23.

Caudal Skeleton of Bermuda Shallow Water Fishes. I. Order Isospondyli: Elopidae, Megalopidae, Albulidae, Clupeidae, Dussumieriidae, Engraulidae.[1]

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(Text-figures 1 to 53).

OUTLINE.

INTRODUCTION.

The following paper is a study of the caudal skeleton of the Bermuda isospondylids. It deals principally with the adult fish but when young specimens were available these have been included. The Isospondyli of Bermuda are represented by six families, eight genera, and eight species.

In the genus *Harengula* no specific name has been given to the material examined. These fish have at various times been called *H. macrophthalmus* or *H. sardina,* and their proper specific determination is a problem for future study.

This study was made from specimens which were cleared by potassium hydroxide and stained by alizarin. Alizarin is a vital stain for bone and the determination of the presence and position of bones is greatly facilitated by its use. The term KOH, which stands for potassium hydroxide, the clearing chemical, was adopted in our field laboratory at Nonsuch, Ber-

[1] Contribution No. 515, Department of Tropical Research, New York Zoological Society. Contribution from the Bermuda Biological Station for Research, Inc.

muda, as a designation for specimens cleared and stained. They are numbered as such in a KOH catalogue. This term appears in the list of catalogue numbers and in general usage. For details of this clearing process see "Clearing and Dyeing Fish for Bone Study," *Zoologica*, Vol. XII, No. 10, and "Fish Magic," in the *Bulletin* of the New York Zoological Society for March-April, 1930. (Vol. XXXIII, No. 2).

The length of specimens in this paper is standard length, unless otherwise stated.

I am especially indebted to Mr. and Mrs. George Arents, Jr., and Mr. and Mrs. Bernard Baruch, Jr., for specimens of large *Tarpon*, and to the American Museum of Natural History for a specimen of *Elops*. I thank for their cooperation Dr. William Beebe and Mr. John Tee-Van of this department. The drawings are by Edward Delano, George Swanson, and Helen Tee-Van.

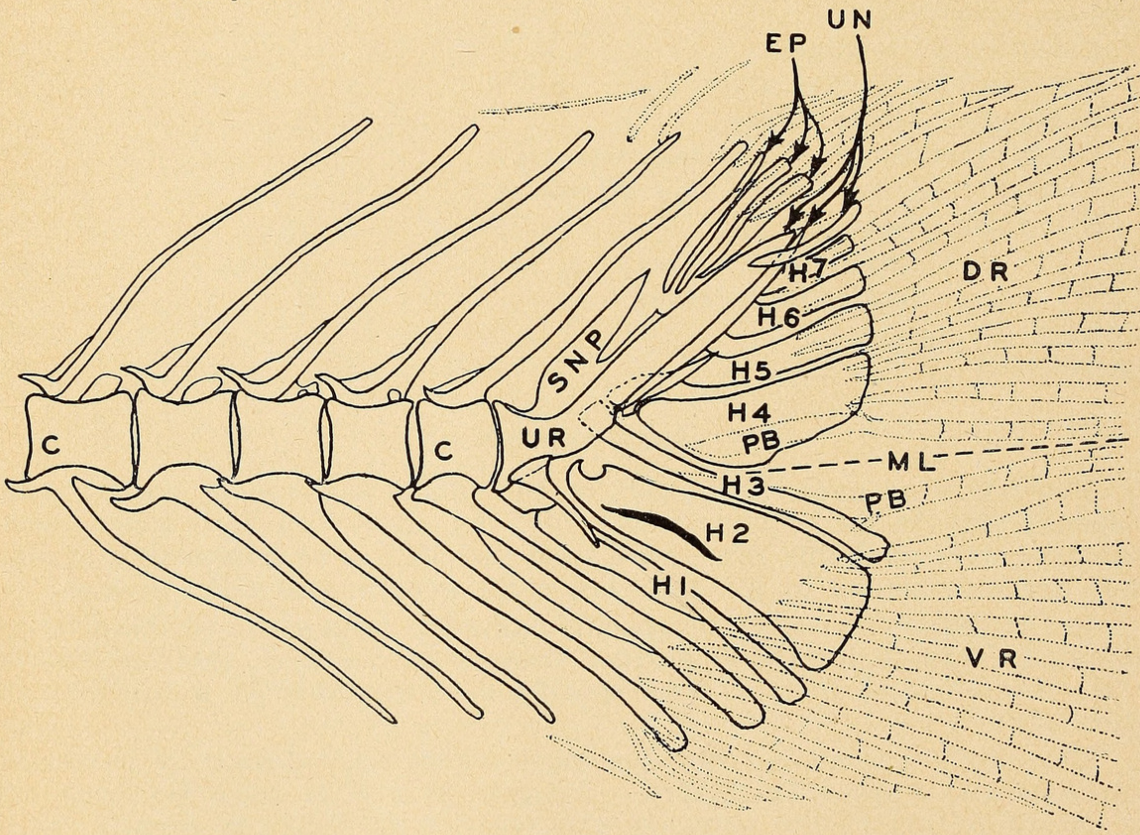
Caudal Fin Terminology.

(Text-figs. 1, 2).

Caudal Ray Count: The dorsal and ventral counts of fin rays are considered separately. The dorsal count begins anteriorly and continues around the fin to the median division in the rays. The ventral count begins anteriorly and continues around the fin to the median division. The count is expressed as follows:

$$\frac{\text{Dorsal raylets+rays=Total:}}{\text{Ventral raylets+rays=Total:}} \quad \frac{2+10}{2+10} \text{ or } \frac{12}{12}$$

Caudal Ray: A branched (usually) caudal element possessing one or more transverse joints.

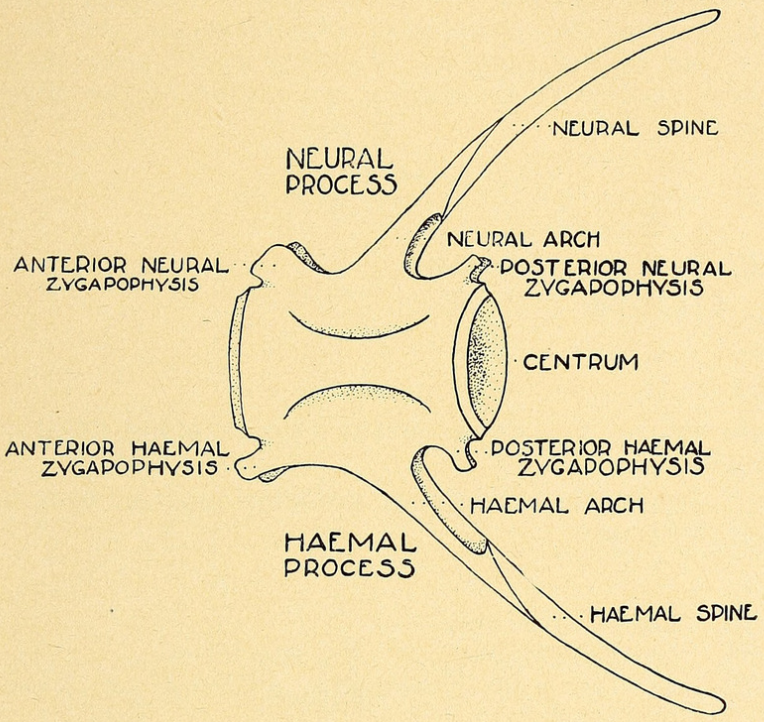


Text-figure 1.

Typical tail of a Bermuda Isospondyli. C, centrum; DR, dorsal ray; EP, epural; H, hypural; ML, median line; PB, prolonged base; SNP, specialized neural process; UN, uroneural; UR, urostyle; VR, ventral ray.

Caudal Raylet or *Simple Ray:* An unbranched caudal element possessing no transverse joints. Raylets are always anterior to the rays.

Caudal Region: The vertebral column is divided into a trunk and caudal region. The caudal region begins where the first or anterior haemal process forms a closed haemal arch with a single haemal spine projecting. Ribs are absent in the caudal region.



Text-figure 2.
Typical caudal vertebra.

Centrum: The central element of a vertebra on which the neural and haemal processes are formed.

Epural: Any bone, or bones, that are dorsal to the urostyle and support one or more caudal fin rays or spines. The bases are always unattached.

Haemal Arch: The arch on the ventral surface of a vertebral centrum through which passes the haemal vessel.

Haemal Process: The haemal arch and haemal spine on the ventral surface of a vertebral centrum.

Haemal Spine: The ventral projection below the haemal arch.

Hypural: Any bone that is ventral or posterior to the urostyle and supports one or more caudal fin rays or raylets. An expanded haemal spine. The hypural count is made from the anterior ventral part of the urostyle around to its posterior and dorsal end. The anterior hypural is called the first hypural.

Median Caudal Line: The median line is the natural median division seen in the caudal rays. This line determines whether the rays are dorsal or ventral.

Neural Arch: The arch on the dorsal surface of a vertebral centrum through which passes the nerve cord.

Neural Process: The neural arch and the neural spine on the dorsal surface of a vertebral centrum.

Neural Spine: The dorsal projection above the neural arch.

Uroneurals: The uroneurals are paired bones which are directed upward and backward on the lateral and dorsal surfaces of the urostyle. They probably represent specialized neural processes so developed to protect the sharply upturned caudal. This term is adopted from Regan (1910. 2).

Urostyle: The posterior terminal vertebral segment or segments which follow the last undoubted centrum. The urostyle is considered as one in the total vertebral count.

Zygapophysis: The dorsal and ventral articulating process of a centrum.

The inserted key illustrates the outstanding differences and similarities found in the study of the caudal skeleton of the Bermuda isospondylids. It will be noted that the three clupeids (*Harengula, Opisthonema,* and *Sardinella*) are included under one caudal pattern. Further study with more material is necessary in these species to determine the status of the three forms as shown by the caudal skeleton.

Elopidae.

Elops saurus Linnaeus.

(Text-figs. 14, 15).

Diagnostic Characters:

9 hypurals.

2 reduced posterior neural processes on the two anterior urostyle centra. Dagger-shaped.

4 distinct pairs of uroneurals. Origin of anterior pair on first or anterior urostyle centrum.

Vertebral count:

49 + 26 = 75. Haiti specimen.
57 + 24 = 81. Gravesend Bay, N. Y., specimen.
43 + 29 = 72. Jordan and Evermann, "Fishes of North America."
78-79. *Elops saurus* and *affinis.* Regan 1909.

This variation may, with further study, be correlated with geographical distribution.

Material Studied.

The following description is taken from two specimens: one caught in Haiti, Cat. No. 7172, KOH Cat. No. 2030, length 258 mm., from which this description has been made, and one caught at Gravesend Bay, which was kindly supplied by the American Museum of Natural History, Cat. No. 669, KOH Cat. No. 2136, length 280 mm. *Elops saurus* is included with the group of Bermuda Isospondyli on the basis of a single record, that of E. Linton in 1908, "Notes on Parasites of Bermuda Fishes," Proc. U. S. Nat. Mus., XXXIII, No. 1560.

Caudal Osteology.

Urostyle Centra: Four centra form the upturned caudal end of the vertebral column. The anterior three are regularly shaped. The fourth (and posterior) one is an irregular thin bony rod which curves upward posteriorly and extends as far as the anterior dorsal edge of the 7th hypural. This may represent three centra fused as it extends over the bases of three hypurals. A cartilaginous notochord extends into the dorsal contour, 1 mm. beyond the dorsalmost hypural, and is embedded between the bases of the 11th dorsal ray, above the median line (Text-fig. 15). There are about 35 horizontal striae in the cartilaginous notochord. Embedded between the striae spool-shaped centra can be seen. This condition resembles that found in the young rather than the adult *Tarpon.*

Uroneurals: This term is adopted from Regan (1910.2). There are four pairs of uroneurals, which correspond to ancestral posterior neural

Key to Caudal Fin of Bermuda Shallow Water Isospondylid Fishes.
(Text-figs. 3-13).

1.

Group A

25 to 26 haemal arches.
(Total vertebral count 37 to 40).

Harengula sp.
(See Text-figs. 47 and 48).

Group B

29 to 32 haemal arches.
(Total vertebral count 45 to 46).

Opisthonema oglinum
(See Text-figs. 49, 50 and 51).

Sardinella anchovia
(See Text-figs. 52 and 53).

Text-figure 12.

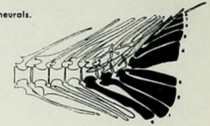
Text-figure 13.

KEY TO CAUDAL FIN OF BERMUDA SHALLOW WATER ISOSPONDYLID FISHES.
(Text-figs. 3-13).

I S O S P O N D Y L I

Group I
9 hypurals;
4 pair of uroneurals.

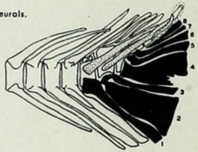
ELOPIDAE
Elops saurus



Text-figure 3.

Group II
8 hypurals;
3 pair of uroneurals.

MEGALOPIDAE
Tarpon atlanticus

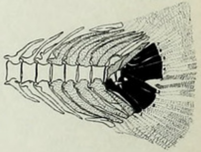


Text-figure 4.

Group III
7 hypurals;

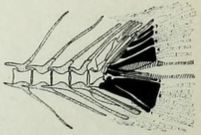
Sub-Group A
Massive neural and haemal spines on the 4 posterior vertebrae; no prolonged ray bases of the 2 median caudal rays.
2 pair of uroneurals.

ALBULIDAE
Albula vulpes



Text-figure 5.

Sub-Group B
Slender neural and haemal spines on the 4 posterior vertebrae; prolonged ray bases of the 2 median caudal rays.

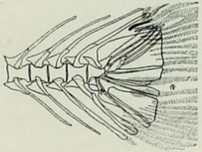


Text-figure 6.

Division I
1 epural.
Caudal rays 26, (14/12).

Text-figure 7.

DUSSUMIERIIDAE
Jenkinsia lamprotaenia



Text-figure 11.

Division II
More than 1 epural; 2, 2½, or 3. Caudal rays 33 to 37.

Text-figure 8.

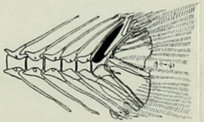
Text-figure 9.

Text-figure 10.

Sub-Division A

ENGRAULIDAE
Anchoviella choerostoma

Long neural process of urostyle extending dorsally at least one half the length of the anterior epural.
First closed haemal arch above anterior spine of anal fin.
Caudal and trunk vertebrae almost evenly divided.
Caudal rays 33 to 37, 17/16 to 19/18, never 19/16 as in Sub-Division B, Clupeidae.

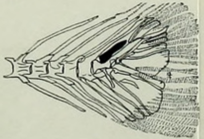


Text-figure 12.

Sub-Division B

CLUPEIDAE

Short neural process of urostyle extending to the ventral tip, or slightly beyond, of the anterior epural.
First closed haemal arch well in advance of the anal fin.
More caudal vertebrae than trunk.
Caudal rays 35, 19/16.



Text-figure 13.

Group A
25 to 26 haemal arches.
(Total vertebral count 37 to 40).

Harengula sp.
(See Text-figs. 47 and 48).

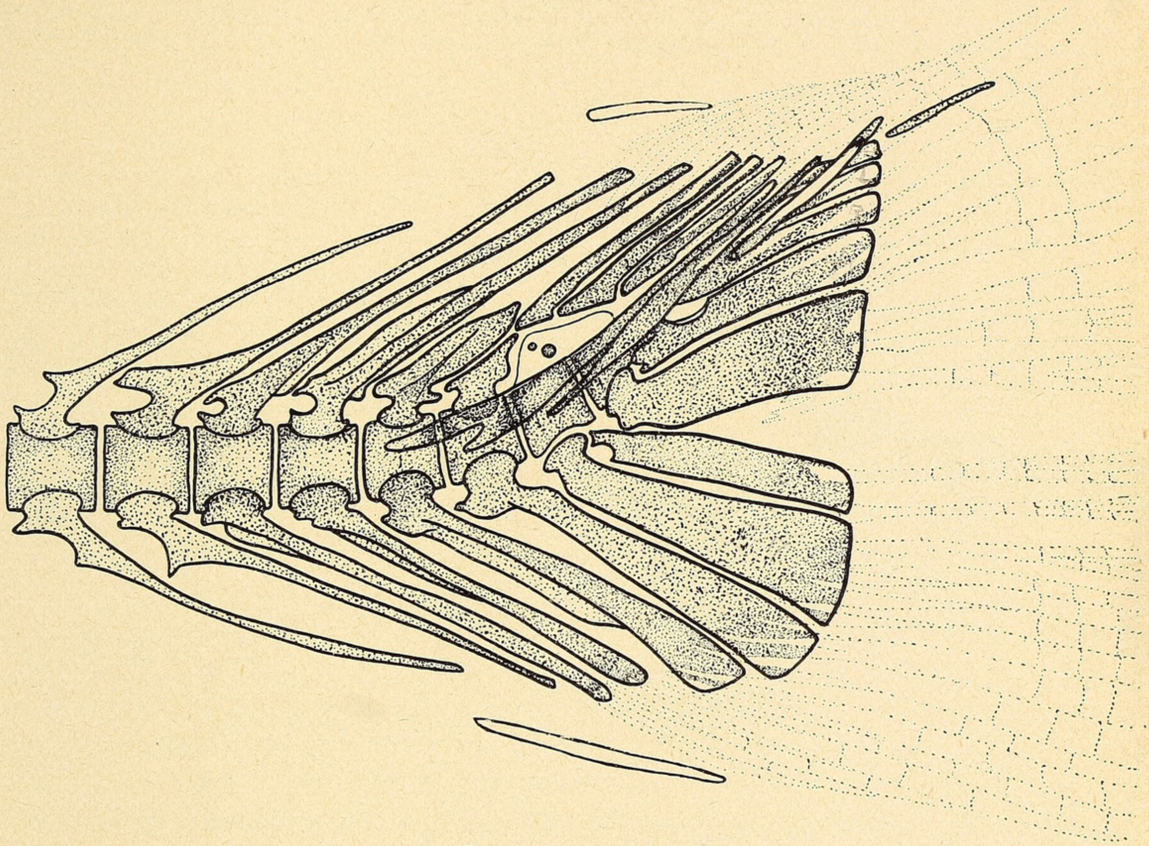
Group B
29 to 32 haemal arches.
(Total vertebral count 45 to 46).

Opisthonema oglinum
(See Text-figs. 49, 50 and 51).

Sardinella anchovia
(See Text-figs. 52 and 53).

processes. All four are elongated and crowded together on the lateral and dorsal surfaces of the upturned centra.

The uroneural whose position is the most anterior and the most dorsal is the longest (16 mm.) and the stoutest (1.5 mm. at the deepest point) and extends from the first upturned centrum as far as the center of the anterior base of the 9th (dorsalmost) hypural. Here it terminates in a blunt tip. Anteriorly this uroneural is forked, the dorsal part commencing on the first urostyle centrum which is the fourth from the last. According to Regan (1910.1) "the forking indicates the compound nature of this bone,



Text-figure 14.
Elops saurus. Tail of a 258 mm. specimen (x 2.8).

and in some specimens the line of junction between the two component elements can be clearly seen." In our Haiti specimen of 258 mm. and Gravesend Bay specimen of 280 mm., the line of junction is not evident. The anterior pair of uroneurals is the only one that covers in part the dorsal, as well as the lateral surfaces of the urostyle. The anterior half is entirely lateral but above the posterior, or last, centrum the lateral parts meet dorsally, but do not fuse, and extend for a short distance covering both the dorsal and upper lateral surfaces of the urostyle.

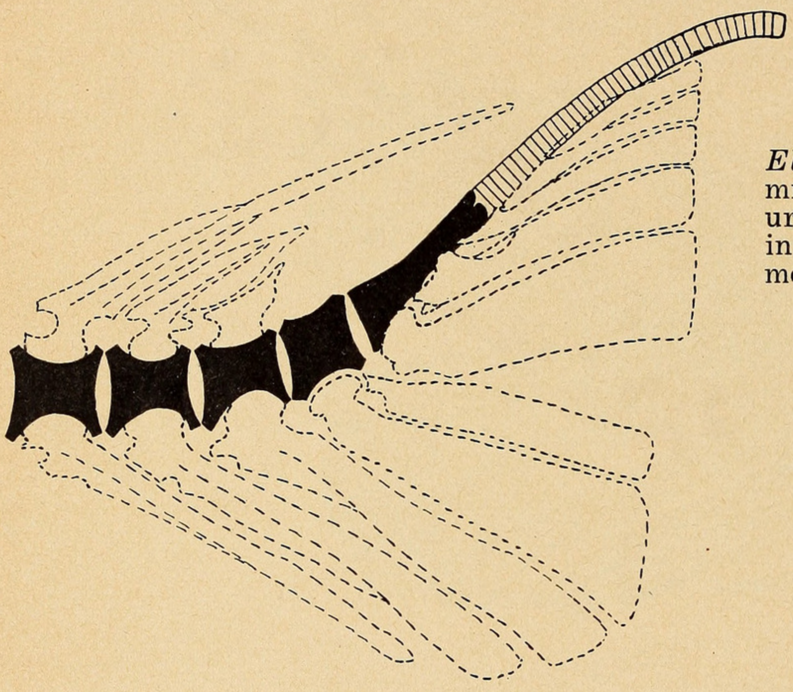
The bones of the second pair of uroneurals are spindle-shaped, 12.5 mm. long and 1 mm. deep, unforked and extend along the ventral surfaces of the first pair. The second pair arises anteriorly on the third centrum and ends between the bases of the 11th caudal ray, extending 2 mm. beyond the first pair.

The third pair resembles the second in shape but the bones are one-half the size. The length is 6.43 mm. and the depth .43 mm. This pair arises at the posterior third of the second pair and extends slightly beyond it, ending posteriorly between the bases of the 11th ray.

The fourth pair is the smallest, length 3.86 mm. and depth .29 mm. The bones extend obliquely across the 10th dorsal ray with the anterior tips on the dorsal side and the posterior on the ventral side of the ray. The direction does not parallel that of the other three pairs; instead there is a decided posterior slant. The entire length of the two bones is free in the tissue that covers the ray bases; whereas the dorsal tips of the other three uroneurals are between the bases of the 11th caudal ray.

None of these pairs are fused one with the other. The two bones of each pair are distinctly individual.

Hypurals: There are nine hypurals on the urostyle, four below and five above the median line. Two additional anterior long haemal spines project into the ventral caudal contour with fin rays attached. The third hypural (counting from the anterior to the posterior dorsal) is the largest.



Text-figure 15.
Elops saurus. Tail of 258 mm. specimen with paired uroneurals removed showing, in black, the vertebral segments of the urostyle (x 3).

The ninth and dorsalmost hypural is the smallest. The bases of the third and fourth hypurals are ventral and adjacent to a single centrum. This is also shown in Regan's drawing (1910.1) and is present in *Tarpon* and *Albula* and indicated in all the Bermuda isospondylids. None of the hypurals are fused. All of the bases are cup-shaped and the two dorsal ones are more pronounced, almost bifid, the basal tips extending on either side of the notochord. The Haiti specimen is more developed in this respect, the bases being noticeably longer. (Text-fig. 17 for example in *Tarpon*).

Epurals: There are three epurals, all long flat bones expanded at the ventral ends. The first and anterior epural is the longest, its ventral end slightly over-lapping the tip of the anterior reduced neural process.

Specialized Neural Processes: There are two reduced neural processes on the first and second upturned urostyle centra. Both are short, broad, dagger-shaped bones, the anterior one being the larger. The anterior neural process is on the first centrum that shows a tendency to turn upward. So this centrum is considered the first of the urostyle series and the attached haemal spine is called the first hypural in this paper.

The shape of the neural processes of the Gravesend Bay specimen is different from the Haiti specimen, the tips being blunt and the same depth as the rest of the process. There is a third smaller process, which is not present in the Haiti specimen. This may be an individual irregularity and not a common variation. But as there are only two specimens from which to draw conclusions this point will be left open to be determined later. This study is too new to base specific differences on characters such as the neural processes without more specimens to establish the normal range of variation.

Dorsal to the third urostyle centrum are two small round islands of bone surrounded by a median plate of cartilage. In Regan's illustration a solid bone is shown filling this entire area below the three epurals. The Gravesend Bay specimen has one round island of bone which is of interest because of the smaller size of the fish. Regan's specimen is undoubtedly older than both of ours, although no length is given. In certain fishes of other families where a series of specimens is available for study, ranging in development from young to adult, this particular area is one of the last to ossify. Our adult six-foot *Tarpon* is a striking example.

Caudal Fin Ray Count:

258 mm. $\frac{2+16=18}{1+15=16}$ Haiti specimen. There are two dorsal and one ventral anterior raylets which lack the characteristic cross bars of the rays.

280 mm. $\frac{2+17=19}{1+15=16}$ Gravesend Bay specimen.

Specialized Ray-scales: Partly covering the first dorsal and ventral raylets there is a thick elongate bony ray-scale. This was present in *Leptolepidae,* and of the Bermuda isospondylids, is seen in a more reduced size in *Tarpon, Albula,* and most of the clupeids.

MEGALOPIDAE.

Tarpon atlanticus (Cuvier & Valenciennes).

(Text-figs. 16-20).

Diagnostic Characters:

8 hypurals.

Small pointed reduced neural process on the anterior part of the first urostyle centrum.

3 distinct pairs of uroneurals.

Vertebral count: 33 + 24 = 57.

In the closely related Pacific and Indian Ocean *Megalops cyprinoides,* the vertebral count is 38 + 30 = 68. (Delsman, 1926).

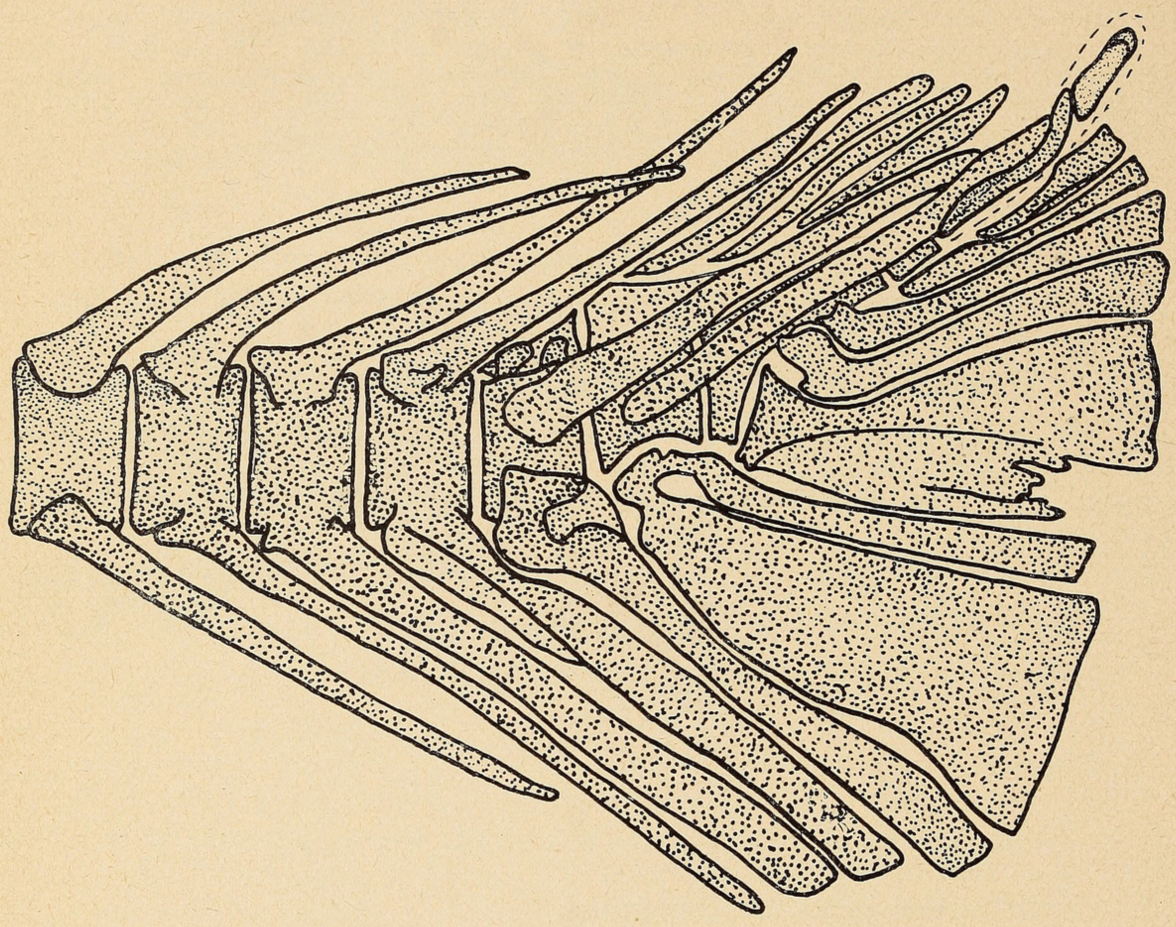
Material Studied.

The following description is from one adult fish, weight one hundred pounds, length six feet, or 1,800 mm. (Text-figs. 16, 17, 18). This specimen was taken in Florida, the gift of Mr. and Mrs. George Arents, Jr., KOH Cat. No. 2085. Any differences in younger stages are mentioned, being described from a two-foot fish, 635 mm., caught in Florida, the gift of Mr. and Mrs. Bernard Baruch, Jr., KOH Cat. No. 2083, and from three specimens, (Text-figs. 19, 20), taken in Haiti, Cat. No. 7303, KOH Cat. Nos. 2031 and 2033, lengths 140, 120, 115 mm. At the time of writing (October, 1936), the 115 mm. specimen is the smallest *Tarpon* available for study in the collection of the Department of Tropical Research and in all other institutions with which I communicated. The two-foot specimen is essentially like the six-foot fish and the drawing for the latter represents both stages and all those in between.

In Bermuda *Tarpon* are rare. A single skin was seen by G. Brown Goode, (Catalogue of the Fishes of the Bermudas, 1876), in the collection of John T. Bartram of St. George. We have seen *Tarpon* only occasionally while helmet-diving.

Caudal Osteology.

Urostyle Centra: In the six-foot fish two complete centra, one elongate centrum and an additional reduced terminal centrum, form the urostyle. The elongate element extends from the fourth hypural to the tip of the seventh. This is heavier and larger than in the younger specimens. It is

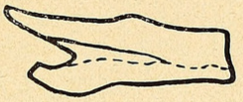


Text-figure 16.
Tarpon atlanticus. Tail of 1,800 mm. specimen (x 4/5).

irregularly shaped throughout and in the center of its length on the ventral side it resembles a thin keel which lies between the pseudoarches of the fifth and sixth hypurals. The terminal bony segment, which is not present in the smaller specimens, extends three-fourths of the length of the base of the seventh hypural. It is open above but complete below and the ossification is thin and delicate (Text-fig. 16). The notochord is seen extending from this last ossified segment into the caudal contour 10 mm. beyond the dorsal, or eighth hypural. Its end is embedded in the eleventh dorsal ray above the median line. Enclosed in a tough fibrous sheath are 18 or more separate irregular vertebral elements. All are slightly ossified. The ossification of the tip end which extends beyond the hypurals is heavier on the edges and the tip than in the center. Ventrally, this seems to be solid but dorsally it appears cleft and may be two lateral plates in close proximity (Text-fig. 18).

In the smallest specimens (Text-fig. 19), two complete centra and one elongate terminal centrum form the urostyle. This posterior rod-like centrum shows definite indication of fusion of two centra. As it extends over three hypurals, the fourth, fifth, and sixth, similar to *Elops,* it may be a composite of three centra. The cartilaginous notochord prolongation from this last centrum, very similar to that of *Elops,* extends from the base of the sixth hypural into the dorsal caudal contour, 3 mm. beyond the eighth hypural (Text-fig. 20). As in *Elops,* it is embedded in the base of the 11th dorsal ray, above the median line.

Uroneurals: There are three pairs of uroneurals, which correspond to ancestral posterior neural processes. All three are elongated bones and are close together on the dorsal and lateral surfaces of the upturned uro-

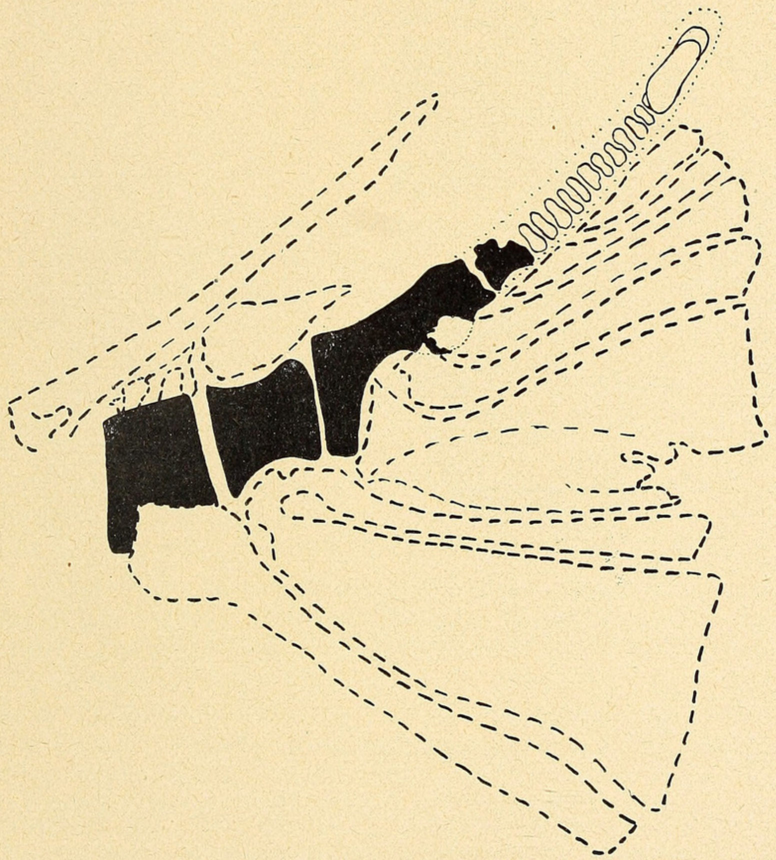


Text-figure 17.

Tarpon atlanticus. The eighth hypural showing the bifid, arch-like base in three-quarter view (x 1).

style, covering the three centra and the cartilaginous notochord, all except the extreme tip which extends beyond the hypurals. None of these pairs is fused one with the other and the two elements of each pair remain distinct.

The first uroneural, anterior and dorsalmost in position, is the longest (67 mm.) and the widest (8 mm.) at the deepest part, which is the anterior end. (The measurements of the small specimens are 11 mm. by .8 mm. wide). The bones of this pair extend from the anterior edge of the first centrum of the urostyle, above, but on a vertical line with the center of the dorsal side of the 8th hypural. They end in tapering pointed tips. The an-



Text-figure 18.

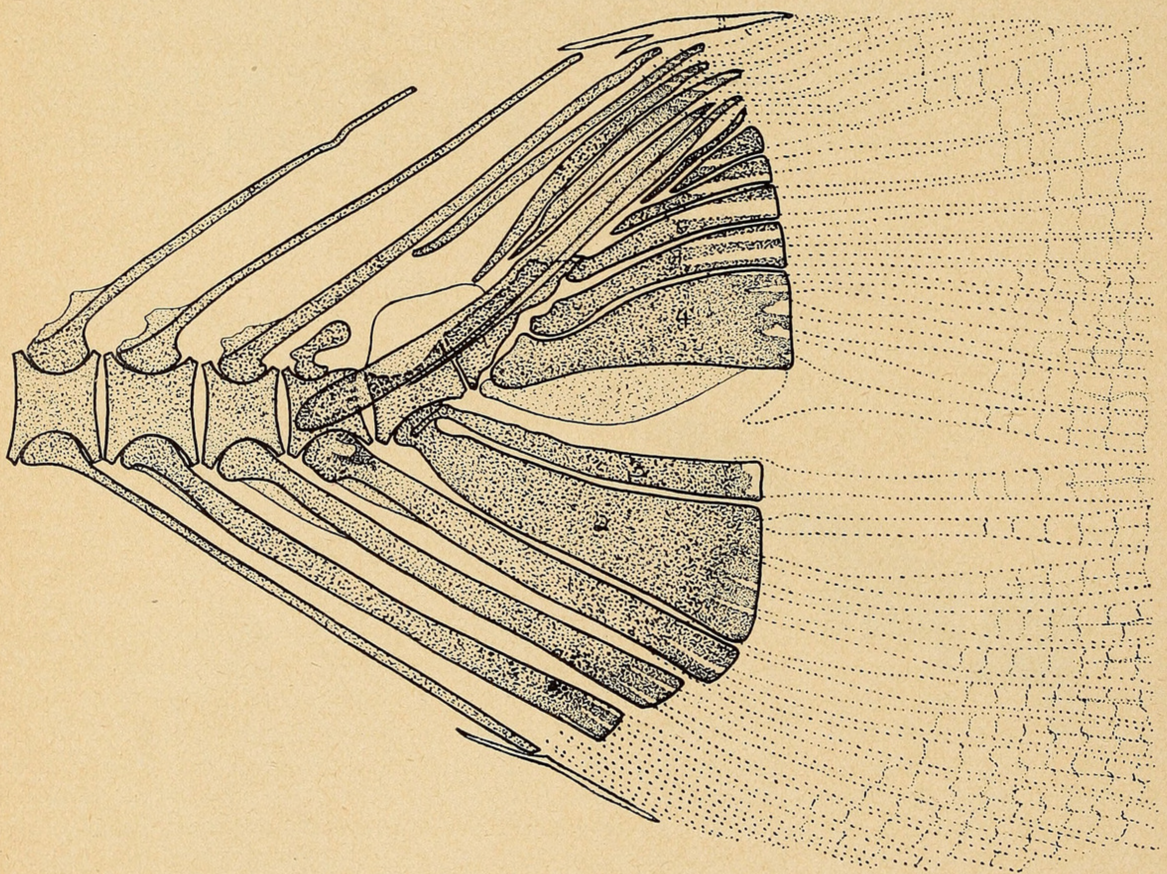
Tarpon atlanticus. Tail of 1,800 mm. specimen with paired uroneurals removed showing, in black, the ossified vertebral segments (x 4/5).

terior is rounded and unforked and differs in this respect from *Elops.* This is the only pair to cover in part the dorsal as well as the lateral surfaces of the urostyle. The anterior half is entirely lateral and above the third urostyle centrum the two lateral bones meet dorsally, but do not fuse.

The bones of the second pair of uroneurals are spindle-shaped with rounded anterior ends. This differs from the three small specimens of 115, 120, and 140 mm. as the illustration shows (Text-figs. 16, 19). The length of the uroneurals is 61 mm. and the width at the widest part in the center, is 6 mm. They arise one-fourth of the distance from the anterior edge of the second centrum of the urostyle and extend ventral and parallel to the first pair. Distally they end between the bases of the 10th and 11th caudal rays, above the median line, and extend 8 mm. beyond the first pair. (The measurements of the three small specimens are 9.2 mm. by .4 mm. wide).

The third pair of uroneurals is very small, the left bone being longer and more slender than the right and less closely associated with the underlying uroneurals. The length of the left bone is 25 mm. and the width 3 mm. It arises, approximately, at the posterior third of the second pair above the tip of the 8th hypural. The bones extend across the tips of the 2nd uroneurals, bending obliquely upward and projecting across the notochord beyond the epurals. (The measurements of the small specimens are 3 mm. by .1 mm.).

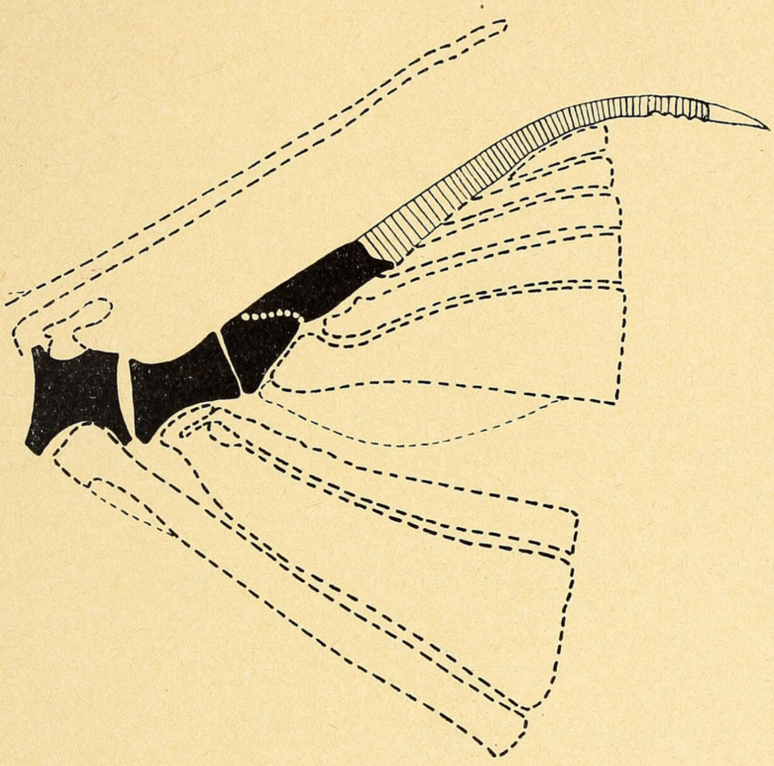
Hypurals: There are eight hypurals on the urostyle, three below and five above the median line. Three additional long haemal spines project into the caudal contour with fin rays attached. As in *Elops* there are two



Text-figure 19.
Tarpon atlanticus. Tail of 150 mm. specimen (x 4.75).

hypurals ventral and adjacent to a single centrum, the second. In *Tarpon* the basal ends of the two hypurals are closely associated in the small fish and appear as one in the two-foot and six-foot specimens. In our *Elops* the basal ends are distinct. The association of two hypurals with the 2nd centrum is also present in *Albula vulpes* where in the adult they are in close proximity to each other and the centrum. In all of the Bermuda Isospondyli, other than *Elops, Tarpon,* and *Albula,* the larger and ventral bone of the two below the 2nd centrum is entirely free from the centrum but the smaller and dorsal bone has become united with it.

All of the hypurals remain unfused and separate for their entire length. As in many specimens of other families, there is a noticeable band of cartilage on the extremity of all of the hypurals and in the big *Tarpon* there is a trace, here and there, of ossification on the outer edge of this band. As in *Elops,* the bases of the hypurals are cup-shaped and bifid (Text-fig. 17).



Text-figure 20.
Tarpon atlanticus. Tail of 140 mm. specimen with paired uroneurals removed showing, in black, the ossified vertebral segments of the urostyle (x 5.5).

Epurals: There are three epurals which are all long and rod-like. They differ slightly in shape and length, the anterior epural being the longest and the most slender and the posterior two being the shortest and the stoutest.

In the three small specimens there is an unossified area between the ventral tips of the epurals and the urostyle centra. There is a plate of cartilage here which, in both the two-foot and six-foot specimens, is ossified. In *Elops* this area is considerable smaller, being partly filled by the overlapping of the reduced neural processes and the tips of the epurals. In *Elops* a cartilage plate is present with two small round ossified islands in the larger and one center of ossification in the smaller.

Specialized Neural Processes: In the three small fishes there is one reduced neural process which is located on the first upturned urostyle centrum. This is a rounded hook-shaped bone which curves abruptly toward the posterior. In the six-foot specimen this hook-shaped reduced neural arch is present but in addition there is a second smaller one arising on the same centrum and both are united by and appear embedded in a median bony plate filling the area above this centrum. Possibly this is an individual irregularity or malformation during growth of this particular specimen.

Caudal Fin Ray Count:

	1,800 mm. fish.	16
		13
	635 mm. fish.	17
		14
140, 120, 115 mm.	3 + 13 =	16
	1 or 2 + 13 =	14 or 15

Specialized Ray-scales: Without the study of cleared and alizarin stained specimens, the single dorsal and ventral ray-scale would be counted as caudal rays, so perfectly do their extremities form part of the series of graduated caudal raylets. But in the cleared specimens the bases are seen to be quite unlike the rays in shape, origin, and position and resemble more the structure of the ray-scales found in *Elops* and *Albula,* and some of the clupeids, than that of raylets. Regan (1910.1) made the following note: "In *Elops,* but not in *Megalops,* there is an oblong ray-scale above and below, partly covering the first upper and lower rays."

ALBULIDAE.

Albula vulpes (Linnaeus).

(Text-figs. 21-39).

Diagnostic Characters:

7 hypurals.

No reduced neural processes as in *Elops* and *Tarpon.*

2 distinct pairs of uroneurals in the largest adult.

4 distinct pairs in the smallest adults of 47, 40 and 36 mm.

Vertebral count in large adults:

42 + 27 = 69. Bermuda specimens.

42 + 28 = 70. Jordan and Evermann, "Fishes of North America."

47 + 27 = 74. Delsman, Java Sea specimens.

Material Studied.

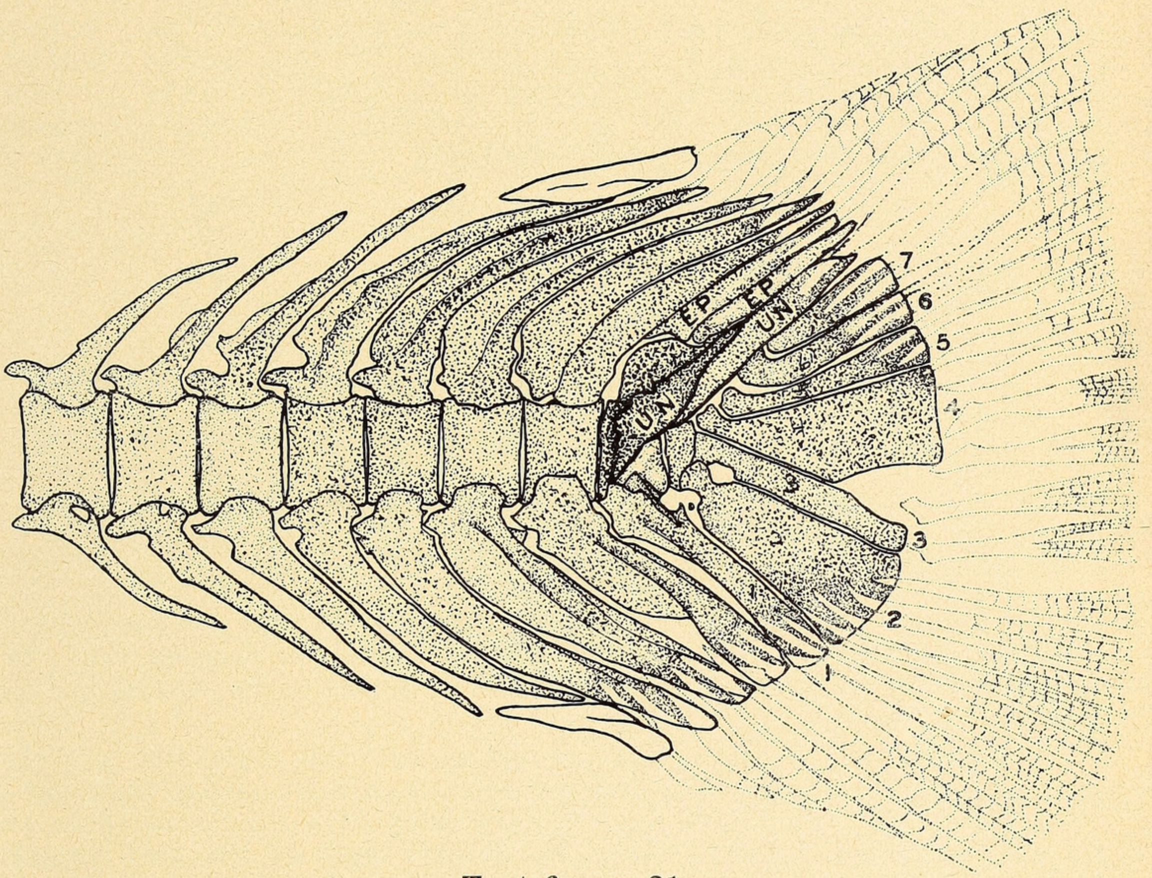
	Group	*Length*	*Cat. No.*	*KOH Cat. No.*	*Text-fig. No.*
10 Adults, ranging from 560 to 22 mm.	A	560 mm.		1134	21, 29
	A	510 mm.		1084	21, 29
	A	403 mm.		815	21
	A	206 mm.	9647	670	21, 28
	B	87 mm.	25184	768	29
	B	84 mm.	25183	767	25, 26
	C	47 mm.	25181	2057	22, 23, 24
	C	40 mm.	25182	2060	22, 23, 24
	C	36 mm.	25185	2081	22, 23, 24
	D	22 mm.	25208	2120	34
1 Intermediate		26 mm.	25209	2119	33
Leptocephalus .... (3 out of 15)		30.8 mm		2115	32
		45 mm.		2080	31
		55 mm.		147	30

This paper dealing with isospondyls is concerned more particularly with adult specimens. *Albula* is an exception in its series of fish which range in size from young to adult. The following does not aim to be a complete description of the leptocephalus phase but rather a summary of the outstanding changes occurring in the different growth stages. During seven seasons of work in Bermuda specimens of the above range in lengths were collected and studied. The figure at the top of the column represents the largest and oldest and the last figure, 55 mm., the youngest. It will be seen by reading the column from the bottom to the top that the young in growing first decrease in length; at the same time they change from ribbon-like creatures to the shape of the adult. Then growth continues by lengthening.

Although specimens have been had in collections which show *Albula* in both phases, it has not been known just when the change occurs and the rapidity of this change. I definitely established these facts by observations on a living *Albula* which grew and shrank from 55 mm. to 20 mm. in ten days' time. During this time it changed from the leptocephalus to the adult in body shape.[2]

Caudal Osteology.

Urostyle Centra: The fully adult urostyle (560, 510, 403 and 206 mm.) is composed of two complete centra, the posterior one being greatly reduced in size (Text-figs. 21, 29). Almost completely hidden under the uroneurals is a posterior terminal bony mass which probably represents several fused centra (Text-fig. 28). In the three small specimens of 47, 40, and 36 mm., four centra can be distinguished (Text-figs. 22, 23, 24). The two posterior ones are rod-shaped and very close together. The posterior terminal bone



Text-figure 21.

Albula vulpes. Tail of 560 mm. specimen (x 1.4).

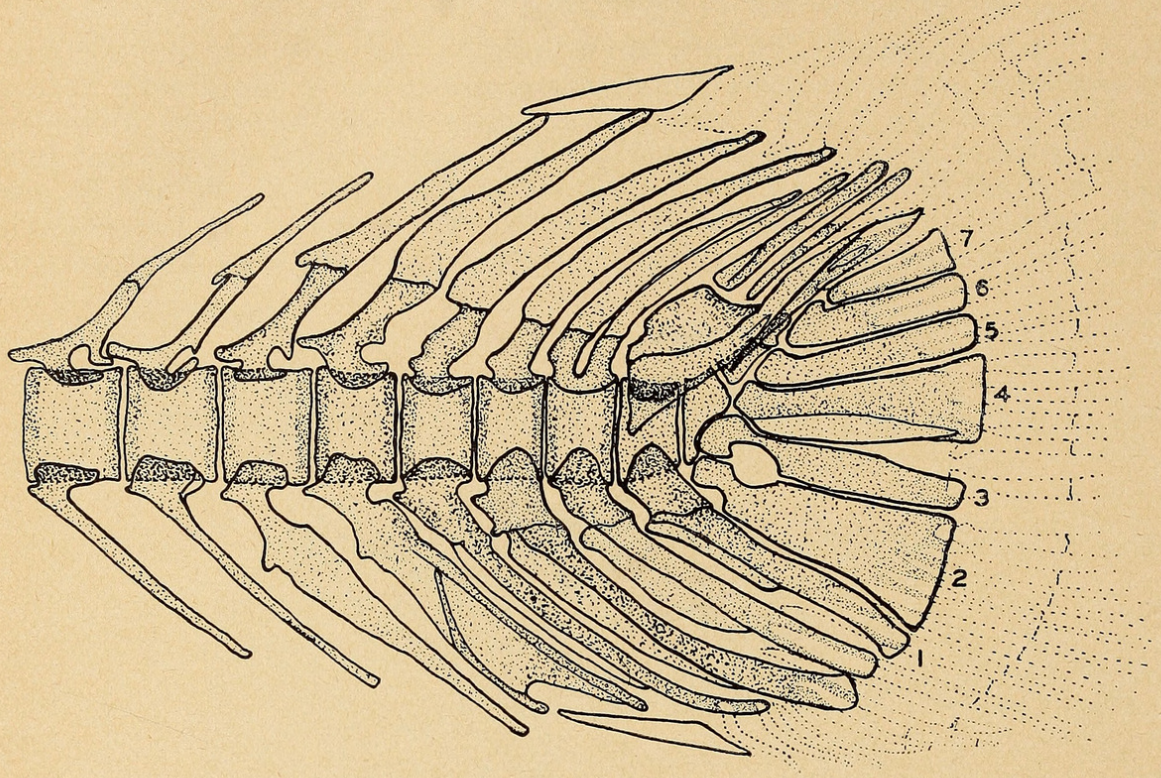
is above the center of the base of the sixth hypural (third above the median line). In the 87 and 84 mm. specimens there are only three centra, the posterior two having fused (Text-figs. 25, 26, 27).

In dissecting the 206 mm. specimen (Text-fig. 28) the second urostyle centrum was found noticeably reduced and the fourth hypural elongated with its base in the position of the third centrum as seen in the 84 mm. specimen (Text-figs. 25, 26). The terminal fused centrum is pushed out of its youthful position, where it formed the upward curve in the urostyle, and its anterior basal end is almost superimposed on the second urostyle centrum. The notochord is seen extending posteriorly as in smaller speci-

[2] See *Bulletin*, New York Zoological Society, May-June 1936, Vol. XXXIX, No. 3.

mens. Anterior to the base is a minute reduced bony element which looks like a miniature arch base. This is median in position, lying between the sides of the specialized neural process of the urostyle.

In the two largest specimens (560 and 510 mm.), no cartilaginous notochordal prolongation can be found after dissecting away the heavy uroneurals. But in all others, including the 206 mm. specimen, a delicate



Text-figure 22.
Albula vulpes. Tail representing 47, 40 and 36 mm. specimens (x 15.5).

notochord extends, within the uroneurals, into the caudal contour, ending between the bases of the eleventh caudal ray above the median line. The notochord extends to below the tip of the sixth dorsal raylet, counting from the anterior (Text-fig. 28).

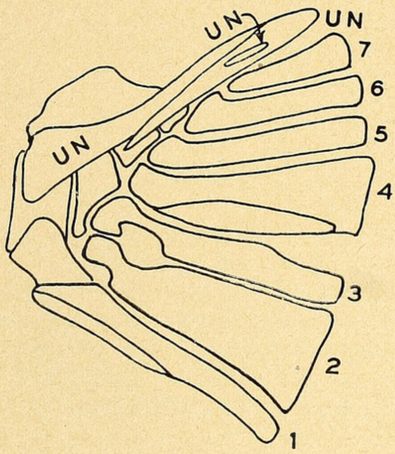
Uroneurals: In the four largest specimens (560, 510, 403, and 206 mm.) there are two pairs of heavy uroneurals which overlap each other (Text-figs. 21, 29). The irregular forward edge of the anterior pair can be traced very plainly, as it covers the greater part of the first urostyle centrum. Ventrally, its long slender tip meets the dorsal edge of the corresponding hypural. This anterior pair extends dorsally and posteriorly to about mid-length of the seventh hypural, which is the dorsalmost of the series. The posterior half is completely covered by the second pair of uroneurals, whose origin is in the center of the second urostyle centrum, dorsal to the second and third hypurals. This pair extends almost to the extremity of the seventh hypural.

In the smallest specimens (47, 40, and 36 mm.), there are four pairs of uroneurals (Text-figs. 23, 24). The two pairs which correspond to those of the adult elongate anteriorly with growth (Text-figs. 23, 29). In comparison with the 45 mm. leptocephalids (Text-figs. 36, 37), these bones have almost doubled in length, and overlap each other. In the leptocephalids only the distal and proximal ends meet. The uroneurals appear stained in the 30.8 mm. leptocephalus. In 84, 47, and 40 mm. specimens the anterior tips of the first uroneural is on the third urostyle centrum (Text-figs. 23, 25).

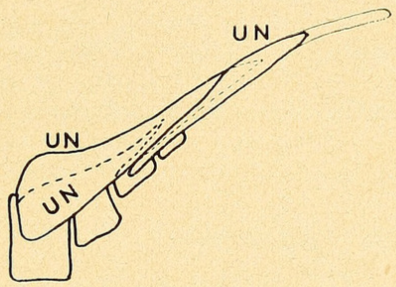
In the 87 mm. and all larger specimens it is on the second urostyle centrum (Text-figs. 27, 29). There is a third pair seen only in leptocephalus stages and 87, 84, 47, 40, 36 and 22 mm. specimens. In the leptocephalus this pair is the most dorsal and posterior (Text-fig. 36). These uroneurals do not elongate with growth and remain identical in length from the leptocephalus to the 87 mm. stage and become fused in the center of the first uroneural. In specimens of 206 mm. and over, there is no trace of this third pair (Text-fig. 29). A fourth pair is seen in the 47, 40, and 36 mm. specimens, extending in a dorsal direction posteriorly from the reduced neural process. This is not to be found in the largest or fully adult specimen (Text-fig. 24).

Hypurals: There are seven hypurals ventral and posterior to the urostyle, three below and four above the median line. Four additional haemal spines project into the caudal contour. The anterior one has above it the specialized ray-scale, and the three others have fin-rays attached (Text-fig. 21).

As in *Elops* and *Tarpon* the two hypurals immediately ventral to the median line arise from what appears to be a single centrum. In all other Bermuda adult Isospondyli the larger hypural of the two is well separated from any centrum attachment and is one of the largest hypurals. It resembles an isolated triangular island of bone. In the very young stages of several of the clupeids there is to be seen this same attachment to a



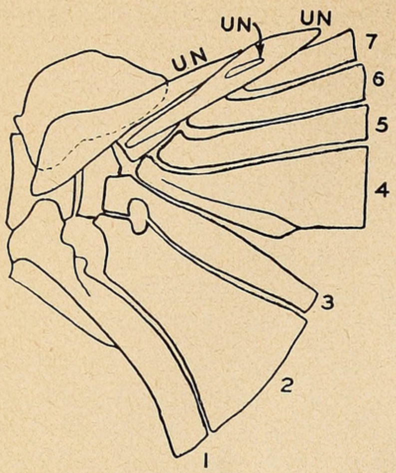
Text-figure 23.
Albula vulpes. Tail of 47, 40 and 36 mm. specimens showing the position of the three pairs of uroneurals in relation to the urostyle segments and hypurals (x 20).



Text-figure 24.
Albula vulpes. Dissection of Text-fig. 23 showing four urostyle segments and a fourth pair of uroneurals which are dotted and lettered, being under the anterior uroneurals. The smallest pair of uroneurals has been omitted in order to show the extent of the underlying tips of the anterior uroneurals (x 20).

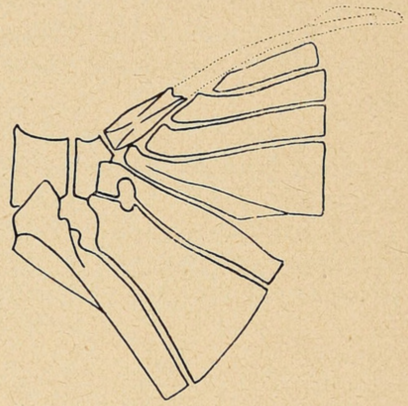
single centrum as in *Elops, Tarpon,* and *Albula* (Text-figs. 14, 16, 21). The bases of the hypurals are bifid as in *Elops* and *Tarpon* (Text-fig. 17, *Tarpon*).

Epurals: In the adult there are two epurals which are heavy irregular bones and in such close proximity that their respective outlines are difficult to trace (Text-fig. 21). In the young of 47, 40, and 36 mm. the two epurals are distinct (Text-fig. 22). The area above the urostyle in the young and adult is almost completely filled with the uroneurals and the specialized neural process. It is interesting to note here that in the longest and consequently the youngest of the leptocephali, where there is no evidence of



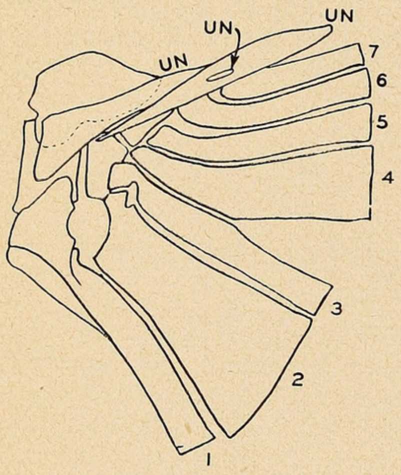
Text-figure 25.

Albula vulpes. Tail of 84 mm. specimen showing the positions of the three pairs of uroneurals in relation to the urostyle segments and hypurals. The large pairs have lengthened with growth but the small pair has remained the same (x 9).



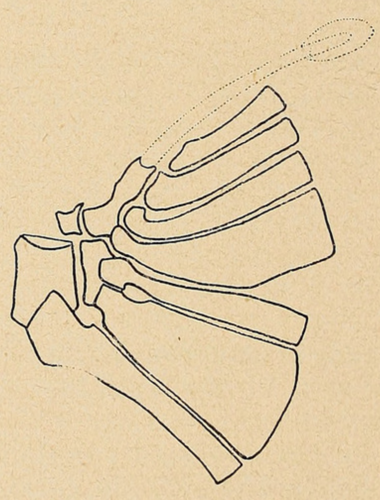
Text-figure 26.

Albula vulpes. Dissected tail of 84 mm. specimen showing three urostyle segments instead of four as seen in the younger stages (x 7.8).



Text-figure 27.

Albula vulpes. Tail of 87 mm. specimens showing the positions of the three pairs of uroneurals in relation to the urostyle segments and hypurals. The bones of the dorsalmost uroneural have lengthened and the anterior tips are on the second urostyle segment instead of the third as in smaller specimens. The length of the small pair has remained unchanged (x 8).



Text-figure 28.

Albula vulpes. Dissected tail of 206 mm. specimen showing the more consolidated urostyle and remains of the fourth uroneurals of Text-fig. 24 (x 2.5).

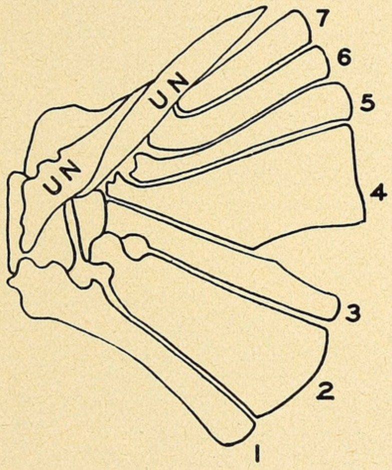
segmentation in the notochord nor absorption of alizarin, the basal ends of the two epurals are united (Text-fig. 36).

Specialized Neural Process: There is one reduced neural process on the first centrum of the urostyle (Text-fig. 21). This is ossified and developed in the 36 mm. young-adults but cannot be detected, even in cartilage form, in any of the younger specimens (Text-figs. 22, 36).

Caudal Fin Ray Count:

55 mm.	11	Leptocephalus. Caudal rays unstained (Text-fig. 36).
	11	
45 mm.	11	
	11	
30 mm.	2 + 10 = 12	Caudal rays stained.
	2 + 10 = 12	
26 mm.	3 + 10 = 13	
	2 + 10 = 12	
22 mm.	4 + 10 = 14	No trace of dorsal or ventral caudal ray-scale or body scales. (Text-fig. 37).
	4 + 10 = 14	
36 mm. 40 mm. 47 mm.	6 + 12 = 18	Caudal ray-scale present. Body scales present. (Text-fig. 22).
	3 + 13 = 16	
84 mm.	3 + 15 = 18	
	2 + 14 = 16	
87 mm.	3 + 15 = 18	
	1 + 15 = 16	
206 mm. 403 mm. 510 mm.	1 + 17 = 18	(Text-fig. 21).
	1 + 15 = 16	
560 mm.	18	(Text-fig. 21).
	16	

Specialized Ray-scales: As in *Elops* and *Tarpon,* a thick, elongate, bony ray-scale partly covers the first dorsal and ventral anterior raylet. In *Albula* this structure is heavier than in any of the other isospondylids (Text-figs. 21, 22). It is well developed in all specimens 36 mm. and longer



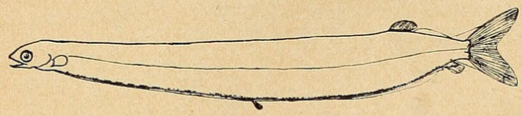
Text-figure 29.

Albula vulpes. Tail of largest adult showing uroneurals and segments of the urostyle reduced to two elements respectively (x 1.5).

but not evident, even in cartilage form, in any of the younger stages or leptocephalids.

Additional Characters Worthy of Note: All of the posterior neural and haemal spines are very heavy and thick and by this character alone adult *Albula* can be identified and distinguished from all other Bermuda isospondylids (Text-fig. 21). It is interesting to note that in several specimens there is a double neural spine structure (Text-figs. 21, 22). This

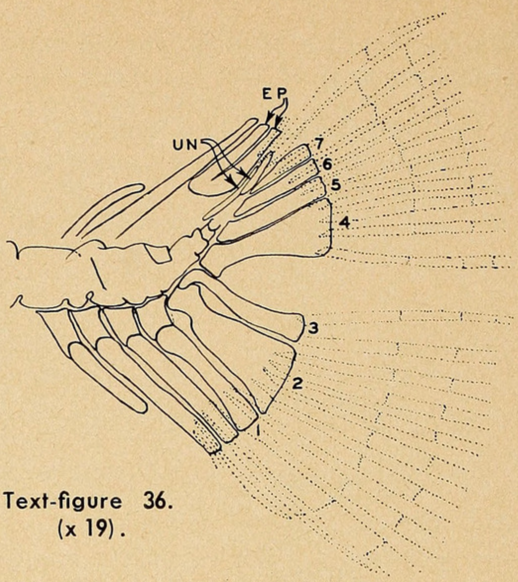
Text-figure 30.



Text-figure 31.

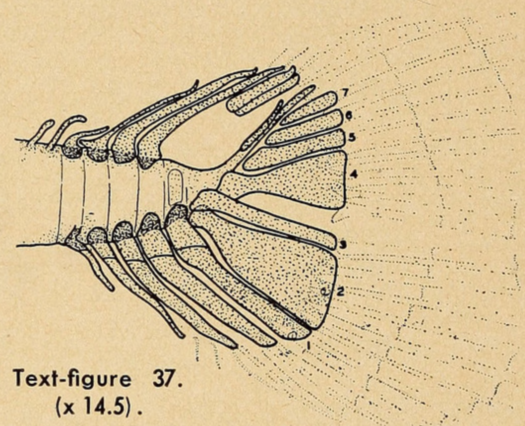
Text-figure 32.

Text-figure 33.

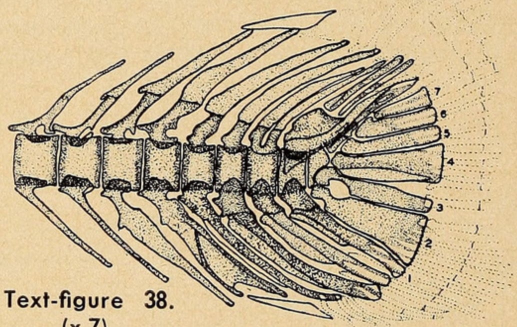


Text-figure 36.
(x 19).

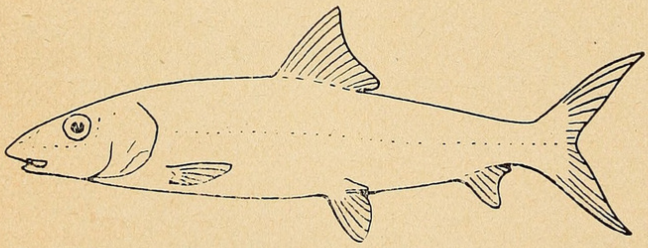
Text-figure 34.



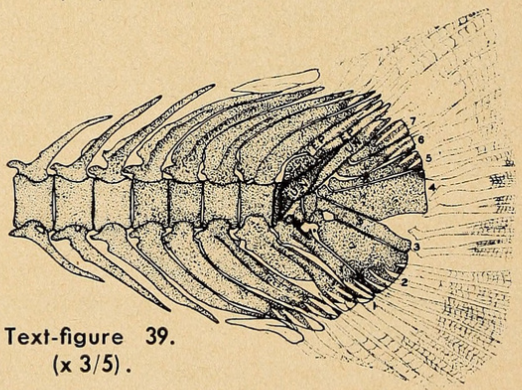
Text-figure 37.
(x 14.5).



Text-figure 38.
(x 7).



Text-figure 35.



Text-figure 39.
(x 3/5).

Text-figures 30-39.

Albula vulpes. Summary of the caudal skeleton development and corresponding change in body form from a 55 mm. leptocephalus to a 560 mm. adult. The five upper figures in the left column are natural size. Text-figure 35 is x 1/9.

occurs in specimens of the following lengths: 510, 403, 87, 47, and 36 mm. In two of these the double structure is on the next to the last, and in the other specimens it is on the last vertebra. This is not correlated with size, for in the other specimens of the series which are 560, 84, 40, and 22 mm., no double neural structure is present.

The comparative development of the skeleton is interesting in the series at hand. In the longest leptocephalus (55 mm.) the notochord is not yet segmented, nor has it taken up any alizarin (Text-fig. 36). In the successively shorter leptocephali more and more vertical lines appear at regular intervals which are the antecedents of the adult centra (Text-fig. 37). In all of the small specimens having the form of the adult, 22 mm. and larger, there is vertebral differentiation which is less distinct in the smallest specimen. Here the centra have not yet developed the shape of the adult centra. The vertebrae in the smallest specimens are rectangular and about twice as deep as wide (Text-figs. 21, 22). In all the small specimens there is ossification in the head and caudal regions. In the smallest fish of 22 mm. the only ossification of the notochord is in the caudal region, on the dorsal and ventral surfaces, near the bases of the neural and haemal spines.

It is consistent with the digging habits of *Albula* that one of the first areas of ossification should be the snout and head.

The first appearance of scales is in the 36 mm. specimen where they appear heavily stained. No scales are apparent on the 22 mm. fish.

The first appearance of ossification in the notochord is in the 22 mm. fish, and the urostyle segments are more definitely defined than in the younger intermediate 26 mm. specimen.

The dorsal fin-fold is absent for the first time in the 22 mm. specimen (Text-fig. 34).

It is interesting to note the rapidity of development which occurs between the 30.8 mm. leptocephalus and the 20 mm. young. In the *Albula*[3] that lived for ten days it took exactly six days to grow from 30 to 20 mm. It is just here during the life span of *Albula* that the unossified ribbon-like leptocephalus changes into an ossified, compact fish. In the shortening of the length the embryonic fin-folds disappear, the dorsal and anal fins and anus move forward (Text-figs. 32, 33, 34).

In the 26 mm. specimen, which is here termed an intermediate stage, change in the external shape of the body is more advanced than that of the internal and caudal skeleton, (Text-fig. 33). This resembles the 30.8 mm. leptocephalus more than the 22 mm. older form. In the 22 mm. fish the external body form resembles that of the adult (Text-figs. 34, 35). Again the development of the body is more advanced than that of the internal and caudal skeleton. In this stage is the first appearance of ossification around the notochord.

TABLE I.

Records of Extreme Lengths	*Leptocephalus*	*Adult*
From Literature	85 to 40 mm.	44 to 1220 mm.
From Bermuda Specimens	55 to 30.8 mm.	20[3] to 560 mm.
	Intermediate 26 mm.	

[3] This specimen is not cleared and stained, as it is the fish reared from a 55 mm. leptocephalus to a 20 mm. young *Albula*, where the body resembled the adult. It will be seen from the figures stated above in literature that this specimen probably is the smallest *Albula vulpes* in any collection. See the New York Zoological Society *Bulletin*, May-June 1936, Vol. XXXIX, No. 3.

DUSSUMIERIIDAE.
Jenkinsia lamprotaenia (Gosse).
(Text-figs. 40-44).

Diagnostic Characters:

7 hypurals.

1 reduced neural process. This is situated on the anterior part of the urostyle and, unlike *Elops* and *Tarpon,* it is forwardly directed.

3 distinct pairs of uroneurals.

Vertebral count: 27 + 16 = 43.

1 epural, the only isospondylid with one.

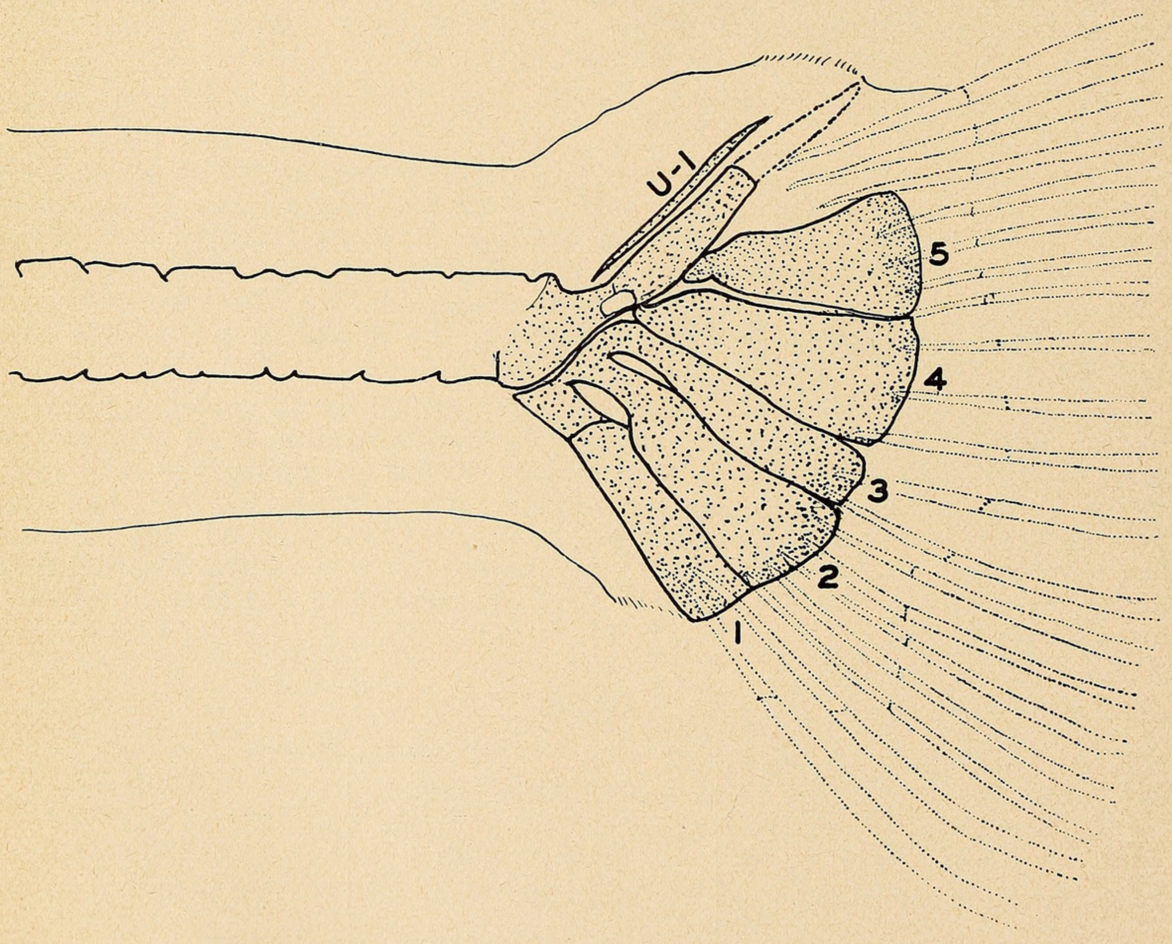
Prolonged bases of the two median caudal rays.

Total caudal ray count of 26, the smallest of the whole group.

Specialized neural processes unlike those of all other Bermuda isospondylids.

Material Studied.

This description is taken from the five following specimens and com-



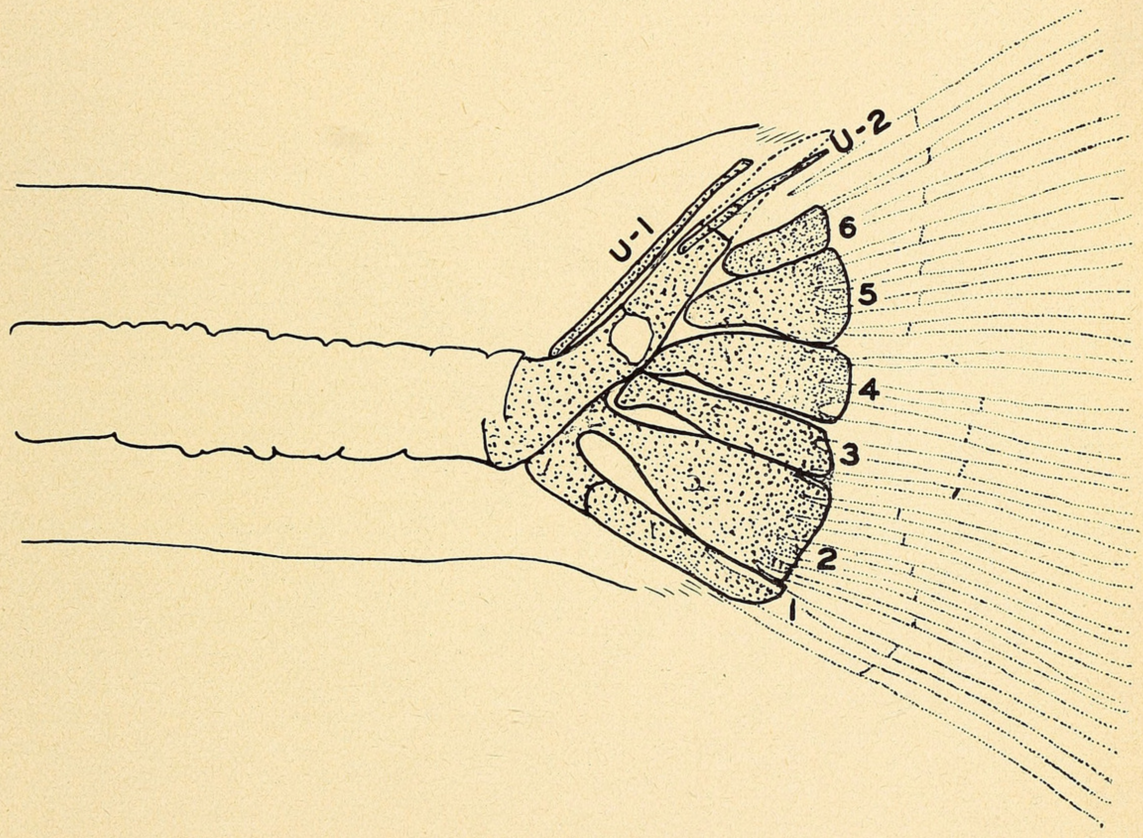
Text-figure 40.
Jenkinsia lamprotaenia. Tail of 10 mm. specimen with unossified and unsegmented vertebral column. There are only five hypurals and one pair of uroneurals ossified (x 140).

parative studies were made with fifty-five additional fish which range in size from young to adult.

Length	*KOH Cat. No.*	*Text-fig. No.*
40 mm.	2096	
26 mm.	343	44
18 mm.	657	43
15 mm.	657	42
11 mm.	657	41
10 mm.	657	40

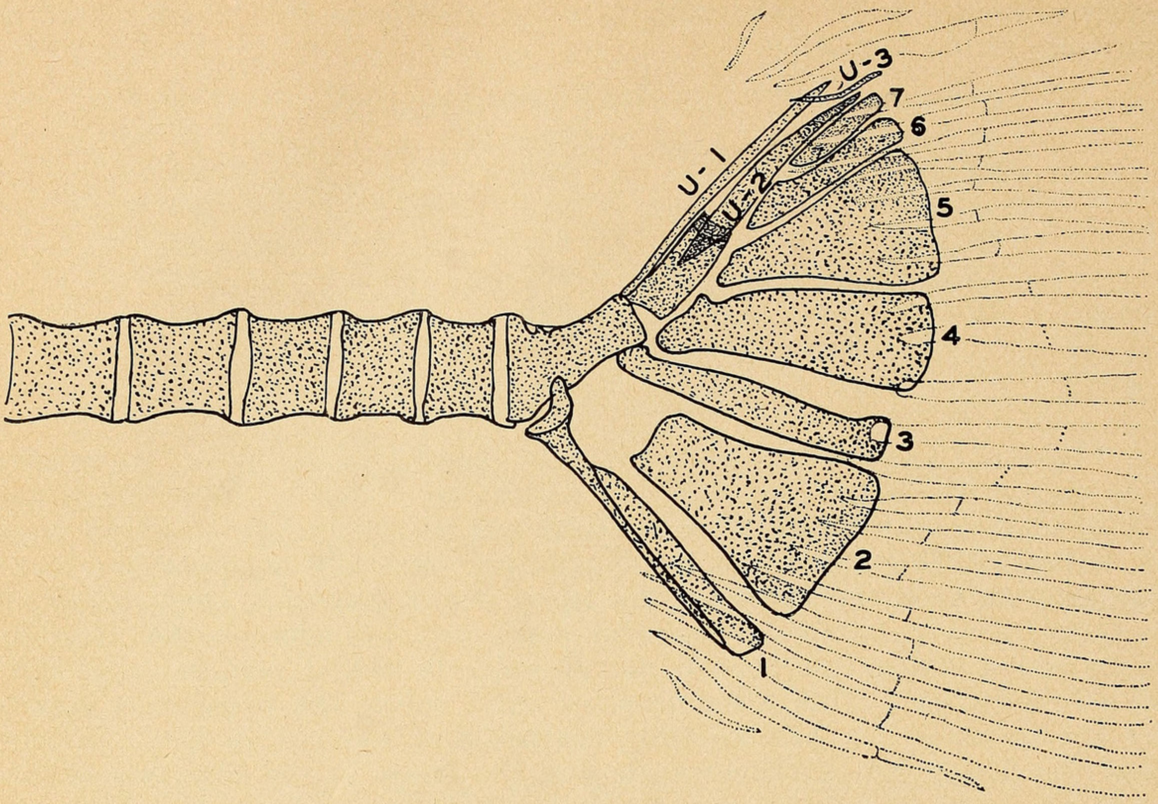
Caudal Osteology.

Urostyle Centra: The adult urostyle appears as one bone. Anteriorly it is shaped like a half centrum and posteriorly it has a slender upturned end which is situated between the fourth and fifth hypurals, counting from the anterior. The distal end has projecting ventrally a fan-shaped bone that extends over the bases of the three dorsal hypurals, and covers an unossified area between the hypural bases and the end of the urostyle. In the young stages this bone is not present. It is first seen in an 18 mm. fish (Text-fig. 43). This space does not exist before the uroneurals appear and the urostyle has become fully ossified and reduced in size. In this stage the distal end of the urostyle and the bases of the hypurals almost meet (Text-fig. 43). With growth more and more space in this area appears. The urostyle is definitely divided into two parts in the young stages. The line of junction shows plainly in the adult (Text-fig. 44).



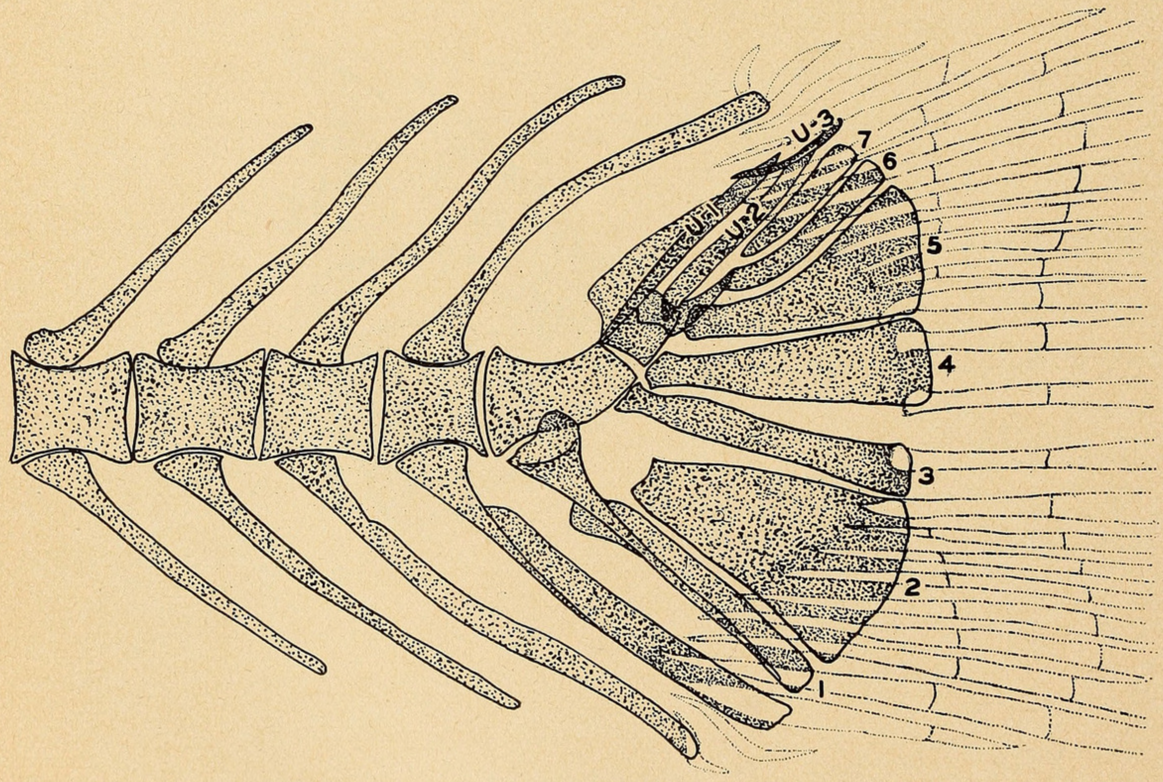
Text-figure 41.

Jenkinsia lamprotaenia. Tail of 11 mm. specimen with unossified and unsegmented vertebral column. There are six hypurals and two pairs of uroneurals ossified (x 108).



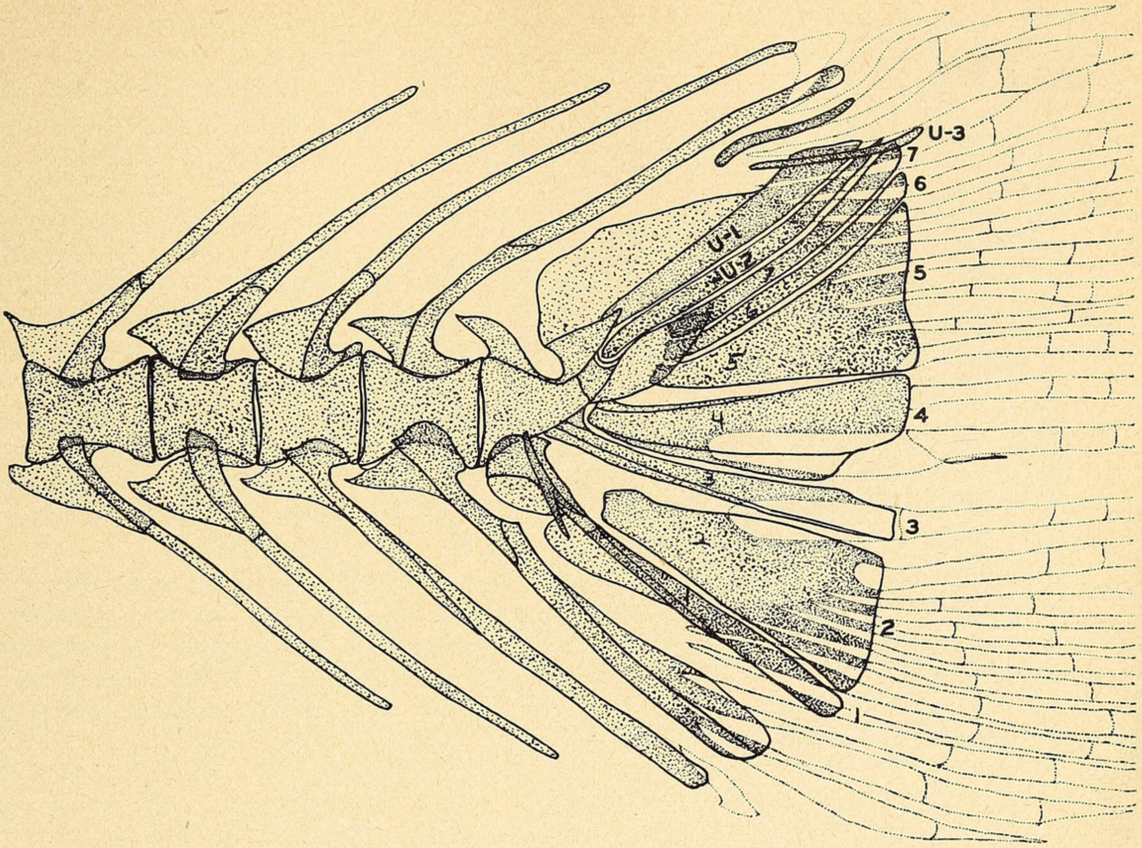
Text-figure 42.

Jenkinsia lamprotaenia. Tail of 15 mm. specimen with ossified and segmented vertebral column. There are seven hypurals and three pairs of uroneurals ossified. The basal end of the second hypural is reduced (x 64).



Text-figure 43.

Jenkinsia lamprotaenia. Tail of 18 mm. specimen with ossified neural and haemal processes (x 59).



Text-figure 44.

Jenkinsia lamprotaenia. Tail of 26 mm. specimen with single epural ossified (x 39).

Uroneurals: There are three pairs of uroneurals in the adult. Each pair is quite different in shape, size, and general position, as may be seen in the accompanying drawings. The bones are numbered according to the order of their appearance. In several young stages the first pair appear as two separate bones which in the older stages fuse into a solid structure which is directly dorsal to the urostyle. It extends from the tip of the reduced adult urostyle into the caudal contour. In the older fish of 18 mm. and larger there is a median wing-shaped bone on the anterior three-fourths of the dorsal side. In specimens of 26 and 30 mm. this bone fills all the center of the unossified area which is between the posterior neural spine, the reduced neural process on the urostyle, and the epural.

The second pair of uroneurals first appears in the 11 mm. specimen. Here the two short lateral bones extend along the cartilaginous tip of the urostyle. In a 15 mm. specimen the bones are still separate but have enlarged in length and depth. In specimens of 18, 26, and 30 mm. the two bones are united. In each example the proximal ends overlap the tip of the ossified urostyle. The two bones of the diminutive third pair remain individual in all stages. They cannot be distinguished in a 11 mm. fish but in a 15 mm. specimen they are present. Their position is between the bases of the 10th and 11th dorsal caudal rays which are above the median line. There is a noticeable space in specimens of all lengths and here the cartilaginous prolongation of the notochard extends. The posterior ends of these bones arise beyond the caudal contour of the hypurals and extend obliquely forward and downward. (Text-figs. 41, 42).

The third pair of uroneurals is first seen in a 15 mm. specimen. This is the smallest of the three pairs, and the direction of the bones is more toward the anterior than that of the others. In the 15 mm. specimen the position is between the dorsal tips of the first and second uroneurals with the anterior end of each bone crossing the end of the first uroneural. The posterior ends extend beyond the distal edge of the hypurals and occupy the area between the ray bases where the notochord extends. The accompanying drawings show the position and lengthening with growth (Text-figs. 42, 43, 44).

Hypurals: There are seven hypurals, three below and five above the median line. Two additional long haemal spines project into the caudal contour with fin-rays attached. In eleven young fish between the lengths of 10 and 13.44 mm., the second hypural is complete and the same length as the other hypurals. In twenty specimens between the lengths of 13.58 mm. and 40 mm., the base of the second hypural is reduced. It is entirely separate and free from the other hypurals and appears as a triangular island.

Epurals: There is only one epural in *Jenkinsia* which is first seen ossified in the 26 mm. fish. This bone can be seen in the smaller specimen but it is entirely unossified. *Jenkinsia* is the only Bermuda isospondyl having but one epural.

Specialized Neural Processes: In the completely ossified specimens of 26 mm. and larger there is a hook-shaped neural process on the posterior part of the urostyle. In the center of the urostyle this becomes very narrow and again expands posteriorly. The proximal end of the first uroneural is inserted between its tip ends. Dorsal to both is a thin median wing-like bone which is first seen in the 26 mm. specimen (Text-fig. 44).

Caudal Fin Ray Count:

26 mm.	2 + 12 = 14	(Text-fig. 44).
	1 + 11 = 12	
18 mm.	3 + 11 = 14	(Text-fig. 43).
	2 + 10 = 12	
15 mm.	2 + 11 = 13	(Text-fig. 42).
	1 + 10 = 11	
11 mm.	10	(Text-figs. 41, 40).
10 mm.	9	

Additional Characters Worthy of Note: In the fully ossified specimens of 26 mm. and larger the two median caudal rays have enlarged bases which project anteriorly half the length of the hypurals (Text-fig. 44). Among the Bermuda isospondyls this character is seen also in *Anchoviella* and the clupeids.

Enlarged wings on the anterior margin of the proximal ends of the haemal and neural spines are seen first in the 26 mm. specimen (Text-fig. 44).

In the youngest specimens vertebral ossification and individual vertebrae are first seen in 15 mm. fish. Here the urostyle, hypurals and caudal rays are well ossified. In the 10 mm. and 11 mm. specimens the vertebral column is not constricted and there is no ossification anterior to the urostyle.

According to caudal pattern and characters *Jenkinsia* seems to stand apart from the other Bermuda isospondyls. Conversely the three clupeids and *Anchoviella* are closely associated by similar patterns and characters.

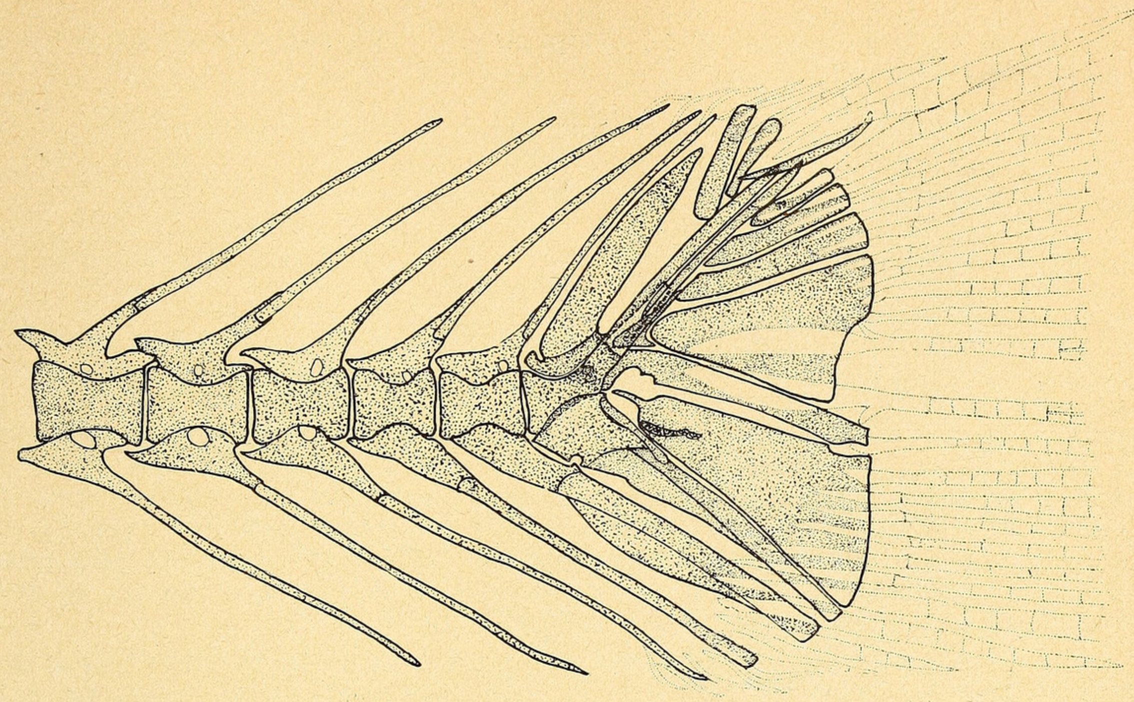
ENGRAULIDAE.

Anchoviella choerostoma (Goode).

(Text-figs. 45, 46).

Diagnostic Characters:

7 hypurals.



Text-figure 45.
Anchoviella choerostoma. Tail of 57 mm. specimen (x 11.5).

1 small reduced neural on the anterior base of the elongate neural process of the urostyle.

Vertebral count:

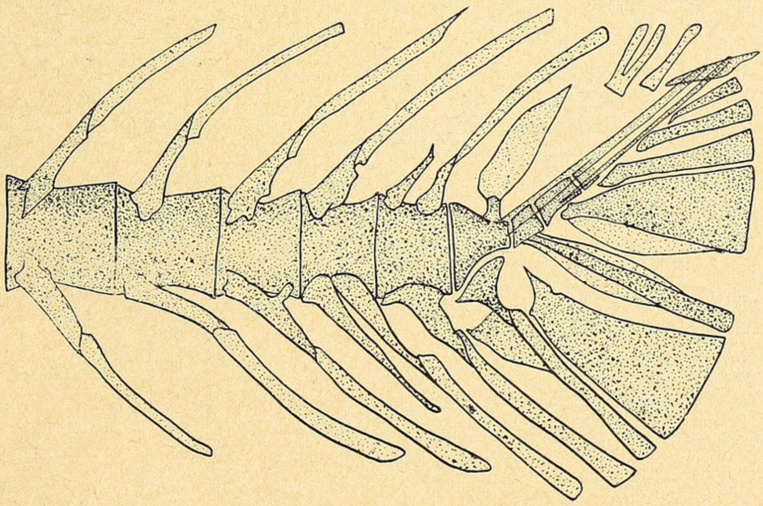
20 + 20 = 40. 58 mm.
21 + 20 = 41. 50 mm.
21 + 21 = 42. 42 mm.

2 epurals and occasionally $2\frac{1}{2}$.

Prolonged bases of the two median caudal rays.

Material Studied.

This description is based on twenty-nine specimens ranging in size from 20 to 59 mm. The 20 mm. fish is the smallest *Anchoviella* in our collection and is identical externally with the largest (59 mm.) fish. But the internal caudal development is not the same in the young specimen, which



Text-figure 46.
Anchoviella choerostoma. Tail of 20 mm. specimen (x 28).

can be seen by the accompanying illustrations. The two specimens studied in particular are:

Length	*KOH Cat. No.*	*Text-fig. No.*
57 mm.	875	45
20 mm.	2095	46

Caudal Osteology.

Urostyle Centra: The interpretation of the adult urostyle is clarified by first studying the structure of the youngest specimen at hand. Here there are three distinct vertebral segments and the anterior part of a fourth is partly visible. (Text-fig. 46). In the large specimen, judging by the comparative position of the hypurals with that in the small fish, the two anterior segments fuse and the two posterior segments fuse. The posterior segment in the large specimen is further complicated by the presence of a small arch-like bone on the ventral side. This surrounds the proximal end of the fourth hypural. A similar structure is found in adults of the three clupeids.

Uroneurals: There are three pairs of uroneurals in the adult and the young specimen. The relative length, proximal and distal positions are the same in both fish. The anterior end of the pair that arises on the first urostyle centrum is not distinctly defined but there is little doubt that a smaller specimen would show the definite outline of the end of this bone.

Epurals: There are two and sometimes two and a half epurals in *Anchoviella.* The variation always occurs in the anterior bone which may be split in the form of a Y or have a hole in the center. This variation does not correlate with size. In fifteen specimens six have two epurals and the others have either the split or a hole in the anterior bone.

Specialized Neural Process: In the large specimens a long dagger-shaped bone extends from the anterior urostyle centrum to about the center of the anterior epural. In the 20 mm. specimen this bone is shorter and does not reach the basal end of the epural. This character, along with several others, distinguishes *Anchoviella* from the clupeids.

Caudal Fin Ray Count:

$$57 \text{ mm.} \quad \frac{5 + 13 = 18}{5 + 12 = 17}$$

In seven specimens out of fifteen, the caudal count is as stated above and is found in fish from 28 to 59 mm. In eight specimens there is variation in the total count from $\frac{17-19}{16-18}$. In the specimens examined the count of the dorsal and ventral is never $\frac{19}{16}$ as in the clupeids.

Clupeidae.

1. *Harengula* sp.

(Text-figs. 47, 48).

Diagnostic Characters:

7 hypurals.

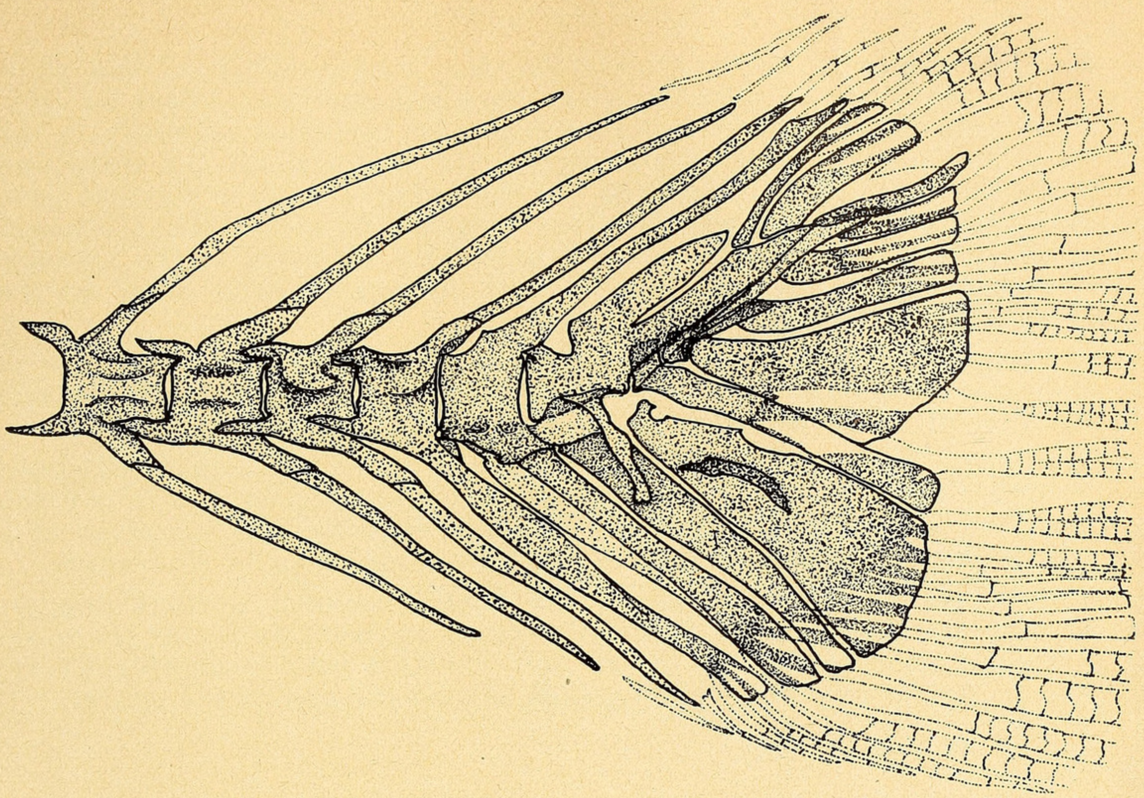
1 reduced neural process. This process is insignificant and resembles the anterior neural zygapophysis.

3 pairs of uroneurals.

Vertebral Count: 12 to 14 + 25 to 26 = 37 to 40.

2 or 3 epurals.

Prolonged bases of two median caudal rays.

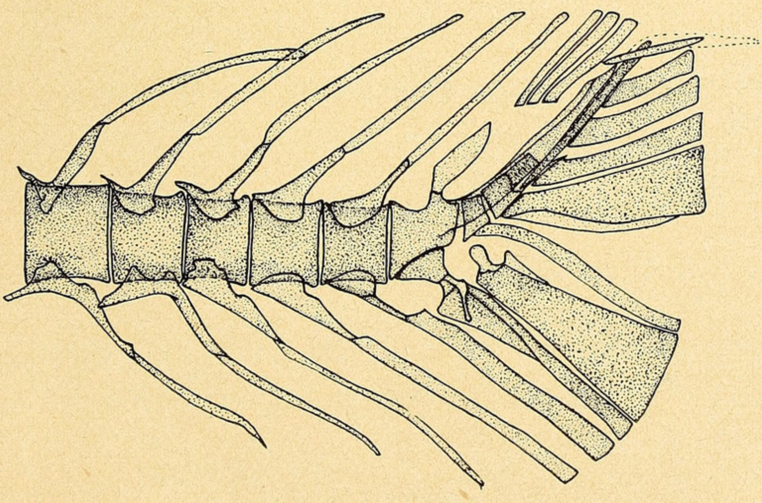


Text-figure 47.
Harengula sp. Tail of 165 mm. specimen (x 3.6).

Material Studied.

The KOH collection contains seventeen specimens ranging from 22 to 180 mm. The figure of the adult represents the tail structure of fish from 70 mm. to the largest. The illustration of the 22 mm. specimen, which is the smallest in the department collection, shows slight differences in degree of development. The two specimens studied in particular are the following:

Length	*KOH Cat. No.*	*Text-fig. No.*
165 mm.	847	47
22 mm.	656	48



Text-figure 48.
Harengula sp. Tail of 22 mm. specimen (x 21).

Caudal Osteology.

Urostyle Centra: As in *Anchoviella,* the interpretation of the adult urostyle is best made by examining the youngest specimen (Text-fig. 48). Here, as in *Anchoviella,* there are four centra or vertebral segments in the urostyle. The anterior or first and second are separate but the third and fourth appear fused. In the adult all but the anterior or first segment have become comparatively reduced. The fourth cannot be seen under the heavy uroneurals. As in *Anchoviella* the first hypural is attached to the anterior urostyle segment and the third and fourth hypurals are attached to the second and third urostyle segment.

Uroneurals: As in Anchoviella there are three pairs of uroneurals in the adult and the young specimens. The illustrations show the relative size and position of these bones.

Epurals: There are two or three epurals in *Harengula.* In seven specimens ranging from 35 to 180 mm., I found two epural bones and in five fish ranging from 22 to 173 mm. there were three epurals. The variation of a split or perforated bone in *Anchoviella* has not been found in *Harengula.*

Specialized Neural Process: In the large specimen a stout dagger-shaped bone extends from the anterior urostyle segment as far as the basal end of the anterior epural. In the 22 mm. fish this bone is shorter (Text-fig. 48). In *Anchoviella* this bone extends beyond the end of the epural.

Caudal Fin Ray Count:

165 mm.	1 + 18 = 19	(Text-fig. 47).
	1 + 15 = 16	
40 mm.	5 + 14 = 19	
36 mm.	4 + 12 = 16	

In the specimens counted the dorsal and ventral combination was constant, 19/16, and never like that in *Anchoviella.*

Additional Characters Worthy of Note: The caudal pattern of *Harengula* is very like the two other Bermuda clupeids. In the number of *Harengula* specimens examined, only minor differences have been seen, such as the variation in the number of the epurals. This variation occurs in all the clupeids and in *Anchoviella.* Most Bermuda *Harengula* key to *sardina* as described in the "Field Book of the Shore Fishes of Bermuda," Beebe and Tee-Van.

2. *Opisthonema oglinum* (Le Sueur).
(Text-figs. 49, 50, 51).

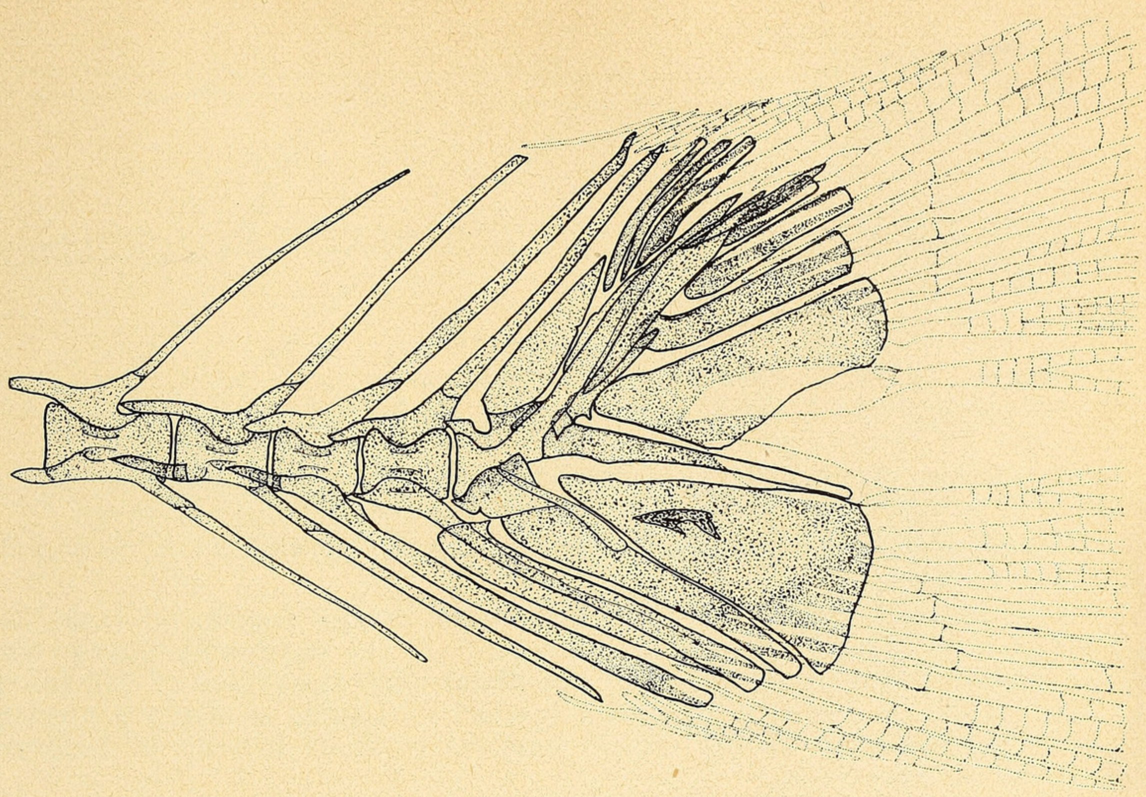
Diagnostic Characters:

7 hypurals.
Small reduced pointed neural on the anterior of the urostyle.
Vertebral Count: 16 + 29 = 45.
3 epurals.
Prolonged bases of two median caudal rays.

Material Studied.

This description is based on five specimens of the following lengths:

No. of specimens	*Length*	*KOH Cat. No.*	*Text-fig. No.*
2	110 mm.	850	
3	75 mm.	849	49, 50, 51



Text-figure 49.
Opisthonema oglinum. Tail of 75 mm. specimen (x 4.3).

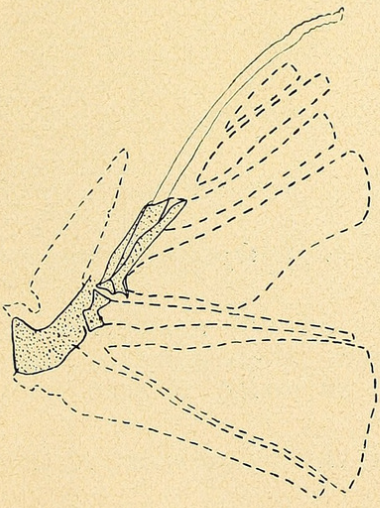
These lengths represent the smallest and largest *Opisthonema* captured during our seven years in the field in Bermuda. The 75 mm. specimens are identical in development with the 110 mm. fish.

Caudal Osteology.

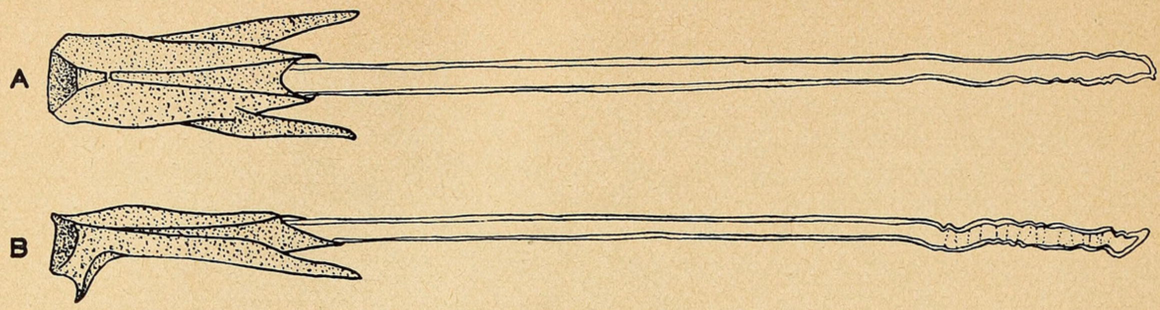
Urostyle Centra: This is very like *Harengula,* as the figures show. The dissection made by removing the superimposed uroneurals shows the adult elements of the urostyle. This condition is probably representative of all the Bermuda clupeids.

Uroneurals: The bones of the second pair of uroneurals are stout and noticeable heavier than those of *Sardinella* and *Harengula.* In other respects there is similarity between the three genera.

Epurals: There are three epurals found in the five specimens examined.



Text-figure 50.
Opisthonema oglinum. Tail of 75 mm. specimen dissected to show structure of the urostyle (x 3.7).



Text-figure 51.

Opisthonema oglinum. Last ossified segment of urostyle with cartilaginous notochord extending. A. View from the top; B. View from the side (x 8.5).

Specialized Neural Process: This stout neural bone is similar to that of *Sardinella* and *Harengula* in relative size and position.

Caudal Fin Ray Count: The count is identical with that of *Sardinella* and *Harengula,* 19/16.

Additional Characters Worthy of Note: In the specimens examined, *Opisthonema* differs from the other clupeids in the noticeably heavier second uroneurals and in the shape of the distal ventral surface of the fourth hypural, which is more or less even instead of having a sharp projecting point. The basal end of the second hypural is blunt instead of hammer-shaped as in *Sardinella.*

3. *Sardinella anchovia* Cuvier and Valenciennes.
(Text-figs. 52, 53).

Diagnostic Characters:

7 hypurals.

Small reduced blunt neural on the anterior part of urostyle.

Vertebral Count: 14 or 15 + 31 or 32 = 46.

2½ or 3 epurals.

Prolonged bases of the median caudal rays.

Material Studied.

Seven KOH specimens have been examined, which range in size from 32 to 135 mm. The caudal pattern is identical in specimens of 50 mm. and larger.

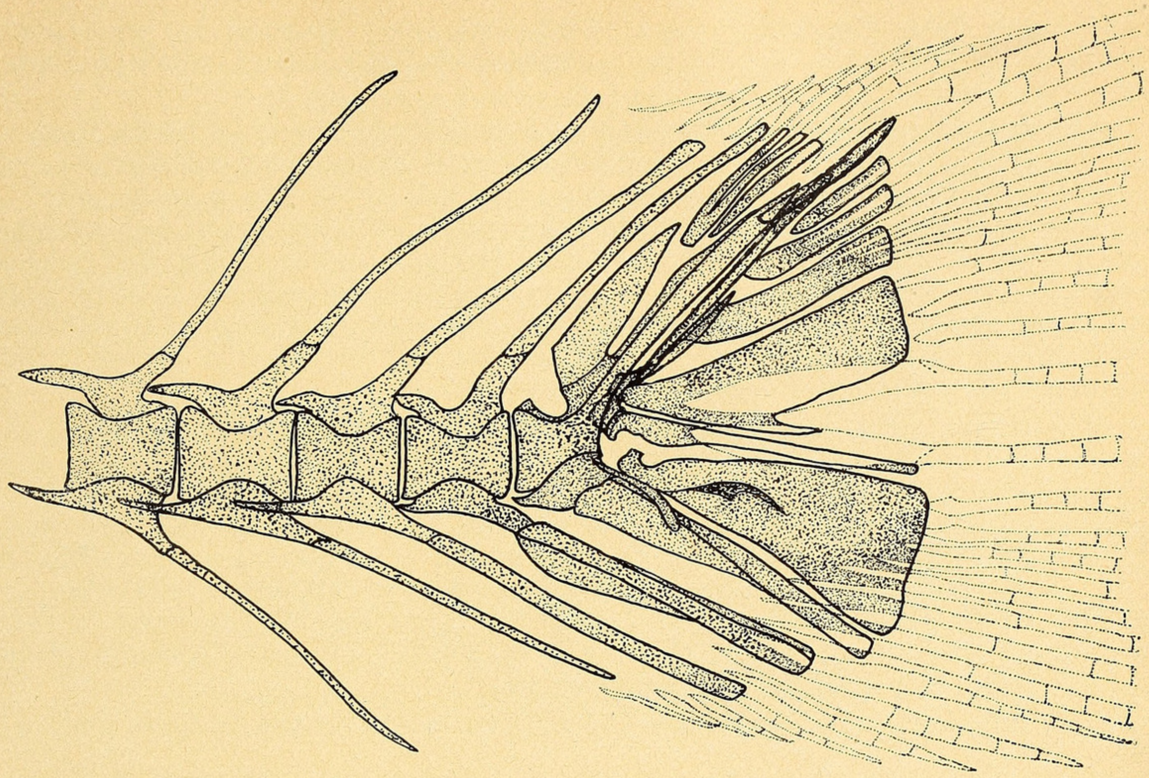
Length	*KOH. Cat. No.*	*Text-fig. No.*
60 mm. 50 mm.	671	52
34 mm. 32 mm.	2112	53

Caudal Osteology.

Urostyle Centra, Uroneurals: Almost identical with *Opisthonema* and *Harengula.*

Epurals: There are three epurals in the 32 and 34 mm. specimens. In the four larger specimens ranging from 50 to 135 mm., there are two and a half, the anterior bone being dorsally bifid. This variation is seen occasionally in *Anchoviella.*

Specialized Neural Process: This bone is almost the counterpart of that seen in *Opisthonema.*



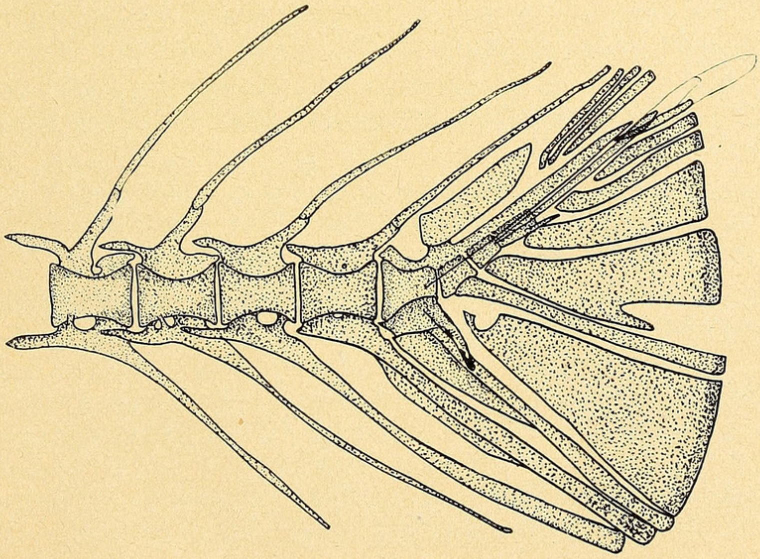
Text-figure 52.
Sardinella anchovia. Tail of 60 and 50 mm. specimens (x 28).

Caudal Fin Ray Count: As in *Opisthonema* and *Harengula,* the caudal count is 19/16.

Additional Characters Worthy of Note: The shape of the ventral distal edge of the fourth hypural differs from *Opisthonema* in that it has a sharp point. The basal end of the second hypural is hammer-shaped and this, too, differs from *Opisthonema.*

SUMMARY.

The following paragraphs correlate the salient similarities and differences found in the study of the caudal skeletons of the Bermuda Isospondyli. According to caudal pattern and characters *Jenkinsia* seems to



Text-figure 53.
Sardinella anchovia. Tail of 34 and 32 mm. specimens (x 16.5).

stand apart from the other Bermuda Isospondyli. Conversely, the three species of clupeids and *Anchoviella* are closely associated by similar patterns and characters.

Hypurals: In the first three families described, Elopidae, Megalopidae, and Albulidae, there is no noticeable deviation of the general pattern of the hypurals from that of *Leptolepis dubius*, which is the most primitive ancestor of the Isospondyli. All the hypurals are long, expanded haemal bones. But in the adults of all the other Bermuda Isospondyli the second hypural lacks the basal part and is a triangular bone with a reduced and free base. However in the few young specimens of *Jenkinsia* available for study the primitive, ancestral, unreduced, second hypural is present and resembles that of adult *Elops, Tarpon,* and *Albula.*

There are nine hypurals in *Elops,* eight in *Tarpon,* and seven in *Albula.* In the first two, where the urostyle is turned up less abruptly and the segments are less consolidated than in the other Bermuda Isospondyli, there are more hypurals. It will be seen in the figures of the key that *Elops* has one more hypural than *Tarpon,* which is numbered 0 (Text-figs. 3 & 4). Also that the dorsalmost hypural which is numbered 8 in *Tarpon* is not present in *Albula. Albula vulpes* and the other species described in this paper have seven hypurals. Hypurals with similar numbers correspond in position in all the specimens. (Text-fig. 5).

The following table correlates the hypural count in the various genera:

	Elops	*Tarpon*	*Albula*	All other Bermuda Isospondyli
Total hypurals	9	8	7	7
Dorsal hypurals / Ventral hypurals	5/4	5/3	4/3	4/3

Epurals: All Bermuda Isospondyli have more than one epural with the exception of *Jenkinsia* which has only one. This is the last bone to become fully ossified in *Jenkinsia.*

Caudal Ray Count: With growth and increase in size the dorsal and ventral raylets change into rays, resulting in a shift of relative numbers of the two elements.

In *Albula* the total caudal count of dorsal 18 and ventral 16 remains constant in specimens ranging from 36 to 560 mm. But the dorsal and ventral raylets diminish from 6 and 3 respectively to dorsal 1 and ventral 1, with a corresponding increase of rays.

Jenkinsia has the smallest caudal count of the Bermuda Isospondyli, which is a total of 26 as opposed to 30 or more in the other species.

The long functional caudal rays are present in *Albula* leptocephali and also in very small *Jenkinsia.* With growth, additional smaller anterior rays and raylets appear.

Prolonged Median Rays: In *Elops, Tarpon* and *Albula* there are no prolonged bases of the two median caudal rays. All the other Bermuda Isospondyli have these bases prolonged.

Ray-scale: The ray-scale which is prominent in *Elops, Tarpon* and *Albula* is less obvious in the remaining Isospondyli.

General Observations: The study of a series of young *Albula* and *Jenkinsia* show that development in the caudal region commences at the posterior extremity and progresses toward the anterior. Segmentation and ossification of the notochord begins in the urostyle region and the hypurals are the first bones to appear. The neural and haemal processes increase anteriorly with growth, the first to appear being near the urostyle. In

Jenkinsia the anterior-ventral hypurals appear first and with increase in size additional dorsal hypurals appear.

In *Albula* and *Jenkinsia* the caudal skeleton becomes ossified when the fish is very small and from this stage the changes that occur during growth are changes of degree and not of kind.

In *Tarpon* and *Elops* the last part to ossify is the area directly above the urostyle. This is filled by a preformed cartilage plate. In our two *Elops* specimens of 258 and 280 mm. there are two round islands of bone within this cartilage which indicate centers of ossification. Regan's specimen has a solid bone.

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