.996	2.504	2.031	1.774
Intestine	0.928	0.982	0.678	0.642	0.600	0.417	0.717	0.822	0.639	0.602	0.529	0.528
Liver	0.852	0.826	0.723	0.841	0.769	0.836	0.849	0.856	1.201	1.391	1.502	1.825
Gall bladder	0.099	0.081	0.045	0.072	0.060	—	0.069	0.062	0.051	0.063	0.055	0.045
Spleen	0.092	0.116	0.125	0.124	0.114	0.082	0.104	0.104	0.116	0.095	0.111	0.111
Kidney	0.906	0.925	0.915	1.056	0.762	0.648	0.838	0.827	0.848	0.822	0.856	0.768
Testes	0.216	0.224	0.360	0.451	0.750	0.333	1.266					
Ovaries								1.521	2.641	5.007	5.467	8.338

in which the percentages of the total body weight made up by the intestine were much higher than in any other size groups.

The reason for the apparent decrease in the relative size of the intestine with the increasing size of the fish is not known. So far as is known, a white marlin that weighs 20 pounds eats much the same kind of food as the larger individuals except for a size differential.

The relative weight of the liver in the male white marlin is considerably smaller than that of the female for all size groups, with the possible exception of the smallest females examined. There is apparently no indication of any real difference in relative weight among the other size groups for each sex. However, in the 60-, 70-, and 80-pound groups the relative weights of the livers of the females are at least 30 per cent greater than those among the males. So far as is known there is no definite relationship between the liver and the reproductive processes of the white marlin, and any other reason for such a difference is not obvious.

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SOME FOODS OF MARLINS NEAR BIMINI, BAHAMAS[1]

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DURING THE FIRST SEVEN MONTHS of 1956, the stomachs of 50 white marlin, *Makaira albida* (Poey), and 14 blue marlin, *Makaira ampla* (Poey), were examined and the contents were identified. Of these, the stomachs of 42 white marlin and two blue marlin were examined by Krumholz, the stomachs of two white marlin and six blue marlin by both authors, and those of the remaining fish by deSylva. Forty-four of the white marlin and eight of the blue marlin were examined on the docks of the Lerner Marine Laboratory of the American Museum of Natural History located on North Bimini, and the remaining fish were examined on other docks either at Bimini or at Cat Cay.

All fish reported in the present study were caught by anglers from the waters of the Florida Current near Bimini or Cat Cay. Forty-four of the white marlin and three of the blue marlin were caught by contestants in either the White Marlin or the Blue Marlin Tournament of the Bimini Marlin Tuna Club, and the remainder were caught by other anglers.

This is not intended as a comprehensive study of the food habits of the Atlantic marlins, but rather as an indication of the food preferences of individuals taken from a single general region. The findings show that the two species of marlin ate both invertebrates and vertebrates and that they sought their food in deep water as well as at or near the surface. The bait fishes found in many of the stomachs are not included here as food items.

Only nine (18%) of the 50 stomachs of white marlin examined contained food. Those nine stomachs contained a total of 17 organisms, as indicated in table 3, and the numbers of organisms per stomach ranged from one to four; four stomachs each contained only one organism, three contained two organisms each, one contained three, and

TABLE 3

STOMACH CONTENTS OF WHITE MARLIN TAKEN BY ANGLERS NEAR BIMINI, BAHAMAS, TOGETHER WITH THE DATE OF CAPTURE AND THE WEIGHT AND SEX OF EACH FISH

Date Caught (1956)	Weight (Pounds)	Sex	Contents of Stomach
Jan. 27	75	♀	Shell and partial remains of octopod
Mar. 12	*ca.* 60	♀	Beaks of three squids
Mar. 13	60	♀	Beaks of two squids
Mar. 15	81	♀	Fragment of octopod shell
Apr. 25	31.5	♂	Filefish about 4 inches long
Apr. 25	29	♂	Small octopod; fragment of crab shell
June 6	*ca.* 40	♂	Unidentified fish vertebrae
July 10	43.5	♂	Beaks of two squids; vertebrae of two balao
July 13	40	♀	Unidentified vertebrae from two fish

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one contained four. The different kinds of organisms found in the stomachs of the white marlin were:

Invertebrates
  Mollusks (Cephalopoda)
    Squids
    Octopods (*Argonauta* sp. and unidentified octopod)
  Arthropods (Crustacea)
    Crab (*Portunus* sp.)
Vertebrates
  Fishes
    Filefish (*Monocanthus* sp.)
    Halfbeak or balao (Hemiramphidae)
    Unidentified vertebrae

Of the 17 organisms in the stomachs of the white marlin, 11 (65%) were invertebrates and six (35%) were vertebrates, as listed in table 4. Most of the invertebrates were squids and octopods which, as is well known, are a preferred food of the white marlin (LaMonte, 1955, p. 329). The only fish that was whole or nearly whole was a small filefish (*Monacanthus* sp.) about 4 inches long. The only other identifiable fish remains were the vertebrae of two balao. Several vertebrae were found that could not be identified.

Among the blue marlin examined, 10 (71%) of the 14 stomachs contained food. Of these, two contained only unidentifiable material in an advanced stage of decomposition, and the other eight contained a total of 21 organisms that could be identified (table 5). The numbers of organisms in each of those eight stomachs ranged from one to seven;

TABLE 4

FREQUENCY OF OCCURRENCE OF DIFFERENT ORGANISMS IN STOMACHS OF WHITE MARLIN CAUGHT NEAR BIMINI, BAHAMAS

Organism	Number	Percentage
Invertebrates		
Squid	7	63.7
Octopod	3	27.2
Crab	1	9.1
Total	11	100.0
Vertebrates		
Filefish	1	16.7
Balao	2	33.3
Unidentified fish	3	50.0
Total	6	100.0

five stomachs each contained only one organism, one contained three, one contained six, and one contained seven. The different kinds of organisms found in the stomachs of the blue marlin were:

Invertebrates
  Mollusks (Cephalopoda)
    Octopods
      Paper nautilus, *Argonauta argo* Linnaeus
      Octopod, *Ocythöe tuberculata* Rafinesque
Vertebrates
  Fishes
    Scombridae
      Frigate mackerel, *Auxis thazard* (Lacépède)
      Blackfin tuna, *Thunnus atlanticus* (Lesson)
      Oceanic bonito, *Katsuwonus pelamis* (Linnaeus)
    Coryphaenidae
      Common dolphin, *Coryphaena hippurus* (Linnaeus)

Contrary to the findings for the white marlin, only three (14%) of the identifiable organisms in the stomachs of the blue marlin were invertebrates, whereas 18 (86%) were vertebrates (table 6). All these vertebrates were fishes that ranged in length from about 8 to about 40 inches. Some were fairly well digested, and others were quite fresh. Some of the stomachs were greatly distended, especially those that contained six or seven fish. Most of the fish were extended their full length in the marlin stomach, but the largest dolphin was folded back on itself at about its middle. From our observations, all fish except the two blackfin tuna and the largest dolphin had been ingested head first. Both tuna had been ingested tail first; the dolphin had apparently been ingested with the fold foremost, as both the head and the tail were in the anterior part of the stomach.

The bait fishes found in the stomachs of the white marlin reported here were mostly mullet (*Mugil* spp.) and balao which had been imported from Florida. Occasionally, one of the local mullets, *Mugil curema* Cuvier, which had been used as bait, was found. From these observations and from the data in tables 3 and 4 it is apparent that the only fish that had been used as bait by the anglers and that was found as food in the stomachs of the white marlin was the balao.

A greater variety of fishes was used as bait

TABLE 5

STOMACH CONTENTS OF BLUE MARLIN TAKEN BY ANGLERS NEAR BIMINI, BAHAMAS, TOGETHER WITH THE DATE OF CAPTURE AND THE WEIGHT AND SEX OF EACH FISH

Date Caught (1956)	Weight (Pounds)	Sex	Contents of Stomach
Jan. 28	162	♂	Unidentified; decomposed material
Jan. 29	*ca.* 160	♂	Unidentified; decomposed material
Feb. 3	158.75	♂	Vertebral column of oceanic bonito about 20 inches long
Feb. 4	208	♀	Octopod about 24 inches long
Feb. 5	230	Gutted	Two octopods; one oceanic bonito about 20 inches long
Apr. 27	159.25	♂	Six frigate mackerel 8 to 12 inches long
July 8	552	♀	Five common dolphin 20 to 40 inches long; one oceanic bonito about 24 inches long; one blackfin tuna about 20 inches long
July 10	140	♀	One blackfin tuna 16½ inches long
July 13	440	♀	Pelvic fins of one common dolphin
July 19	356	—	One oceanic bonito about 16 inches long

in fishing for the blue marlin than for the white marlin used in this study. They were: bonefish, *Albula vulpes* (Linnaeus); cero, *Scomberomorus regalis* (Bloch); Spanish mackerel, *Scomberomorus maculatus* (Mitchill); mullet; little tuna, *Euthynnus alleteratus* (Rafinesque); oceanic bonito; and common dolphin. Of these fishes that were used as bait, only the oceanic bonito and the common dolphin were found as food in the stomachs examined.

The range in size of the various organisms found in the stomachs of the white marlin was not great. The smallest fish was only about 4 inches long, whereas the balao vertebrae in the stomach of the marlin caught July 10 indicated that the balao was about 12 inches long. Among the invertebrates, the range in size was even less. All the squids and octopods were relatively small, and the crab, as indicated by the size of the carapace, was no more than 4 inches in width.

TABLE 6

FREQUENCY OF OCCURRENCE OF DIFFERENT ORGANISMS IN STOMACHS OF BLUE MARLIN CAUGHT NEAR BIMINI, BAHAMAS

Organism	Number	Percentage
Invertebrates		
Octopod	3	100.0
Total	3	100.0
Vertebrates		
Frigate mackerel	7	38.8
Blackfin tuna	2	11.1
Oceanic bonito	3	16.7
Common dolphin	6	33.4
Total	18	100.0

As might be expected in two species of such unequal size as the two Atlantic marlins, the size of the organisms taken as food by the white marlin usually was considerably smaller than that of the organisms eaten by the blue marlin. However, the size range of the vertebrates eaten by the blue marlin was fairly large. The over-all range in length of fishes was from about 8 to about 40 inches; for a single species, the range from 20 to 40 inches for the dolphin was the greatest. The range in the size of the invertebrates eaten by the blue marlin was also rather large. One of the small octopods was probably no more than about 6 inches long, whereas the largest one was about 2 feet long.

One of the most important aspects of this study is that the food of each of the two Atlantic marlins consists of a rather large variety of both vertebrate and invertebrate organisms which occupy widely different ecological habitats. Some of the invertebrates, such as the Atlantic squids, normally live near the surface only at night and remain in the deeper waters during the daylight hours. Although the larger portunid crabs usually live near or on the bottom in relatively shallow water, smaller individuals are frequently found among floating Sargassum weed. The small filefish eaten by the white marlin belongs to the group frequently found among the large mats of Sargassum weed out in the open water, and it is well known that the balao usually occurs near the surface in open water but usually not very far from reef areas. All fishes found in the stomachs of the blue marlin reported here are known to inhabit open water. However, some, such as the common dolphin, may be found at depths of more than 200 feet as well as at the surface. The frigate mackerel is known to be a deep-water fish (Kishinouye, 1923) and is not frequently found near the surface. Although both the oceanic bonito and the blackfin tuna frequently occur near the surface, their food indicates that they usually feed in deep water. When examining the stomach contents of these species, deSylva consistently has found such forms as the deep-water squids, prawns (*Systellapsis debilis*), hatchetfishes (Sternoptychidae), and lanternfishes (Myctophidae). Also, Kishinouye (1923, p. 381) stated that scombrid fishes generally swim to the shallower strata of water at night and return to the deeper layers in the daytime.

The present findings indicate that both species of Atlantic marlin normally feed in both the deep and the shallow water and near the shore as well as out in the open sea. In addition, there are good indications that the marlins may be more numerous in the deeper waters than at the surface during the daytime. Personnel of the Marine Laboratory of the University of Miami (1956) fishing with flag lines near Cat Cay, Bahamas, in May, 1956, caught four white marlin at depths of from 14 to 30 fathoms between 5:00 A.M. and 10:00 A.M. In addition, one blue marlin was hooked at a similar depth late in the afternoon but was not brought to gaff. Each of the white marlins caught on those flag lines contained from two to five small porcupine fish, *Diodon hystrix* Linnaeus, in their stomachs and one contained a small, unidentified parrotfish. Porcupine fish of the size found in the stomachs of the white marlin usually are pelagic swimmers, but the parrotfish are only infrequently found out in the open water away from reefs.

There is relatively little published information on the food of the Atlantic marlins. LaMonte, in her recent review and revision of the marlins (1955), summarized the few available data on the food preferences of these fishes and stated that the food depends to some extent on the local supply, but that squid seemed to be the most favored item. However, in addition to squid and other invertebrates, a variety of fishes was listed. In several blue marlin taken near Bimini, she found " . . . small *Scomberomorus* partially digested; in one fish, the skull and bones of a small grunt; in another, some squid and a few unidentifiable fish bones; in another, an almost untouched *Caranx latus* about 15 inches long; in another, the bait (a bonefish); and in one, a bonito that weighed $5\frac{1}{2}$ pounds, doubled tail to head and almost whole—the only food in the stomach." Other fishes taken from the stomachs of blue marlin caught elsewhere included snappers off the coast of Texas, and triggerfish (*Xanichthys ringens*), silvery filefish (*Monocanthus hispidus*), and blackfin tuna off Puerto Rico. The occurrence of fishes, notably scombrids and carangids, in the diet of marlins has also been noted by Rivas (1956). Of all the fishes listed for the present study, we found only the blackfin tuna and possibly the same kind of bonito listed by LaMonte in the blue marlin examined.

Although LaMonte (1955) did not report the stomach contents of any white marlin taken near Bimini, she stated that specimens caught off New Jersey " . . . were full of flying fishes, small bluefish, bonito, skipjack, and gulf weed." In the only other published account of the food of white marlin, Wallace and Wallace (1942) reported that the two most predominant food items in the stomachs of 86 fishes taken off Ocean City, Maryland, were the round herring, *Etrumeus sadina*, and the squid, *Loligo* sp. In addition to those two organisms, they listed the following: anchovy, *Anchoviella browni;* dolphin, *Coryphaena hippurus;* thimble-eye mackerel, *Pneumatiphorus grex;* sand lance, *Ammodytes americanus;* and a crevalle, *Caranx* sp. None of these kinds of fishes were found in the white marlin examined by us.

From the foregoing discussion it is obvious that both species of Atlantic marlins feed on a rather wide variety of organisms.

A total of four different invertebrates and 14 identifiable species of fishes have been reported in the literature from the stomachs of white marlin, whereas three different invertebrates and 11 kinds of fishes have been reported among the contents of blue marlin stomachs. However, among the invertebrates, only the squid and the octopods were reported for both species, whereas among the 24 kinds of fishes reported, only the dolphin, the bonito, and possibly the filefish were common to the diets of both marlins. It is also apparent that fishes constitute the major portion of the diet for both species. Such differences indicate that there may be a rather marked dissimilarity in the diets of the two species of Atlantic marlins. In each instance, the reported food from one locality was quite different from that of another.

Similar observations have been made on the food habits of the striped marlin, *Makaira mitsukurii* (Jordan and Snyder), of the Pacific Ocean. LaMonte (1955) found only squid in the stomachs of individuals examined in Peru and Chile, whereas Hubbs and Wisner (1953) suggested that about 75 per cent of the food of the striped marlin, off California, was the saury, *Cololabis saira.* In addition to the saury, they found the following fishes in the stomachs of 32 individuals caught near San Diego: northern anchovy, *Engraulis mordax;* Pacific sardine, *Sardinops caerulea;* jack mackerel, *Trachurus symmetricus;* halfmoon, *Medialuna californiensis;* Pacific mackerel; probably a California bonito, *Sarda lineolata;* and the beaks of at least two species of squids. Morrow (1952), in his study of the food of the striped marlin in New Zealand, stated that the local saury, *Scomberesox saurus*, constituted 74.1 per cent of the total number of individuals of all species eaten, including the squids.

As mentioned above, the stomachs of many of the white marlins used in the present study were empty when examined. Of the 42 fish examined from April 24 through April 27, only two of the stomachs contained food. Conversely, only four of the 14 stomachs of blue marlin we examined were empty. The reason for this lack of food in the stomachs of such a large percentage of individuals is not known. Although 30 of the 42 fish were caught before noon and none was examined until after 5:00 P.M., it is unlikely that complete digestion took place during that time. Some of the fish caught before 10:00 A.M. still contained bait fish that were only slightly digested. Neither the small octopus nor the filefish was in an advanced stage of decomposition, and the fish which contained them were caught at 11:30 A.M. and 1:30 P.M., respectively.

Possibly the fish caught by the anglers during the tournament were generally strays and were away from their normal habitat. At the present time there is little concrete evidence available to substantiate such an assumption. However, several inferences based on the food habits of the marlins and the ecology of the food organisms indicate that the marlins are not primarily surface feeders but that they probably obtain a large proportion of their food at depths as great as several hundred feet.

LaMonte (1955, p. 329) suggests that marlins off the Chilean and Peruvian coasts feed on squid primarily at night. That suggestion was based on observations on the squid themselves and on the stage of decomposition of squid in the stomachs of striped marlin taken at various times during the daylight hours. At night, the squid were observed in great numbers near the surface and several feet down but were not seen during the daytime. In marlin taken during the morning the squid were less thoroughly digested than those taken in the afternoon, and by late afternoon the stomachs usually contained only the eyes and beaks of the squid. Whether the marlins feed on fish principally during the night was not mentioned. The meager information obtained during the present study neither corroborates nor discredits this suggestion. However, the stage of decomposition of some of the fishes taken from the stomachs of the white marlin and the blue marlin that were caught late in the afternoon indicates that the food was captured during the daylight hours.

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JUVENILE BLUE MARLIN, *MAKAIRA AMPLA* (POEY), FROM MIAMI, FLORIDA, AND WEST END, BAHAMAS[1]

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ONE OF THE GREATEST GAPS in our knowledge of the marlins (*Makaira*) is due to lack of data on larval and juvenile forms, in spite of the excellent summaries of the systematics and biology of this group by Nakamura (1938, 1949) and LaMonte (1955). It seems appropriate, therefore, to present data on what appear to be juvenile forms of the blue marlin, *Makaira ampla* (Poey).

Through the kindness of Mr. Joseph T. Reese, the author was able to obtain measurements from an accurate plaster-cast replica of a five-pound specimen which had been caught on December 26, 1955, about 1½ miles southwest of West End, Bahamas, by Capt. Roland Garnsey, Jr. The fish was one of two which were approximately identical in size and which had been hooked at about 10 A.M. by surface trolling with a large balao (Hemiramphidae) in water of about 1000 feet in depth. The weather was fair and clear, with a slight northeast wind. According to Captain Garnsey, the two fish were hooked at the same time, but one was lost. Each fish was said to bear peculiar chain-like markings on the sides. (See pl. 81, figs. 1, 2.)

A second specimen, which was donated through the courtesy of Mr. Al Pflueger, was caught off Miami by Capt. Lou Case on May 8, 1956. This second fish weighed 30½ pounds, and the reticulations were again said to be quite visible (pl. 81, fig. 3). The specimen was measured by F. G. Walton Smith, John K. Howard, and Al Pflueger.

When the first specimen was examined, it was suspected of being a young spearfish, *Tetrapturus belone* Rafinesque, but a further comparison of the characteristics of the various species of Istiophoridae, along with a second specimen and additional information from Pflueger, led the author to believe that the two specimens represent juvenile stages of the blue marlin of the Atlantic.

A list of certain proportional and meristic characters of the blue marlin and of the white marlin, *Makaira albida* (Poey), and the measurements of the two juveniles are given in table 7. These are the only two valid species of *Makaira* described from the western North Atlantic (LaMonte, 1955). Measurements were taken in the manner suggested by Rivas (1956a). Those for the adult blue marlin are taken from Rivas (1956b, pp. 64–65). Owing to the size discrepancy between the two juveniles (846 and 1320 mm.) and of the adult blue marlin and white marlin (1482 to 2680 mm.), it is not possible to compare specimens directly. Therefore, owing to allometric growth, it would be expected that certain characters will fit in neither species for the sizes presented herein. Also it is not surprising that the measurements for many characters overlap to a considerable extent in such closely related species. Nevertheless, it is apparent that the majority of the characters may be placed in one species or the other.

In order to facilitate comparisons in table 7, those measurements that do not overlap are connected by a line. In the column headed "Species," numbers are given that represent the relationships between the measurements for the juveniles and those of the adults of the two species. The significance of each number is explained at the bottom of the table.

It may be seen that, because of the discrepancy in proportional characters between juveniles and adults, direct comparison is difficult. However, it is also evident that the measurements given for the juvenile specimens more often fit those of the adult blue marlin than they do those of the white marlin. Most of the measurements that do not fit the blue marlin or are close to those of the

[1] Contribution No. 170 from the Marine Laboratory, University of Miami; this paper constitutes a technical report to the Charles F. Johnson Foundation.

TABLE 7

COMPARISON BETWEEN TWO JUVENILE BLUE MARLIN (*Makaira ampla*) AND ADULT BLUE MARLIN AND WHITE MARLIN (*Makaira albida*)

(A line connecting two species indicates that the range of measurements does not overlap in the two species. Proportions are expressed in thousandths of the body length. Measurements are in millimeters.)

Species	Juveniles		Adults			
	No. 1 (5 lbs.)	No. 2 (30½ lbs.)	*Makaira ampla* (*N*=10) Mean	*Makaira ampla* (*N*=10) Range	*Makaira albida* (*N*=4) Mean	*Makaira albida* (*N*=4) Range
1						
Body length	846	1320	2304	(1773–2680)	1613	(1482–1787)
Second predorsal length	777	777	772	(761–785)	— 814	(800–825)
Prepelvic length	—	236	243	(230–260)	— 280	(269–296)
First preanal length	580	568	562	(554–579)	— 595	(581–611)
Second preanal length	767	758	759	(752–772)	— 802	(788–815)
Head length	239	220	233	(227–240)	— 252	(241–267)
Maxillary length	—	137	143	(134–148)	— 161	(159–163)
Length of anal base	—	53	52	(45–56)	— 41	(40–43)
Length of upper caudal lobe	188	258	269	(252–300)	— 220	(189–246)
Number of pectoral rays	—	20	21.4	(20–22)	— 16.5	(16–17)
First predorsal length	183	208	216	(206–227)	224	(210–238)
Prepectoral length	240	227	232	(221–249)	254	(244–271)
Length of upper caudal keel	—	42	41	(35–53)	38	(34–41)
Length of lower caudal keel	—	44	37	(32–45)	32	(29–34)
Snout length	100	96	101	(94–105)	135	(102–188)
Length of second dorsal base	—	49	49	(42–56)	40	(36–43)
2						
Origin of first dorsal fin to origin of pectoral fin	—	129	154	(140–166)	— 131	(122–132)
Origin of first dorsal fin to origin of pelvic fin	—	158	185	(175–199)	— 163	(153–167)
Greatest depth	—	169	202	(183–225)	— 155	(123–175)
Depth at origin of first dorsal fin	139	152	181	(172–195)	— 151	(145–158)
Width at pectoral fin	—	76	96	(87–104)	— 80	(74–85)
Width of caudal peduncle	—	34	50	(44–55)	— 36	(32–40)
Origin of second dorsal fin to origin of anal fin	—	98	110	(99–123)	95	(92–102)
Height of first anal fin	—	109	134	(122–146)	122	(107–136)
3						
Width at origin of second anal fin	—	64	74	(52–81)	63	(59–67)
Depth of bill	9	12	13	(10–16)	10	(8–12)
Width of bill	—	15	17	(15–20)	15	(14–17)
Length at first anal base	—	151	166	(149–174)	150	(139–156)
Anterior height of second dorsal fin	—	37	42	(33–49)	41	(37–44)
Length of lower caudal lobe	182	242	257	(236–289)	238	(183–309)
Number of dorsal spines	44	40+	41.8	(39–45)	41.0	(40–42)
Number of dorsal rays	6	7	6.6	(6–7)	6.5	(6–7)
Number of anal rays	6	7	6.7	(6–7)	5.0	(4–6)

TABLE 7—(*Continued*)

Species	Juveniles		Adults			
			Makaira ampla (*N*=10)		*Makaira albida* (*N*=4)	
	No. 1 (5 lbs.)	No. 2 (30½ lbs.)	Mean	Range	Mean	Range
4						
Width at origin of first anal fin	65	76	105	(93–117)	— 82	(81–83)
Origin of pelvic fin to nape	—	148	169	(160–184)	165	(154–174)
Depth at origin of first anal fin	—	133	170	(142–190)	144	(142–147)
Bill length	149	212	269	(238–284)	308	(266–349)
Anterior height of first dorsal fin	137	144	158	(145–171)	181	(166–198)
Length of pectoral fin	—	181	210	(195–223)	220	(186–240)
Length of pelvic fin	—	218	167	(133–215)	178	(154–200)
Number of anal spines	—	13+	15.5	(14–17)	15.0	(14–16)

1, One or both juvenile specimens fall into the range of *Makaira ampla* but not that of *M. albida.*
2, One or both juvenile specimens fall into the range of *Makaira albida* but not that of *M. ampla.*
3, The juvenile specimens fit the range of both species.
4, The juvenile specimens do not fit the range of either species.

white marlin can be explained by ponderal index or coefficient of condition changes (Lagler, 1950, p. 73), such as the great changes in body width and depth which accompany increase in length and weight. In the Istiophoridae this is exemplified by the closely related *Istiophorus americanus* (Cuvier and Valenciennes). This species is very slender up to about 4 feet in total length, at which point it suddenly begins to fatten (deSylva, 1957). Absolute differences shown between the blue marlin and the white marlin are characters not greatly affected by body condition, such as predorsal length, preanal length, and maxillary length. However, the most obvious difference between the two species is the difference in both mean number and range of pectoral rays, a character that is theoretically unaffected by size, although the sample for each species is too small on which to base definite conclusions.

The two specimens are not spearfish (*Tetrapturus*). Although the bill is quite short in the five-pound juvenile from West End, Bahamas, an illustration (Nakamura, 1938) of the Japanese short-nosed spearfish (*T. angustirostris* Tanaka) shows that the spear is relatively shorter in a five-foot spearfish than in the three-foot, five-pound specimen from the Bahamas. Furthermore, the pectoral fin of the spearfish is somewhat shorter than in either of the juvenile specimens. The caudal lobes and caudal peduncle are also much slimmer in the spearfish, and the profile of the dorsal fin in the spearfish is concave in its anterior portion and convex posteriorly. Because Nakamura (1949) believes that the species of the Pacific may be synonymous with that of the Atlantic, we feel justified in making these limited comparisons with the Pacific species and concluding from them that our two specimens are not juvenile spearfish.

The most trenchant difference between the blue marlin and the other Atlantic members of the Istiophoridae, and also the most obvious separating character, is the presence of a well-developed lateral line in *Tetrapturus* (Nakamura, 1949), in the white marlin (*M. albida*), and in the sailfish (*Istiophorus*). The sailfish may be readily distinguished from any of the others by its dorsal fin, which even in a small-sized fish (less than one pound) is well developed and quite high (Beebe, 1941; Voss, 1953).

The complex nature of the lateral line of *Eumakaira nigra* (=*Makaira mazara*, LaMonte, 1955, pp. 341–342) has been partially described by Nakamura (1949) and was the basis for the erection of his new genus *Eumakaira*. The blue marlin is the only Atlantic istiophorid possessing this complex lateral-line system. In skins of adult blue marlin these reticulations are very evident when the dried skin is held up to the light, but they are not visible in a fresh specimen (pl. 82). The anatomy of this complex lateral-line system is described above (p. 386) by LaMonte.

Juvenile blue marlin are apparently more common than the literature on the group would indicate. Several specimens which fit the description of the five-pound fish have been reported to the author by sports fishermen as being seen "in pairs" in the vicinity of West End, Bahamas. Bullis (1956 and earlier reports) states that spearfish were taken occasionally from the Gulf of Mexico and the north central Caribbean, but subsequently has stated (personal communication) that these specimens might actually have been young blue marlin. LaMonte (1955, pp. 346–347) notes a juvenile specimen, originally thought to be *Tetrapturus*, which she believed to be a *Makaira*, taken in the Gulf Stream between Bimini, Bahamas, and Miami, Florida. The long spear and the high dorsal fin seem to describe a young white marlin rather than a blue marlin.

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