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A Systematic Study of the Pacific Tunas

BY

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AND

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2. INTRODUCTION AND SUMMARY

The classification of the tunas throughout the world has remained unsatisfactory for many years due chiefly to the difficulties involved in comparing large specimens from many localities. On the eastern side of the Pacific are found several species which have not been clearly separated from those of the Western and Mid-Pacific. of these forms four play an important role in the fisheries of California, Mexico and Central America. The present study was undertaken in March 1940, to determine the geographical range of these species and the relationships between them and similar ones occurring in the Central, Western and Equatorial Pacific. This was the first essential step in a comprehensive investigation of the tuna populations supporting the California industry. In particular, it was necessary to explore the differences between the bluefin and the oriental tuna and to know whether or not the yellowfin tuna, the skipjack and the albacore are of the same species as those taken in Japanese and Hawaiian waters. If such proved to be the case additional studies would be required to determine if any intermingling occurred between the populations in the different localities. If on the other hand, the species proved to be distinct the Eastern Pacific population might be exploited without regard to the fisheries of Hawaii and Japan.

The only comprehensive work on the systematics of the Pacific tunas was published by Kishinouye.[1] He found that separation of the various species required a careful study of the anatomy of these fish. To follow the approach laid down in his paper, a similar detailed anatomical treatment of the problem was required to compare those species supporting the California fishery with Kishinouye's descriptions. Although this work appears to be principally morphological, the great detail in which the anatomy of the Eastern Pacific tunas has been studied will form a firm foundation upon which investigations may be extended into lines more directly applicable to conservation.

Concerning the skipjack, this work has demonstrated that within the entire fishing area in the Eastern Pacific extending along the Central and North American coastline from the Equator to California and off-shore to include all the outlying islands, there is but a single species, and specimens from all these areas are furthermore individually indistinguishable from those obtained from Japan and the Hawaiian Islands and described as Katsuwonus pelamis.

In the case of the yellowfin tuna a similar conclusion was reached. A single species, Neothunnus macropterus, exists throughout this fishing area, and these fish are individually indistinguishable from the specimens obtained from the Hawaiian Islands, from Japan and from Peru. Here again the range of the species spans the Pacific and extends southward to Callao, on the Peruvian coast. Within this large area distinct populations may exist, but conclusions concerning this must await the analysis of all the data collected.

[1] Kishinouye, Kamakichi. "Contributions to the Comparative Study of the So-called Scombroid Fishes." Tokyo University. College of Agriculture. Journal, vol. 8, no. 3, 1923.

The albacore obtained from Japan and from the Hawaiian Islands likewise proved to be similar to the fish of the North American coastline. All must be considered of the same species, Thunnus germo, with a geographical distribution extending across the north temperate Pacific. The authors agree with Kishinouye that the albacore belongs in the genus Thunnus, and should not be separated therefrom.

The bluefin tuna from Southern and Lower California are essentially one species,[2] and until adequate descriptions are available from all localities, must be assigned to the same species as Thunnus thynnus of the Atlantic. Similarly, lacking material from Japan with which to compare directly the local specimens, it was necessary to base this comparison upon these findings and Kishinouye's description of Thunnus orientalis. Although very similar to Thunnus thynnus, T. orientalis (the oriental bluefin) as described by Kishinouye, differs in several respects from the local bluefin, and pending a direct comparison it must be concluded, tentatively, that the two are different, and that the local species is limited in distribution in the Pacific to the Eastern, temperate waters.

Lack of time prevented similar studies on the bonito, Sarda velox and S. lineolata, and on the black skipjack, Euthynnus lineatus. It is hoped that these forms may be investigated at some future date. These species are not reported, however, from Mid- and Western Pacific waters and their distribution does not present as great complexities as the other four species mentioned above.

Reports from fishermen and an observation by Kishinouye concerning the occurrence of Parathunnus mebachi, in the Eastern Pacific have been confirmed. This fish is very similar to the yellowfin tuna, but differs from it in outline, in the length of the pectoral and the size of the head and eye. The body and head are deeper than in the yellowfin, the pectoral is longer and the eye is conspicuously larger. For this reason, and because the specific name means, in Japanese, "big-eye," we suggest as a common name for this fish, the "big-eyed tuna." The name is descriptive, and is, moreover, commonly applied by fishermen to this fish. The species was first described by Kishinouye from Japanese waters. Except that it is taken occasionally at the Galapagos Islands and sometimes at Guadalupe Island (Mexico) and in the vicinity, nothing is known of its habitat on this coast. Kishinouye states, p. 444, that it is: "probably widely distributed in the deeper layer of the subtropical region of the Pacific Ocean."

2.1. Objectives

The existing literature does not permit a positive identification of the Pacific tunas. Thus, Jordan and Evermann[3] separate the yellowfin into two species on the basis of the height of the "dorsal and anal lobes," and the length of the pectoral fin. Neothunnus macropterus, with higher dorsal and anal lobes and a longer pectoral, is supposedly abundant

[2] There is a prevailing conviction among many fishermen that a second species of bluefin tuna enters our fishery occasionally. In the course of this work we obtained one fish which differed in a number of significant respects from the remaining bluefin, and it is possible that the above conviction may be correct. Additional data are needed however to decide this question.

[3] Jordan, David Starr, and Evermann, Barton Warren. A review of the giant mackerel-like fishes, tunnies, spear-fishes and swordfishes. California Academy of Sciences. Occasional papers, vol. 12, 1926.

"along the coast of tropical Mexico from Cape San Lucas to the Galapagos * * *," whereas N. catalinae, "* * * the northern representative of Neothunnus macropterus, is like the latter in almost all respects except that the fins are less developed." However, there is no justification for this separation and it is impossible to classify any given specimen on this basis.

Kishinouye's monograph, "Contributions to the Comparative Study of the So-called Scombroid Fishes," contains the most complete descriptions extant of the Pacific tunas. When, however, specimens of yellowfin tuna from the American coast were compared with his description of N. macropterus, a number of important differences were found superimposed upon a general, fundamental similarity. To identify positively the yellowfin of this coast, and thus determine the geographical range of the species, it was necessary to secure specimens from Japan for a direct comparison. The results of this comparison indicated a number of discrepancies in Kishinouye's work. These will be discussed when necessary in the text.

2.2. Scope of Investigation

Specimens of yellowfin tuna, skipjack and albacore were obtained from Japan and the Hawaiian Islands. Specimens of yellowfin tuna only were obtained from Peru. In regard to the origin of these fishes, the Hawaiian specimens were taken in the vicinity of Honolulu, and the Peruvian yellowfin were shipped from, and probably caught in the proximity of, Callao; but of the Japanese specimens it is known only that they were shipped by freight from Japan. This material was compared directly with a large collection of local specimens collected in the course of research trips aboard the "N. B. Scofield" to all parts of the extensive local fishing grounds. All specimens were frozen and retained in cold storage until needed. A comparison of the bluefin tuna from California and from Lower California was also made, and the big-eyed tuna is described for the first time from this coast. Table 1 shows the origin and number of specimens of each species examined, with the identifying code used in the illustrations and throughout the text.

2.3. Procedure

Preparatory to this work a study was made of the literature and in particular of Kishinouye's monograph, and a list of all characters used in the classification of the tunas was compiled. Preliminary dissections of local specimens were then made and characters offering little promise and those not amenable to routine examination were rejected, and others added. The final list was then organized into a procedure standard for the dissection of each species, and a corresponding blank was prepared for every specimen. A reproduction of the forms used is shown in the appendix. The method proved very satisfactory and is heartily recommended because it insures continuity and comparability of observations throughout. The comparisons were made as exhaustive as circumstances permitted, in the hope that this publication might serve as a basis for a thorough and permanent classification of the Pacific tunas.

Foreseeing the necessity of a more detailed population study of some species, a large number of both external and internal measurements and

TABLE 1

The origin of individual specimens and the identifying symbols applied to each. (The two specimens Yf.1 and Yf.2, illustrated in Figure 21, are not included in the above tabulation. These two yellow-fin were taken from a commercial load originating in Lower California waters in order to get visceral views of tuna smaller than any included in the collection. They were used for no other purpose, and are not included in any list.)

Locality	Code	Skipjack=Sk.		Yellowfin=Yf.		Albacore=Al.		Bluefin=Bf.		Big-Eyed Tuna	
		No.	Origin	No.	Origin	No.	Origin	No.	Origin	No.	Origin
Japan	J	1 to 10 incl.	Known only to have been shipped from Japan	1 to 5 incl.	Known only to have been shipped from Japan	1 to 9 incl.	Known only to have been shipped from Japan				
Hawaii	H	1 to 10 incl.	Vicinity of Honolulu	1 to 12 incl.	Vicinity of Honolulu	1 2 3	Vicinity of Honolulu				
Clipperton Is.	Cl.	1 2	ca. 10° 30′ N. 109° 00′ W.	1 2 3	ca. 10° 30′ N. 109° 00′ W.						
Galapagos Is.	G.	1 to 8 incl.	ca. 0° 00′ Lat. 91° 00′ W.	1 to 8 incl.	ca. 0° 00′ Lat. 91° 00′ W.					1	Cape Berkeley, ca. 0° 5′ S. 90° 55′ W.
Cocos Island	C.I.			1 to 5 incl.	ca. 5° 20′ N. 87° 00′ W.						
Peru	P.			1 to 6 incl.	ca. 12° 00′ S. 77° 30′ W.						
Costa Rica	C.R.	1 to 4 incl.	ca. 90° 10′ N. 85° 25′ W.	1 to 5 incl.	ca. 9° 20′ N. 85° 10′ W.						
Punta Galera, Mexico	P.G.			1 to 6 incl.	ca. 15° 55′ N. 97° 40′ W.						
Lower California, Mexico	L.C.	1 to 14 incl.	Coronado Is. ca. 32° 15′ N. 117° 25′ W.	1 2 to 11 incl.	Discarded Natividad Is. ca. 27° 55′ N. 115° 20′ W.			1 2 to 12 incl.	Discarded Guadalupe Is. ca. 29° 00′ N. 118° 10′ W.	2	Guadalupe Is. ca. 29° 00′ N. 118° 10′ W.
Local (W. Coast U. S. A.)						1 to 8 incl. 9 10 11	Vicinity of Columbia River, Oregon. ca. 35° 00′ N. 121° 30′ W. 33° 10′ N. 119° 47′ W.	1 to 6 incl. 7 to 11 incl.	Catalina Is. 1941 ca. 33° 25′ N. 118° 15′ W. ditto 1942		
Totals........	......	48		60		23		22		2	

TABLE 1

The origin of individual specimens and the identifying symbols applied to each. (The two specimens Yf.1 and Yf.2, illustrated in Figure 21, are not included in the above tabulation. These two yellow-fin were taken from a commercial load originating in Lower California waters in order to get visceral views of tuna smaller than any included in the collection. They were used for no other purpose, and are not included in any list.)

counts was added to the routine. These, however, will be reserved for a biometrical analysis in a future publication and not discussed herein. In addition routine sketches were made of every organ system examined and the final illustrations were prepared from these without embellishment. of the five species investigated, a representative specimen from each widely separated area (Japan, Hawaii, local, etc.), was photographed.

3. COMPARATIVE ANATOMY OF THE TUNAS

3.1. External

In general external appearance the five tunas investigated fall into two broad groups. The skipjack alone constitutes one group, and is immediately recognized by its distinctive coloration and markings. The remaining four tunas fall into a second group. All are generally similar in color and appearance,[4] and identification depends upon one or more particular characters which differ in the various species. Even in these cases overlapping variation occurs which sometimes precludes positive recognition. A synopsis of identifying characters will be found at the end of this section.

3.2. Proportional Measurements

Proportional measurements are of little value in the identification of similar tunas, because the proportions change with the size of the fish, and values for the different species overlap extensively. Table 2 shows for comparison the range in some of the body proportions. The manner in which these measurements were made and the procedure followed in meristic counts are described in the appendix.

Similarly the meristic counts are of limited value for specific identification. The following tabulation shows, in the case of the fin-ray counts, that only in the count of the first dorsal spines is any separation of species possible, and then it is only possible to distinguish the skipjack. The combined count of the gill-rakers upon both upper and lower arches is more satisfactory, though even here the ranges overlap in most cases.

3.3. Mouth Parts and Gill Arches

These structures were examined in detail only in the case of the skipjack, and the reader is referred to that section for a description of these parts. In the remaining species observations were limited to a routine count of gill-rakers.

3.4. Viscera

The appearance of the viscera in situ is a valuable identifying character. Figure 1 shows for each species a typical ventral view of the viscera. These and all comparable drawings were made with the walls of the body cavity cut away, exposing the undisturbed viscera to a ventral view from heart to anus. Throughout this publication "right" and "left" are used to refer to the right and left side of the fish, irrespective of the view portrayed. In this view the liver is located in all the tunas at the extreme anterior end of the abdominal cavity. This is the centre

[4] The authors had hoped to reproduce the colored plates by Malmquist appearing in L. A. Walford's "Marine Game Fishes of the Pacific Coast." Unfortunately the cuts for these excellent illustrations were destroyed. The reader is therefore necessarily referred to this volume for an accurate portrayal of the color and markings of the species discussed.

TABLE 2

The range, for the five species, in the various body proportions. The range in size of fish examined is shown in the first line of the table. The manner in which the measurements were made is discussed in the appendix.

Body proportion	Skipjack	Yellowfin	Albacore	Bluefin	Big-eyed Tuna
Range in body length—mm.	443–680	506–1200	540–1006	628–888	569–910
Body length / Head length	3.20– 3.45	3.31– 4.00	3.27– 3.62	3.16– 3.38	3.13– 3.29
Body length / 1st dorsal insertion	2.71– 3.02	2.96– 3.55	2.86– 3.14	2.91– 3.13	2.96– 3.05
Body length / 2d dorsal insertion	1.54– 1.64	1.76– 1.98	1.64– 1.72	1.68– 1.77	1.73– 1.74
Body length / Anal insertion	1.43– 1.51	1.57– 1.75	1.51– 1.58	1.49– 1.56	1.54– 1.56
Body length / Ventral insertion	2.89– 3.16	2.99– 3.56	2.85– 3.13	2.84– 3.02	2.74– 2.89
Body length / Body depth	3.43– 4.55	3.50– 4.09	3.61– 4.26	3.30– 3.73	3.35– 3.53
Body length / Body width	4.64– 6.21	5.20– 6.20	5.00– 5.72	4.92– 5.69	5.03
Body length / Dorsal-ventral distance	3.79– 4.77	3.64– 4.35	3.83– 4.42	3.53– 3.85	3.70
Body length / Dorsal-anal distance	2.29– 2.61	2.45– 2.69	2.41– 2.61	2.32– 2.48	2.47
Body length / Length 1st dorsal base	3.19– 3.71	3.88– 4.30	3.50– 3.87	3.65– 4.01	3.86
Body length / Pectoral length	5.84– 7.70	3.11– 4.21	2.16– 3.00	4.84– 5.95	2.59
Body length / Height 1st dorsal	6.08– 7.28	7.54–10.61	8.47–10.46	8.38–11.00	8.58
Body length / Height 2d dorsal	9.33–13.58	5.39–10.17	9.42–11.25	9.70–10.16	8.05
Body length / Height of anal	8.97–13.22	4.43–11.76	8.09–12.72	9.31–10.63	8.20
Body length / Length 2d dorsal base	9.71–14.50	8.57–12.41	8.31–12.02	8.49–11.15	9.68
Body length / Length of anal base	------------	9.89–14.68	10.80–13.90	9.23–13.85	12.82
Body length / Spread of caudal	3.35– 4.32	3.27– 3.97	3.05– 4.17	3.64– 3.93	3.27
Head length / Diameter of iris	6.05– 8.08	5.57– 8.56	5.33– 6.26	6.93– 8.14	6.76
Head length / Maxillary length	2.53– 2.79	2.46– 2.67	2.54– 2.81	2.42– 2.58	2.66

TABLE 2
The range, for the five species, in the various body proportions. The range in size of fish examined is shown in the first line of the table. The manner in which the measurements were made is discussed in the appendix

TABLE 3

Fin-ray counts by species

	First Dorsal Fin					Second Dorsal Fin			Dorsal Finlets			Second Dorsal plus Dorsal Finlets				Anal Fin			Anal Finlets			Anal Fin plus Anal Finlets		
Count	12	13	14	15	16	14	15	16	7	8	9	21	22	23	24	14	15	16	6	7	8	21	22	23
Skipjack	--	--	--	36	5	3	34	2	4	38	--	1	4	32	1	2	37	1	1	40	1	2	36	1
Yellowfin	2	20	37	--	--	3	53	2	--	56	3	--	--	56	2	54	5	--	--	3	56	--	56	2
Albacore	--	4	19	--	--	--	5	15	17	6	--	--	1	19	--	3	20	--	--	21	2	1	22	--
Bluefin	1	4	17	--	--	--	22	--	--	20	2	--	--	20	2	3	18	--	--	19	3	1	19	1
Big-Eyed Tuna	--	--	2	--	--	--	2	--	--	2	--	--	--	2	--	2	--	--	--	--	2	--	2	--

TABLE 3
Fin-ray counts by species

TABLE 4

The frequency of occurrence of the gill-raker counts by species on upper and lower limbs, separately and combined

Upper limb

Gill-rakers	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Skipjack	----	----	----	----	----	----	----	----	----	1	----	6	21	6	4	1
Yellowfin tuna	----	4	23	26	7	----	----	----	----	----	----	----	----	----	----	----
Albacore	----	7	15	1	----	----	----	----	----	----	----	----	----	----	----	----
Bluefin tuna	----	----	----	1	1	13	6	1	----	----	----	----	----	----	----	----
Big-eyed tuna	1	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Lower limb

Gill-rakers	19	20	21	22	23	24	25	35	36	37	38	39	40	41	42	43
Skipjack	----	----	----	----	----	----	----	2	1	4	10	6	7	6	2	1
Yellowfin tuna	4	14	35	7	----	----	----	----	----	----	----	----	----	----	----	----
Albacore	2	16	5	----	----	----	----	----	----	----	----	----	----	----	----	----
Bluefin tuna	----	----	2	3	10	6	1	----	----	----	----	----	----	----	----	----
Big-eyed tuna	2	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Combined count on upper and lower limb

Gill-rakers	26	27	28	29	30	31	32	33	34	35	36	37	38	39	53	54	55	56	57	58	59	60	61	62	63
Skipjack	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	1	6	6	5	4	8	1	4	1
Yellowfin	--	1	3	7	20	22	6	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Albacore	--	1	5	13	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bluefin	--	--	--	--	--	--	2	1	1	9	5	3	--	1	--	--	--	--	--	--	--	--	--	--	--
Big-eyed tuna	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 4

The frequency of occurrence of the gill-raker counts by species on upper and lower limbs, separately and combined

lobe which abuts against the posterior tip of the heart, and with the caecal mass conceals the anterior portions of the alimentary canal. The stomach, intestine, in most cases the spleen and frequently the gall-bladder complete the list of organs generally seen. Whereas there is considerable variation in the organs of fish of the same species, illustrated in the specific sections, there is nevertheless a fundamental specific pattern so constant that a positive identification of any fish is easily made, based upon this view alone. In the skipjack the centre lobe of the liver is distinctively shaped and without surface markings; the intestine is straight, without convolutions, and the spleen is not seen. In the big-eyed tuna the liver is marked peripherally with fine striations; the intestine is folded and the spleen is almost entirely hidden. In the yellow-fin the liver is regular in shape, quite different from the skipjack, and without surface markings; the spleen is conspicuously located, usually to the right of the median line and of characteristic shape and the intestine is folded as in the big-eyed tuna. The two species of Thunnus are readily identified by the prominent, radiating striations on the liver. In the bluefin the fold of the intestine is long, lying usually on the median line, and the spleen is larger than in any other tuna. In the albacore the spleen is small and it is invariably located on the left side. The fold of the intestine is short and the course of the intestine differs from that of any other tuna. It crosses from the right side, anteriorly, to the left, running posteriorly always on the left side of the abdominal cavity. The gallbladder is conspicuous only in this species, adhering to the intestine.

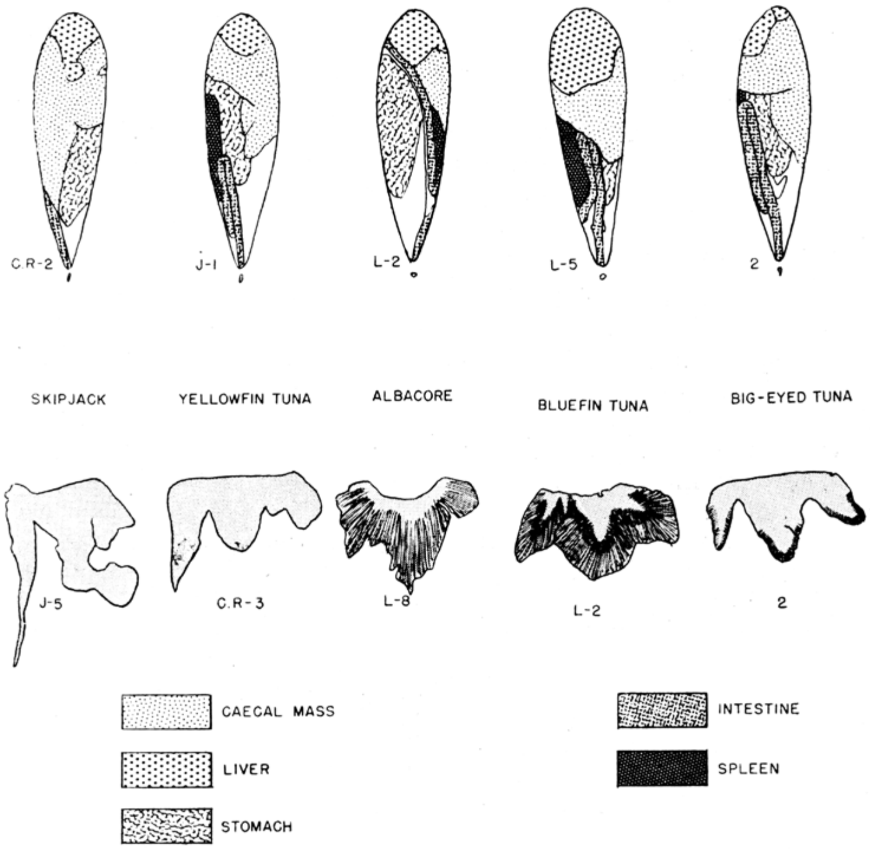

FIGURE 1. Ventral view of the viscera, *in situ*, above. Ventral view of the excised liver, below.

FIGURE 1. Ventral view of the viscera, in situ, above. Ventral view of the excised liver, below

3.5. Caecal Mass

The caecal mass is a large organ lying in the anterior portion of the abdominal cavity. It is roughly triangular in ventral view, with the base anteriorly and the apex posteriorly. When dissected out it has the approximate shape of a "Y," the arms of which partially encircle the stomach in its anterior region and are accordingly not seen in ventral view. The caecal mass consists of myriads of tubules (pyloric caecae) enclosed within a membrane as a unit. These tubules open into the duodenum by a number of compound, collecting ducts, the number of which, though relatively constant, is difficult to count. No detailed examination of the caecal mass was attempted.

3.6. Liver

The liver in the tunas investigated consists typically of three lobes. A view of the excised liver from each of the five species is shown in figure 1. Whereas the extent and form of the different lobes varies considerably, either the centre or the right lobe is the longest, depending upon the species. In the yellowfin, skipjack and big-eyed tuna the right lobe is the longest. The liver of the skipjack is easily identified by its attenuated right lobe, the lobulated centre lobe and the absence of surface markings. That of the yellowfin and big-eyed tuna are similar in shape, but the liver of the latter is marked peripherally with faint striations, whereas there are no markings on the liver of the yellowfin. In the genus Thunnus, the centre lobe is the longest and the livers in both species are similarly marked with conspicuous, radiating striations. However the liver of the bluefin is more regular in shape and less extensively lobulated than that of the albacore.

3.7. Alimentary Canal

The stomach is largely concealed by the caecal mass, and generally the posterior portion only shows in ventral view. In all tunas the stomach is proportionately longer in small fish, and considerable variation in its length was found in all species. The apex of the stomach lies generally on the same side in the majority of specimens of a given species, but not with sufficient regularity to be of any systematic value.

The intestine arises from the anterior ventral wall of the stomach and, as the duodenum, curves anteriorly to form a loop and then runs posteriorly, with or without convolutions, to the anus. The various portions of the intestine are named arbitrarily as in figure 2, which shows the course of the alimentary canal in the yellowfin tuna. The names applied to the various portions throughout this text are defined as follows. The duodenum is the extreme anterior portion of the intestine from its origin in the stomach to that point where it turns posteriorly. As used herein, this term includes the pyloric region. The ducts from the caecal mass empty into the duodenum. The straight intestine is that portion between the duodenum and the point, called the posterior bend, where the intestine bends forward upon itself to run anteriorly again. The intestine, in most cases, runs anteriorly a variable distance and

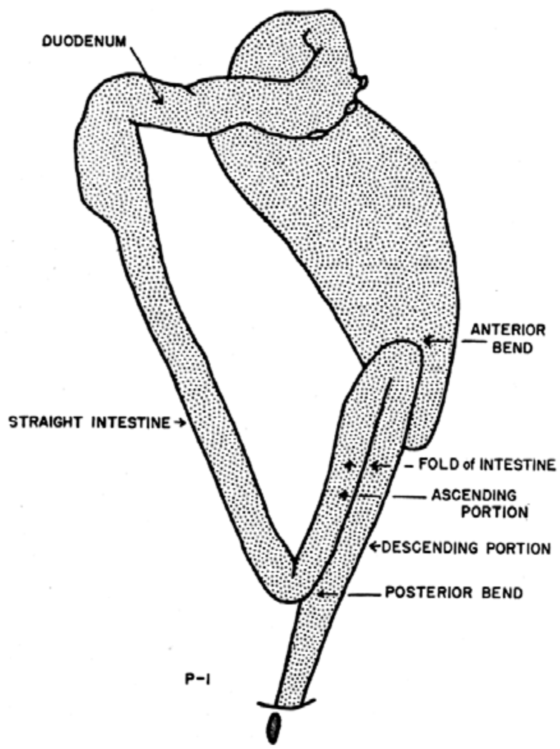

FIGURE 2. Ventral view of the alimentary canal of the yellowfin tuna

then bends abruptly backwards. This second bend is the anterior bend of the intestine and the region between anterior and posterior bends is termed the ascending portion. From the anterior bend the intestine runs straight and directly back to the anus. This portion is called the descending portion. Although it consists largely of the rectum, no attempt was made to distinguish the latter from the intestine proper.

The descending portion is closely associated with, and adherent to the ascending portion. These two parts, making up the convolution of the intestine, are referred to as the fold of the intestine.

The course of the intestine and the extent of the convolutions are characteristic of the species. The skipjack is the only species in which the intestine is straight, having no fold. The albacore is equally distinctive because in this species the intestine has a short fold and crosses the abdominal cavity anteriorly from right side to left. In the yellowfin and big-eyed tuna the intestine is similar, but the fold appears longer in the latter. In the bluefin the fold is long, and the straight intestine is separated from the ascending portion by the width of the large spleen.

3.8. Spleen

The spleen is a dark red, conspicuous organ in the majority of these tunas. In all, the spleen is attached to the straight intestine, and in most to the ascending portion also. In the majority of cases it lies ventral to the intestine, but in the skipjack and in the big-eyed tuna it is dorsal to the intestine and thus hidden in ventral view. The head, or anterior portion of the spelen, is in some cases attached to the right lobe of the liver. In shape, size and location the spleen is distinctive in each species, but this distinctiveness depends upon its relation with other organs, and is discussed under the heading "viscera."

3.9. Gall-bladder

The gall-bladder is a long, tubular sac attached to the straight intestine. In four species the gall-bladder is hidden in ventral view by the intestine, and in three of these species only the posterior extremity is seen projecting freely beyond the posterior bend of the intestine. This projection of the gall-bladder is frequently attached by a membrane to the adjacent portion. In the albacore only, is the gall-bladder conspicuous, for in this species it is seen in ventral view throughout its greatest extent attached to and accompanying the intestine across the abdominal cavity.

3.10. Air-bladder

An air-bladder is present in four of the five species investigated, being absent in the skipjack. It is always located in the anterior portion of the abdominal cavity, extending a variable distance posteriorly, and always adherent to the dorsal wall of this cavity. Anteriorly it abuts against, or approximates to, the transverse septum, and its head, or anterior end, is frequently embedded in a characteristic pit or depression in the substance of the kidney. This pit extends to and thus exposes the adjacent vertebrae, and its shape, size and location are characteristic of the species. In the bluefin there is no pit. In the albacore the pit is large and exposes the sixth, seventh and eighth vertebrae. In the yellowfin the pit is small but deep and ventral to the sixth vertebra. In the big-eyed tuna this pit is intermediate in size but shallower than in the yellowfin, exposing the sixth and seventh vertebrae. When present, this pit is always divided into two symmetrical halves by the dorsal aorta, and this in turn results in a central, longitudinal cleft in the head of the air-bladder. In the albacore this cleft is shallow and superficial, deeper in the big-eyed tuna and conspicuous in the yellowfin. The shape of the air-bladder, although quite variable, is also characteristic.

A peculiar feature of the air-bladder was noted in all the tunas. When the ventral wall of this organ is opened there appears in the anterior half a large circular orifice in the membrane which apparently constitutes its dorsal wall. This orifice opens into a deeper (more dorsal) chamber which projects posteriorly to or beyond the posterior margin of the air-bladder proper. The lateral anterior margins of this chamber are distinct but posteriorly they become very obscure and in many cases it is quite impractical to determine where this chamber stops. The lateral walls converge, and the chamber tapers until one is reduced to separating the two membranes composing its floor and roof, without at any point finding the termination. For this reason the projection of the deeper chamber is not included in the measured length of the air-bladder. This structure is referred to as the circular orifice, and the membrane in which it is located as the internal septum. Kishinouye describes and figures it for T. orientalis, only.

Although the air-bladder is a useful specific character it is characterized by extreme variability, and abnormalities are of such frequent occurrence as to suggest instability in this organ. In all cases there is a fundamental specific pattern which, with experience, can be plainly recognized, but there is the suggestion in abnormal cases of atrophy of all or parts of the air-bladder. The head, or anterior end, is most frequently affected, and in both the yellowfin and in the albacore this portion is frequently collapsed and shrivelled, so that it lies loosely in the abdominal cavity without reaching or occupying the pit into which it is normally inserted. In the bluefin the air-bladder has apparently degenerated still further.

3.11. Excretory System

The kidney is an extensive organ lying predominantly in the thoracic region ventral to the vertebral column. Anteriorly it extends as a narrow tongue of tissue almost to the base of the skull. In the region of the heart the kidney expands laterally and extends ventrally on either side for a considerable distance in the lateral body wall. Within this expanded portion lies the pit of the air-bladder, when such is present. At the extreme anterior end of the abdominal cavity the kidney again becomes reduced in width, and in the majority of species it continues posteriorly a variable distance as a median wedge of tissue embedded in the dorsal wall of the abdominal cavity.

Those portions of the kidney anterior to the pit of the air-bladder and in the lateral wall of the thoracic region were not investigated. Observations were confined to the posterior portion only, and in particular to the posterior projection in the dorsal wall of the abdominal cavity. The extent of this projection was measured, and its shape recorded because this portion of the kidney differs strikingly in some species. In the skipjack and in the yellowfin the posterior projection is long. The outline of this portion is crenulated in the skipjack and more regular in the yellowfin. In the bluefin and big-eyed tuna there is a short, triangular projection of kidney tissue, the two species being similar in this respect. The albacore is distinctive inasmuch as the kidney tissue ends in a short transverse margin at the posterior edge of the pit of the air-bladder.

The extent of the posterior projection of kidney tissue determines the course of the ureter. Following this structure anteriorly from the urinary bladder, it will be found just dorsal to the peritoneum in the dorsal wall of the abdominal cavity. It runs along the median line until it reaches the posteriorly projecting tongue of kidney tissue. At this point, usually shortly after entering the kidney, it divides and the two branches run together anteriorly, each paralleling the respective outline of this tongue of tissue. As the kidney mass widens anteriorly the ureters gradually separate until, reaching the expanded portion about the oesophagus, they turn more or less abruptly outward to serve this extended region. Beyond this they ramify extensively and were not subsequently followed. Throughout their course within the kidney they receive numerous collecting tubules.

In the skipjack and yellowfin where there is a long posterior projection of kidney tissue, the two ureters run together for a considerable distance, diverging gradually. The division of the ureter occurs earlier in the skipjack and the two branches run parallel for a greater distance than in the yellowfin. In the albacore there is almost no posterior kidney mass and in consequence the ureter divides in a wide angle and the two branches separate immediately. The bluefin and big-eyed tuna are similar in this respect and occupy a position intermediate between the extremes.

The urinary bladder is a relatively inconspicuous organ located at the posterior end of the abdominal cavity and opening to the exterior through an aperture which is near the posterior rim of the cloaca-like vent. In the skipjack, albacore and bluefin the bladder is embedded throughout its length in the median, dorsal wall of the abdominal cavity, whereas in the yellowfin and big-eyed tuna the anterior end projects freely into the cavity attached only to the rectum.

The ureter joins the median dorsal wall of the urinary bladder at or near its anterior end. In some cases the ureter opens directly into the bladder at this point, but in others the ureter may continue posteriorly a short distance in the dorsal wall of the bladder and open into it posterior to the point of attachment. This is not apparent until the bladder is opened ventrally.

3.12. Circulatory System

According to Kishinouye the blood-vascular system of the tunas is in many respects unique, and it is the basis of his separation of these fishes into the order Plecostei. Within the order Kishinouye enumerates striking differences between species and genera, and uses many such differences in his classification of the tunas.

Observations were confined largely, but not exclusively, to the arterial system, and the portions examined are conveniently grouped under four headings. Those features common to all the tunas will now be described, and omitted as far as possible in the subsequent specific sections. An arterial injection was necessary in all cases, and portions of the venous cutaneous system were also injected. The larger veins, however, can be easily followed without this aid. The injection technique is described in the appendix.

I. *Anterior Arterial System.* This includes the dorsal aorta from its origin anteriorly to the point where it enters the haemal canal, the vessels arising from the aorta and the structures associated with them in this region.

The dorsal aorta originates as the result of the fusion of the two short anterior epibranchials, each of which results from the union of the first and second efferent branchial on each side. This point, i.e., the origin of the aorta, is referred to throughout this publication as the "Y" of the aorta, and within narrow variational limits its location is constant for each species. Immediately posterior to this point (within the length of one vertebra) the united third and fourth efferent branchials join the aorta on each side as a pair of very short posterior epibranchial arteries. Posterior to this, again within the length of a single vertebra, the large unpaired coeliac-mesenteric artery originates, always on the right side. It subsequently divides into two or three major branches which nourish the entire viscera. Dorsal or slightly posterior to the origin of the coeliac-mesenteric artery a pair of small subclavian arteries originates of which one runs principally to the pectoral fin on each side. Partially encircling the aorta at this point is a peculiar ligament, found in all the tunas. This ligament, from an anterior but undetermined origin, runs posteriorly and passes ventral to the aorta and just posterior to and touching the coeliac-mesenteric and subclavians; then it turns forward again and runs towards the occipital region on the opposite side. It is a small weak ligament and is almost transparent, but it was found with such regularity that it was recorded in each instance, and it is casually referred to in the specific descriptions as "the ligament."

At a varying distance of one to three vertebrae (depending upon the species) posterior to this ligament, a large cutaneous artery arises on each side. Its course may be perpendicular to the aorta, or it may be inclined posteriorly in a gentle curve, but in either case it runs laterally towards the pectoral fin through the kidney tissue. Posterior to the cutaneous arteries the dorsal aorta disappears into the kidney tissue and thence enters the haemal canal.

The arrangement of the various vessels and structures enumerated and their orientation with reference to any particular vertebra differs considerably in the several species, and considering this entire region as a single character, it suffices to differentiate, in one or more respects, any species from the remaining four. The yellowfin and big-eyed tuna are distinguished by the fact that the cutaneous arteries originate ventral to the seventh or eighth vertebra, whereas in the skipjack, bluefin and albacore they originate ventral to the fifth vertebra. The yellowfin differs from the big-eyed tuna—and from all others—in the possession of a pair of parallel arterial trunks, which are described in the specific section. The skipjack is separated from the bluefin and albacore by the fact that its cutaneous arteries are small and pass laterally perpendicular to the aorta. In the bluefin and albacore the cutaneous arteries are large and they incline posteriorly at their origin in a gentle curve. The shape of the kidney and the presence of the pit of the air bladder in the albacore differentiates these two species.

Included under this heading is a pair of pharyngeal muscles, found in all species. As their vertebral attachment differs in some cases, they supplement the differences described. They are included here because they were observed simultaneously with the anterior arterial system.

II. *Visceral Arterial Circulation.* The large coeliac-mesenteric artery originates in the dorsal aorta, curves posteriorly at its origin around the right pharyngeal muscle and shortly thereafter divides either into two or three main branches, the number characterizing the species. There are three main branches in the skipjack, yellowfin and big-eyed tuna, and only two in the albacore and bluefin. For lack of adequate names, and following the precedent of Kishinouye, these branches will be consistently designated throughout this publication the number I, the number II, and the number III branch. The numbering proceeds in accordance with the origin of the branch. Thus, the No. I branch is the one that arises nearest the median line, the No. II is the middle branch and the No. III is the branch originating laterally. It is the No. I branch that is sometimes missing. The three branches originate at the same point, the No. I and No. II branches frequently originating from a short, common trunk.

The No. I branch is always the smallest and least complex. It arises with the other branches just posterior to the pharyngeal muscle, turns towards and crosses the median line of the fish and runs to the left side through the musculature of the dorsal wall of the oesophagus which it nourishes. Entering the body cavity, it nourishes mainly the left dorsal wall of the stomach, and sometimes the left gonad. In those species in which it is lacking, a minute vessel is sometimes seen nourishing the wall of the oesophagus, but because this originates directly from the trunk prior to the major division of the coeliac-mesenteric artery, it is not homologous to this branch.

The No. II branch passes dorsal to the right Cuvierian duct into the abdominal cavity and goes directly to the right lobe of the liver. This it always nourishes, in some cases with individual vessels, and in other species with a peculiar and complicated vascular plexus. Beyond this it continues and various branches of it nourish the air-bladder, spleen, portions of the intestine, gall-bladder and the right dorsal wall of the stomach.

The No. III branch is perhaps the largest. Accompanying the No. II branch it passes dorsal to the right Cuvierian duct into the abdominal cavity. Entering this it turns ventrally and runs to the centre lobe of the liver. Here it divides, sending usually a moderate branch to the left lobe of the liver. The centre and left lobes of the liver are thus supplied with arterial blood by the No. III branch of the coeliac-mesenteric artery. As in the right lobe, this supply may be carried by a few distinct vessels or by a complex vascular network which characterizes some species. The branch through the centre lobe emerges therefrom and in all cases nourishes the caecal mass and the ventral wall of the stomach to its posterior tip. In some species it also sends a tributary to the rectum. The branch to the left lobe after nourishing that organ emerges and runs to the anterior caecal mass on the left side, and a branch frequently runs the length of the stomach on its left dorsal face to its posterior tip.

This description is general and applies to all species. Superimposed upon this are a few important characters which were particularly observed because they differentiate the species.

In the bluefin and in the big-eyed tuna the No. III and No. II branches are joined by a small to moderate connecting vessel as these two branches enter the centre and right lobes of the liver respectively. This vessel is absent in the skipjack, in the yellowfin and in the albacore.

A further striking difference in these tunas is the extent to which the branches of the coeliac-mesenteric artery break up in the substance of the liver. In the extreme case, the genus Thunnus, the two branches of this artery give rise to a remarkable and complex vascular plexus. Upon reaching the liver each branch gives off myriads of minute vessels which run directly to and ramify throughout the substance of the respective lobes. A transverse section of the liver of an injected specimen resembles in structure the cross-section of a rope, in that the liver is literally composed of these minute strands. Some of these vessels reach the ventral surface of each lobe and result in the conspicuous and characteristic striations of the liver which constitute one of the most striking features of the bluefin and albacore.

Beneath (dorsal to) each lobe in the above cases are a number of large cone-shaped vascular masses, consisting (apparently) entirely of minute blood vessels within an enveloping membrane. These cones result from the progressive and ultimate break-up of the branches supplying the three lobes of the liver. The innumerable vessels into which each branch breaks up are assembled within one or more conical membraneous sacs, the bases of which are apposed to the distal portion of that diminishing branch. It is the vessels emerging from the apex of these cones that supply the visceral arterial circulation described above. In some cases this supply is via bundles of minute vessels, whereas in others the picture suggests that the minute vessels have converged and fused into a few larger ones which run as distinct arteries to the various organs.

In passing it should be stated that the above remarks apply in full to the venous circulation also. A vein runs with each visceral artery and breaks up within the conical vascular sacs as described for the arteries. Within the liver also the veins take part in the vascular complexity, and the superficial striations are venous as well as arterial. This was shown by a venous injection, although no routine examination was made of the visceral venous system.

At the other extreme are the skipjack and yellowfin, in which the branches of the coeliac-mesenteric artery pass directly through the substance of the liver without any plexus formation. Here the liver is nourished by a few discrete vessels from those branches which can be followed continuously to the various visceral organs. Between these extremes is the big-eyed tuna, in which there is a slight or partial plexus formation. Accordingly, this character serves as an additional generic one.

The peculiar differences in the visceral arterial circulation discussed above were regularly observed in all specimens, and may be regarded as specific or generic characters. With regard to the terminal course of the visceral vessels, depicted in the sketches and detailed descriptions, it should be emphasized that the accuracy of these descriptions is limited by the varying difficulty of injection and by the normal variation to be expected in such a system. For this reason the details of this portion of the system are of no great systematic value.

III. *Cutaneous System:* From its origin in the dorsal aorta each cutaneous artery runs laterally through the kidney tissue towards the surface, emerging in the superficial musculature just posterior to the pectoral insertion. At some point within this distance each artery divides into two, and the two branches run posteriorly, roughly parallel, on either side of the lateral median line to the region of the caudal peduncle, separated by the width of the dark flesh of the lateral median line (the zone separating the dorsal and ventral musculature of the body).

Throughout its course each cutaneous artery gives rise to a segmental artery to each body segment which it traverses. Dorsal cutaneous arteries give off dorsal segmentals, which run towards the mid-dorsal line, and ventral cutaneous arteries give rise to ventral segmental arteries which run towards the mid-ventral line. In both cases the segmentals incline posteriorly, curving gently backwards.

In addition to the segmentals, each cutaneous artery gives rise to one or two continuous rows of small arterioles which run into and nourish the dark flesh of the lateral median line. A vascular sheet arising from this row of arterioles also appears to separate the dark from the light flesh in this region. These arterioles are in most cases numerous, but their frequency of origin decreases posteriorly, in which region they often become more irregular. Throughout they may originate in one or more distinct rows, the arrangement being characteristic of the species.

Associated with each cutaneous artery is a corresponding cutaneous vein, which, like the artery gives rise to a segmental vein (dorsal or ventral) to each segment of the body, and one or more continuous rows of venules corresponding to and intimately associated with the row of arterioles. A segmental vein flows together with a segmental artery, and in all species the vein is generally but not invariably anterior to the artery. Throughout their course in the surface musculature, the cutaneous arteries, though adherent to the veins, are a trifle deeper, and they always run on that side of the vein nearest the lateral median line. The sketches clarify this statement, but to avoid any subsequent confusion it is advisable to define the terms to be used.

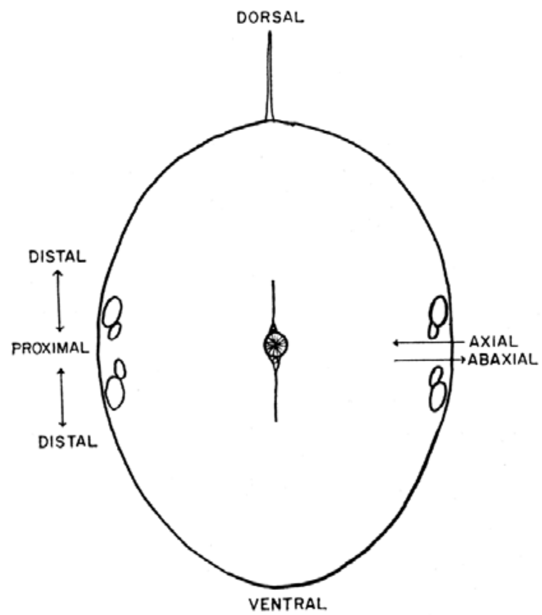

FIGURE 3. Diagrammatic cross section of a tuna to illustrate the location of the cutaneous vessels and the definitions of terms

The word "proximal" is used to denote that direction, in the vertical plane of the fish, towards the lateral median line. The opposite of this direction, *i.e.,* away from the lateral median line in the vertical plane is implied by the term "distal."

The word "axial" is used to denote that direction, in the horizontal plane of the fish, towards the vertebral column. The opposite direction, *i.e.,* away from the vertebral column, in the horizontal plane, is implied by the word "abaxial" (Fig. 3).

The above restricted definitions apply only to the description of the cutaneous system, and if these terms are used elsewhere in the text, their generally accepted meaning is to be inferred.

In some species the dorsal and ventral branch of the cutaneous artery fuse in the lateral median line in the superficial musculature on the caudal peduncle. This junction is called the "posterior commissure," and the term is extended to include a similar fusion, or division, of the corresponding cutaneous vein at the same point. Inasmuch as the posterior course and ultimate destination of the cutaneous vessels differ in almost every species, the presence or absence of this posterior commissure is frequently mentioned. Similarly, a fusion of the dorsal and ventral cutaneous veins in the region of the pectoral insertion is referred to as the "anterior commissure," and this term is used when necessary for the corresponding division at this point of the cutaneous arteries. A posterior arterial commissure is always associated with, and accompanied by, a posterior venous commissure, and this is always implied unless the contrary is expressly stated.

The posterior venous commissure, when present, is connected to the caudal vein by a short horizontal venous trunk running directly inwards, perpendicular to the surface of the fish. The corresponding arterial trunk is usually though not invariably divided, with one branch adhering to the anterior face of the vein and the other to its posterior face, so that the vein is sandwiched between two arterial strands.

The emphasis on a posterior commissure in this publication is due in part to a discrepancy in Kishinouye's text, wherein the author states that this commissure is found in all species of the family Thunnidae, and hence regards it as a family character. In the course of this work it was discovered that a typical commissure, such as he figures, is found in only the yellowfin. In place of this commissure in the remaining forms, the cutaneous vessels terminate differently and characteristically in each species.

Within the cutaneous system constant and characteristic differences occur in the several species. The course of the cutaneous arteries at their origin in the aorta may be perpendicular to the latter, or they may curve posteriorly. The point of division into dorsal and ventral branches occurs usually near the surface, but in the case of the skipjack each artery divides invariably deep within the substance of the kidney. On each side the cutaneous artery passes laterally between specified ribs, and these differ in the different groups. In the skipjack the dorsal cutaneous vessels pass laterally between the first and second ribs, and the ventral branches pass anterior to the first rib. In the yellowfin and big-eyed tuna, vein and artery pass between the fifth and sixth ribs, and in the bluefin and albacore they pass between the third and fourth ribs. Similarly the artery of each side usually divides as it passes between the intermuscular bones, and the particular bones between which this division occurs differ in the various species. In the yellowfin and big-eyed tuna the division occurs between the sixth and seventh intermuscular bones, and in the bluefin and albacore between the fourth and fifth. The course of the cutaneous vessels on the surface differs. The origin and arrangement of the arterioles and venules differ, and finally the terminal course of the cutaneous vessels on the caudal peduncle differs radically in almost every species.

Post-cardinal Vein: The tunas investigated fall into two groups, according to whether a post-cardinal vein is present or absent. This portion of the system was segregated for separate discussion because of the association of the cutaneous veins with the post-cardinal vein when this is present. In the genus Thunnus, the post-cardinal is wanting, and in the three remaining species its course and degree of development differ.

The post-cardial vein emerges anteriorly through the first haemal arch in the yellowfin and big-eyed tuna, and through the third haemal arch in the skipjack. It is always a conspicuous and sometimes a remarkably large vessel. From the haemal canal it runs anteriorly and curves always towards the right side of the fish, where it usually joins, or is joined by, the right cutaneous vein, and flows thence to the right Cuvierian duct. In the skipjack there is no connection between the post-cardinal vein and the cutaneous veins. In the yellowfin the right cutaneous vein empties into the post-cardinal, and the left cutaneous vein sends part of its supply to the post-cardinal and the remaining blood directly to the left Cuvierian duct. In the big-eyed tuna the post-cardinal terminates in the right cutaneous vein which continues to the right Cuvierian duct, and the left cutaneous vein empties directly into the left Cuvierian duct. A post-cardinal is absent in the bluefin and albacore, and the cutaneous vein on each side empties into the corresponding Cuvierian duct.

A peculiar feature noted in the post-cardinal vein and the largest veins in all species was the presence of a delicate perforated membrane at those points where one large vein joined another. Thus, in the yellowfin tuna, where the right cutaneous vein empties as a large vessel into the equally large post-cardinal, the actual opening of the cutaneous vein is seemingly closed at this point by a fine perforated membrane. In the genus Thunnus, the cutaneous veins are similarly, and in a more complicated manner, closed at their junction with the Cuvierian ducts, so that it could be maintained that these veins do not empty directly into the latter vessels, as described. To determine the precise relationship here, one would be compelled to make an extremely careful and painstaking investigation of all the numerous tributary vessels and their interrelationships. This was not attempted, and the above statements are based upon the gross dissections, ignoring the detailed complexity which undoubtedly exists in this genus, as a result of these peculiar membranes.

Another peculiar feature about the larger veins is the extent to which their walls are supplied with arterial capillaries, which literally enmesh the walls of the largest veins, with the result that their course is easily followed in an arterially-injected specimen.

3.13. Skeleton

The skeletal elements in the Thunnidae are remarkably alike in all species examined, and many of the bones from different species are indistinguishable. Minor differences between species noticed at the beginning of the investigation were subsequently found to overlap in their variation. Therefore it is our belief that the skeletal elements offer less promise for specific identification than other anatomical parts. The bones of the cranium and spinal column provide the most useful characters for the identification of a species. In each specific section the most characteristic bones are described first and this is followed by supplementary bone characters which will further assist in the identification.

All species of the Thunnidae were readily distinguished from the skipjack.[5]

In the preliminary investigation the following bones in the five species were compared simultaneously:

vomer	spinal column	premaxillary
ethmoid	hyomandibular	interhyal
prefrontal	symplectic	epihyal
frontal	quadrate	ceratohyal
sphenotic	articular	basihyal
parietal	pterygoid	glossohyal
epiotic	palatine	urohyal
supraoccipital	mesopterygoid	branchiostegal assembly
pterotic	metapterygoid	pharyngeals
opisthotic	preopercle	nasal
exoccipital	opercle	post-temporal
basioccipital	subopercle	supracleithrum
parasphenoid	interopercle	cleithrum
basisphenoid	angular	scapula
prootic	dentary	coracoid
alisphenoid	maxillary	pectoral girdle

A comparison of the ribs showed great variation occurring between mates in the same fish. Similar variation occurred in the branchial assembly. From the preceding list were eliminated all those bones that lacked specific differences, and the bones that did not lend themselves to an accurate comparison because of their concealment by other skeletal elements. The final list was as follows:

1. vomer
5. sphenotic
8. supraoccipital
6. parietal
9. pterotic
10. opisthotic
12. basioccipital
13. parasphenoid
14. basisphenoid
15. prootic
16. alisphenoid spinal column
17. hyomandibular
19. quadrate
22. mesopterygoid
23. metapterygoid
24. preopercle
25. opercle
26. subopercle
27. interopercle
28. articular
34. epihyal
35. ceratohyal
37. glossohyal
38. urohyal
54. supracleithrum
55. cleithrum assembly
53. post-temporal
62. pelvic girdle

These bones were then checked against all the available material in each species. Bones separating a particular species from its relatives are listed under the discussion of the respective species.

The following key will spearate those species discussed in this publication. The distinction between Neothunnus and Parathunnus is based upon only two specimens of the latter.

Key to Those Species of Thunnidae and Katsuwonidae Herein Described

1a First vertebra reduced in size, anchylosed to the skull; vertebrae typically 18+21=39, alisphenoids meet in the median line, vomerine teeth present.........Thunnidae

2a First completely enclosed haemal arch occurs typically on the 10th vertebra. –

3a First haemal arch subcircular, bent forward at an approximate angle of 45 degrees to the vertebral column, alisphenoids not

[5] According to Kishinouye, the skipjack is in the family Katsuwonidae. Kishinouye's classification has been followed throughout.

projecting below a line drawn between the prefrontal notch and the upper corner of the basisphenoid's anterior process ....Thunnus germo

3b First haemal arch triangular, not bent forward at an angle of 45 degrees to the vertebral column, alisphenoids definitely project below a line drawn as in 3a . ...Thunnus thynnus

2b First completely enclosed haemal arch occurs typically on the 11th vertebra. –

4a The postero-ventral margin of the cranium formed by the parasphenoid and basisphenoid is rounded convexly when viewed laterally ....Parathunnus mebachi

4b The postero-ventral margin of the cranium is straight, slightly concave or includes a slightly obtuse angle ....Neothunnus macropterus

1b First vertebra not reduced in size, vertebrae typically 20+21=41, alisphenoids not meeting in the median line, vomerine teeth absent ....Katsuwonus pelamis

3.14. Synopsis

The major differences occurring in the five species, and those of value in an exact identification are listed in tabular form in table 5. In conjunction with the skeletal key given above, this will summarize the results of this study.

3.15. Taxonomy

In view of the purpose of this study no attempt was made to determine accurately the proper generic and specific names. Before attempting an extensive revision, if this should prove necessary, it would seem advisable to await such time as the anatomy of all the commoner tunas is better known. Accordingly, the nomenclature of Kishinouye has been followed. In the case of the bluefin tuna, this is described as Thunnus thynnus, freely admitting that little is known of its fundamental relationship with the Atlantic and Mediterranean form.

The only change suggested is the transference of the albacore from the genus Germo to the genus Thunnus, where it undoubtedly belongs. No one could compare this species with the bluefin tuna without appreciating the striking similarity. This was obvious to Kishinouye who affected the change. In California the albacore has hitherto been classified as Germo alalunga, in accordance with the opinion of Jordan and Evermann, who separated this form from Thunnus, solely on the basis of the long pectoral fin.

TABLE 5

Summary of anatomical differences in five tunas

	Skipjack	Yellowfin Tuna	Albacore	Bluefin Tuna	Big-eyed Tuna
External					
Color	4 or 5 oblique dark lines on silvery belly; specific	Yellow band on sides and on fins; not specific	Not specific	Not specific	Not specific
Pectoral fin	Reaches 9th or 10th dorsal spine	Reaches 2d dorsal insertion; not reaching anal insertion	Reaches beyond anal insertion	Reaches 11th or 12th dorsal spine	Reaches beyond anal insertion
Vent	Slit	Oval or tear-drop	Round	Round	Oval or tear-drop
Preoperculum	Post-ventral angle rounded	Post-ventral angle square	Post-ventral angle square	Post-ventral angle rounded	Post-ventral angle square
Internal					
Viscera	See figure	See figure	See figure	See figure	See figure
Liver	Not striated	Not striated	Radially striated	Radially striated	Peripherally striated
Intestine	Straight—no fold; specific	Folded—on right side	Folded; crosses diagonally from right to left; specific	Folded—median	Folded—on right side
Spleen	Not seen in ventral view; specific	On right side; shape specific	On left side; small; specific	Median; large	Mostly hidden in ventral view; specific
Gall-bladder	Nonspecific	Nonspecific	Conspicuous in ventral view	Nonspecific	Nonspecific
Air-bladder	None	Shape specific; pit beneath 6th vertebra	Shape specific; pit beneath 6th, 7th and 8th vertebrae	Shape specific; no pit	Shape specific; pit beneath 6th and 7th vertebrae
Kidney (posterior projection)	Long; reaches beyond 15th vertebra; end indeterminate	Moderate; reaches 14th or 15th vertebra	None; kidney specific in shape	Short; reaches 10th or 11th vertebra	Short; reaches 11th to 13th vertebra
Ureter	Divides beneath 17th or 18th vertebra; runs parallel before diverging	Divides beneath 11th vertebra; diverges gradually	Divides beneath 9th vertebra and separates immediately at 90 degrees or more	Divides beneath 10th or 11th vertebra; separates gradually	Divides beneath 10th vertebra; separates gradually: as in bluefin
Coeliac-mesenteric artery	3 branches; no conical plexuses; II and III branches not connected; specific	3 branches; no conical plexuses; II and III branches not connected; specific	2 branches; large conical plexuses; II and III branches not connected; specific	2 branches; large conical plexuses; II and III branches connected; specific	3 branches; small conical plexuses; II and III branches connected, specific
Anterior arterial	Cutaneous arteries small; originate perpendicular beneath 5th vertebra; no parallel trunks	Cutaneous arteries moderate; originate beneath 7th or 8th vertebra; parallel arterial trunks present	Cutaneous arteries large; curved at origin, beneath 5th vertebra; no parallel trunks	Cutaneous arteries large; curved at origin, beneath 5th vertebra; no parallel trunks	Cutaneous arteries large; curved at origin, beneath 7th or 8th vertebra; no parallel trunks
Cutaneous system	Arteries divide in kidney; vessels pass anterior and posterior to 1st rib; no posterior commissure; no anterior venous commissure	Arteries divide near surface; vessels pass between 5th and 6th ribs; strong posterior commissure	Arteries divide near surface; vessels pass between 3d and 4th ribs; no posterior commissure	Arteries divide near surface; vessels pass between 3d and 4th ribs; weak posterior commissure	Arteries divide near surface; vessels pass between 5th and 6th ribs; no posterior commissure
Post-cardinal vein	Present: emerges through 3d haemal arch; not connected with cutaneous veins	Present; emerges through 1st haemal arch; receives cutaneous blood	Absent; cutaneous veins go directly to cuvierian ducts	Absent; cutaneous veins go directly to cuvierian ducts	Present; emerges through 1st haemal arch; empties into right cutaneous vein

TABLE 5
Summary of anatomical differences in five tunas

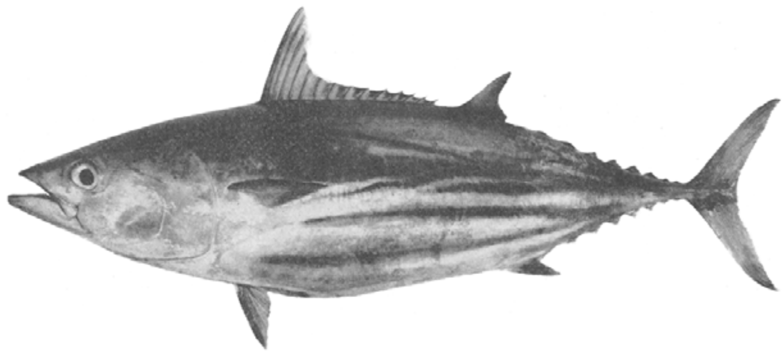

FIGURE 4. Skipjack, *Katsuwonus pelamis.*

FIGURE 4. Skipjack, Katsuwonus pelamis

4. SKIPJACK
Katsuwonus pelamis (Linnaeus) 1758

This study is based upon 48 specimens, originating as follows:

Japan	10
Hawaii	10
Clipperton Island	2
Galapagos Islands	8
Costa Rica	4
Lower California	14
Total	48

External: In external appearance the skipjack is quite distinct and can be readily identified by the four or five oblique dark stripes on the silvery belly. The back is blue to violet in color: the body is full in outline, and the pectoral fin is short and triangular, reaching posteriorly to the ninth or tenth dorsal spine, to the eighth in exceptional specimens and rarely to the eleventh.

In table 6, are tabulated the range, within each geographic sample, in the various proportions measured, and the comparable meristic counts are shown in tables 7 and 8.

Teeth: The dentition is somewhat weak and confined to a single row of teeth on both upper and lower jaw, with numerous long teeth on the pharyngeals. No teeth are present on the vomer or palatines. Calcareous plates are present on the base of the tongue at the symphysis of the gill arches. These are somewhat irregular in shape but resemble in general the sketch in figure 6. No differences were found in fish from different regions.

Tongue: The tongue is quite smooth with a verticle ridge on each side. This consists of a thin film of cartilage with a broad base and a rounded free margin. Considerable variation was found in the shape of these ridges. The typical appearance is as shown in figure 5, but in individual cases the posterior margin of this ridge was more or less steep and in extreme cases almost perpendicular to the base. However, similar variations were found in material from all the geographical regions.

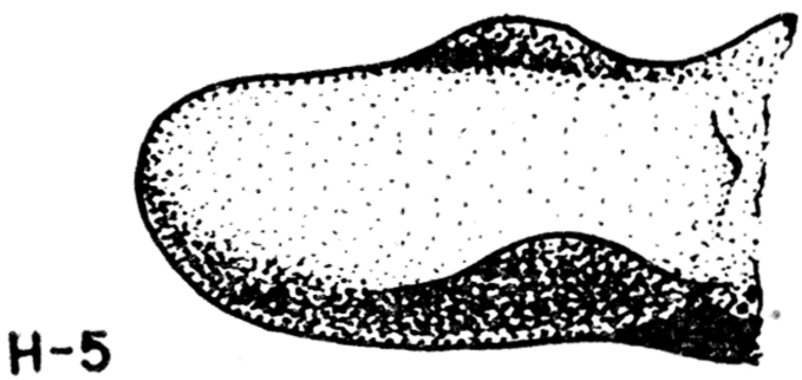

FIGURE 5. Skipjack: Dorsal lateral view of the tongue, illustrating the vertical cartilaginous ridge on each side

Branchial Assembly: A sketch of the branchial assembly is shown in figure 6. Posterior gill rakers are moderately and uniformly developed on all four arches. Anterior rakers, on the contrary, are fully developed only on the first gill arch. On the remaining arches the anterior rakers are rudimentary, and they are confined to the angle of the arch, extending a variable distance on to the upper limb. In place of anterior rakers on these arches, there are narrow transverse plates forming a continuous sheath on the median or inner face of the arch, and the appearance suggests that the missing anterior rakers had been rotated through an angle

TABLE 6

Skipjack: The range, within geographic samples, of the various body proportions. The range in the size of the fish examined is shown in the first line of the table.

Body proportion	Japan	Hawaii	Clipperton	Galapagos	Costa Rica	Lower Calif.
Range in body length—mm.	470–525	606–680	572–647	443–489	534–556	451–522
Body length / Head length	3.28–3.45	3.21–3.41	3.20–3.34	3.24–3.35	3.21–3.33	3.37–3.45
Body length / 1st dorsal insertion	2.76–2.93	2.71–2.90	2.80–2.85	2.77–2.88	2.81–2.92	2.83–3.02
Body length / 2d dorsal insertion	1.54–1.61	1.55–1.61	1.60–1.63	1.59–1.64	1.60–1.63	1.57–1.64
Body length / Anal insertion	1.43–1.48	1.43–1.49	1.47	1.47–1.50	1.46–1.50	1.46–1.51
Body length / Ventral insertion	2.94–3.16	2.93–3.08	2.93–3.01	2.89–3.01	2.89–2.97	2.93–3.09
Body length / Body depth	3.43–4.10	3.66–4.02	3.92–3.94	3.66–4.10	3.78–3.86	3.59–4.55
Body length / Body width	5.22–6.21	4.64–4.98	4.83–5.11	5.33–5.61	5.02–5.24	5.32–6.00
Body length / Dorsal-ventral distance	3.79–4.21	3.84–4.22	4.07–4.14	3.88–4.28	4.03–4.06	4.07–4.77
Body length / Dorsal-anal distance	2.29–2.44	2.36–2.45	2.41–2.47	2.41–2.52	2.34–2.46	2.35–2.61
Body length / Length 1st dorsal base	3.19–3.55	3.37–3.54	3.55–3.61	3.47–3.68	3.51–3.67	3.21–3.71
Body length / Pectoral length	6.27–7.70	5.91–6.83	5.84	6.16–6.99	6.11–6.36	6.36–7.42
Body length / Height 1st dorsal	6.44–6.93	6.08–6.41	6.41	6.24–6.88	6.18–6.85	6.33–7.28
Body length / Height 2d dorsal	10.74	9.33–11.14	11.44–12.21	11.60–13.58	11.74–11.83	11.27–12.51
Body length / Height of anal	12.02	8.97–11.55	------------	11.88–13.22	11.87–13.17	10.55–12.95
Body length / Length 2d dorsal base	12.05–14.11	9.71–13.80	12.94–13.00	12.27–13.88	12.56–13.02	12.18–14.50
Body length / Spread of caudal	------------	3.40–3.85	3.35–3.81	3.69–4.08	3.59–3.81	3.63–4.32
Head length / Diameter of iris	6.27–7.25	7.00–7.88	7.16–8.08	6.05–7.26	6.92–7.52	6.45–7.14
Head length / Maxillary length	2.65–2.79	2.57–2.70	2.66–2.71	2.53–2.71	2.58–2.68	2.54–2.74

TABLE 6
Skipjack: The range, within geographic samples, of the various body proportions. The range in the size of the fish examined is shown in the first line of the table

TABLE 7

Skipjack. Frequency of occurrence of the various fin-ray counts, by geographic samples

	First Dorsal Fin		Second Dorsal Fin			Dorsal Fin-lets		Second Dorsal plus Dorsal Finlets				Anal Fin			Anal Finlets			Anal Fin plus Anal Finlets				
Count	15	16	14	15	16	7	8	21	22	23	24	14	15	16	6	7	8	20	21	22	23	24
Japan	8	1	1	5	---	---	8	---	1	4	---	1	5	---	---	7	---	---	1	4	---	---
Hawaii	7	3	1	8	1	3	7	---	3	7	---	---	10	---	---	10	---	---	---	10	---	---
Clipperton	2	---	---	1	1	---	2	---	---	1	1	---	2	---	---	2	---	---	---	2	---	---
Galapagos	6	---	---	7	---	---	7	---	---	7	---	---	7	---	---	8	---	---	---	7	---	---
Costa Rica	3	---	---	3	---	---	4	---	---	3	---	1	3	---	---	3	1	---	---	4	---	---
Lower California	10	1	1	10	---	1	10	1	---	10	---	---	10	1	1	10	---	---	1	9	1	---
Totals	36	5	3	34	2	4	38	1	4	32	1	2	37	1	1	40	1	0	2	36	1	0

TABLE 7

Skipjack. Frequency of occurrence of the various fin-ray counts, by geographic samples

TABLE 8

Skipjack. Frequency of occurrence of the gill-raker counts on upper and lower limbs, separately and combined by geographic samples

Upper limb

Gill-rakers	16	17	18	19	20	21	22
Japan	1	--	2	3	2	--	--
Hawaii	--	--	--	8	2	--	--
Clipperton	--	--	1	--	--	--	--
Galapagos	--	--	1	3	1	1	--
Costa Rica	--	--	1	2	1	--	--
Lower California	--	--	1	5	--	3	1
Totals	1	0	6	21	6	4	1

Lower limb

Gill-rakers	35	36	37	38	39	40	41	42	43
Japan	--	1	1	3	1	1	1	--	--
Hawaii	--	--	3	2	2	2	--	1	--
Clipperton	1	--	--	--	--	--	--	--	--
Galapagos	--	--	--	2	3	--	--	--	1
Costa Rica	--	--	--	--	--	2	1	1	--
Lower California	1	--	--	3	--	2	4	--	--
Totals	2	1	4	10	6	7	6	2	1

Upper and lower limb combined

Gill-rakers	53	54	55	56	57	58	59	60	61	62	63
Japan	1	--	1	2	1	--	1	2	--	--	--
Hawaii	--	--	--	3	2	2	--	2	1	--	--
Clipperton	1	--	--	--	--	--	--	--	--	--	--
Galapagos	--	--	--	1	1	2	--	1	--	--	1
Costa Rica	--	--	--	--	--	1	1	1	--	1	--
Lower California	1	--	--	--	2	--	2	2	--	3	--
Totals	3	0	1	6	6	5	4	8	1	4	1

TABLE 8

Skipjack. Frequency of occurrence of the gill-raker counts on upper and lower limbs, separately and combined by geographic samples of 90 degrees and bent over the inner face of the arch to form a solid protecting sheath. These plates are loosely attached to the arch and easily removed.

The anterior gill-rakers of the skipjack have peculiar serrations or undulations on the inner margin of each raker. (Fig. 7). However, this character is extremely variable and in some fish these serrations are almost lacking. Moreover, the condition of different rakers in individual fish varied as much as between fish. This variation is random, and was found equally in all geographical samples.

Viscera: The ventral view of the viscera is distinctive and differentiates the skipjack from the remaining tunas. The shape of the center lobe of the liver is quite different from that of the remaining species, and in the majority of specimens a portion of the left lobe shows also in this view. The caecal mass is relatively large and its apex lies centrally or on the right side of the fish, instead of on the left as in the other tunas. Moreover only a short portion of the straight intestine is seen posteriorly, and the spleen is completely hidden. Figure 8, illustrates the extent of variation encountered.

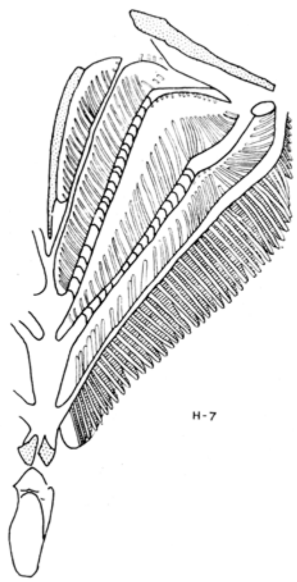

FIGURE 6. Skipjack: Antero-dorsal view of the gill-arches on the left side. Upper and lower pharyngeal bones and the calcareous plates at the base of the tongue shaded

Caecal Mass: The apex of the caecal mass lies either in the median line, or it is displaced to the right side of the fish. The size of the caecal mass decreases proportionately with the size of the fish. Whereas in small fish it frequently extends the full length of the body cavity so that little else is seen in ventral view, in large skipjack it may cover little more than the anterior half of the abdominal cavity. The caecal mass is connected to the duodenum, in the majority of specimens, by nine ducts, but this number varies in individuals from seven to ten.

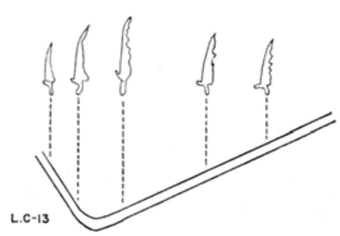

FIGURE 7. Skipjack: Lateral view of the serrations on the inner margin of the gill rakers, showing the variation on a single arch

4.1. Liver

Three camera lucida sketches of the excised liver are shown in figure 9. It will be noted that the right lobe is invariably the longest, and it is always attenuated. The irregularity in the shape of the center lobe is characteristic of the species. The ventral surface of the liver is uniform in color and there are no characteristic markings, neither are there conical vascular plexuses on the dorsal face. Collectively, these characters separate the liver of the skipjack from that of all other species. Beyond a random variation in the shape of the liver and the length of the lobes no locality differences were observed.

4.2. Stomach

The length of the stomach decreases proportionately with an increase in the size of the fish. In small fish it extends the full length—or nearly so—of the abdominal cavity, but in larger fish it is generally considerably shorter. The sketches of the viscera (Fig. 8) illustrate this point. In all but large fish where the caecal mass is relatively short, the posterior exposed portion of the stomach is situated on the left side of the fish.

4.3. Intestine

Discounting the loop of the duodenum, the intestine is straight. It runs directly back on the right side of the fish from duodenum to anus, without any fold or convolution. This differentiates the skipjack from the four remaining tunas. Figure 10 illustrates the course of the alimentary canal.

4.4. Spleen

The spleen lies at the anterior end of the

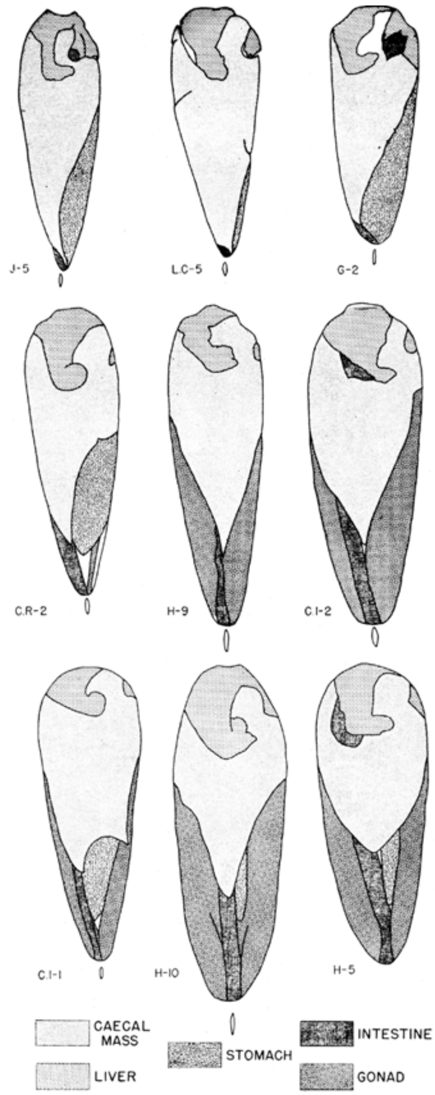

FIGURE 8. Skipjack: Ventral view of the viscera in nine specimens to indicate the extent of variation encountered

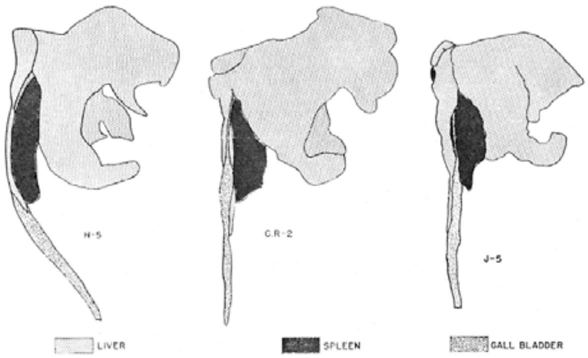

FIGURE 9. Skipjack: Ventral view of the excised liver, with the spleen and a part of the gall-bladder attached

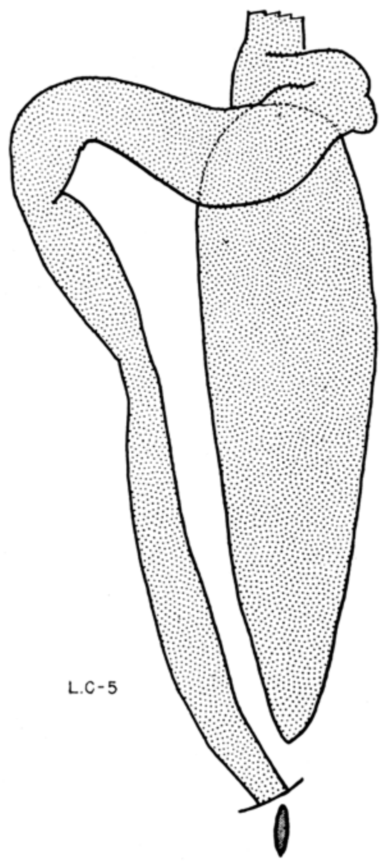

FIGURE 10. Skipjack: Ventral view of the alimentary canal

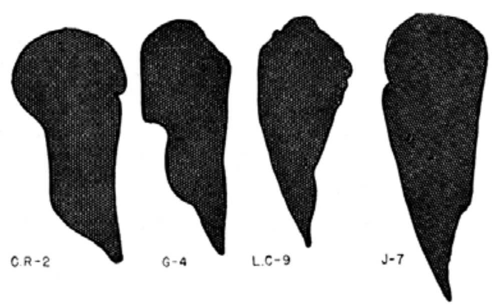

FIGURE 11. Skipjack: The spleen from four specimens: The two sketches on the left depict the dorsal view and those on the right the ventral view

abdominal cavity between the dorsal face of the caecal mass, on the one hand, and the intestine and stomach on the other hand. The head of the spleen is likewise enclosed by the right and center lobes of the liver, with one side of the spleen paralleling, and attached to, the intestine. In consequence it does not show in ventral view until the caecal mass is removed, and in this respect it differs from all species except the big-eyed tuna. In shape and size it is quite variable (Fig. 11). The sketches depicting the excised liver (Fig. 9) also show the general shape and location of the spleen. Variations found were random, and apparently not correlated with locality.

4.5. Gall-bladder

The gall-bladder runs posteriorly with and attached to the intestine. It is a long narrow structure, and anteriorly it is intimately associated with the right lobe of the liver. Little attention was paid this organ, and its location and extent were merely recorded incidentally.

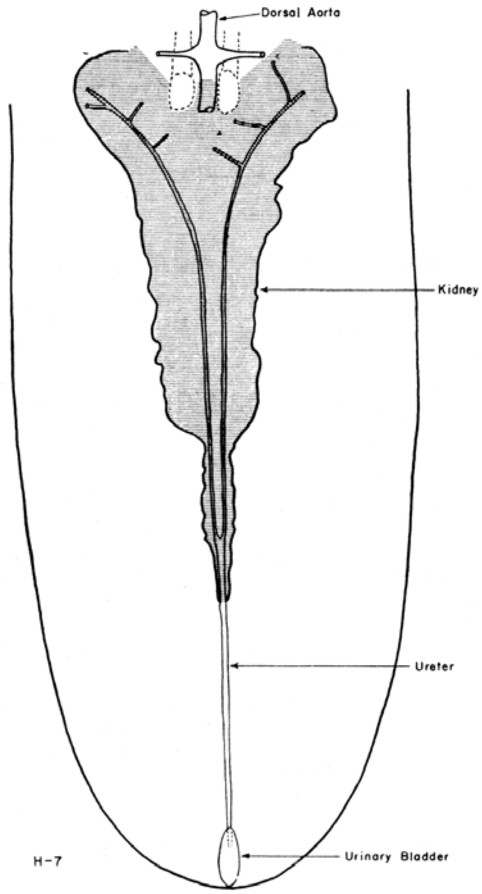

FIGURE 12. Skipjack: Ventral view of the posterior projection of the kidney. The ureter and urinary bladder are also shown

4.6. Air-bladder

There is no air-bladder in the skipjack.

4.7. Excretory System

Kidney. (Figs. 12 and 16.) The posterior extension of the kidney is long and projects as a narrow wedge of tissue far back in the dorsal wall of the body cavity, invariably reaching the middle of its length (about the 15th vertebra) and generally a considerable distance beyond. The outline of the kidney is strongly crenulated and irregular in shape, tapering gradually. In many instances this wedge of kidney tissue extends as a fine thread over the remaining length of body cavity, so that the posterior limit is indeterminate. Attempts to measure its extent were abandoned early in the work. The shape and extent of the kidney were quite variable, but such variations were random, and not associated with the geographical origin of the specimen.

Ureter. The course of the ureters and their detailed structure can be seen clearly only after suitable injection. (Figs. 12 and 16.) The single ureter divides, typically, beneath the 17th or 18th vertebra, although this point is quite variable. In thirty specimens carefully investigated the division occurred beneath the 17th or 18th vertebra in 18; beneath the 16th in 6; beneath the 15th in 3; beneath the 19th in 2; and beneath the 20th in 1 specimen. The two resulting branches continue anteriorly along the median line, parallel to and almost touching each other, and at the level of the 14th vertebra the two are further separated by the post-cardinal vein which emerges through the haemal arch on that vertebra. Bordering the post-cardinal vein, the two ureters continue anteriorly with this vessel, and in the vicinity of the 10th vertebra they begin to diverge outward in a gentle curve. That of the right side follows the post-cardinal vein to the right, and the branch on the left curves outward along a comparable path. (Fig. 16.) In the anterior kidney mass each ureter divides into a number of collecting vessels. One such branch on each side runs anteriorly towards the median line, serving the narrow tongue of kidney that runs far anteriorly beneath the vertebral column and between the pharnygeal muscles. Throughout their course in the kidney substance the ureters receive innumerable small collecting vessels, and these, or some of them, are shown diagrammatically in the sketches. A preliminary study of the data showed no significant differences.

Urinary Bladder. The urinary bladder in the skipjack is short and inconspicuous. It lies embedded in the dorsal wall of the abdominal cavity and at no point does it project freely into the latter. In consequence, it follows the curvature of the cavity, so that the bladder bows or inclines horizontally in its anterior extent. The ureter joins the bladder near the anterior end at its point of inflexion or curvature, and in extreme cases, where the bladder is long, this may be close to the

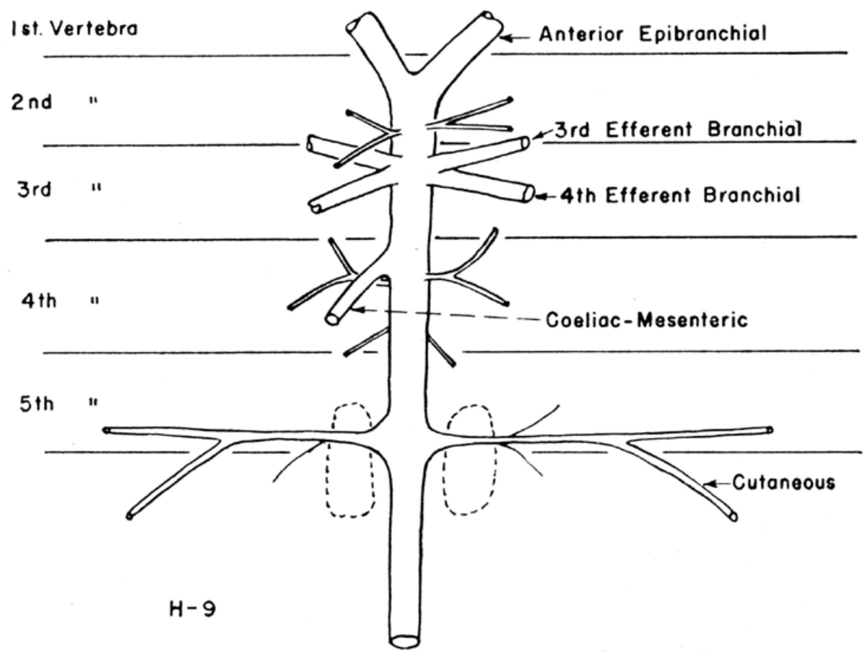

FIGURE 13. Skipjack: Ventral view of the anterior arterial system. The dotted outline indicates the vertebral attachment of the pharyngeal muscles.

FIGURE 13. Skipjack: Ventral view of the anterior arterial system. The dotted outline indicates the vertebral attachment of the pharyngeal muscles

middle of the bladder. The juncture is, however, invariably in the anterior half of the bladder. Variations in this character were found in specimens from every geographical region.

4.8. Circulatory System

I. *Anterior Arterial* (Fig. 13): The "Y" of the aorta is characteristically beneath the anterior half of the second vertebra. A posterior epibranchial is practically nonexistent in this species, inasmuch as the third and fourth efferent branchials meet only at the point of entry into the aorta. This point is located typically beneath the junction of the second and third vertebrae, and occasionally beneath the anterior portion of the third vertebra. The coeliac-mesenteric artery arises beneath the junction of the third and fourth vertebra, varying perhaps half the length of a vertebra on either side. Laterally, at the same point (slightly dorsal to the coeliac-mesenteric) a small subclavian originates on each side. A cutaneous artery originates laterally on each side, typically beneath the posterior half of the fifth vertebra. These vessels are relatively small in the skipjack and they run laterally perpendicular to the aorta. Attached to the fifth and sixth vertebrae on either side of the aorta is a pharyngeal muscle which runs obliquely forward and is inserted into the wall of the pharynx between the cutaneous and coeliac-mesenteric arteries. Posterior to the origin of the cutaneous arteries a number of minute vessels are given off into the kidney. One pair, originating in the region of the sixth vertebra, was seen quite consistently, but the others are easily overlooked. No routine examination was made posterior to this point.

In two cases of the total number investigated, the origin of the cutaneous arteries was irregular. In one, H-5, the cutaneous arose normally on both sides, but each was shortly joined by a supplementary vessel originating in the aorta posterior to the subclavians. In the other case (C.R.-1) the ventral branch of the cutaneous on one side arose in the subclavian of that side, and the trunk of the cutaneous artery gave rise directly and solely to the dorsal branch of the cutaneous. It is quite possible that such anomalies are common.

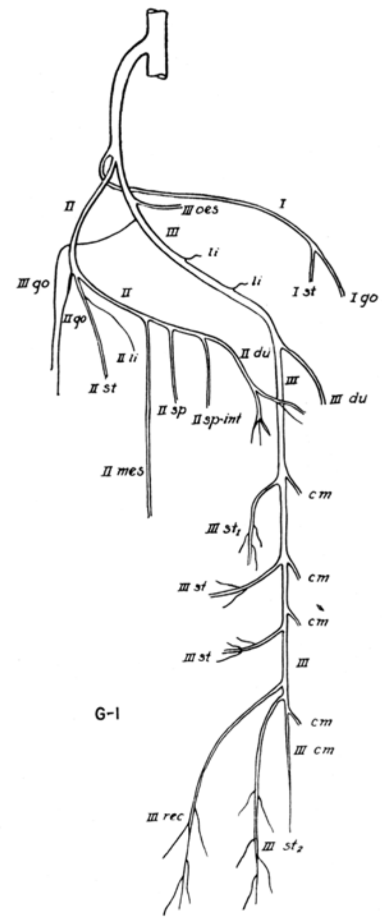

FIGURE 14. Skipjack: Diagrammatic ventral view of the coeliac-mesenteric artery and its branches. See text, pp. 36–38

II. *Visceral arterial system* (Fig. 14): In this species the coeliac-mesenteric artery divides characteristically and invariably into three major branches. The No. I branch is relatively small. Turning toward the left side of the body it runs transversely through the musculature of the oesophageal region and thence into the anterior portion of the abdominal cavity. Between this point and its origin it possibly gives off one or two fine branches to the dorsal wall of the oesophagus. This was indicated in two or three dissections. Entering the abdominal cavity the No. I branch divides into two. One branch (I-st.) runs to the dorsal anterior wall of the stomach and continues posteriorly along its left dorsal face. The second branch (I-go.) continues in a transverse and posterior direction and runs to the left gonad. This branch is quite conspicuous and runs at least half the length of the gonad.

The No. II branch runs dorsal to the right Cuvierian duct and enters the abdominal cavity. Here it runs ventralwards along the transverse septum, and reaching the right lobe of the liver, divides into three. The first branch (II-go.), which is an extremely small vessel, continues on the right side and is shortly joined by another fine branch from the No. III branch of the coeliac-mesenteric artery (III-go.), and with this runs to the right gonad. It becomes a conspicuous vessel, but apparently is in reality two vessels, one of which runs half the length of the gonad on the surface and then disappears as it goes deeper, whereas the other continues posteriorly on the surface of the gonad. The second branch (II-st.) runs to and nourishes the right dorsal wall of the stomach, continuing far posteriorly as a fairly conspicuous vessel. Branchlets, (II-li.) or tributaries, from this vessel run into and nourish the right lobe of the liver. The third branch, (II in the figure) continues ventrally towards the head of the spleen and gives off II-mes., which runs posteriorly in the narrow mesentery between the intestine on the one hand, and the right lobe of the liver, the gall-bladder and the spleen on the other, all of which organs it nourishes through tributaries. A short distance beyond, this branch (II) gives rise to a relatively large vessel (II-sp.) which runs into and ramifies throughout the spleen. This vessel was overlooked in many of the earlier specimens, and its presence can be detected only by careful dissection of the vessel as it contacts the spleen. Between the origin of II-mes. and II-sp. two or more minute vessels originate, one of which (not shown in the figure) appears to run to the bile duct. Next, the branch marked II-sp.int. is given off, and this runs posteriorly along the surface of the spleen, branching profusely and nourishing its surface, and also the left side of the intestine. Beyond this, II dips dorsal to and traverses the duodenum, and on the posterior face of the loop of the duodenum breaks up into a number of vessels which supply the posterior wall of the duodenum and the anterior end of the caecal mass. The course of this vessel (II-du.) is shown diagrammatically, and no effort was made to trace the destination of each terminal branch.

The No. III branch is the largest. From its origin with the other two branches it runs dorsal to the right Cuvierian duct with the No. II branch, and then gives off a small vessel (III-oes.) to the ventral wall of the oesophagus or vicinity, and then two or more small vessels (III-li.) to the substance of the liver as it traverses the center lobe of the latter. The trunk of III continues through the substance of the liver and shortly before it emerges gives off the branch III-du. which runs to and feeds the anterior face of the duodenum. Beyond this III continues as a large conspicuous vessel along the dorsal face of the caecal mass, ramifying extensively throughout its substance. The sketch is purely diagrammatic as no attempt was made to follow the individual path of the numerous branches in this vicinity. However, the course of the main trunk was followed, and is correctly described. As it emerges on the dorsal face of the caecal mass, and shortly after giving rise to the vessel III-du., to

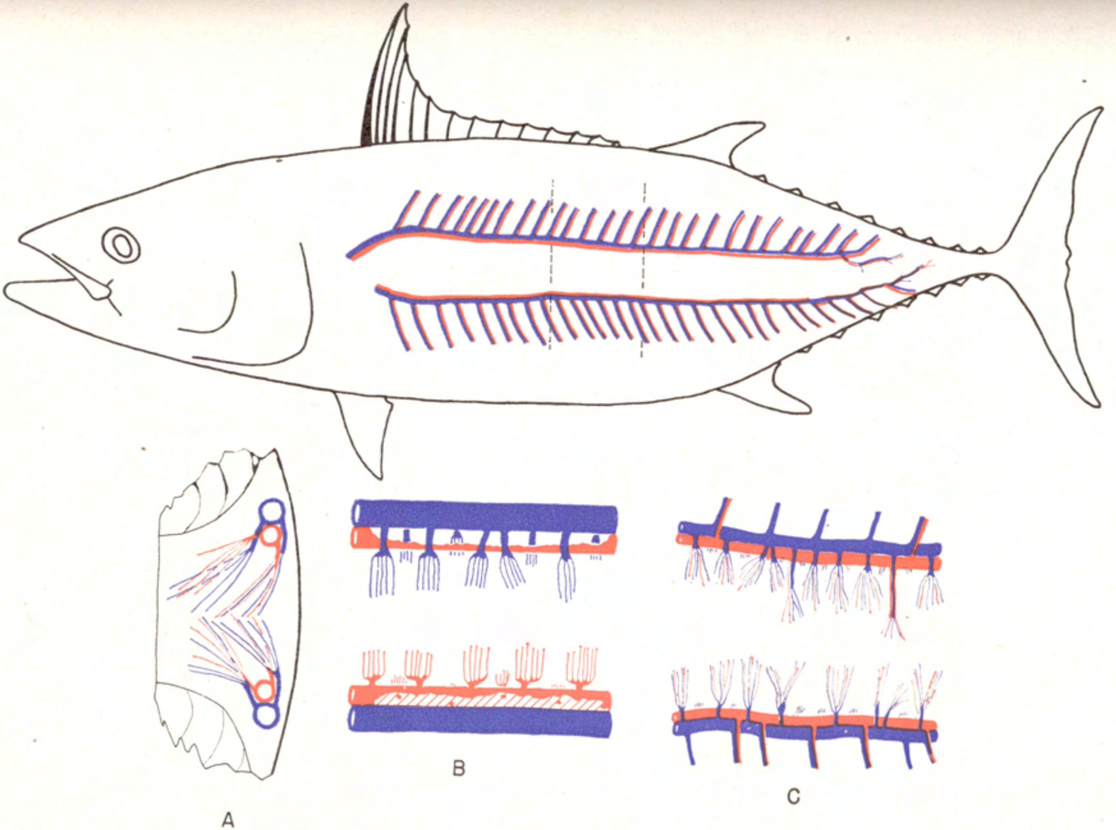

FIGURE 15. Skipjack: Cutaneous system. Upper: Course of cutaneous vessels in superficial musculature. A: Enlarged transverse section. B: Enlarged partial views of C, with portions of arterial walls cut away to show origin of arterioles and venules. C: Enlarged view of region between dotted lines in upper figure. See text, pp. 38-39.

the duodenum, III gives off on its dorsal side the vessel marked III-st_1 in the sketch. This feeds the anterior ventral wall of the stomach. The branches marked cm. in the figure ramify throughout the caecal mass, whereas those marked III-st. flow through the mesentery to the ventral and left wall of the stomach. (It is these vessels which are shown in many of the sketches of the viscera *in situ*.) Continuing posteriorly along the dorsal face of the caecal mass, the main trunk may be said to divide into three terminal branches: one, labeled III-cm., continues to the tip of the caecal mass; another, marked III-st_2., crosses to the stomach and continues along its ventral wall to its posterior extremity; the third branch, III-rec., runs dorsally to the rectum and continues posteriorly thereon, branching profusely. All specimens examined were essentially similar and no locality differences were observed.

III. *Cutaneous System* (Fig. 15): The examination of this system presented greater difficulties in the skipjack than in any other species The cutaneous vessels are very much smaller, their walls seem much more delicate and the number of successful injections was small.

From its origin in the aorta, the cutaneous artery on each side runs laterally, perpendicular to the aorta into the kidney. At a short distance from the aorta each branch divides into two. The location of this division is quite variable, and not infrequently the trunk on one side is considerably longer than on the other. However, the division is invariably median to the first rib. One branch passes between the first and second ribs and runs outwards towards the surface, emerges at the base of the pectoral fin and continues posteriorly dorsal to the lateral line as the dorsal branch of the cutaneous artery. The second branch runs towards the surface and passes anterior to the first rib, emerges posterior to the insertion of the pectoral fin, and continues posteriorly as the ventral branch of the cutaneous artery. This arrangement was constant in all fish examined and is very typical and distinctive of the skipjack. of the five species examined this is the only one where the common trunk of the cutaneous artery on each side is short, and where the division into dorsal and ventral branches is deep within the body. In the remaining species the common trunk on each side divides as it approaches the surface.

On the surface the cutaneous arteries, as relatively small vessels, continue posteriorly, approximately parallel, to the region of the caudal peduncle. As in all these tunas, each artery is accompanied by a corresponding cutaneous vein, but in the skipjack the relation of the two vessels becomes erratic posteriorly, and the artery often crosses and re-crosses the vein, in exceptional cases twining around it.

Throughout their length on the surface the cutaneous vessels, both veins and arteries, give rise to a series of fine vessels which nourish the dark flesh of the lateral median line. These vessels are relatively sparse in the skipjack, their origin is more erratic and their course differs from that of comparable vessels in the remaining tunas. They are illustrated diagrammatically in figure 15. In the later, arterioles and venules break up immediately into capillary sheets, whereas in the skipjack these vessels often continue an appreciable distance into the tissue before they divide into capillaries, and this is particularly true in the caudal region. In the anterior region there are only a few such vessels, and usually they break up into small, individual and isolated plexuses. They are most numerous in the central portion of the cutaneous system and decrease in number posteriorly. Throughout, the venules arise on both the proximal, axial[6] and the proximal, abaxial face of the vein and they thus cross both inner and outer face of the respective artery. This results in a loop of venules encircling the artery. However, there is considerable variation in individual fish, and in some the majority of venules cross the abaxial face of the artery, with only occasional venules traversing the axial face. Such variations are random, and are not associated with geographical origin.

The arterioles are very small and they originate predominantly on the proximal face of each artery in a somewhat irregular row. Isolated arterioles, however, arise at other points, and many such vessels originate on the distal face of the artery opposite the more numerous row. Such vessels run irregularly at all angles into the deeper musculature.

Approaching the caudal peduncle, the cutaneous veins and arteries diminish gradually in size and in the region of the finlets they disappear as fine branching vessels. The figure depicting this region is typical of all specimens examined. There is no posterior commissure, either venous or arterial. The course of the vessels resembles superficially the condition found in the albacore, and an effort was made to determine what connection existed between the cutaneous and axial systems. Only one satisfactory injection of these terminal vessels was obtained, and the following description, based upon this fish, H-10, is essentially tentative.

The arterial blood from the dorsal and ventral cutaneous arteries appeared to pass via individual horizontal trunks to the caudal artery. Such a connecting vessel joined, on either side, the ventral cutaneous artery with the caudal artery in the 26th vertebra. On the 24th vertebra a similar vessel was observed on one side only connecting the caudal artery with the dorsal cutaneous artery. No comparable venous vessels were seen. The last segmental vessels were followed to the mid-dorsal and mid-ventral line, but at this point the vessels disappeared, and no connection was established between these segmentals and the caudal vessels, such as exists in the albacore.

The cutaneous system of the skipjack differs in a number of respects from that of the remaining tunas. It is the only species investigated in which the cutaneous arteries divide before reaching the ribs. In the skipjack the venules and arterioles are considerably less numerous and more erratic in both course and origin than in the other tunas. The terminal course of the cutaneous vessels likewise differs, and in these respects the cutaneous system separates positively the skipjack from the four remaining tunas.

4.9. Post-Cardinal Vein

A post-cardinal vein is present in the skipjack (Fig. 16), and it is invariably prominent and of large size. It emerges from the haemal canal through the third haemal arch which is on the 14th vertebra. In the 45 specimens examined, only one was found to vary in this respect, and in this case (J-1), the post-cardinal emerged through the arch on the 15th vertebra. It continues anteriorly along the median line within the

[6] See figure 3, and definitions of terms on page 19.

substance of the kidney separating the paired ureters, to the vicinity of the 9th or 10th vertebra. At this point it swings gradually to the right of the fish as a large vessel, and empties into the right Cuvierian duct. No exceptions to this were found.

The relationship between the post-cardinal vein and the cutaneous veins differs in the skipjack from the other tunas. The skipjack is the only species in which dorsal and ventral branch of the cutaneous vein do not fuse in an anterior commissure. With the corresponding artery, the dorsal cutaneous vein passes inward posterior to the first rib, and the ventral cutaneous vein passes anterior to the first rib. Just beyond this point the relatively small veins break up into a series of short ducts or tubules in the substance of the kidney, and the venous cutaneous blood apparently enters the Cuvierian ducts on each side through a number of small orifices. The lack of an anterior venous commissure is a distinctive feature of the skipjack, and the lack of any major connection between the post-cardinal vein and the cutaneous veins is another. Thus, the skipjack in this system also is sharply differentiated from the remaining tunas.

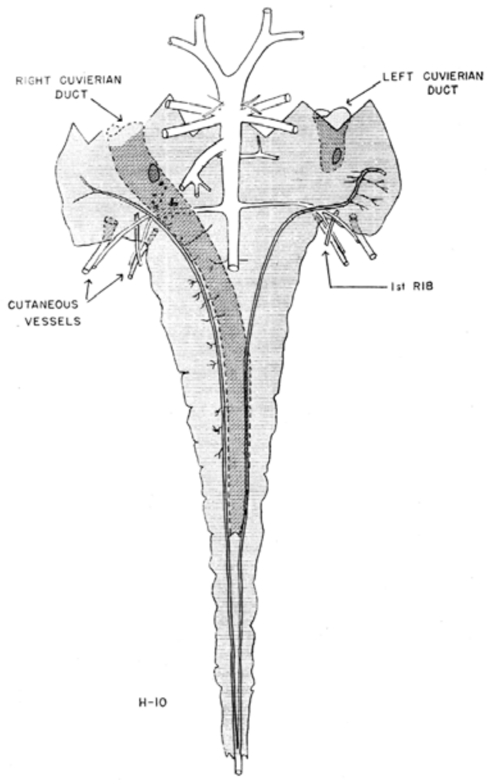

FIGURE 16. Skipjack: Ventral view of the posterior projection of kidney, showing the course of the ureter and the post-cardinal vein which empties into the right cuvierian duct

4.10. Skeleton

Material examined. The skeletons of all specimens mentioned at the beginning of this section were examined, supplemented by the following additional material: Clipperton Island, three; Galapagos, two;

Lower California, two. No specific differences were found between fish of the various localities.

The skipjack is the easiest of the five species to identify. The characters are numerous and the differences between it and the other species are marked; in fact the characters listed below will separate it from all of the tunas.

FIGURE 17. Cranium. Skipjack. Dorsal view

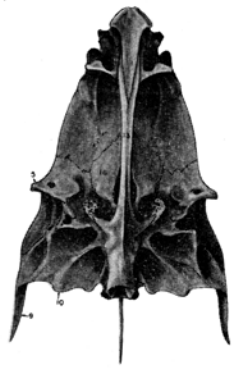

FIGURE 18. Cranium. Skipjack. Ventral view

General appearance of the cranium.[7] See figures 17, 18 and 19. Dorsally, the skull appears more slender and delicate than it does in the other tunas. Laterally, the alisphenoids project only slightly downward between the orbits. From the ventral aspect it may be seen that the alisphenoid bones do not meet on the median line, as they do in the other species, but remain apart forming a long narrow foramen in the floor of the brain case. The absence of vomerine teeth in the skipjack identifies it immediately.

Vomer (1).[8] This bone lacks a median dentigerous plate which is present in all the other species. The ventral surface may be perfectly smooth and concave, or, as often occurs, it may have a thin sharp longitudinal ridge on its anterior ventral surface.

Sphenotic (5). The distance from the postero-lateral corner of the sphenotic process to the nearest point on the lateral margin of the pterotic is more than twice the terminal width of the process itself. In all other species, the distance across the tip of the process is equal to or somewhat greater than the distance from the tip of the process to the pterotic margin when measured as above.

Supraoccipital (8). The perpendicular height of the supraoccipital crest measured at the vertical of the most anterior point of the epiotic

[7] Figures 70 to 76 show the bones of the five species grouped together to facilitate comparisons.

[8] The numbers accompanying the bones correspond with the numbers assigned in Starks, E. C. Synonomy of the fish skeleton. Washington academy of sciences. Proceedings, vol. 3, 1901.

is not over one-half the length of the epiotic measured from the anterior suture line to the tip of its posterior process. In the other species this height of the crest is as great as or greater than the length of the epiotic.

Pterotic (9). The pterotic process is very thin and flexible in the skipjack, terminating posteriorly in a long tapering point. In the other species the process is broad at the tip.

Opisthotic (10). In the skipjack conspicuous semicircular projections on the posterior margin may be seen from both the dorsal and ventral surface. In the other species the posterior margin of this bone is straight.

Parasphenoid (13). The lateral wings of the parasphenoid curve upward and outward in a smooth curve and form an extensive flaring anterior opening to the myodome. In all of the other species the wings turn outward much more abruptly and form a more or less flat rim around the opening of the myodome instead of a well defined funnel leading into it. A small rounded notch occurs in the lower margin of the lateral wing on a level conspicuously above the ventral termination of the basisphenoid. In all other tunas investigated this notch is sharper and on a level with or definitely below the lower end of the basisphenoid.

Basisphenoid (14). A pair of slender spine-like processes is given off posteriorly from the dorsal end of the shank of the basisphenoid. They are well developed, conspicuous, and often reinforced by supporting columns from the expanded dorsal portion of the bone. In the other species these processes are not as well developed and are frequently absent. In addition the prominent anterior process characteristic of the other species is absent in the skipjack or so poorly developed as to be scarcely noticeable.

Prootic (15). The lateral wings slope obliquely forward and are unattached distally in this species. The distal end is often finely perforated and it usually has a very irregular margin. In all the other species observed the lateral wings are in sutural connection with the sphenotic.

Alisphenoid (16). The bones do not meet in the median line, in the skipjack; instead the edges form a large irregular foramen that extends along the floor of the brain case. In the other species, the alisphenoids meet in the median line and divide this foramen into two separate openings. Viewed laterally, the alisphenoids in the skipjack project very slightly into the interorbital opening. (Fig. 19.)

Spinal column. The spinal column is extremely complex in this species. In the posterior half of the precaudal, and the anterior part of the caudal region, haemapophyses arise at both ends of each vertebra, with the anterior haemapophyses of one vertebra articulating with the posterior haemapophyses of the preceding vertebra. These haemapophyses project far below the spinal column and alternate with the longer haemal spines described below. An osseous bridge roughly parallel with the spinal column unites the anterior and posterior haemapophysis of each vertebra. Viewing the spinal column laterally, the bridge and the circular opening it forms may be easily seen. A branch arises from each bridge and extends downward to unite in the median line with its fellow from the opposite side. This forms the haemal arch from the tip of which a single haemal spine continues ventralward. This complex basket-work occurs only in the skipjack. The first haemal arch is on

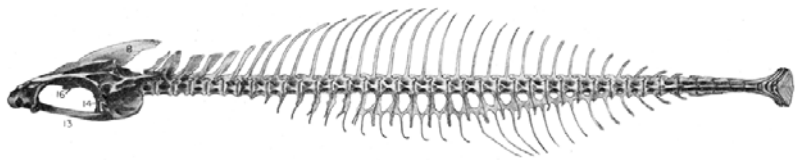

FIGURE 19. Axial skeleton. Skipjack. Lateral view.

FIGURE 19. Axial skeleton. Skipjack. Lateral view

the 12th vertebra and there are a total of 41 vertebrae, whereas the remaining species have only 39. In counting the caudal and precaudal vertebrae throughout this work, the first conspicuously lengthened haemal spine was counted as belonging to the first caudal vertebra (Fig. 19).

Vertebral counts on 44 specimens gave the following frequency distributions: one specimen, 19 precaudal + 22 caudal: 38 specimens, 20 + 21 : five specimens, 21 + 20. The first vertebra is not conspicuously reduced as it is in the other tunas but is the same size as the second vertebra. In the skipjack, a small flattened disc occurs ventrally on each end of the third and fourth vertebrae and usually also on the posterior end of the second. This feature is limited to the above species.

Hyomandibular (17). In this species a sharp, slender, spine-like projection is given off posteriorly from the center condyle. In the other species a spur of bone occurs in the same position, but it is thick in proportion to its length, and it is blunt-ended or slightly notched (Fig. 72).

Quadrate (19). In the skipjack the ventro-posterior external margin is distinctly angular and expanded to form a slight wing. This expansion at its widest point usually conceals the internal ventro-posterior margin. In the other species the ventro-posterior external margin assumes a gentle curve and is quite narrow, the whole length of the internal ventro-posterior margin being visible when viewed from the outside of the bone (Fig. 73).

Mesopterygoid (22). This bone is unmistakable in the skipjack, being perfectly smooth ventrally, without a dentigerous area of any kind. In the other species the dentigerous area is always present.

Opercle (25). This species may be identified by the heavily ribbed area along the lower portion of the bone's outer surface. This ribbing is rather narrow, and extends in a slight arc to the postero-ventral corner of the bone, giving off a short, diverging, dorsal branch at approximately the mid-point. The distance from the upper end of this dorsal branch to the ventral margin of the bone divided into the overall height of the bone gave a value between 2.2 and 2.8 in a sample of 20 fish. Both measurements were taken perpendicularly to the ventral margin at the same place. In the other tunas described, this ribbed area diverges over a greater area and the above proportional values are not over 2.0 (Fig. 73).

Subopercle (26). In the skipjack the axis length, or the posteroanterior distance, was equal to or greater than the overall height in the 20 fish measured. In the other species the height of this bone is definitely greater than its length (Fig. 74).

Interopercle (27). The most conspicuous specific character is the concave posterior margin in the skipjack. In some specimens the posterior margin is nearly straight, but it may still be distinguished from the convex margin of the other species (Fig. 74).

Articular (28). On the ventral marginal surface of the articular the expanded wing terminates in a short sharp spine in this species. In the other species the wing terminates in a much broader but narrowly rounded tip which could hardly be designated as a spine.

Epihyal (34). The posterior half of the ventral margin is strongly convex. This region is quite straight in all the other species (Fig. 75).

Ceratohyal (35). Only two expanded processes are present on the ventral edge of this bone in the skipjack. In the other species there are three processes, with the anterior one reduced to a low, gently-rounded wing. The most striking difference, however, is the deep cleft between the broad anterior base and the narrow ventral arm of the ceratohyal. This cleft is unique as it does not exist in any of the other forms (Fig. 75).

Basihyal (36). In this species it terminates posteriorly in a spine that fits into the above mentioned cleft of the ceratohyal.

Urohyal (38). This bone has a very definite character and one that is quite uniform. The bone when held up to the light has a long, narrow translucent area along the ventral margin. This translucent area is present only in the skipjack.

Post-temporal (53). From the upper anterior angle of the main, external, plate-like expansion of this bone, a well-developed flange extends forward and is attached to the ventro-lateral edge of the base of the flattened and elongated anterior arm. This flange is somewhat developed in other species, but it should not be easily confused with the more obvious enlargement in the skipjack.

Supracleithrum (Supraclavicle) (54). The anterior ventral margin of the supracleithrum is notched and bent backwards, forming a crease in the bone which runs dorso-ventrally in this species. In the other species this notch and crease are absent although a groove is present in this region.

Cleithrum (Clavicle) (55). The concave antero-dorsal border of the cleithrum bears, opposite the middle of the cleithro-coracoid foramen, a prominent wing-like expansion of its mesially directed flange. In the other species this wing is absent, the edge of the flange being practically straight. (Fig. 76).

Pelvic Girdle (62). In all tunas the pelvic girdle is characterized by a pair of thin translucent plates of bone which flare forward on each side. These plates are strengthened by dorsal and ventral marginal thickenings, and by a mesially directed longitudinal flange extending roughly through the middle of the plate. In the skipjack the plate is very broad and the vertical distance from the flange to the tip of the ventral expansion divided into the length of the plate (measured from the anterior end of the plate between the marginal thickenings to its extreme posterior tip) gave a value of three to four, whereas in all other species the comparable measurements gave a value of five to nine (Fig. 75).

4.11. Conclusion

In the characters investigated there are no indications of regional differences, and all specimens were essentially similar. Hence it is apparent that in the area investigated there is but a single species of skipjack, Katsuwonus pelamis.

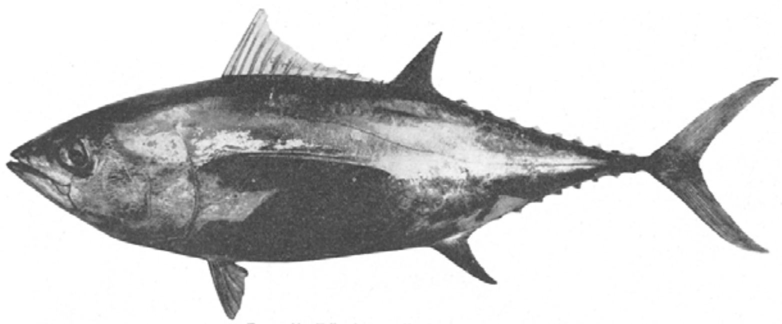

FIGURE 20. Yellowfin tuna, *Neothunnus macropterus*.

FIGURE 20. Yellowfin tuna, Neothunnus macropterus

5. YELLOWFIN TUNA

Neothunnus macropterus (Temminck and Schlegel 1842)

This study is based upon a detailed laboratory examination of 60 specimens, and a partial examination, made in the course of field trips, of 41 additional fish. The origin of these fish is as follows:

	Number of fish	
Origin of fish	*Laboratory*	*Field trip*
Japan	5	—
Hawaii	12	—
Clipperton Island	3	8
Galapagos Islands	8	10
Cocos Island	5	7
Peru	6	—
Costa Rica	5	7
Guatemala	—	1
Gulf of Tehauntepec	—	1
Punta Galera, Mexico	6	6
Lower California, Mexico	10	—
Origin doubtful, local	—	1
Total	60	41

5.1. External

The length of the pectoral fin is perhaps the best superficial identifying character (Fig. 20). Reaching beyond the insertion of the second dorsal fin, it thus differentiates the yellowfin from the bluefin. However the pectoral of the yellowfin does not normally extend to or beyond the anal insertion, and this fact will generally separate the yellowfin from the albacore and the big-eyed tuna, in both of which the pectoral fin is longer. The eliptical vent, and the angular ventro-posterior margin of the gill-covers will also aid in an identification of the yellowfin. At times, however, it is necessary to resort to internal characters for a positive identification.

The range, within geographic samples, in the various body proportions is shown in table 9, and tables 10 and 11 are tabulations of the various meristic counts made upon each fish.

5.2. Viscera

The ventral view of the viscera of the yellowfin tuna resembles that of the big-eyed tuna, and differs from that of the remaining tunas (Fig. 1). The yellowfin differs from the big-eyed tuna mainly in two respects. The fold of the intestine, located on the right side of the fish in both these species, is noticeably shorter in the yellowfin than in the big-eyed tuna, and in the case of the latter, the spleen is almost hidden in this view by the fold of the intestine, whereas in the yellowfin the spleen is invariably seen on the right side of the fish. Although there is considerable variation in individual visceral organs, the fundamental pattern is always apparent, and this view therefore affords a means of positive identification. Figure 21, depicting the viscera in six fish, illustrates this pattern and the variation to be expected.

TABLE 9

Yellowfin tuna. The range, within geographic samples, in the various body proportions. The range in the size of the fish examined is shown in the first line of the table.

Body proportion	Japan	Hawaii	Clipperton	Galapagos	Cocos Island	Peru	Costa Rica	Punta Galera	Lower Calif.
Range in body length—mm.	970-1200	537-573	655-693	506-661	626-661	818-901	619-640	662-727	539-728
Body length / Head length	3.86- 4.00	3.35- 3.52	3.43- 3.58	3.31- 3.44	3.37- 3.42	3.51- 3.68	3.35- 3.54	3.39- 3.53	3.40- 3.57
Body length / 1st dorsal insertion	3.47- 3.55	3.01- 3.19	3.14- 3.18	2.96- 3.16	3.05- 3.16	3.17- 3.29	3.02- 3.20	3.06- 3.23	3.06- 3.24
Body length / 2d dorsal insertion	1.91- 1.98	1.77- 1.83	1.82	1.77- 1.82	1.76- 1.82	1.81- 1.88	1.76- 1.85	1.81- 1.85	1.78- 1.84
Body length / Anal insertion	1.70- 1.75	1.61- 1.67	1.63- 1.64	1.59- 1.64	1.60- 1.64	1.60- 1.69	1.58- 1.65	1.62- 1.65	1.57- 1.65
Body length / Ventral insertion	3.37- 3.56	3.07- 3.17	3.02- 3.18	2.99- 3.14	3.01- 3.12	3.07- 3.26	2.99- 3.17	3.05- 3.12	3.01- 3.19
Body length / Body depth	3.89- 4.08	3.56- 4.09	3.67- 3.99	3.57- 3.80	3.68- 3.73	3.61- 4.00	3.50- 3.75	3.62- 3.87	3.63- 3.95
Body length / Body width	5.26- 5.92	5.56- 5.99	5.29- 5.96	5.49- 6.06	5.35- 5.58	5.70- 6.18	5.20- 5.57	5.27- 5.54	5.23- 6.20
Body length / Dorsal-ventral distance	4.09- 4.35	3.81- 4.21	3.85- 4.16	3.74- 4.05	3.82- 3.87	3.84- 4.27	3.64- 3.88	3.82- 4.01	3.82- 4.02
Body length / Dorsal-anal distance	2.60- 2.67	2.52- 2.61	2.54- 2.62	2.47- 2.56	2.52- 2.58	2.49- 2.69	2.46- 2.58	2.51- 2.61	2.45- 2.69
Body length / Length 1st dorsal base	4.00- 4.24	3.90- 4.16	4.02- 4.17	3.92- 4.17	4.01- 4.22	3.88- 4.30	3.95- 4.21	4.02- 4.23	3.95- 4.26

TABLE 9
Yellowfin tuna. The range, within geographic samples, in the various body proportions. The range in the size of the fish examined is shown in the first line of the table

Body length / Pectoral length	3.40- 3.76	3.11- 3.56	3.47- 3.89	3.38- 3.80	3.34- 3.76	3.46- 4.15	3.33- 3.93	3.39- 3.76	3.48- 4.21
Body length / Height 1st dorsal	8.45- 9.10	7.54- 9.43	9.24	8.33- 9.94	8.78-10.61	8.07- 9.47	8.21- 9.65	8.07- 9.32	8.40- 9.10
Body length / Height 2d dorsal	5.39- 5.99	7.83- 8.95	....	9.82	....	6.98- 7.38	....	7.48- 9.19	8.09-10.17
Body length / Height of anal	4.43- 5.66	7.72- 9.76	....	8.72- 9.39	....	6.14- 7.94	9.43	7.48- 8.95	8.65-11.76
Body length / Length 2d dorsal base	8.57-10.00	8.66-11.63	8.77- 9.92	9.70-10.73	9.30-10.16	9.08-12.41	9.41-11.68	8.87-10.81	9.46-11.30
Body length / Length of anal base	10.81-12.93	11.67-12.93	12.83-13.82	9.89-14.68	10.10-13.83	12.27-13.77	11.25-12.80	12.36-13.96	10.57-14.17
Body length / Spread of caudal	3.45- 3.59	3.27- 3.85	3.75- 3.90	3.64- 3.90	3.48- 3.78	3.41	3.55- 3.97	3.29- 3.79	3.31- 3.77
Head length / Diameter of iris	7.69- 8.56	5.64- 6.27	6.82- 7.15	6.04- 6.48	6.57- 7.15	7.00- 8.00	6.40- 6.89	6.61- 7.15	5.57- 7.03
Head length / Maxillary length	2.53- 2.64	2.50- 2.56	2.57- 2.58	2.48- 2.65	2.54- 2.67	2.53- 2.64	2.54- 2.62	2.55- 2.64	2.46- 2.65

TABLE 9—Cont'd.

TABLE 10

Yellowfin tuna. Frequency of occurrence of various fin-ray counts, by geographic samples

	First Dorsal Fin			Second Dorsal Fin			Dorsal Fin-lets		Sec. Dor. plus Dor.Finlets		Anal Fin		Anal Finlets		Anal Fin plus Anal Finlets	
Count	12	13	14	14	15	16	8	9	23	24	14	15	7	8	22	23
Japan	-	2	3	-	5	-	5	-	5	-	5	-	-	4	4	-
Hawaii	-	1	11	1	11	-	11	1	12	-	12	-	-	12	12	-
Clipperton	-	3	-	-	1	1	3	-	1	1	3	-	-	3	3	-
Galapagos	-	2	5	-	6	-	6	-	6	-	6	1	1	6	7	-
Cocos	-	-	4	-	5	-	5	-	5	-	4	1	1	4	5	-
Peru	-	3	3	1	5	-	5	1	6	-	5	-	-	6	5	-
Costa Rica	1	1	3	1	4	-	4	1	5	-	4	1	-	5	4	1
Pta. Galera	-	4	2	-	6	-	6	-	6	-	6	-	-	6	6	-
Lower California	1	4	6	-	10	1	11	-	10	1	9	2	1	10	10	1
Totals	2	20	37	3	53	2	56	3	56	2	54	5	3	56	56	2

TABLE 10

Yellowfin tuna. Frequency of occurrence of various fin-ray counts, by geographic samples

TABLE 11

Yellowfin tuna. Frequency of occurrence by geographic samples of the gill-raker counts on upper and lower limbs, separately and combined

	Upper limb				Lower limb				Upper and lower limbs combined						
Gill-rakers	8	9	10	11	19	20	21	22	27	28	29	30	31	32	33
Japan	1	2	2	-	1	2	2	-	1	-	2	-	2	-	-
Hawaii	1	3	6	2	-	2	9	1	-	-	1	4	5	2	-
Clipperton	-	2	1	-	-	-	3	-	-	-	-	2	1	-	-
Galapagos	-	3	4	1	-	2	5	1	-	-	1	2	4	1	-
Cocos	-	3	2	-	-	1	3	1	-	-	1	2	1	1	-
Peru	1	2	3	-	2	1	2	1	-	1	2	2	-	1	-
Costa Rica	-	2	3	-	-	1	3	1	-	-	-	2	3	-	-
Pta. Galera	-	3	2	1	1	2	3	-	-	1	-	3	2	-	-
Lower California	1	3	3	3	-	3	5	2	-	1	-	3	4	1	1
Totals	4	23	26	7	4	14	35	7	1	3	7	20	22	6	1

TABLE 11

Yellowfin tuna. Frequency of occurrence by geographic samples of the gill-raker counts on upper and lower limbs, separately and combined

5.3. Caecal Mass

The caecal mass varies considerably in length. It is proportionately longer in small fish, in which it sometimes extends the full length of the abdominal cavity. In larger fish it is shorter, and in the specimens examined its least length equalled 0.42 of the length of the abdominal cavity. The apex of the caecal mass lies on the left side of the fish. Although this is characteristic it is not invariable, because in two cases out of sixty (C.R.-2 and Cl.-1) it was found on the right side of the fish.[9] The caecal mass opens into the duodenum through seven ducts. This number appeared fairly constant, but the complexity of these ducts sometimes makes the count subject to different interpretations. The caecal mass is similar in most of the tunas and its appearance and location in the yellowfin are not distinctive.

[9] In regard to such anomalies, see further the discussion of the anterior arterial system, where the customary arrangement is occasionally reversed.

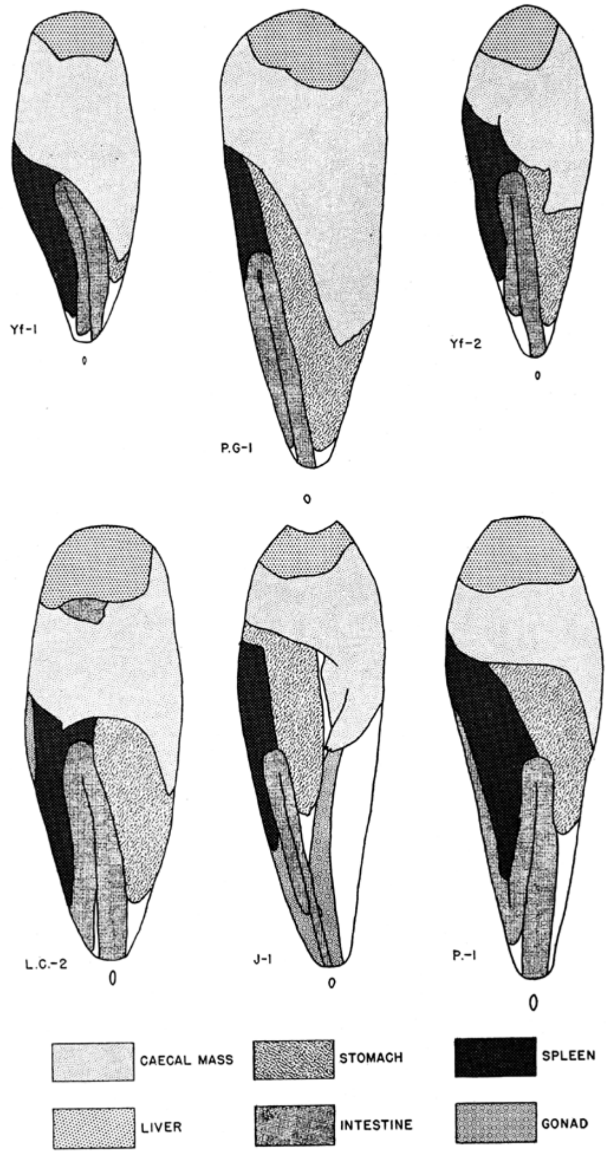

FIGURE 21. Yellowfin tuna: Ventral view of the viscera in six specimens.

FIGURE 21. Yellowfin tuna: Ventral view of the viscera in six specimens

5.4. Liver

Camera lucida sketches of the excised liver of 6 specimens are shown in figure 22 to illustrate its characteristic shape and the variations that may be encountered. Typically the liver is composed of three lobes. In occasional fish a small lobule exists between the center and left lobes. Whereas the right lobe is invariably the longest, its extent varies considerably. In some instances it is little, if any, longer than the center lobe, and in others it becomes extremely long. It is never attenuated, however, as in the skipjack. The size of the liver varies generally with the size of the fish; but independent of the size of the fish there is considerable

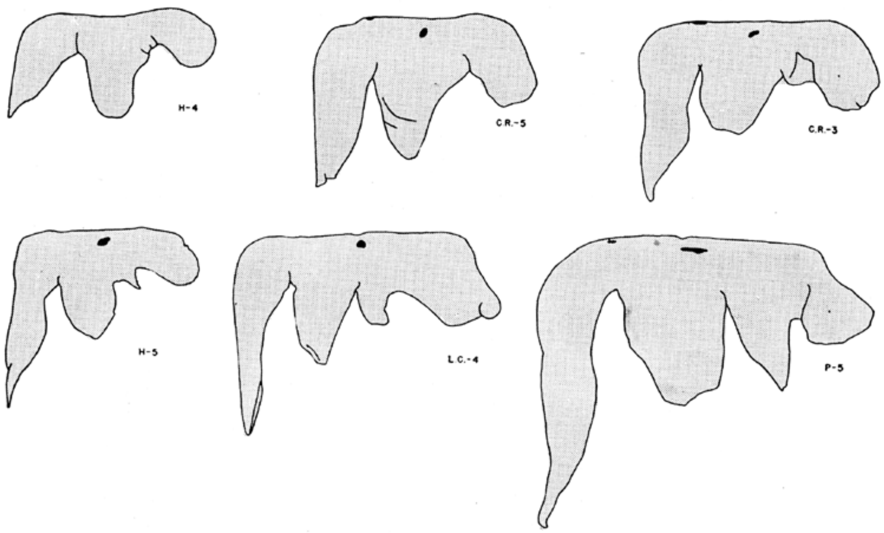

FIGURE 22. Yellowfin tuna: Ventral view of the excised liver from six specimens. The small, darkened areas indicate the location of the severed veins.

FIGURE 22. Yellowfin tuna: Ventral view of the excised liver from six specimens. The small, darkened areas indicate the location of the severed veins

variation in the bulk or massiveness of the liver, and there are indications that the weight of the liver might be correlated with geographical origin. Thus the livers of fish from Lower California and the Mexican coast appeared thicker and more massive than those of fish from the more southern grounds. In particular, the livers of the Hawaiian specimens appeared noticeably thin. The possibility that seasonal variation may account for this difference has not been investigated.

The liver of the yellowfin is uniformly colored, and there are no surface markings; neither are there capillary plexuses dorsal to the liver as there are in the bluefin, albacore and big-eyed tuna. From that of the skipjack, the liver of the yellowfin differs in shape, so that the liver is in reality a distinctive and specific character.

5.5. Stomach

The apex of the stomach is usually but not invariably on the left side of the fish. The length of the stomach is quite variable, and is relatively longer in small fish than in large fish. Expressed in relation to the length of the abdominal cavity, the stomach varied in length between 0.41 and 0.96 of the latter.

5.6. Intestine

A sketch of the alimentary canal is shown in figure 2. The intestine is folded as in the majority of tunas, and in the yellow-fin the fold lies invariably on the right side of the abdominal cavity. In this respect it is similar to the big-eyed tuna, but in the yellowfin the fold is shorter. The course of the intestine is fairly distinctive, but is not sufficient alone for positive identification of the species.

5.7. Spleen

The spleen (Fig. 23, P-1 and LC-2 and Fig. 1) is moderately large and quite conspicuous, and it is situated on the right side of the abdominal cavity between the straight intestine and the ascending portion of the intestine. Its location and general shape were constant but the posterior extension of the spleen was quite variable. In some cases this barely reached the center of the distance between the bends of the intestine, whereas in others the spleen extended almost to the posterior bend. In its relation to the other organs, the spleen of the yellowfin is distinctive, and may be considered as a specific character.

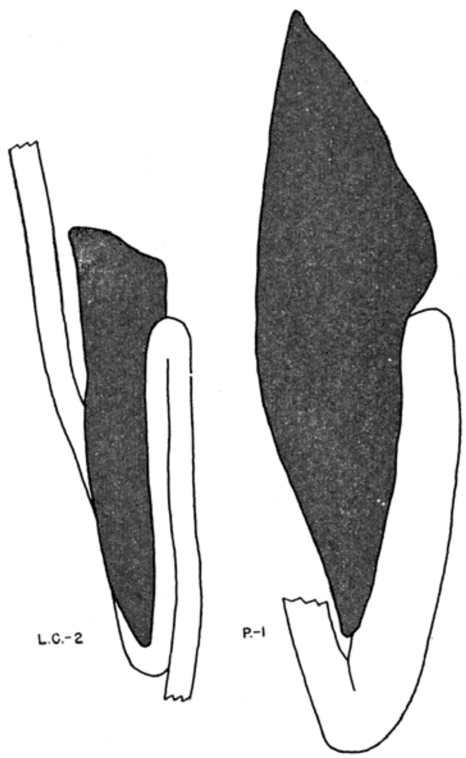

FIGURE 23. Yellowfin tuna: Ventral view of the spleen, in two specimens

5.8. Gall-bladder

The gall-bladder is located on the right side of the body, paralleling and adhering to the straight intestine. It lies dorsal to the spleen and intestine and therefore is not seen in the ventral view of the viscera. It extends to or beyond the posterior bend of the intestine, and just anterior to the tip of the right lobe of the liver it tapers gradually into a bile-duct. Typically, an accessory duct—or possibly a ligament—runs at right angles to the axis of the gall-bladder to the tip of the right lobe of the liver.

In one specimen (J-2) the gall-bladder was marked with three marginal yellowish stripes as in the albacore. In this case the gall-bladder was similar in structure and position to that of all other yellowfin and differed only in the possession of the marginal stripes. Such markings were at first considered characteristic of the albacore, but the above observation and two comparable observations in the case of the bluefin suggest that such markings should not be considered as specific characters.

5.9. Air-bladder

The air-bladder in the yellowfin is about half the length of the body cavity, varying in individuals from 0.3 to 0.67 of the latter. It is relatively narrow, and shaped typically as in L.C.-4, figure 24. The walls of the air-bladder are uniformly thin, and of a dull silvery color. The posterior end is generally rounded, but in some cases it is more sharply pointed as in LC-7, figure 24. The anterior end is deeply cleft dorsally and thus divided into two pockets, or "horns," which fit on either side of the dorsal aorta into the pit for the air-bladder, which is directly and characteristically beneath the sixth vertebra. The "horns" are typically hollow pockets, and at the tip of each is a small mass of reddish tissue, which for convenience is designated as the "glandular mass," because its appearance suggested a glandular function. The circular orifice and internal septum are always present, and are usually located in the anterior half of the air-bladder, near the middle of its length. Towards the anterior end of the air-bladder, and in its ventro-lateral wall, there is on each side a peculiar fern-like plexus, apparently associated with the arterial supply from the viscera. This is always present. Sometimes it is very conspicuous and at others it is barely apparent.

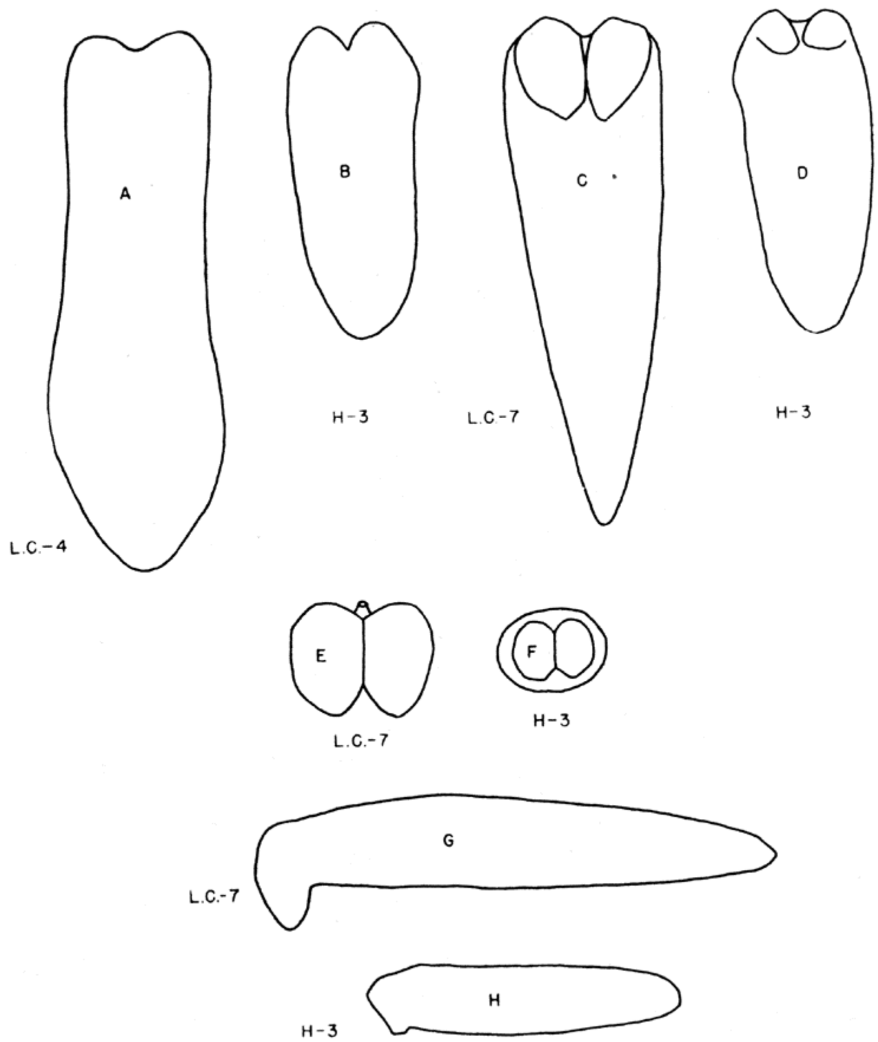

FIGURE 24. Yellowfin tuna: Various views of the air-bladder in three specimens. A and B: Ventral view of the air-bladder in situ. C and D: Dorsal view of the air-bladder dissected intact from the fish. E and F: Anterior (end) view of the air-bladder dissected intact from the fish. The median, dorsal protuberance in L.C.-7, is the severed branch of an artery. G and H: Lateral view of excised air-bladder

The cleft in the head of the air-bladder owes its depth to a ligament peculiar to this species, rather than to the dorsal aorta. This ligament originates in another characteristic structure as follows: In the dorsal wall of the abdominal cavity there is present mesially a sheet of thick tough connective tissue which increases in thickness anteriorly, until, in the anterior region of the abdominal cavity, it rises above the wall of the cavity as a solid cord of tissue. The development of this cord increases with the size of the fish. In small fish it is little more than a narrow median sheet, whereas in large fish it is a heavy conspicuous cord of considerable depth. In all cases, however, it terminates anteriorly in a characteristic manner. Reaching the posterior margin of the pit for the air-bladder, the cord flattens, and sends an arm to each side, thus encircling, and as it were, reinforcing the posterior margin of this pit. The structure in this region has the shape of an open "Y," and is illustrated diagrammatically in figure 25. From the throat of this "Y" a small, tough ligament extends anteriorly and horizontally in the median line, and attaches to the dorsal wall of the stomach at its origin in the oesophagus. It is this ligament that actually divides the head of the air-bladder. This ligament and the dorsal connective tissue cord were found only in the yellowfin, in which they were invariably present.

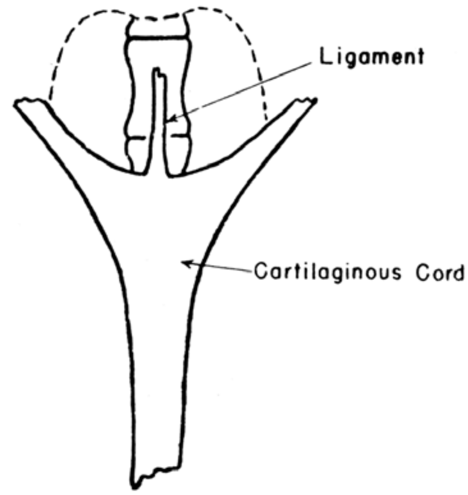

FIGURE 25. Yellowfin tuna: A diagrammatic ventral view of the connective tissue cord in the median dorsal body wall. See text, pp. 54–55

The air-bladder receives arterial blood from two sources. The Number II branch of the coeliac-mesenteric artery sends a small branch to the anterior ventral wall of the air-bladder, joining it in the mid-ventral line between the two fern-like plexuses mentioned above. The second source of supply is the axial system. In the posterior half of the air-bladder a number of small arteries, originating presumably in the dorsal aorta, traverse the heavy connective tissue in the dorsal wall of the abdominal cavity, and entering the air-bladder, they give rise in its dorsal wall to an extensive and complicated capillary network. Although this was observed only in an occasional fish, the existence of this arterial network was demonstrated in one or more specimens from each sample, thus showing that it was common to local, Japanese, Hawaiian and Peruvian fish. It is interesting to note that the most complete injections were obtained in small fish, suggesting that the heavier connective tissue cord of the larger fish effectively constricted the arteries and so prevented the penetration of the injection mass.

As in the other tunas, the air-bladder of the yellowfin is extremely variable, and anomalies are of frequent occurrence. In some cases the air-bladder tapers posteriorly to a point, as in L.C.-7. In other cases the air-bladder is small and the head fails to reach and is therefore not inserted into the pit. In such cases the bladder is connected with the pit by a peculiar, filmy, mucilaginous tissue which also fills the pit. In all cases, however, the head of the air-bladder is divided. The two "horns" may be large and conspicuous as is L.C.-7, or quite small as in H-3, and whereas they are typically hollow sacs, they are occasionally partly filled with a hard cellular tissue. Throughout all these variations, however, a fundamental plan or pattern is apparent, and this differs from that of the other tunas and separates the yellowfin from all.

The structure of the air-bladder has been discussed in considerable detail for two reasons. In the first place the five Japanese specimens differed from all the remaining yellowfin in one minor respect: and in the second place they differed from Kishinouye's description which does not accord with these findings.

In the five Japanese yellowfin examined, the air-bladder was collapsed in all. This in itself is not significant because the air-bladder in many local specimens was similarly collapsed. But in every Japanese specimen the appearance of the air-bladder suggested atrophy. Immediately posterior to the head of the bladder there was a constriction as though the tissues had shrivelled to form a neck or isthmus separating the head of the bladder from the posterior portion. When, however, the ventral wall of the air-bladder was slit, the constriction appeared to be due to corrugations in the lateral walls at this point. If the walls were stretched, these corrugations disappeared and the view then obtained was essentially similar to that presented by a normal air-bladder. Thus in fundamental design these air-bladders agreed with the above description based upon the remaining specimens.

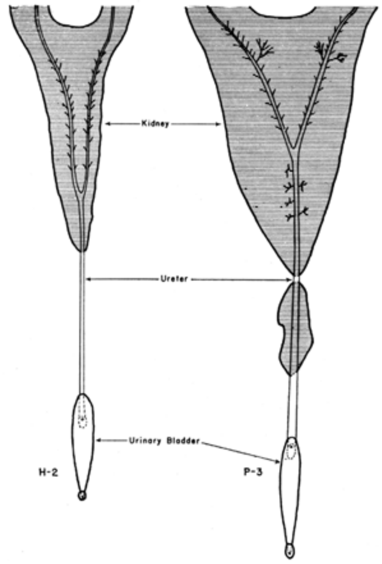

FIGURE 26. Yellowfin tuna: Ventral view of the excretory system in two specimens

Turning now to Kishinouye's description, neither the present findings nor the irregularities encountered in the Japanese specimens agree in any particular with the illustrations of his text. On page 355, Kishinouye figures the air-bladder, and on page 446, describes it as: "narrow and long, not divided at the anterior end." Every specimen of yellowfin examined in the course of this work, without exception and including the five Japanese specimens, possessed an air-bladder deeply divided at the anterior end. In page 446, he continues: "* * * thick strong connective tissue protects the ventral part of the air-bladder." This was never encountered in the present study, and it is the authors' opinion that Kishinouye was in reality referring to the connective tissue cord described above lying dorsal to the air-bladder.

On page 356 Kishinouye continues: "The air-bladder of the Scombridae and Cybiidae receives blood from the dorsal aorta at several points, and pours its venous blood to the posterior cardinal vein at several spots; but in the Plecostei the arterial blood is received from a special branch of an artery, running along the right hand side of the stomach, and the venous blood pours to the caudal or the posterior cardinal vein through a segmental vein. Thus the arterial system of the air-bladder belongs to the axial system in the Scombridae and Cybiidae, but to the visceral system in the Plecostei." In view of the results presented above, this statement seems unwarranted, because in the Japanese yellowfin as in all others, the air-bladder receives an appreciable arterial supply through its dorsal wall from the axial system. This was also true of the albacore and big-eyed tuna.

The above substantiates the conclusion that the Japanese yellowfin are not specifically different from all others. In all probability the air-bladders of the five Japanese specimens examined were abnormal to this extent, and the universal variability of the air-bladder in this family lends considerable support to this suggestion.

5.10. Excretory System

Kidney: The kidney extends posteriorly to approximately the middle of the abdominal cavity. In 58 specimens it terminated beneath the 13th vertebra in one case: beneath the 14th vertebra in 25 cases: beneath the 15th vertebra in 23 cases, and beneath the 16th vertebra in 9 cases. It thus resembles that of the skipjack, although it is not usually as long, and it is more regular in outline and less crenulated. What appears to be an accessory kidney mass is occasionally seen just posterior to and slightly detached from the tip of the kidney (Figs. 26 and 32). The kidney was essentially similar in all fish examined and no significant differences were observed in the various samples.

Ureter: (Figs. 26 and 32) Typically the ureter divides in the vicinity of the 11th vertebra, but the division may occur at any point between the 10th and 14th vertebrae. Normally the ureters begin to separate at the point of division, but in those cases where this occurs far posteriorly, the two branches may run together and parallel for a short distance (H-2 of figure 26). The ureters of the yellowfin resemble only those of the skipjack, which however, run parallel for an appreciable distance, separated invariably by the post-cardinal vein.

Urinary Bladder: The urinary bladder measures approximately 0.2 of the length of the abdominal cavity. The most characteristic attribute of the bladder in this species is the fact that the anterior portion projects freely into the body cavity dorsal to the rectum and between the gonads. In this respect it resembles the big-eyed tuna, and differs from the three remaining tunas. The ureter joins the bladder at its anterior end, but in the majority of cases it actually opens into it a few millimeters (five, or thereabouts) posterior to the point of juncture.

5.11. Circulatory System

1. Anterior Arterial System: The complexity found in this region differentiates the yellowfin from all other species in this family (Fig. 27).

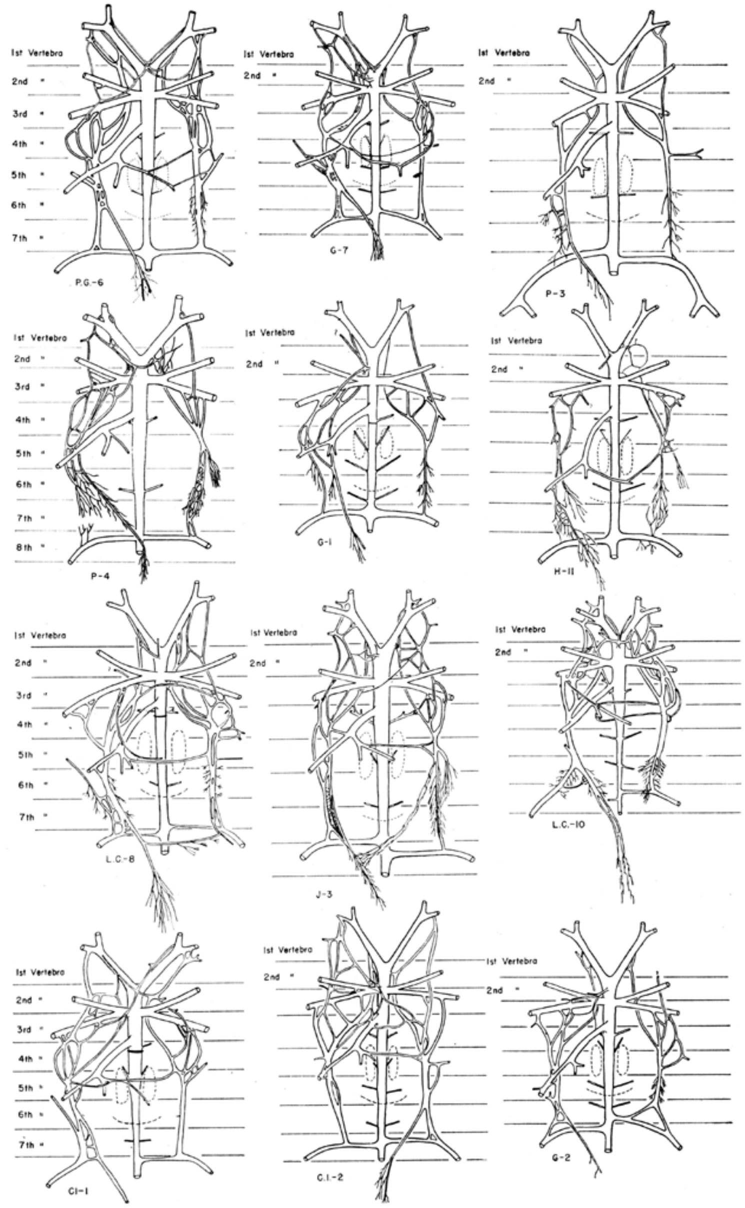

FIGURE 27. Yellowfin tuna: Ventral view of the anterior arterial system in twelve specimens to show the variations and anomalies occasionally encountered.

FIGURE 27. Yellowfin tuna: Ventral view of the anterior arterial system in twelve specimens to show the variations and anomalies occasionally encountered

The "Y" of the aorta is beneath the anterior end of the second vertebra or beneath the junction of the first and second vertebrae. A short posterior epibranchial joins the aorta on each side beneath the anterior half of the third vertebra. The coeliac-mesenteric artery arises beneath the junction of the third and fourth vertebrae. The subclavians arise at the same point or slightly posterior, and the ligament traverses the aorta at this point also. The pharyngeal muscles are attached to the fifth vertebra, and in part to the fourth and sixth. Beneath the fifth, sixth and seventh vertebrae small paired arteries leave the aorta and run, in the case of the first pair, diagonally forward, and in the case of the others, approximately at right angles, laterally. The pit of the air-bladder is located typically beneath the sixth vertebra, and beyond this the moderate to large cutaneous arteries arise beneath the junction of the seventh and eighth vertebrae, or as frequently, beneath the anterior portion of the eighth vertebra. In the majority of cases they run laterally perpendicular to the aorta, but occasionally they may curve posteriorly as in the albacore and bluefin. In most cases the cutaneous arteries arise directly opposite each other on either side of the aorta, but not infrequently they are staggered in their origin, and in the majority of such cases the cutaneous artery on the left side is slightly anterior to that of the right. The location of the origin of the cutaneous arteries beneath the junction of the seventh and eighth vertebrae separates this species from the skipjack, albacore and the bluefin. The big-eyed tuna resembles the yellowfin in this respect, but the latter differs in the possession of a character unique to this species.

Paralleling the aorta, a large vessel connects the efferent branchials with the cutaneous artery on each side, and we shall call these vessels the "parallel trunks." Their extreme variability makes an adequate description difficult, but in the maze of individual variation there appears to be a basic or fundamental pattern. An interpretation of this, based upon the examination of 60 injected specimens, is shown in the diagrammatic sketch (Fig. 28) and in the following description.

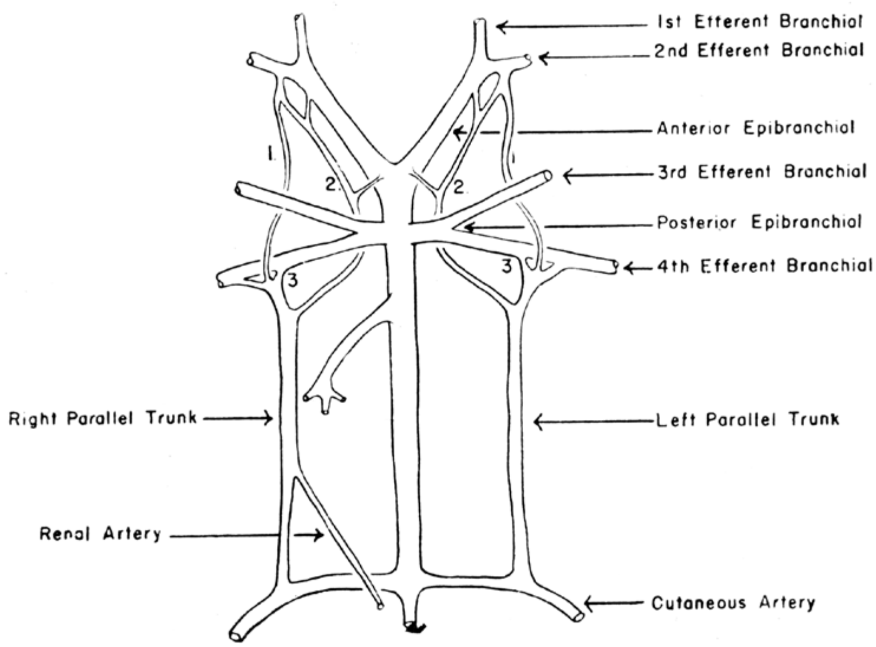

FIGURE 28. Yellowfin tuna: Diagrammatic ventral view of the simplified anterior arterial system.

FIGURE 28. Yellowfin tuna: Diagrammatic ventral view of the simplified anterior arterial system

The parallel trunk on each side is formed by the fusion of three small arteries: (1) From the fork of the anterior epibranchial (or thereabouts) a vessel originates and runs posteriorly dorsal to the third efferent branchial and ventral to the fourth efferent branchial. Just posterior to the latter vessel it is joined by the two remaining vessels now to be described. (2) A second small vessel arises in a multiple origin in the first or second efferent branchial and the anterior epibranchial and runs posteriorly and mesially to pass dorsal to the posterior epibranchial. Here it swings laterally and joins the two other tributaries. (3) The third vessel arises in a complex and multiple origin from the fourth efferent branchial and immediately joins Number 1 and Number 2, described above, to form the large parallel trunk. That of each side differs in its course. The left parallel trunk is relatively simple inasmuch as it runs posteriorly to join directly the left cutaneous artery. The right parallel trunk runs postteriorly dorsal to the coeliac-mesenteric artery with which it is interconnected. Invariably a small to moderate branch connects the parallel trunk with the Number 3 branch of the coeliac-mesenteric artery, and frequently smaller vessels connect the remaining branches of the coeliacmesenteric artery, and even this vessel anterior to its division, with the parallel trunk. Beyond this point, in the vicinity of the seventh vertebra, the right parallel trunk divides into two. One branch runs obliquely towards the median line and as a renal artery nourishes the kidney. This artery, in the vicinity of the ninth vertebra, meets and accompanies a renal vein, and rapidly breaks up into minute vessels which are lost to view in the kidney substance. The second branch of the right parallel trunk runs directly to and fuses with the right cutaneous artery.

Superimposed upon this basic pattern is a wealth of detail and individual variation which defies description. For this reason and because specimens from different geographic regions appeared to differ slightly in this character, it was sketched in each dissection. The sketches in figure 27 were selected to illustrate the variations encountered. It will be noted that there is extreme variation in the size of the parallel trunks. In some specimens these are large, conspicuous vessels, whereas in others each is in reality a narrow bundle of fine, anastomosing vessels connecting the efferent branchials with the cutaneous artery. The latter type may degenerate still further until this connection is established only by anastomosis of small branching vessels originating in the efferent branchials on the one hand, and in the cutaneous artery on the other hand. In such cases it will be noted that the cutaneous artery tends to curve posteriorly as in the genus Thunnus, whereas in those cases where the parallel trunks are moderate or large, the cutaneous arteries run laterally perpendicular to the aorta, which is more or less characteristic of this species. Similarly the size of the cutaneous arteries at their origin in the aorta appears to be inversely correlated with the size of the parallel trunks. In cases where the parallel trunks are small, the cutaneous arteries are large; and conversely, in cases where the parallel trunks are large, the cutaneous arteries—at their origin—are frequently small. In fact there are six instances (LC-5, LC-10, CR-3, PG-1, P-2, Cl-1), some of which are illustrated with other anomalies in figure 27 where the cutaneous artery on the right side has aparently become completely atrophied at its origin in the aorta, and the entire arterial supply to the cutaneous system on this side flows through the right parallel trunk. A comparable condition was not found on the left side. The extreme variability of this system suggests evolutionary instability.

A final variation encountered constitutes, in all probability, an anomaly. In two instances out of the total 60, the symmetry of this anterior arterial system was in part reversed. In these two instances

(C.I.-2, and C.R.-5) the renal artery originated in the left parallel trunk instead of the right, as is customary. Moreover, the post-cardinal vein which characteristically turns towards the right side of the fish to empty into the right Cuvierian duct ran, in these two cases, towards the left, and emptied into the left Cuvierian duct. In all other respects these two fish were normal. In still another instance (J-3) the left parallel trunk, which was decidedly atypical, sent a number of fine tributaries to the renal artery, which arose normally in the right parallel trunk. In view of these observations caution is necessary in interpreting isolated findings.

A study of the individual variations in this system revealed that small, anastomosing parallel trunks characterized the majority of Hawaiian specimens and many from the Galapagos Islands. However, the types are not distinct as they are bridged by intermediate variants. Although larger parallel trunks characterized the remainder of the samples there was in each one or more specimens with the small, anastomosing type. Hence the difference is not constant or of specific significance.

2. *Visceral Arterial System* (Figs. 29 and 30): In this species there are three major branches of the coeliac-mesenteric artery. Characteristically the No. I and No. II branches arise on a very short common trunk, as shown in both the above figures.

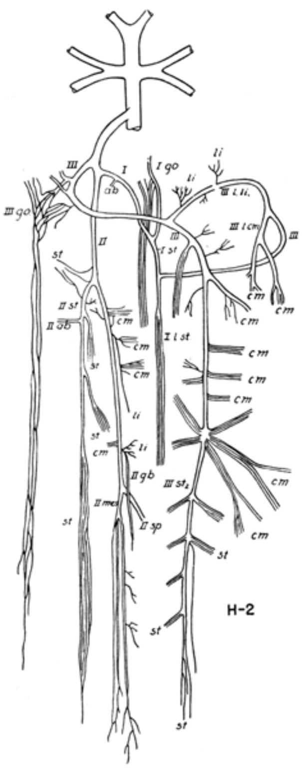

FIGURE 29. Yellowfin tuna: Diagrammatic ventral view of the coeliac-mesenteric artery and its branches, in a small specimen

The No. I branch runs toward the median line of the fish and entering the body cavity on the left side, it runs posteriorly in the left dorsal wall of the stomach, continuing almost to its posterior tip, usually as a bundle of minute vessels which run together and parallel. In the region where the No. I branch joins the wall of the stomach it is joined by a small branch (I-go. in both figures) which originates in, or perhaps runs to, the left parallel trunk, and it is this connecting vessel that apparently gives rise to a series of small vessels which nourish the gonad. The arrangement in this region is obscure, but in large fish this connecting vessel is quite prominent and in the dissection of J-5, figure 30, it was followed and the course of its tributaries recorded. In this fish I-go.

was a moderate-sized vessel. From its origin in the No. I branch it ran obliquely anteriorly and shortly gave rise to a pair of vessels (I-a. st.) which nourished the anterior, dorsal stomach wall. Branch I-go. continued and shortly divided into two. I-h ran anteriorly and ventral-ward to the transverse septum, and apparently contributed to the arterial supply of the heart muscles.[10] The second terminal branch, I-p, joined, through one or more subsequent branches, the left parallel trunk. The origin of the vessels to the left gonad was not seen in this case.

In perhaps the majority of dissections, a connection between the No. I and No. III branches was observed. This connection (labelled I-l.st.), shown in figure 29, and indicated in figure 30, will be discussed under the heading of the No. III branch. The connection is variable in its course, and although not always seen it is probably present in all specimens. Failure to observe it was no doubt due to the inadequacy of the injection.

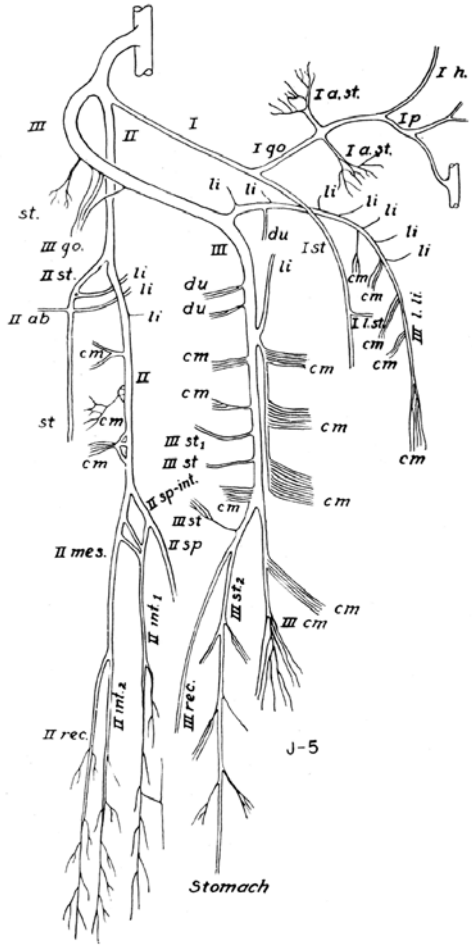

FIGURE 30. Yellowfin tuna: Diagrammatic ventral view of the coeliac-mesenteric artery and its branches, in a large specimen

The No. II branch passes dorsal to the right Cuvierian duct into the abdominal cavity, and thence it runs posteriorly with the right lobe of the liver, giving off a number of small vessels which run into the substance of this lobe. In the anterior region of the stomach the No. II branch gives rise to the branch II-st. (Fig. 29) which goes to the right dorsal wall of the stomach, and continues to its posterior tip, generally as a bundle of small parallel vessels. Shortly beyond its origin this vessel (II-st.) gives rise in all cases to the vessel labelled II-a.b., which runs to the ventral wall of the air-bladder, and generally through a

[10] This branch is apparently the mate to a vessel seen regularly on the right side and originating in the right parallel trunk, and likewise running in the transverse septum to the wall of the heart.

number of capillary bundles to the stomach and liver. The main trunk of the No. II branch continues posteriorly, giving off in its course a complex system of fine vessels to the right lobe of the liver, and to the caecal mass. Occasionally a small vessel (II-g.b.) is seen to originate in this portion and run to the gall-bladder. Beyond this the No. II branch divides into two terminal branches. One, II-sp., goes into the substance of the spleen, ramifying throughout, and continuing to its posterior end. The other branch, II-mes., subsequently divides into three vessels, all of which run in the mesentery between the spleen and the intestine. These vessels nourish the surface of the spleen, and mainly the walls of the intestine, sending tributaries to the fold of the intestine and to the rectum, or descending portion. Considerable minor variation occurs in these terminal branches.

The No. III branch of the coeliac-mesenteric artery is invariably the largest. Near its origin it is connected with the right parallel trunk as described in a preceding section, and in this vicinity the No. III branch gives rise to a number of fine vessels which, joining similar vessels from the right parallel trunk, run to the right gonad. Beyond this the No. III branch turns ventralward and runs to the dorsal face of the center lobe of the liver. Here it gives rise to a large branch, labelled III-l. li., in the figures. This vessel runs on the dorsal surface and sometimes within the substance of the liver, across the anterior ventral stomach wall, to the left lobe of the liver, nourishing both center and left lobes. Eventually it breaks up into two or three large terminal vessels which enter the anterior caecal mass. It is this branch that is connected with the No. I branch of the coeliac-mesenteric artery. In many specimens a tributary was seen leaving the vessel (III-l. li) just prior to its terminal break-up. The tributary (labelled III-l.st.) leaves the dorsal surface of the left lobe of the liver and runs dorsally across the left anterior wall of the stomach, and there joins the No. I branch. In some cases it fails to fuse with the No. I branch, and instead it turns posteriorly and as a minute vessel accompanies the No. I branch to the posterior extremity of the stomach.

Beyond the origin of III-l. li, the No. III branch continues a short distance in the substance of the center lobe of the liver and then crosses to the dorsal face of the caecal mass. Small tributaries arising from it in this region nourish the duodenum, the liver and the caecal mass. In its course through the caecal mass the No. III branch gives off numerous and complicated branches to all parts of this organ. Eventually it breaks up into a number of terminal branches, frequently resembling a radiating plexus, which nourish the entire organ. One of these terminal branches, however ($III\text{-}st._2$ in both figures), invariably crosses in the mesentery to the ventral wall of the stomach and runs posteriorly therein to its tip. Other smaller branches also traverse the mesentery at different points and nourish the stomach wall. Likewise a small vessel was seen frequently to arise in $III\text{-}st._2$ (Fig. 30 III-rec.), and run through the mesentery to the rectum.

Every specimen of yellowfin tuna examined agreed in general with the above description. Minor variations were random, and in no way correlated with the geographical origin of the specimen.

3. *Cutaneous System:* (Fig. 31) From their origin in the aorta the cutaneous arteries run laterally, generally perpendicular to the aorta.

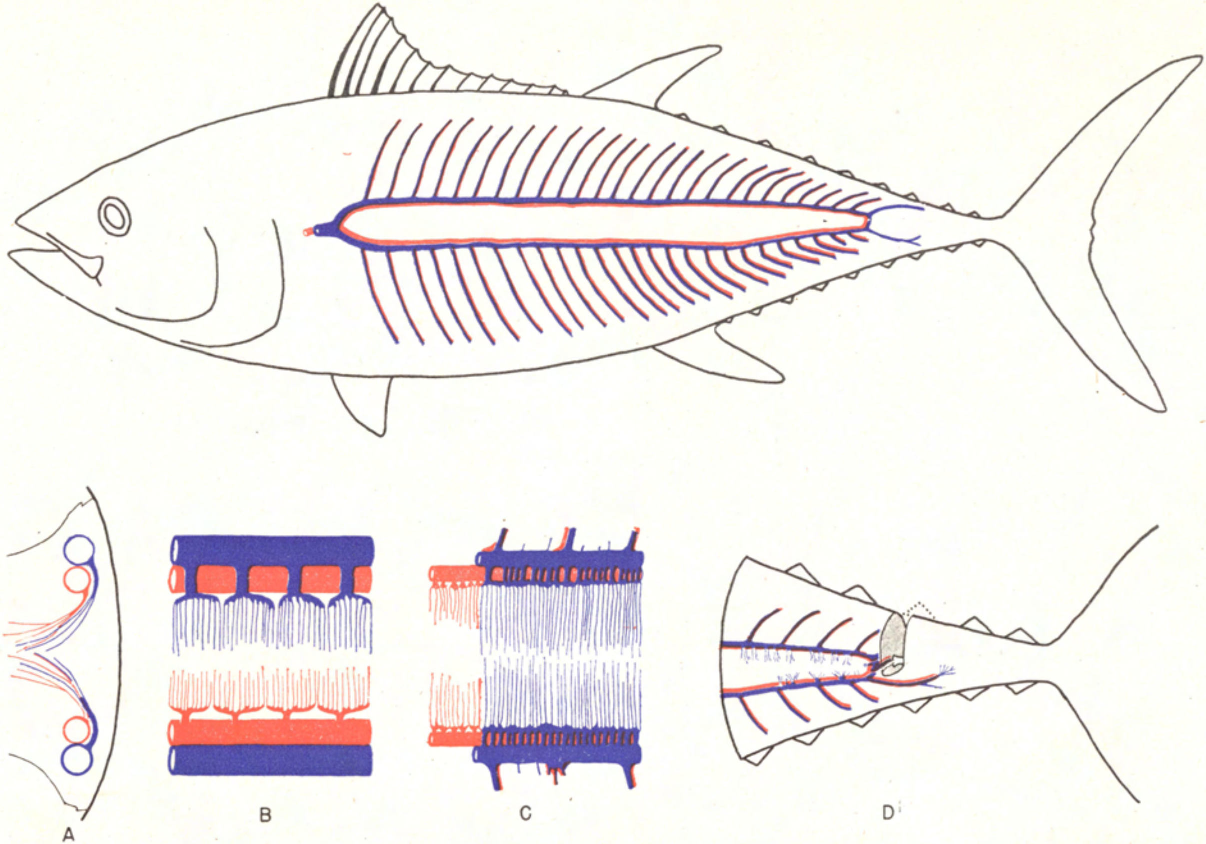

FIGURE 31. Yellowfin tuna: Cutaneous system. Upper: Course of cutaneous vessels in superficial musculature. A: Enlarged transverse section. B: Enlarged partial view of C, to show origin of venules (dorsal) and arterioles (Ventral). C: Enlarged view of cutaneous vessels to show detail. D: Posterior commissure. See text, pp. 65-66.

Variations in this character were discussed in a preceding section. From the point where the parallel trunks join the cutaneous arteries, they curve posteriorly, and with the corresponding vein, pass between the fifth and sixth ribs to the surface of the body. In one instance out of 60, the cutaneous artery and vein passed between the fourth and fifth ribs, on one side. Usually between the sixth and seventh inter-muscular bones, and exceptionally between the seventh and eighth, each cutaneous artery divides into a dorsal and ventral branch. There is a corresponding anterior commissure of dorsal and ventral cutaneous veins at the same point.

The course of the cutaneous vessels on the surface is not particularly distinctive. The vessels are large, and as in the other tunas, the dorsal and ventral pair converge posteriorly.

The distribution of venules and arterioles arising from the cutaneous vessels, and depicted in the figure, was relatively constant. The venules arise in a single continuous row on the proximal[11] face of each vein, and because the artery is a trifle deeper than the vein, the venules run across the external, or ab-axial face of the artery towards the lateral median line, thus obscuring the course of the artery in surface view. The venules then gradually turn towards the vertebral column and run into the dark flesh in several irregular vascular sheets. A few venules arise irregularly. The majority of these run axially, perpendicular to the surface, but a few cross the inner or axial face of the artery to join the vascular sheets. At such points the artery is thus encircled by venules, but this is neither regular nor characteristic of the species.

The arterioles arise similarly in a single, though somewhat irregular row on the proximal face of each artery. They immediately break up into capillary vessels which, with the venous capillaries, run into the dark flesh as a continuous sheet. Venules and arterioles are numerous, and a count of the venules in one specimen indicated approximately 19 to the inch. Arterioles are equally numerous. In large fish these vessels are correspondingly larger and in one such specimen there appeared to be about 12 to the inch.

On the caudal peduncle, approximately beneath the fourth dorsal finlet, the dorsal and ventral branch of each cutaneous artery turn towards and meet in the lateral median line, and thus form a posterior commissure. The veins do likewise, and there is in every fish a definite and strong venous and arterial posterior commissure at this point. The fused veins then turn axially and run perpendicular to the surface, directly into the vertebral column as a large single horizontal trunk. The arteries similarly flow into the vertebral column, but in this case the horizontal arterial trunk is divided into two, with one branch on the anterior and the other on the posterior face of the venous trunk.

In perhaps half the cases investigated the posterior commissures on either side were opposite, and the horizontal trunks entered opposite sides of the same vertebra. In the majority of such cases, this was the 29th or 30th vertebra. In the remaining half of the specimens, however, the two commissures were staggered, and the horizontal trunk from one side connected with the vertebral column one vertebra ahead or behind that of the other. In a few cases there appeared to be two commissures on one or both sides. At the commissure, a small vessel from each dorsal and ventral branch invariably continued posteriorly near the surface, and

[11] See page 19 for a definition of terms.

occasionally these vessels turned proximately to meet in the middle line, thus forming a second commissure, with a corresponding second horizontal trunk (venous and arterial) entering the vertebral column one or two vertebrae posterior to the main commissure. Not infrequently this second horizontal trunk was observed in the course of dissection even though a second commissure had not been detected. Such variations were found in fish from all localities, and were apparently random, so that no particular significance attaches to these observations. In all essential respects the fish from every geographical region were similar.

The characteristics of the cutaneous system separate the yellowfin from every other species. The yellowfin is the only species investigated in which a strong and unmistakable posterior commissure exists.

5.12. Post-Cardinal Vein

The post-cardinal vein emerges from the haemal canal through the first haemal arch on the 11th vertebra. A renal vein from the posterior kidney mass joins it at this point. Thence it curves to the right and as a large vessel, empties directly into the right Cuvierian duct.

The cutaneous veins are intimately associated with the post-cardinal vein in this species. The cutaneous vein on the right side discharges directly into the post-cardinal in the region of the seventh vertebra, whereas the cutaneous vein in the left side empties in part into the post-cardinal vein.

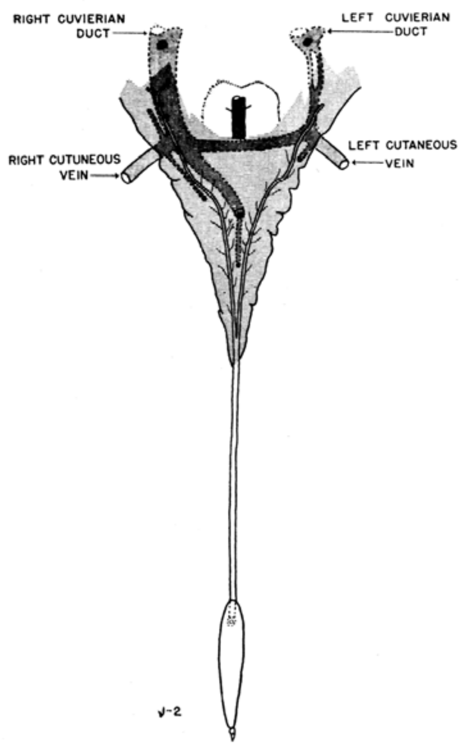

FIGURE 32. Yellowfin tuna: Ventral view of the excretory system and the post-cardinal and cutaneous veins

The left cutaneous vein follows the course of the artery, and after passing mesially between the fifth and sixth ribs the cutaneous vein divides. The larger trunk runs transversly across the fish within the kidney substance in the region of the seventh vertebra, and discharges into the post-cardinal vein at a point directly opposite the entrance of the right cutaneous vein. The second of the two branches is smaller, and it runs anteriorly on the left side paralleling the post-cardinal vein. It follows the left parallel (arterial) trunk for a short distance, and in the region of the Cuvierian duct it terminates in what appears to be a collecting sinus, into which empty a number of vessels from the anterior kidney mass. The sinus appears to discharge by several apertures into the left Cuvierian duct.[12]

[12] These findings do not exactly agree either with Kishinouye's description on page 370, or with his figure on page 369. The alternative arrangement which he describes and figures was never observed.

In large fish a number of other venous vessels may be seen without injection. These, shown in figure 32, enter the post-cardinal in the region where this is joined by the cutaneous vessels. The one most frequently observed originated in the anterior kidney mass on the right side and entered the right cutaneous vein at the point where this joins the post-cardinal. In position and appearance this vessel corresponds with the forward continuation of the left cutaneous vein. Beyond ascertaining that it ramifies throughout the anterior kidney tissue, on the right side, its anterior course was not followed. A pair of vessels was likewise observed in large fish coming from the posterior kidney mass to join, one on each side: (1) the right cutaneous vein at the point where this joins the post-cardinal vein, and (2) the left cutaneous vein at the point where this divided into transverse trunk and anterior continuation. No routine observations were made upon these vessels, but they were encountered with sufficient frequency to insure their constancy.

With two exceptions, the above description fitted every specimen examined, and no consistent differences were observed in the various samples. In the two exceptions (C.I.-2 and C.R.-5, which were discussed in connection with the anterior arterial system) the post-cardinal vein swung to the left instead of to the right, and joined the left Cuvierian duct. These cases were obviously anomalies in which the arrangement was the mirror image of that normally found.

5.13. Skeleton

Material examined: Besides the 60 specimens used in the laboratory dissections, 42 additional fish, from the following regions, were included in the skeletal examination:

Clipperton Island	6
Galapagos Islands	9
Cocos Island	7
Costa Rica	5
Guatemala	1
Gulf of Tehuantepec	1
Punta Galera, Mexico	5
Lower California	8

General appearance of the cranium (Figs. 33, 34, and 35): Viewed laterally, the cranium resembles closely that of the big-eyed tuna, but

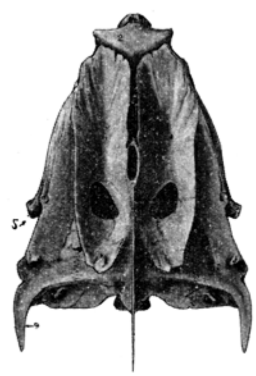

FIGURE 33. Cranium. Yellowfin tuna. Dorsal view

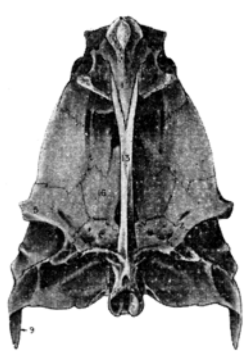

FIGURE 34. Cranium. Yellowfin tuna. Ventral view

the yellowfin may be distinguished by the posterior margin of the parasphenoid and basioccipital being straight, slightly concave, or forming a slightly obtuse angle instead of an even convex curve as in the big-eyed tuna. In the bluefin and albacore this margin forms a definite angle which although usually about 90 degrees may be as great as 130 degrees. Viewed laterally, the parietal crest extends farther anteriorly in the yellowfin than it does in the big-eyed tuna. If the projection of the curve formed by the lateral margins of the prefrontals is extended to the parietal crest it will parallel the crest ventrally in the yellowfin while in the big-eyed tuna this projected curve joins the parietal crest and continues as an unbroken line. of the 60 specimens of yellowfin examined, only three were found to resemble the big-eyed tuna in this respect. The yellowfin cannot be separated from any other species by this character. The basisphenoid leaned slightly forward in 14 cases out of the 60 examined and was perpendicular or slightly posterior to the perpendicular in the remaining cases. In the two specimens of big-eyed tuna the basisphenoid leaned forward.

Vomer (1): The presence of vomerine teeth in the yellowfin differentiates it from the skipjack while the absence of a thin bony ridge posterior to these teeth distinguishes it from the albacore in which this ridge is well developed.

Alisphenoid (16): Viewed laterally, the alisphenoids in the yellowfin meet in the median line and project into the interorbital opening, separating the dorsal profile of this opening into two prominent arches, the anterior one being markedly larger than the posterior one. The albacore is somewhat like the yellowfin although the bones do not project as far into the interorbital opening. In the bluefin the alisphenoids project below an imaginary line drawn from the prefrontal notch to the anterior process of the basisphenoid, whereas in the yellowfin and the other species the alisphenoids are entirely dorsal to this line. The prefrontal notch is on the median line at the very anterior end of the interorbital opening.

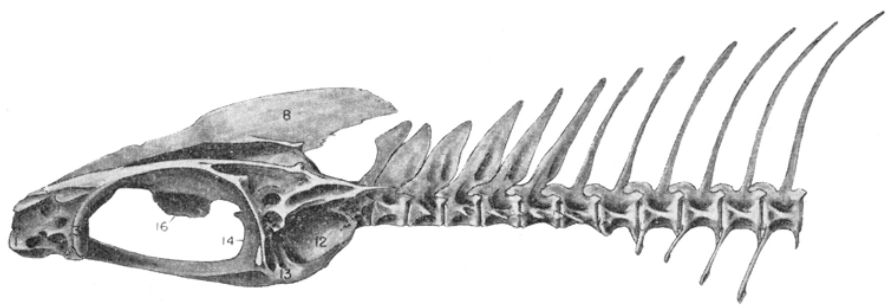

FIGURE 35. Axial skeleton. Yellowfin tuna. Lateral view.

FIGURE 35. Axial skeleton. Yellowfin tuna. Lateral view

Spinal column: The first haemal arch occurring on the 11th vertebra in this species separates it from the other species excepting the big-eyed tuna. In a count of 98 fish, the first haemal arch appeared on the 11th vertebra 89 times, on the 10th vertebra seven times (Clipperton Island fish accounting for three out of the seven) and on the 12th vertebra twice. The yellowfin may be distinguished from the big-eyed tuna by the haemal arches being bowed outward forming a wide haemal canal, while in the latter the haemal arches are straight and more massive with a smaller narrow triangular haemal canal. The internal height of the first haemal arch in the yellowfin is slightly greater than the length of the 11th vertebra while it is equal to or slightly less than the length of the 11th vertebra in the big-eyed tuna.

5.14. Conclusion

Despite the variations discussed above, it is quite apparent that specimens from all geographic regions are essentially the same, and are to be considered as a single species, Neothunnus macropterus, having a range extending across the Pacific, and southward, in the eastern Pacific, to Peru.

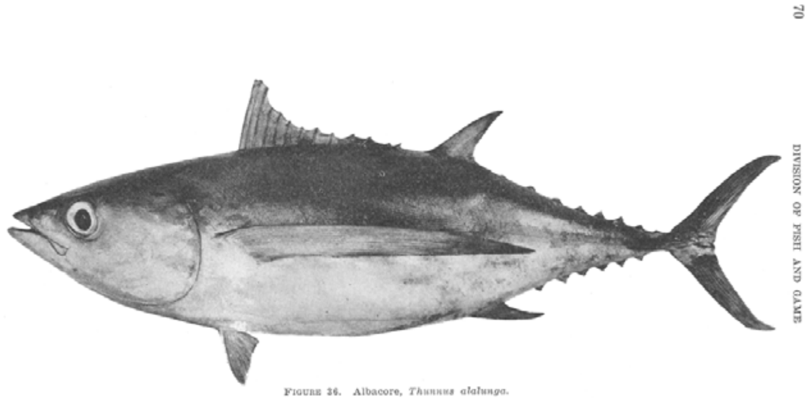

FIGURE 36. Albacore, Thunnus alalunga

6. ALBACORE

Thunnus germo (Lacépède) 1802

This description is based upon a detailed laboratory dissection of 23 albacore, taken from the following regions:

Japan	9
Hawaii	3
Central California	3
Coast of Oregon	8
Total	23

The superficial and visceral characters, and the structure of the air-bladder were examined in an additional 31 specimens taken in the course of a field trip extending from Southern California to British Columbia.

6.1. External

The most conspicuous identifying character of this species is its long pectoral fin. This reaches to and beyond the insertion of the anal fin and distinguishes this fish from all the remaining species except the big-eyed tuna. In the albacore the vent is invariably round, and in the big-eyed tuna it is oval or tear-drop in shape. Several proportions differ in the two species, but are unsatisfactory for the identification of individual fish.

6.2. Proportional Measurements

Table 12, shows the range, within geographic samples, in the various body proportions. The range in size of the fish examined is shown in the first line of the table.

6.3. Meristic Counts

The extent of variation in the various counts is shown in tables 13 and 14.

6.4. Viscera

The view of the viscera *in situ* is strikingly different from that of any other tuna investigated. The course of the intestine from right side to left across the abdominal cavity, the location of the spleen on the left side, and the relatively conspicuous position of the gall-bladder serve to distinguish this tuna from any other. (See figure 1 and figure 37 for greater detail).

6.5. Caecal Mass

The greater portion of the caecal mass lies on the left side of the abdominal cavity, and the apex is invariably on this side. In length the caecal mass is relatively shorter than in the other species, varying in the

TABLE 12

Albacore. The range in the various body proportions within geographic samples. The range in size of the fish examined is shown in the first line of the table.

Body proportion	Japan	Hawaii	Local
Range in body length—mm.	798–906	987–1006	540–844
Body length / Head length	3.41– 3.62	3.48– 3.53	3.27– 3.46
Body length / 1st dorsal insertion	2.88– 3.14	3.01– 3.10	2.86– 3.11
Body length / 2d dorsal insertion	1.64– 1.72	1.71– 1.72	1.66– 1.71
Body length / Anal insertion	1.53– 1.58	1.56– 1.58	1.51– 1.58
Body length / Ventral insertion	2.99– 3.08	3.01– 3.13	2.85– 3.01
Body length / Body depth	3.61– 4.26	3.73– 3.80	3.68– 3.94
Body length / Body width	5.13– 5.69	5.27– 5.38	5.00– 5.72
Body length / Dorsal-ventral distance	3.83– 4.42	4.11– 4.22	3.89– 4.19
Body length / Dorsal-anal distance	2.42– 2.61	2.52– 2.60	2.41– 2.56
Body length / Length 1st dorsal base	3.50– 3.82	3.73– 3.87	3.55– 3.81
Body length / Pectoral length	2.16– 2.43	2.22– 2.29	2.27– 3.00
Body length / Height 1st dorsal	8.47– 9.12	----------	8.73–10.46
Body length / Height 2d dorsal	9.42– 9.88	9.58	9.65–11.25
Body length / Height of anal	8.09– 8.40	8.98	9.59–12.72
Body length / Length 2d dorsal base	8.93–11.31	8.51– 9.11	8.31–12.02
Body length / Length of anal base	11.46–13.90	11.56–12.37	10.80–12.74
Body length / Spread of caudal	4.06	3.05– 3.34	3.39– 4.17
Head length / Diameter of iris	5.48– 6.03	6.06– 6.26	5.33– 6.26
Head length / Maxillary length	2.61– 2.81	2.77– 2.80	2.54– 2.78

TABLE 12

Albacore. The range in the various body proportions within geographic samples. The range in size of the fish examined is shown in the first line of the table

TABLE 13

Albacore. Frequency of occurrence of the varous fin-ray counts by geographic samples

	First Dorsal Fin		Second Dorsal Fin		Dorsal Finlets		Sec. Dor. plus Dor. Finlets		Anal Fin		Anal Finlets		Anal Fin plus An. Finlets	
Count	13	14	15	16	7	8	22	23	14	15	7	8	21	22
Japan	--	9	2	5	6	3	1	6	2	7	8	1	1	8
Hawaii	1	2	--	3	3	--	--	3	--	3	3	--	--	3
Local	3	8	3	7	8	3	--	10	1	10	10	1	--	11
Totals	4	19	5	15	17	6	1	19	3	20	21	2	1	22

TABLE 13

Albacore. Frequency of occurrence of the varous fin-ray counts by geographic samples

TABLE 14

Albacore. Frequency of occurrence of the gill-raker counts by geographic samples on upper and lower limbs, separately and combined

	Upper limb			Lower limb			Upper and lower limb combined			
Gill-rakers	8	9	10	19	20	21	27	28	29	30
Japan	3	5	-	1	5	2	1	1	5	1
Hawaii	1	2	-	-	3	-	-	1	2	-
Local	2	8	1	1	7	3	-	2	6	3
Totals	6	15	1	2	15	5	1	4	13	4

TABLE 14

Albacore. Frequency of occurrence of the gill-raker counts by geographic samples on upper and lower limbs, separately and combined

albacore from 0.3 to 0.7 of the length of the abdominal cavity. As in the other tunas the caecal mass is relatively longer in small fish. In the two specimens investigated there were respectively 8 and 9 compound ducts connecting the caecal mass with the duodenum.

6.6. Liver

The center lobe (Fig. 38) is always the longest, and the outline of all lobes is quite irregular, due to extensive lobulation. The ventral surface of all lobes is always marked with characteristic radiating striations, and large conical vascular cones are invariably present on the dorsal face of each lobe. There are generally two moderate cones beneath the right lobe, one large one beneath the center lobe, and four or five small ones beneath the left lobe.

The liver of the albacore is distinguishable from that of the bluefin in the majority of cases by the greater irregularity of outline in the case of the albacore. The remaining species lack the characteristic surface striations of the albacore and are therefore easily separable.

6.7. Stomach

The stomach lies invariably on the right side of the body cavity, but is extremely variable in length. Generally it is proportionately longer in small fish, sometimes measuring 0.9 of the length of the abdominal cavity. In the largest fish it was extremely short, and in one case measured only 0.32 of the length of the abdominal cavity.

6.8. Intestine

The intestine in the albacore is folded upon itself as in the majority of tunas. The length of the fold is relatively short, varying between 0.27 and 0.41 of the length of the abdominal cavity. It is thus comparable with, although slightly shorter than, the corresponding fold in the yellowfin, and considerably shorter than the fold of the bluefin and the big-eyed tuna.

The course of the intestine, however, differs from all other tunas. In the albacore the straight intestine, in ventral view, appears anteriorly upon the right side of the fish, but in the anterior half of the abdominal cavity it crosses to the left side. Both anterior and posterior bend, and in consequence the fold of the intestine, are located on the left side of the abdominal cavity, and the descending portion of the intestine runs to the vent against the left wall of the body cavity. Thus the course of the intestine differentiates the albacore from all the remaining species.

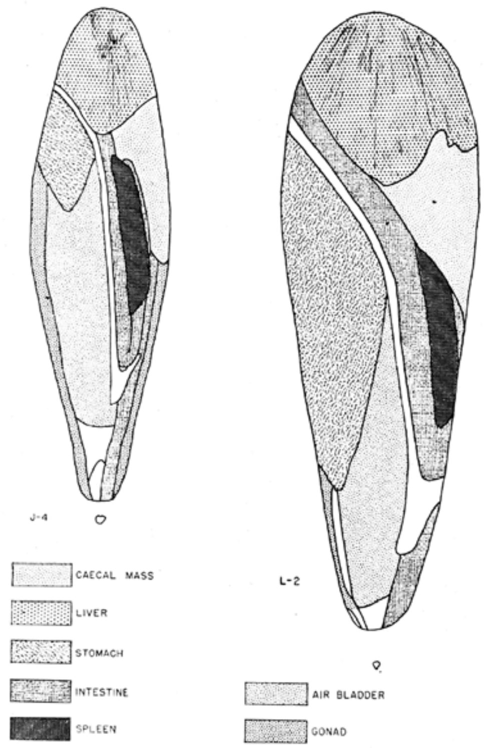

FIGURE 37. Albacore: Ventral view of the viscera, in situ, from two specimens. The narrow, unshaded structure paralleling the straight intestine is the gall-bladder

6.9. Spleen

In shape and location the spleen of the albacore differs from that of the remaining tunas. This is the only species in which the spleen appears on the left side of the abdominal cavity.

In the albacore the spleen is relatively small, and it is located to the left of the straight intestine and usually ventral to the ascending portion. Invariably the inner or mesial margin of the spleen is attached to the lateral margin of the straight intestine, whereas, depending upon its width, the outer or lateral margin of the spleen overlies to a variable extent the ventral face of the ascending portion of the intestine. Anteriorly the spleen reaches to or beyond the anterior bend of the intestine, and the head of the spleen is generally hidden in ventral view by the caecal mass. Posteriorly the spleen extends approximately to the inner margin of the posterior bend of the intestine. The spleen was typical and characteristic in all specimens examined. (Fig. 37).

6.10. Gall-bladder

Due to its location, the gall-bladder is a conspicuous and distinctive character in the albacore. It follows closely the course of the straight intestine from its apparent origin anteriorly on the right side. Crossing with this to the left side of the fish it continues posteriorly beyond the posterior bend of the intestine. It lies on the median side of the intestine as a tubular, green structure and can rarely be overlooked. A short distance beyond the posterior bend of the intestine, the gall-bladder doubles anteriorly upon itself and, reaching the bend of the intestine, terminates here or occasionally again doubles back upon itself. These bends of the gall-bladder are intimately fused and are not apparent without careful dissection. The typical appearance is exemplified in figure 37. In occasional fish the gall-bladder may continue posteriorly without doubling upon itself, but in such cases a suggestion of the normal bend is usually apparent.

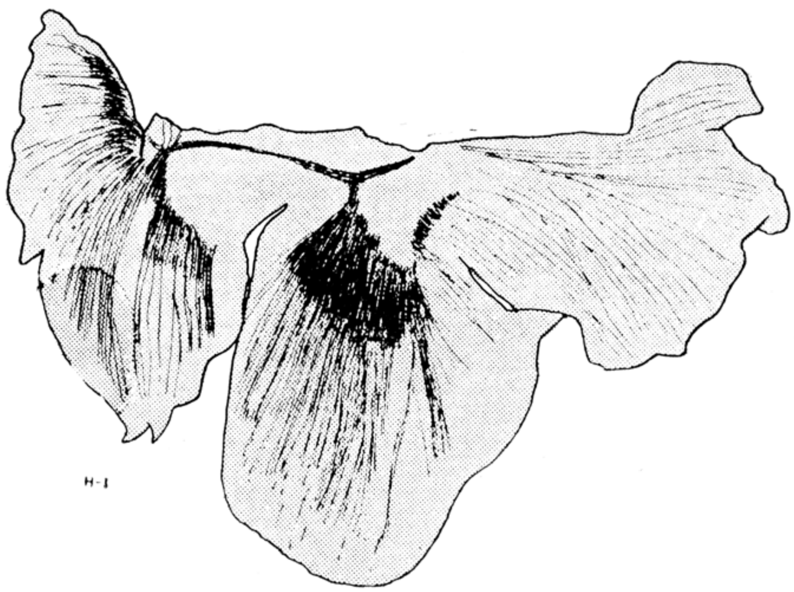

FIGURE 38. Albacore: Ventral view of the excised liver, showing surface markings.

FIGURE 38. Albacore: Ventral view of the excised liver, showing surface markings

The appearance and distinctiveness of the gall-bladder in this species was accentuated by the presence of two narrow, marginal, yellowish stripes which delimited the green bladder throughout its greater extent. These stripes follow the course of the gall-bladder posteriorly and in extreme cases continue along the posterior bends, thus indicating the fold. Actually there is a third marginal stripe, but inasmuch as this lies dorsal to the gall-bladder, it is not seen until the gall-bladder is lifted or removed. In some cases these markings were very clear and striking, but in others they were quite faint and relatively inconspicuous. That they are not a specific character is proved by the fact that they were absent in two of the three Hawaiian albacore, and were present in one specimen (J-2) of the 60 yellowfin examined, and in two of the bluefin. In all probability these markings are affected by physiological condition of the fish.

6.11. Air-bladder

The air-bladder in the albacore (Fig. 39) is a long and relatively wide organ. In the specimens examined it ranged in length from 0.61 to 0.95 of the length of the abdominal cavity, with an average value of about 0.85. Anteriorly it is transversely constricted, and this slight constriction delimits the so-called 'head' of the air-bladder. In this head there is a large dorsal projection which fits into a corresponding pit within the substance of the kidney and extends dorsally to the vertebral column. This is the pit for the air-bladder, and in the albacore it exposes the sixth, seventh, and eighth vertebrae and frequently portions of the fifth and ninth also. Hence the pit is very much larger in this species than in any other.

In the anterior-ventral margin of the air-bladder there is a median depression which simulates the appearance in the yellowfin; but the resemblance stops at this point, because the anterior dorsal projection is not divided as in the yellowfin and in the big-eyed tuna. Instead the dorsal projection assumes roughly a hemispherical outline when the bladder is dissected free. There may be a shallow median furrow on the dorsal face, caused probably by the presence in the pit of the dorsal aorta, but this can not be compared with the deep and permanent cleft found in the yellowfin.

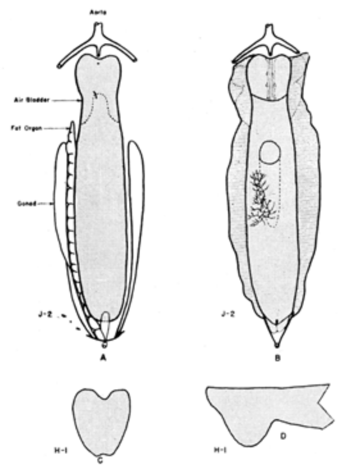

FIGURE 39. Albacore: Air-bladder. A: Ventral view of the air-bladder, in situ. B: Ventral view of the air-bladder, in situ, with its ventral wall opened and turned back to expose internal structures. C: Anterior (end) view of air-bladder dissected intact from the fish. D: Lateral view of air-bladder dissected intact from the fish

Posteriorly, the air-bladder in the albacore is invariably bluntly rounded and in cases where it is exceptionally long, as in J-2, its posterior tip is actually posterior to the anterior tip of the urinary bladder, with the latter overlying (ventral to) the air-bladder, and the ureter dividing the air-bladder posteriorly.

The circular orifice and internal septum were found in all specimens. Also a characteristic thickened and reticular area was found in each anterior lateral wall. As in the yellowfin the air-bladder receives arterial blood from two sources. The ventral wall, and possibly the anterior portion, are nourished by a branch of the coeliac-mesenteric artery, whereas the dorsal wall in the central and posterior region receives arterial blood from vessels originating (presumably) in the dorsal aorta and entering the dorsal wall of the air-bladder through the peritoneum.

The air-bladder in the albacore was found to be highly variable. On the assumption that the above description typifies the normal condition, then 6 of the 11 local specimens investigated, one of the 9 Japanese, and one of the 3 Hawaiian were abnormal. In the majority of these cases the abnormality was confined to the head of the air-bladder, which barely reached the posterior margin of the pit and thus did not project into it. In a few instances there were irregularities in the outline of the bladder and in still others the air-bladder was abnormally short. In one extreme case the air-bladder was rudimentary or vestigial, closely resembling the bladder in the majority of small bluefin.

The high incidence of abnormality was substantiated in 23 subsequent observations, of which 11 were normal and 12 abnormal to the extent that the head did not reach or extend into the pit. of this series 5 consecutive cases were normal, and 7 consecutive fish had abnormal air-bladders. It is therefore probable that the difference in frequency of abnormality in the various samples is due to the small samples handled, and is without significance.

6.12. Excretory System

Kidney: (Fig. 40) It will be noted that there is no posterior projection of kidney tissue, and this character distinguishes the albacore from the four species. Due to the presence of the large pit for the air-bladder, the kidney is conspicuously ring-shaped in this region. In the posterior rim of this pit, the kidney terminates, generally in a short, transverse margin, and in no case was there a posterior projection beyond the division of the ureter.

The kidney extends a variable distance into the pit of the air-bladder. In the majority of cases the walls of this pit are composed of kidney tissue, and in some small fish the kidney extends mesially towards the vertebral column. It never completely covers this region however, and the vertebrae themselves are always exposed. In large fish the entire-pit is almost devoid of kidney.

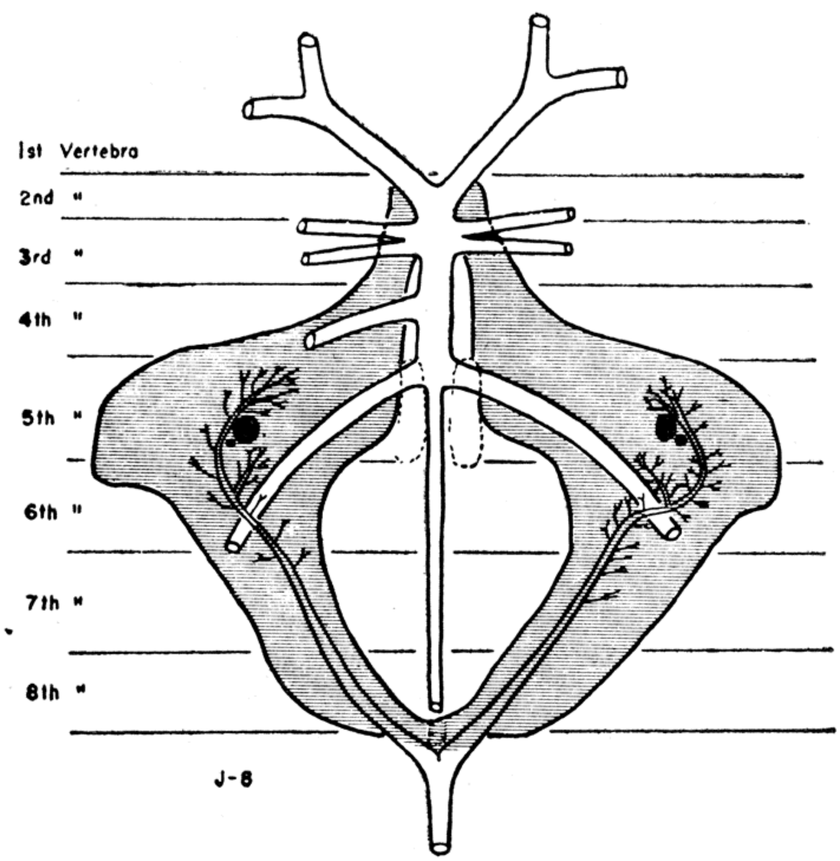

FIGURE 40. Albacore: Ventral view of the kidney and the two branches of the ureter. The clear space surrounded by kidney tissue is the pit of the air-bladder

The kidney may extend through the first haemal arch, but in no case did it extend into the canal through the second haemal arch, although a fine thread of dark tissue continued posteriorly into the haemal canal.

Ureter: (Fig. 41) From the opening into the urinary bladder the ureter runs in the mid-dorsal line to the region of the ninth vertebra, which marks the posterior limit of the kidney and the margin of the pit of the air-bladder. Here the ureter divides, typically as illustrated in the figure, and the two branches separate immediately in a wide angle. This approximates a right angle, but in large specimens the angle included between the two branches may increase to about 130 degrees. Very little variation was found in this character, and all specimens were essentially similar. Thus the ureters of the albacore are very distinctive, inasmuch as in no other species do the two branches separate immediately in a wide angle.

Urinary Bladder: (Fig. 41) In the albacore the urinary bladder resembles somewhat that of the skipjack. Its greatest width is near the rounded anterior end, and it tapers posteriorly to the vent. As in the skipjack, it is embedded throughout its extent in the dorsal wall of the abdominal cavity, and the anterior end does not project freely into the cavity as in the yellowfin and big-eyed tuna.

In small fish the urinary bladder curves gradually towards the vent, following the contour of the adjacent body wall, but in large fish the increased depth of the abdominal cavity results in a sharp bend in the middle of its length. The ureter joins the bladder anteriorly.

In almost every specimen examined, a lobulated mass of fat-like tissue was attached to the gonad. In some cases it was extremely large and well developed, but in others it was quite rudimentary. In all but three cases, however, it was present, and reached its greatest development always on the right side of the fish. This structure was white to creamy in color and always formed in segmental lobes. Usually its extent was coincident with that of the gonad, but it sometimes exceeded this in length, continuing a variable distance anteriorly.

This characteristic structure was absent in the three Hawaiian fish, and inasmuch as its absence was correlated with a similar lack of the marginal stripes on the gall-bladder, and with the indication that these fish were taken in the spawning season, it is therefore probable that the structure under discussion is a reserve of fat which is expended at this time.[13]

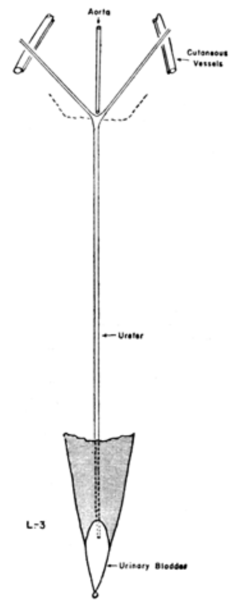

FIGURE 41. Albacore: Ventral view of the ureter and urinary bladder. The shaded area in the vicinity of the latter is a portion of the heavy sheet of connective tissue lining the dorsal wall of the abdominal cavity

A second peculiarity concerns the wall of the abdominal cavity. The dorsal wall, or roof, of this cavity is relatively flat anteriorly, but becomes strongly convex at the posterior end. The tissue lining this wall thickens gradually with the convexity, and in the posterior end of the abdominal cavity becomes an extremely tough and thick sheet. This was true of all specimens. Thus, whereas the yellowfin has a heavy, median connective-tissue cord in the anterior half of the abdominal cavity, the albacore is characterized by a heavy sheet of connective tissue in the posterior portion of the abdominal cavity. Nothing comparable was found in the three remaining tunas.

6.13. Circulatory System

1. *Anterior Arterial System:* (Fig. 42) The "Y" of the aorta occurs typically beneath the second vertebra, and the third and fourth efferent branchials unite in an extremely short posterior epibranchial which joins the aorta beneath the anterior portion of the third vertebra, or sometimes beneath the junction of the second and third vertebrae. The angle between these last two efferent branchials in the albacore is much smaller than in the yellowfin or in the big-eyed tuna, and is more comparable with that of the bluefin. The coeliac-mesenteric artery arises beneath the junction of the third and fourth vertebrae, or beneath the

[13] The three Hawaiian fish were taken on June 10 and June 24. All were females and the gonads suggested that spawning had recently occurred.

anterior half of the fourth, and the subclavians originate immediately posterior to this. The pharyngeal muscles are attached to the fifth vertebra and sometimes to portions of the fourth and sixth also. The large cutaneous arteries originate opposite each other beneath the junction of the fourth and fifth vertebrae, or as often beneath the anterior portion of the fifth vertebra. In the albacore they curve posteriorly, forming an acute angle (approximately 45 to 60 degrees) with the aorta. In this respect they resemble the condition found in the bluefin, and to a less extent in the big-eyed tuna, and differ sharply from the yellowfin and skipjack. The dorsal aorta becomes greatly diminished in size behind the origin of the cutaneous arteries, and as a relatively inconspicuous vessel it traverses the pit for the air-bladder (which occupies the space beneath the sixth, seventh, and eighth vertebrae) to enter the haemal canal.

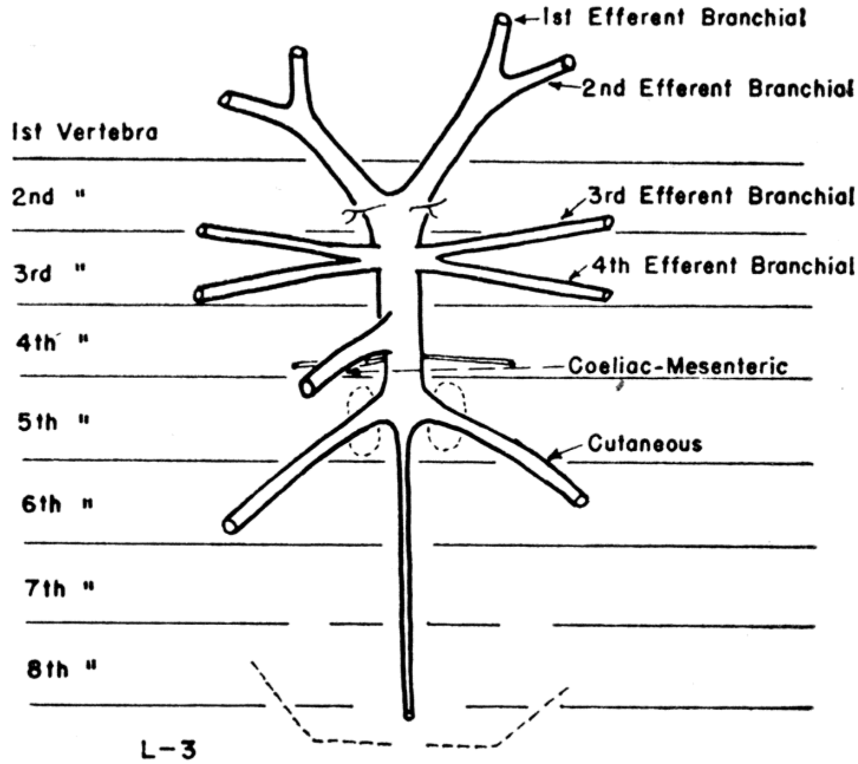

FIGURE 42. Albacore: Ventral view of the anterior arterial system. The vertebral attachment of the pharyngeal muscles, and the posterior margin of the kidney are indicated by dotted outlines

In its arrangement and relative simplicity this system in the albacore resembles the bluefin, but the absence of a pit for an air-bladder in the latter will serve to differentiate the two species. All specimens examined were essentially similar, and no regional differences were found in any sample.

2. *Visceral Arterial System:* (Fig. 43) The large coelic-mesenteric artery in the albacore divides into two major branches. There is no Number I branch. However, at the point of division one or more minute vessels originate and run to the right Cuvierian duct, where they break up into a network which encircles the walls of this duct and extends to the right cutaneous vein.

The Number II branch runs directly to the right lobe of the liver where it breaks up. A part of the blood goes into the capillary system within the substance of this lobe, and the balance into two moderately large conical vascular sacs on the dorsal face of the lobe. Occasionally one or both of these two cones may be subdivided, but in the majority of specimens there are two.

From these conical plexuses, three more-or-less distinct vessels originate. Each may arise as a distinct and individual branch, or it may arise as a series of minute parallel vessels which run together a short distance and then fuse to form a separate artery. This remark applies to all the arteries in the visceral system. One of these three branches (II-a.b. Fig. 43) goes to the anterior portion of the ventral wall of the air-bladder. Reaching this, it breaks up into a network nourishing the anterior ventral and lateral walls of the air-bladder. This branch, or the cone from which it originates, gives off a number of minute vessels which run to and nourish the right anterior wall of the stomach. A second vessel (II-st.) arises from this cone and goes directly to the stomach, running posteriorly in the wall on the right side, giving off numerous tributaries throughout its course. From the second cone a relatively large vessel (II-mes.) originates and runs posteriorly to the mesentery of the straight intestine; and in this region it gives rise to numerous small tributaries to the caecal mass on the one hand and to the straight intestine on the other. Reaching the spleen this vessel, II-mes., divides, typically into two branches. At the point of division a number of small vessels arise from one or the other or both of these two branches, and of these some go to the wall of the straight intestine, some to the gall-bladder,[14] others to the caecal mass, and occasionally some into the substance of the spleen in its anterior region. of the two terminal branches of II-mes.,the largest, II-sp., runs into the substance of the spleen and through subsequent branches nourishes the entire organ. Apparently some of these branches emerge again, for in two or three instances some were observed to pass to and nourish the wall of the intestine. The second terminal branch, II-rec., runs across the face of the spleen to the rectum and continues far posteriorly in its wall.

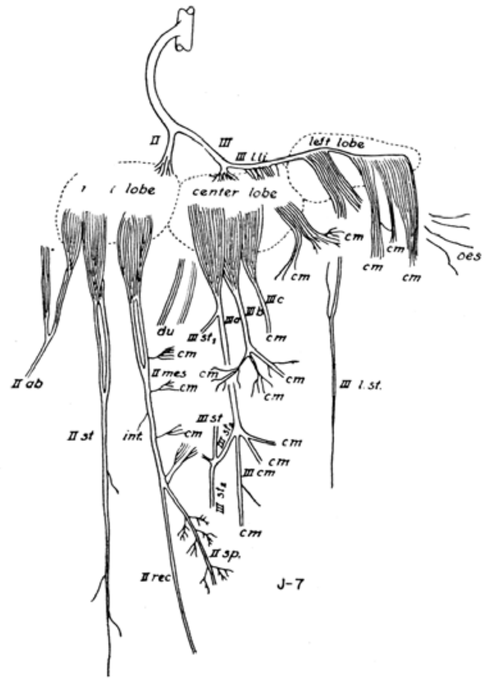

FIGURE 43. Albacore: Diagrammatic ventral view of the coeliac-mesenteric artery and its branches

The Number III branch runs directly to the center lobe of the liver, and reaching this it promptly divides on the dorsal face into two. The larger branch immediately disintegrates, sending a portion of its supply into the center lobe of the liver and the balance into one large and frequently complex conical plexus located dorsal to the center lobe. The smaller branch, III-l.li., runs intact to the left lobe, and on its dorsal face gradually diminishes in size and terminates as it gives rise to four, five, or more small plexuses and innumerable small vessels which nourish the substance of this lobe.

From the large cone beneath the center lobe three more-or-less distinct and large vessels originate. In addition a number of minute arteries, usually grouped in bundles, arise here also. Two of these are shown in the figure, and the majority run to the duodenum. of the three large vessels, the first (III-a.) runs to the caecal mass. Near its origin it gives rise to the vessel III-st.$_1$, which runs in the mesentery to the ventral wall of the stomach. III-a. continues posteriorly on the dorsal face or within the substance of the caecal mass, and as in the yellowfin, it shortly breaks up into a radiating series of branches, the majority of which nourish the caecal mass. One branch (III-c.m.) continues posteriorly to the tip of this organ. Another, III-st.$_2$, crosses in the

[14] In one case the gall-bladder was nourished by an extremely fine vessel which had a separate origin from the plexus. This vessel ran the length of the gall-bladder along its margin, sending tributary vessels to the surface of the gall-bladder and others to the adhering intestine. Although this was seen in only one case, it is possible that it may be generally present.

mesentery to the stomach, and through its subsequent branches this vessel nourishes the entire ventral and left stomach walls.

The second branch (III-b.) arising from the central cone, goes directly to the anterior portion of the caecal mass, wherein it breaks up into a number of vessels which nourish this region.

The third and last branch (III-c.) likewise goes directly to the anterior region of the caecal mass, on the left side, and apparently breaks up therein.

of the smaller plexuses arising from the vessel III-l.li., in the left lobe of the liver, the majority run into the caecal mass. One, however, nourishes the wall of the oesophagus on the left side and possibly the anterior stomach wall also. Another plexus gives rise to a fairly distinct branch (III-l.st.) which runs posteriorly along the left dorsal face of the stomach.

3. *Cutaneous System:* (Fig. 44) From their origin in the aorta, the cutaneous arteries run laterally, and with the corresponding veins they pass to the surface, typically between the third and fourth ribs, and exceptionally between the second and third ribs. In the surface musculature both vein and artery divide, normally between the fourth and fifth intermuscular bones.

The course of the cutaneous vessels on the surface is similar to that of the other tunas, but in the albacore it is perhaps more distinctive. Anteriorly, the dorsal and ventral branches run relatively close together, closer than in any other tuna, and continue thus until they reach a point below the insertion of the second dorsal fin. Here they begin to diverge. The dorsal pair continues posteriorly in a relatively straight line, whereas the ventral vessels incline ventrally, thus increasing the distance between the branches. Subsequently, and towards their termination, the vessels converge slightly again. The ventral branch of both vein and artery is appreciably larger than the dorsal branch.

Venules and arterioles are numerous, and they form a continuous vascular sheet the length of the dark flesh in the lateral median line. The venules arise in a single irregular row (or this could be considered as two apposed rows) on the proxima,[15] axial face of each vein. The venules immediately break up into a capillary sheet which runs, with the corresponding arterial vessels, axially towards the vertebral column. They do not cross the outer, or abaxial face of the artery as in the yellowfin, bluefin, and in the big-eyed tuna, and as a result the course of the artery can be seen in the surface view. A few venules arise abaxially, and these vessels do cross on the outer or abaxial face of the artery, but such venules are few in number and irregular in distribution.

The arterioles arise similarly from each artery in a single irregular row (or possibly two apposed rows) on the distal, axial face of the artery. They break up immediately into a capillary sheet which extends axially into the dark flesh. The origin of venules and arterioles in the albacore thus differs from the remaining tunas and is characteristic of this species. Likewise, the band of dark flesh being narrower in the albacore, the vascular sheets run axially more or less in a single plane instead of in several directions and planes as in the other tunas.

[15] See figure 3 and page 19 for a definition of these terms.

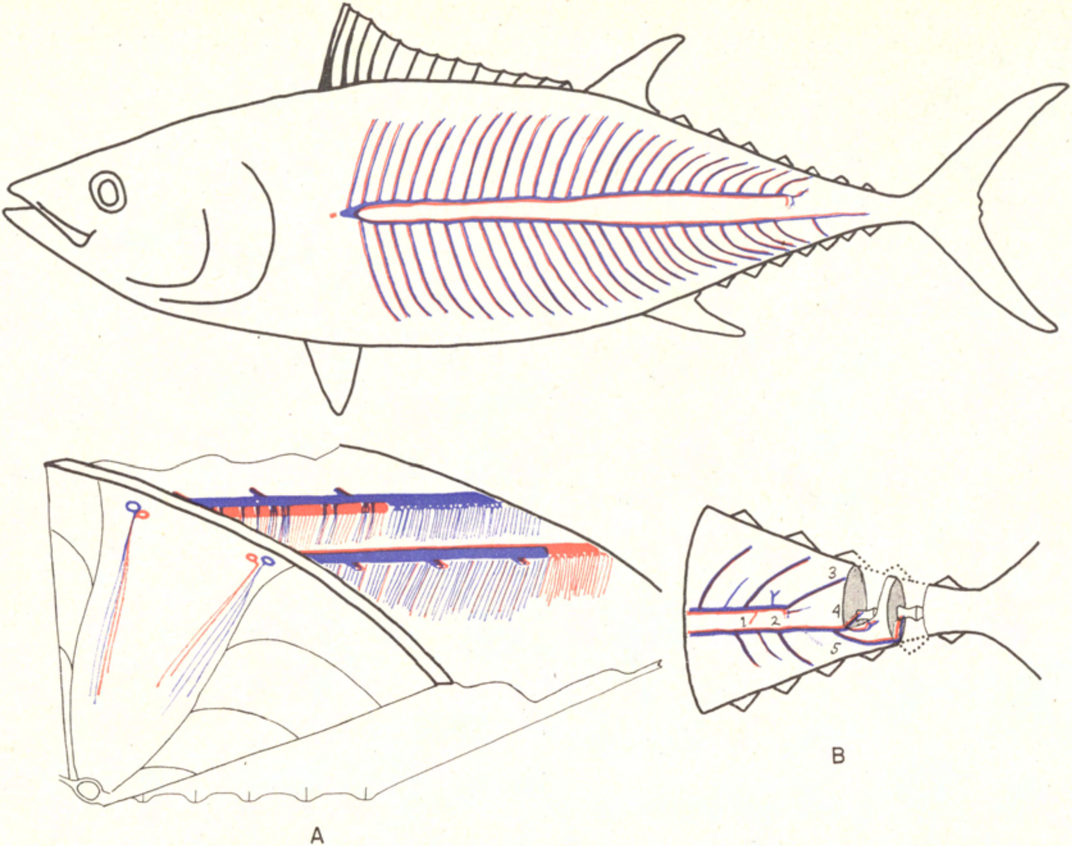

FIGURE 44. Albacore: Cutaneous system. Upper: Course of cutaneous vessels in superficial musculature. A: Enlarged section from central region. B: Posterior, terminal course of cutaneous vessels. See pages 81-84.

In the region of the posterior finlets on the caudal peduncle the cutaneous vessels terminate. There is no posterior commissure in this species. Instead, the cutaneous system is connected in this region with the axial vessels through the enlarged, last segmentals, which run to the dorsal and ventral mid-line, respectively, and there join the corresponding segmentals of the opposite side. A single vertical trunk, running perpendicularly to the surface in the median plane, connects each pair of last segmentals with the axial vessels.

The dorsal cutaneous vessels, vein and artery, terminate approximately beneath the fourth dorsal finlet. Just anterior to this point a small vessel (1 in figure 44) arises proximally from the cutaneous artery and runs horizontally towards the vertebral column and connects with the axial system in the 27th vertebra. This vessel was seen in many dissections.

The dorsal cutaneous vein and artery terminate in three branches. The first is a small continuation of the artery and vein, which runs posteriorly and soon disappears in the superficial muscle. The second branch (2) of vein and artery turns proximally and runs horizontally towards the vertebral column, although in this case a connection with the axial vessels could not be established. The remaining terminal branch (3) is the largest, and is in reality the last segmental. Vein and artery run together obliquely backwards towards the mid-dorsal line. Approaching this each divides into two or more small vessels, which appear to connect in the median plane with the corresponding vessels of the other side in a capillary network, from which a small arterial and a venous trunk run vertically to the axial vessels. Injection in this specimen was incomplete, but in two other instances these small vertical trunks entered the 30th and 31st vertebrae respectively. These vessels are much smaller than those from the ventral branch. The preceding segmental has a similar course, but no connection between this segmental and the axial vessels was found.

The ventral branch of the cutaneous vein and artery continues posteriorly about two segments farther than the dorsal branch. Here it divides into two, with a small group of capillaries sometimes constituting a third branch. Anterior to this point, however, the ventral cutaneous artery gives rise to a small vessel which runs axially to enter the 29th vertebra in a horizontal plane. of the two terminal branches of the ventral cutaneous vein and artery, one continues posteriorly a variable distance, but invariably the artery (4) turns axially and runs horizontally towards the vertebral column, connecting with the caudal artery in this and the majority of cases through the 31st vertebra. The vein apparently does not follow this course, but continues with a small branch of the artery on the caudal peduncle and is eventually lost to view. The second terminal branch (5) is the last segmental. This appears as a large and conspicuous vessel, but because it is always flattened or compressed against the skin, it most probably carries only a small volume of blood. It was always difficult to inject. Vein and artery run together towards the mid-ventral line. Approaching this, vein and artery branch. The smaller vessel of each pair goes posteriorly and disappears in the musculature of the caudal peduncle. The larger branch of both vein and artery continues mesially and in the median plane joins the corresponding vessel from the opposite side. A vertical venous and an arterial trunk connect these fused segmentals with the axial system, entering the vertebral column through the 33d vertebra, or possibly at the junction of the 32d with the 33d vertebra. In a number of dissections it appeared as though many of the preceding ventral segmentals followed a similar or comparable course, but no effort was made to substantiate this.

Considerable variation was found in the ultimate course of the cutaneous vessels, and this must be anticipated in any dissection. Frequently a supplementary segmental arises at the termination of the ventral branch of the cutaneous vessel and then crosses to the dorsal musculature in which it runs as a dorsal segmental. Despite such individual variation all specimens were essentially the same, and no consistent differences could be detected between various samples.

Peculiarities in the cutaneous system of the albacore clearly differentiate it from any other tuna. The absence of a posterior commissure and the characteristic terminal course of these vessels are sufficient to identify this species. The course of the arterioles and venules is likewise distinctive.

6.14. Post-Cardinal Vein

There is no post-cardinal vein in the albacore, and this fact separates it from all but the bluefin tuna.

The cutaneous veins on each side unite between the fourth and fifth intermuscular bones in an anterior commissure, and with the cutaneous artery the vein then runs mesially and passes between the third and fourth ribs. After crossing the ureter the vein leaves the artery and runs directly to and empties into the Cuvierian duct on each side. The course of these vessels is thus the same as in the bluefin tuna. Little variation was found in this character.

6.15. Skeleton

Material examined: The skeletal material consisted of the original 23 specimens mentioned at the beginning of this section and one additional albacore from Oregon. No specific differences between the fish taken from these localities were found. The following characters will separate the albacore from the other four species of tuna discussed in this publication.

General appearance of the cranium: (Figs. 45, 46, 47). Dorsally the cranium of the albacore resembles that of the skipjack, being narrower and more tapering anteriorly than that of the yellowfin, bluefin, or big-eyed tuna. Viewed laterally, it may be distinguished immediately from that of the big-eyed tuna and yellowfin by the prominent acute angle on the posterior margin of the parasphenoid and basioccipital. The presence of vomarine teeth in the albacore will separate it from the skipjack. The large interorbital opening in the albacore, due to the slight ventral extension of the alisphenoids, separates this species from the bluefin.

Vomer (1). In the albacore a thin sharp ridge continues posteriorly from the dentigerous area, which is small and narrowly elliptical in shape. This thin ridge may or may not bear minute teeth. In the event that it bears teeth, it is as a rule slightly thicker and not as long as the untoothed ridge. The ridge is present to a lesser degree in the bluefin, although it is not as sharp and minute teeth are present.

Sphenotic (5). Viewed ventrally, the posterior margin of the sphenotic is curved except in rare cases. Comparisons showed various degrees of curvature, but in 20 specimens examined the posterior margin was definitely curved in 18 and straight in two specimens. Further-more, both sides of the skull may not show the same degree of curvature. Therefore this character is not infallible, but will tend in part to distinguish this species from the big-eyed tuna, in which the posterior

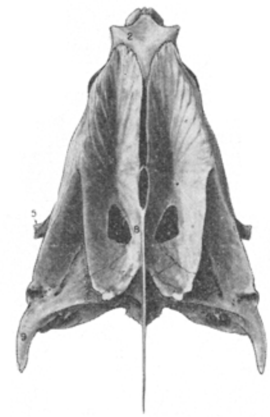

FIGURE 45. Cranium. Albacore. Dorsal view

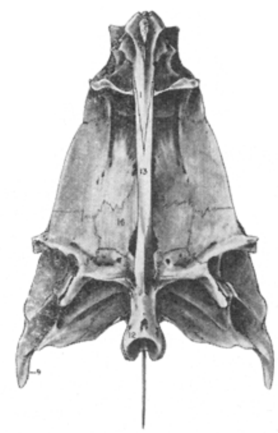

FIGURE 46. Cranium. Albacore. Ventral view

margin is straight. The bluefin and the albacore are much alike in this character. The tip of the sphenotic process is often concave ventro-posteriorly and may be slightly notched.

Supraoccipital (8). This is usually a good identifying character. The posterior tip of the crest normally reaches over the centrum of the third vertebra, and is narrowly acute at the end in this species. This bone will distinguish the albacore from the remaining tunas, as in these species the tip of the crest reaches only as far as the centrum of the second vertebra.

Basioccipital (12). This bone is very similar in the bluefin and the albacore, but as it serves to distinguish the latter from the yellowfin and big-eyed tuna, it is worth including. In lateral view the posterior margin of the parasphenoid and basioccipital forms, in the albacore and bluefin, an angle varying from slightly acute to somewhat obtuse, with the apex of the angle gently rounded.

Basisphenoid (14). As the range of variation in the basisphenoid prevents a certain identification, this bone is not a good character. In general it leans forward at an estimated angle of 10 to 15 degress from the vertical. In the yellowfin and big-eyed tuna it is nearly vertical, leaning but slightly forward of the perpendicular. Since the angles approach each other this character must be used with caution. The development of the anterior and posterior processes of the basisphenoid also vary considerably in degree and are not to be relied upon.

Alisphenoids (16). This is a fairly reliable character. In its extreme form of development it approaches the condition found in the yellowfin, but should be distinguishable with a little care. The alisphenoid bones meet in the median line and project only a short distance into the interorbital opening. It is the slight projection of the alisphenoids that gives the interorbital opening its large area in the albacore.

Spinal column (Fig. 47). The first haemal arch occurring on the tenth vertebra immediately separates the albacore from the big-eyed tuna, yellowfin, and skipjack. Furthermore, the first haemal arch is bent forward at an angle of 45 degrees or less to the axis of the spinal

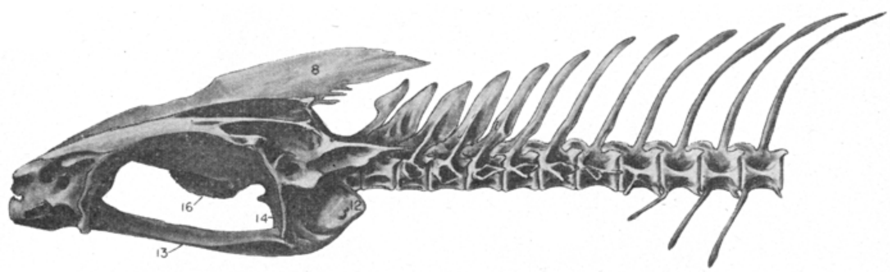

FIGURE 47. Axial skeleton. Albacore. Lateral view

column, and it is not preceded by any partially closed haemapophyses as in the yellowfin and big-eyed tuna. The first haemal arch is rounded in the albacore instead of triangular, as it is in the other four species, and the sides of this haemal arch are very much flattened dorso-ventrally. The haemal arches posterior to the first are narrow and become rapidly reduced in size.

There are normally 18 precaudal and 21 caudal vertebrae, counting the hypural, but of the 24 albacore examined, a single specimen had 20 precaudal and 19 caudal vertebrae.

This species may be separated from the bluefin by the fact that the haemapophyses preceding the first haemal arch extend laterally in the albacore instead of ventrally. The vertebrae are more delicate and fragile in the albacore than they are in the other tunas with the exception of the skipjack.

Hyomandibular (17) (Fig. 72). In general this bone resembles that of the other species, except that in the albacore the arm of the anterior articulating head is conspicuously longer than its least width. In measurements on 20 albacore the proportion of length to width of this arm was 1.7 to 3.0. Measurements on 15 specimens of yellowfin gave the significantly different values of 1.2 to 1.5. The big-eyed and bluefin tunas resemble the yellowfin in this character.

Metapterygoid (23) (Fig. 72). In many cases the albacore can be separated from the other species by the proportional length of the lower metapterygoid margins. The length of the antero-ventral margin divided by the length of the postero-ventral margin was between 1.0 and 1.5 in 20 specimens. In 15 specimens of yellowfin similar measurements gave values that varied between 1.3 and 1.9. The postero-ventral margin was measured from the hyomandibular to the most ventral point, and the antero-ventral margin was measured from the most ventral point to the anterior tip. The bluefin, yellowfin and big-eyed tunas are indistinguishable by this character.

Quadrate (19): This bone resembles the quadrate of the other species with the exception of the skipjack. Proportional measurements of the overall length divided by the width gave a range from 1.8 to 2.3 in 16 albacore. The same measurements in 15 specimens of yellowfin gave values ranging from 1.6 to 1.8. The bluefin, yellowfin and big-eyed tuna have the same proportional range and should not be confused with the albacore (Fig. 73).

6.16. Conclusion

In all essential respects the Japanese, Hawaiian and local albacore are similar and individually indistinguishable. They must therefore be considered as of the same species, Thunnus germo. The range of this species thus traverses the north temperate Pacific.

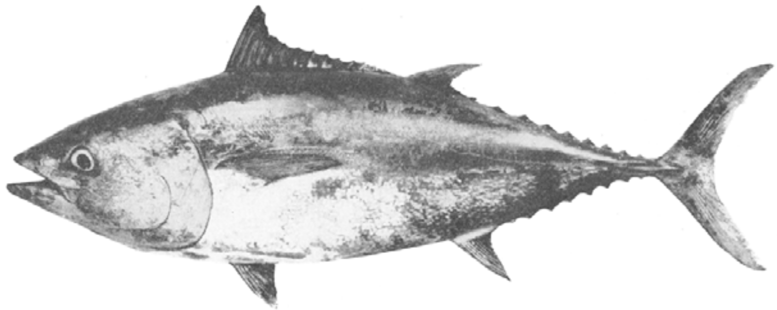

FIGURE 48. Bluefin tuna, *Thunnus thynnus*.

FIGURE 48. Bluefin tuna, Thunnus thynnus

7. BLUEFIN TUNA

Thunnus thynnus (Linnaeus) 1758

This description is based upon a laboratory dissection of 22 specimens, of which 11 were taken off southern California and 11 from Guadalupe Island, Mexico.

7.1. External

The bluefin (Fig. 48) may generally be distinguished from the remaining tunas by its relatively short pectoral fin. Whereas the pectoral of the yellowfin reaches beyond the insertion of the second dorsal fin and that of the albacore and the big-eyed tuna reaches beyond the insertion of the anal fin, the pectoral of the bluefin extends normally only to the insertion of the eleventh or twelfth spine of the first dorsal fin. The margins of the gill-covers are rounded, particularly that of the preoperculum, but in the yellowfin they are quite angular on the posterior ventral corner. Also the vent is round in the bluefin, whereas in the other tunas, excepting the albacore, it is elongated or pear-shaped.

7.2. Proportional Measurements

See table 15.

7.3. Meristic Counts

See tables 16 and 17.

7.4. Viscera

The ventral view of the viscera of the bluefin is distinctive, and alone will differentiate this from the remaining tunas. The shape and location of the spleen, the orientation of the spleen with the intestine, and the striations on the liver are the distinguishing characters (Fig. 49).

7.5. Caecal Mass

The caecal mass is similar to that of the yellowfin and albacore. The bulk of this organ and its apex lie invariably upon the left side of the fish. Its length varies normally between 0.58 and 0.79 of the length of the abdominal cavity, but in one specimen (L.-11) the caecal mass extended to within two centimeters of the vent, entirely concealing the remaining visceral organs. In most specimens the caecal mass is connected to the duodenum by seven ducts, but in one specimen there were only six, and in another, eight.

7.6. Liver

The liver (Fig. 50) is composed of three lobes, of which the center lobe is always the longest. In shape the liver resembles that of the albacore, but its outline is more regular and less lobulated. As in the

TABLE 15

Bluefin. The range, within the two geographic samples, in the various body proportions. The range in size of the fish examined is shown in the first line of the table.

Body proportion	Lower California	Local
Range in body length—mm.	629–888	628–729
Body length / Head length	3.17– 3.38	3.16– 3.36
Body length / 1st dorsal insertion	2.91– 3.13	2.94– 3.08
Body length / 2d dorsal insertion	1.69– 1.77	1.68– 1.74
Body length / Anal insertion	1.49– 1.56	1.50– 1.56
Body length / Ventral insertion	2.86– 3.00	2.84– 3.02
Body length / Body depth	3.30– 3.69	3.40– 3.73
Body length / Body width	5.01– 5.64	4.92– 5.69
Body length / Dorsal-ventral distance	3.53– 3.81	3.53– 3.85
Body length / Dorsal-anal distance	2.36– 2.48	2.32– 2.43
Body length / Length 1st dorsal base	3.77– 4.01	3.65– 3.98
Body length / Pectoral length	4.84– 5.68	5.08– 5.95
Body length / Height 1st dorsal	8.81– 9.53	8.38–11.00
Body length / Height 2d dorsal	9.78–10.08	9.70–10.16
Body length / Height of anal	9.31–10.56	9.45–10.63
Body length / Length 2d dorsal base	8.97–10.28	8.49–11.15
Body length / Length of anal base	10.31–13.85	9.23–13.55
Body length / Spread of caudal	3.81– 3.93	3.64– 3.73
Head length / Diameter of iris	6.96– 8.14	6.93– 7.64
Head length / Maxillary length	2.42– 2.56	2.46– 2.58

TABLE 15

Bluefin. The range, within the two geographic samples, in the various body proportions. The range in size of the fish examined is shown in the first line of the table

TABLE 16

Bluefin. Frequency of occurrence of the various fin-ray counts within the two geographic samples

	First Dorsal Fin			Second Dorsal Fin	Dorsal Finlets		Sec. Dor. plus Dor. Finlet		Anal Fin		Anal Finlets		Anal Fin plus Anal Finlets		
Count	12	13	14	15	8	9	23	24	14	15	7	8	21	22	23
Lower California	-	3	8	11	10	1	10	1	-	11	11	-	-	11	-
Local	1	1	9	11	10	1	10	1	3	7	8	3	1	8	1
Totals	1	4	17	22	20	2	20	2	3	18	19	3	1	19	1

TABLE 16

Bluefin. Frequency of occurrence of the various fin-ray counts within the two geographic samples

TABLE 17

Bluefin. Frequency of occurrence of the gill-raker counts for the two geographic samples on upper and lower limbs, separately and combined

	Upper limb					Lower limb					Upper and lower limbs combined							
Gill-rakers	10	11	12	13	14	21	22	23	24	25	32	33	34	35	36	37	38	39
Lower California	--	1	7	2	1	1	2	6	1	1	1	--	1	6	2	--	--	1
Local	1	--	6	4	--	1	1	4	5	--	1	1	--	3	3	3	--	--
Totals	1	1	13	6	1	2	3	10	6	1	2	1	1	9	5	3	--	1

TABLE 17

Bluefin. Frequency of occurrence of the gill-raker counts for the two geographic samples on upper and lower limbs, separately and combined

albacore, all lobes of the liver are marked ventrally with superficial striations. In the case of the center lobe these striations radiate from a small, relatively clear area near the anterior end of this lobe. The striations are in reality fine blood vessels which extend throughout the substance of the liver. They are perhaps finer in the bluefin than in the albacore, and the substance of the bluefin liver appears to be firmer and less fragile. On the dorsal face of the liver there are the large conical, vascular plexuses which characterize this genus.

7.7. Stomach

In the majority of specimens the stomach was long, varying in length from 0.66 to 0.81 of the length of the body cavity. Generally but not invariably the apex of the stomach is located on the left side of the fish.

7.8. Intestine

As in the majority of tunas the intestine is folded, and the fold appears longer than in the albacore or in the yellowfin. It varied in length between 0.36 and 0.61 of the length of the body cavity. The straight intestine runs posteriorly on the right side of the abdominal cavity, and the posterior bend is invariably on the right side. The ascending portion, however, runs anteriorly usually in the median line, separated from the straight portion by the width of the spleen. In the majority of cases the anterior bend is near the median line and is generally concealed by the caecal mass. In all but exceptional cases the descending portion of the intestine runs posteriorly attached to the ascending portion. The course of the intestine is fundamentally similar to that of the yellowfin, and the difference in its appearance is due mainly to its relation with the spleen. Variations in the intestine affect principally the relative length and postion of the various parts, but in one specimen (L. 11) the intestine was almost straight with a slight loop anteriorly in place of the usual fold. The condition in this fish thus approaches that of the skipjack, in which there is no fold. The caecal mass is unusually large in this fish and the spleen is small. The course of the gall-bladder is likewise irregular.

7.9. Spleen

The spleen is proportionately larger in the bluefin than in any other tuna. Anteriorly, the head of the spleen is usually hidden beneath (dorsal to) the caecal mass, and posteriorly the spleen reaches the posterior bend in the intestine. It is rather irregular in shape and less characteristic than in the other tunas. It is located either mesially or on the right side of the abdominal cavity. One margin adheres to and follows the straight intestine on its median side, and the opposite margin generally follows, in part, the course of the ascending portion of the intestine, although in some cases it may lie ventral to this portion. The spleen normally separates the straight from the ascending portions of the intestine, and it is this fact, associated with its relative size and position, that gives the viscera its distinctive appearance in the bluefin. In one specimen (L.C.-10) the spleen was of exceptional width, equaling that of the body cavity in this region, and lay dorsal to the fold of the intestine and thus between the fold and the straight intestine.

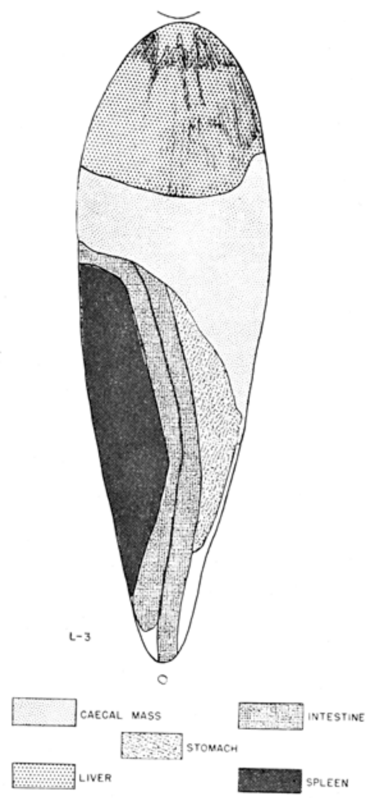

FIGURE 49. Bluefin tuna: Typical ventral view of the viscera, in situ

7.10. Gall-bladder

The gall-bladder is a long, tubular sac that runs posteriorly attached to the dorsal face of the straight intestine. It extends to or beyond the posterior bend of the intestine, and this portion is sometimes seen in the ventral view of the viscera. The posterior extremity of the gall-bladder projects freely into the body cavity and is frequently bent anteriorly as in the albacore. In two specimens the gall-bladder was marked with two marginal white lines, comparable with the yellowish stripes noted in the albacore.

7.11. Air-bladder

In every specimen examined the air-bladder (Fig. 51) was collapsed and consisted of a small structure at the anterior end of the abdominal cavity, varying in length from 37 to 73 millimeters and in greatest width from about 6 to 20 millimeters. It was distinguished from the surrounding peritoneum by the characteristic silvery color typical of the air-bladder. It was at first difficult to believe that this actually represented an air-bladder, but this conclusion was supported by the fact that it consisted of a clearly defined sac and also by the fact that the characteristic branch of the coeliacmesenteric artery ran to this structure as in all tunas. Moreover, upon opening the ventral wall of the air-bladder the characteristic circular orifice and internal septum were found.

FIGURE 50. Bluefin tuna: Ventral view of the excised liver, showing characteristic shape and surface markings

In appearance the air-bladder closely resembles the extreme of variation found in an albacore. However, in every specimen the structure, location, and general picture obtained of the air-bladder were constant, so that there can be no doubt that this is typical and characteristic. Specimens ranged in size from 628 to 888 millimeters body length, and in the largest fish the air-bladder was actually smaller than in many others, measuring only 40 millimeters.

In the case of those species found elsewhere which are comparable with the bluefin, it is recorded in the literature that the air-bladder is small, collapsed, and undeveloped in immature specimens. Thus, speaking of T. orientalis, Kishinouye states on page 438: "In immature tunnies the air-bladder is short, very narrow, and almost collapsed." Serventy,[16] in discussing T. maccoyii, similarly observes: "* * * but as most of the southern bluefin caught are young individuals which have not yet fully developed a swim-bladder this character fails to be of service." We have been told that this is also true of T. thynnus on the Atlantic coast of the United States.

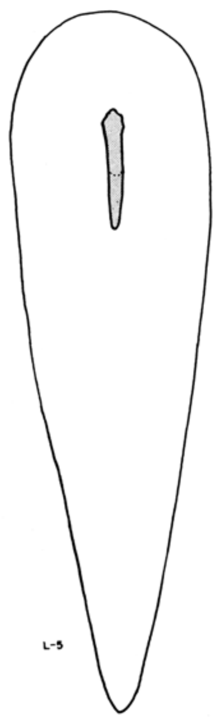

FIGURE 51. Bluefin tuna: Rudimentary air-bladder found in all small and many large fish. The abdominal cavity is shown in outline to emphasize the relative size and location of the air-bladder

[16] Serventy, D. L. The Australian tunas. Australia. Council for scientific and industrial research. Division of fisheries. Report, no. 4, 1941.

In view of these statements the air-bladders of several hundred bluefin were examined at the local canneries. In all cases small fish, under 80 centimeters in body length, had a rudimentary air-bladder comparable with the above description, and the air-bladder in the large fish, ranging in size from 80 to perhaps 130 centimeters in body length, was extremely variable. In many it was rudimentary, but sometimes inflated. In the remainder it was variable in size and shape and it was impossible to recognize in this variation any characteristic shape or fundamental pattern. The air-bladder of the bluefin is therefore an unsatisfactory identifying character, of which it may be said only that it is invariably present though frequently collapsed, and that there is no pit for the air-bladder in this species.

7.12. Excretory System

Kidney: (Fig. 52) Considerable variation exists in the shape of the kidney. There is only a slight posterior projection of the kidney in the bluefin, and it reaches normally to the tenth or eleventh vertebra. In relation to the length of the abdominal cavity this posterior projection of kidney varied between values of 0.15 and 0.26. In this respect it resembles the big-eyed tuna and is intermediate between the condition found in the yellowfin and in the skipjack on the one hand, and the albacore on the other.

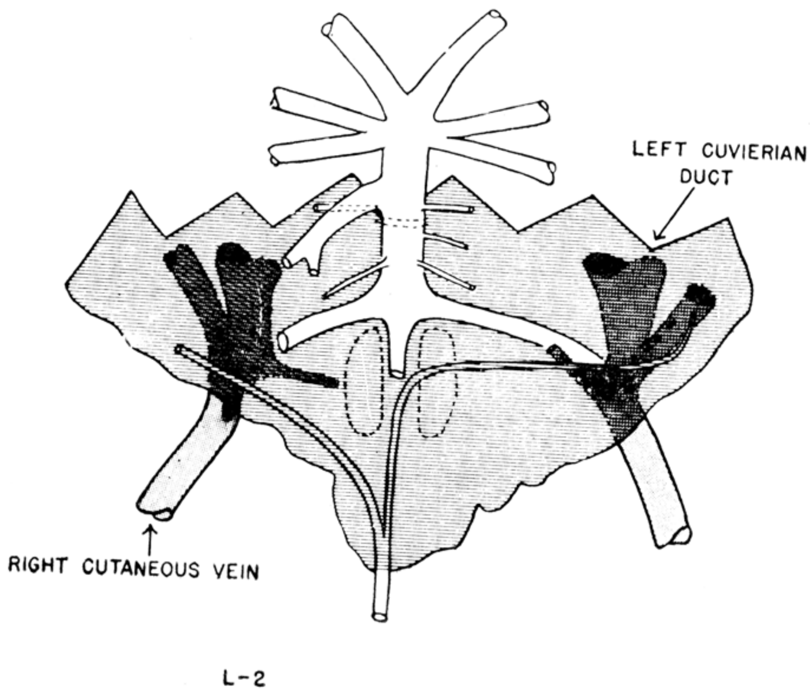

FIGURE 52. Bluefin tuna: Ventral view of the posterior projection of the kidney and the two branches of the ureter.

FIGURE 52. Bluefin tuna: Ventral view of the posterior projection of the kidney and the two branches of the ureter

Ureter: In the majority of cases the ureter divides just after it enters the posterior extension of the kidney, as in figure 52 but in occasional specimens it divides as it meets the kidney. The two branches separate immediately but diverge gradually until they reach the expanded portion of the kidney, whereupon they turn laterally. There seemed to be a tendency for the left branch of the ureter to continue in the median line and turn abruptly outward, whereas the right branch curved outward more gradually from the division.

Considerable variation was found in one respect. In many specimens an internal dividing septum continued posteriorly a distance of several millimeters from the point of external division of the ureter, so that the single ureter in its extreme anterior end was actually divided into two ducts by a median partition. The maximum length of this partition in the specimens examined was 14 millimeters.

Urinary Bladder: The urinary bladder is relatively long in the bluefin measuring from 0.18 to 0.23 of the length of the abdominal cavity. It is attached to the dorsal wall of the body cavity throughout its length, thus resembling the albacore and skipjack. However, it is also attached to the gonads laterally, and when distended is quite conspicuous. The bladder is quite uniform in width and does not taper as it does in the albacore.

The ureter joins the urinary bladder a short distance from its anterior tip. This distance varied from 3 to 12 millimeters. The ureter, however, continues in the dorsal wall of the bladder and opens into it a short distance posteriorly, this distance varying from 2 to 13 millimeters from the point of attachment.

7.13. Circulatory System

1. *Anterior Arterial System:* (Fig. 53) The Y of the aorta is beneath the anterior half of the second vertebra, and the posterior epibranchials join the aorta beneath the anterior extremity of the third vertebra. The large coeliac-mesenteric artery arises beneath the junction of the third and fourth vertebrae, and the very small subclavians originate at approximately the same point, slightly dorsal to the coeliac-mesenteric artery. The ligament crosses the aorta ventrally posterior to the subclavians. The cutaneous arteries are large and in the majority of cases they arise opposite one another. Occasionally they may be slightly staggered in origin with one a trifle ahead of the other. Typically they originate beneath the junction of the fourth and fifth vertebrae or beneath the anterior end of the fifth vertebra. The cutaneous arteries invariably incline posteriorly at an acute angle, which in the majority of cases approximates 60 degrees. The pharyngeal muscles are always attached to the sixth vertebra, and to the posterior half of the fifth vertebra and sometimes to all of it. There is no pit for an air-bladder. Posterior to the origin of the cutaneous arteries the dorsal aorta becomes greatly reduced in size and thus resembles the condition in the albacore.

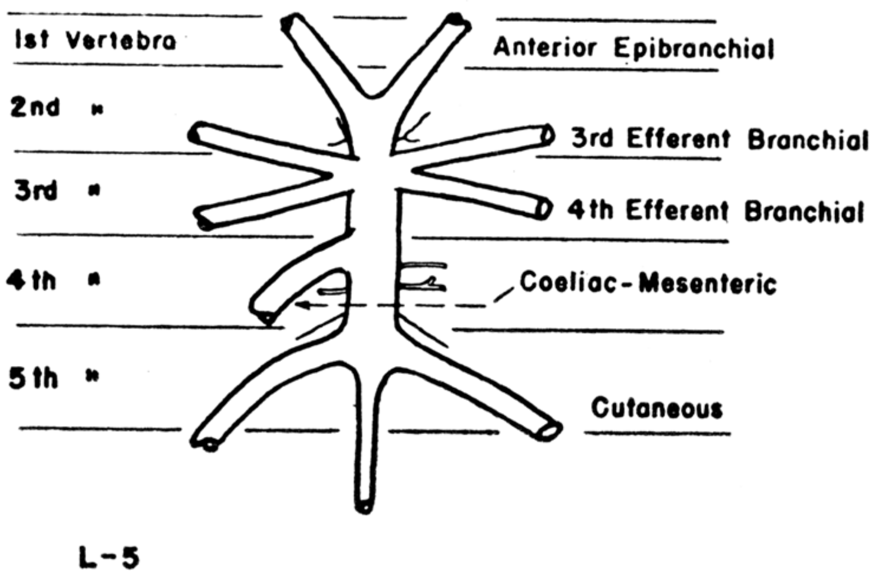

FIGURE 53. Bluefin tuna: Ventral view of the anterior arterial system.

FIGURE 53. Bluefin tuna: Ventral view of the anterior arterial system

The anterior arterial system of the bluefin is thus similar to that of the albacore and may be distinguished from it only by the absence of a pit for the air-bladder in the case of the bluefin.

2. *Visceral Arterial System:* (Fig. 54) All specimens were injected and the proximal vessels were followed. The description of the distal vessels, however, is incomplete, because in the majority of cases the injection mass failed to penetrate beyond the vascular cones, and the description is based upon only two or three partially successful injections.

The coelic-mesenteric artery divides into only two major branches. There is no Number I branch. Just prior to its division this artery gives rise to one or more minute vessels which run to the walls of the right Cuvierian duct.

The Number II branch runs to the right lobe of the liver, where it breaks up completely to supply a capillary plexus within the substance of this lobe and a vascular plexus on the dorsal face of the lobe. This consists typically of two conical, vascular sacs, and from these, three arteries originate. From one cone the vessels II-a.b. and II-st. arise and run respectively to the ventral wall of the air-bladder and to the right dorsal face of the stomach. From the second cone one large and two small vessels arise. The largest of these three branches runs directly to and into the substance of the spleen, sending a bundle of capillaries as it enters, into the caecal mass. Within the spleen, it ramifies to all parts. The two remaining vessels are very small. One, II-g.b., runs to and nourishes the gall-bladder, and the other, II-int., goes to the straight intestine.

The Number III branch goes directly to the center lobe of the liver. Near its origin this branch gives rise to two or more minute vessels which run to the wall of the right Cuvierian duct, and a larger vessel which goes to the transverse septum then continues towards the heart. Reaching the center lobe the No. III branch divides into two. The first branch breaks up immediately and divides its supply of blood between the capillary plexus within the center lobe and one large conical vascular sac beneath (dorsal to) the center lobe. From this cone three or more bundles of small vessels originate. One goes into the anterior caecal mass and possibly to the duodenum. Another (III-st_1) crosses in the mesentery to the ventral wall of the stomach, and the third and largest (III-c.m.) continues posteriorly within the dorsal face of the caecal mass, branching distally to nourish all parts of this organ. Although the injection failed to demonstate it, the appearance suggested that this vessel sends a branch to the posterior ventral wall of the stomach, as in the albacore.

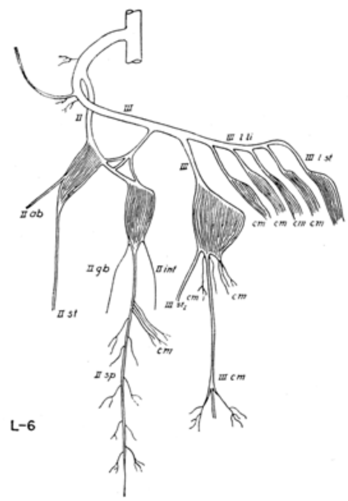

FIGURE 54. Bluefin tuna: Diagrammatic ventral view of the coeliac-mesenteric artery and its branches

The second major vessel (III-l.li.) originating in the No. III branch goes to the left lobe of the liver. Here it supplies the capillary plexus within this lobe and four, five, or more small conical sacs beneath (dorsal to) the lobe, expending itself in their formation. From the apex of four (in the majority of cases) of these cones, minute arterial strands run to the anterior caecal mass on the left side, and from a fifth cone similar strands run to the left anterior stomach wall. Here again the appearance suggests that this branch continues posteriorly in the left dorsal stomach wall as in the albacore, although this was not demonstrated.

In all cases the No. II and the No. III branches of the coeliacmesenteric artery were interconnected by a small to moderate trunk as they entered respectively the right and center lobes of the liver. In the majority of cases this trunk arose as a distinct branch of the No. III branch, and through subsequent branching it joined the No. II branch in two, three, or more points as the latter gave rise to the vascular cones.

Occasionally this trunk may arise as a number of smaller vessels from the No. III branch, in which case these small vessels anastomose profusely as they run parallel to the No. II branch. This connecting trunk is characteristic of the bluefin and distinguishes it from the albacore, in which it is lacking. A similar vessel is found in the big-eyed tuna.

3. *Cutaneous System:* (Fig. 55) The cutaneous arteries run laterally from their origin in the aorta, and with the corresponding veins they pass typically between the third and fourth ribs. Rarely these vessels may pass between the second and third ribs, and in one specimen they passed—on one side—between the first and second ribs. Between the fourth and fifth intermuscular bones both vein and artery divide into dorsal and ventral branches. In one fish this division occurred on both sides between the fifth and sixth intermuscular bones, and in another between the third and fourth, in this case on one side only.

The course of the vessels on the surface is not distinctive. They may run parallel at a considerable distance apart, converging posteriorly; or there may be a slight bulge or divergence posteriorly as in the albacore. In the majority of cases the ventral vessels are slightly larger than the dorsal.

Throughout its course on the surface, each artery gives rise to two distinct and continuous rows of arterioles which break up into capillary sheets in the dark flesh of the lateral median line. One row, in which the vessels are perhaps more numerous and regular, arises on the proximal[17] face of each artery. The second row arises almost directly opposite, on the distal face of the artery.

Each vein similarly gives rise to two continuous rows of venules, which with the arterioles, break up into vascular sheets. One row of venules arises on the proximal axial face of each vein, and the other row has its origin on the proximal, abaxial face. The vessels of the former row run directly into the dark flesh, towards the vertebral column, whereas vessels of the latter row cross the outer or abaxial face of the artery before breaking up. Thus in a surface view the course of the arteries is obscured by these numerous small venous vessels, and in this respect the bluefin resembles the yellowfin and big-eyed tuna, and all differ from the albacore. As in all the tunas these small vessels—both venous and arterial—become less numerous and regular posteriorly.

The terminal course of the cutaneous vessels is quite irregular in the bluefin. Fundamentally, the dorsal branch of vein and artery turn mesially in the vicinity of the 30th or 31st vertebra and as horizontal trunks run directly into that vertebra to connect with the axial vessels. The ventral branch of vein and artery continue posteriorly beyond this point, and in the vicinity of the 32d vertebra they also turn mesially and as short horizontal trunks they connect with the axial vessels through the 32d vertebra. However, the ventral vessels give rise to a small branch, or sometimes a group of capillaries, in the vicinity of the 30th or 31st vertebra, and this small vessel joins the dorsal branch as the latter turns axially to enter the vertebral column. There is therefore a posterior commissure, as in the yellowfin, but generally this commissure is very small or weak, sometimes absent, and only occasionally is it prominent. In an average individual one may expect to find a weak posterior commissure

[17] See figure 3, page 19, for a definition of terms.

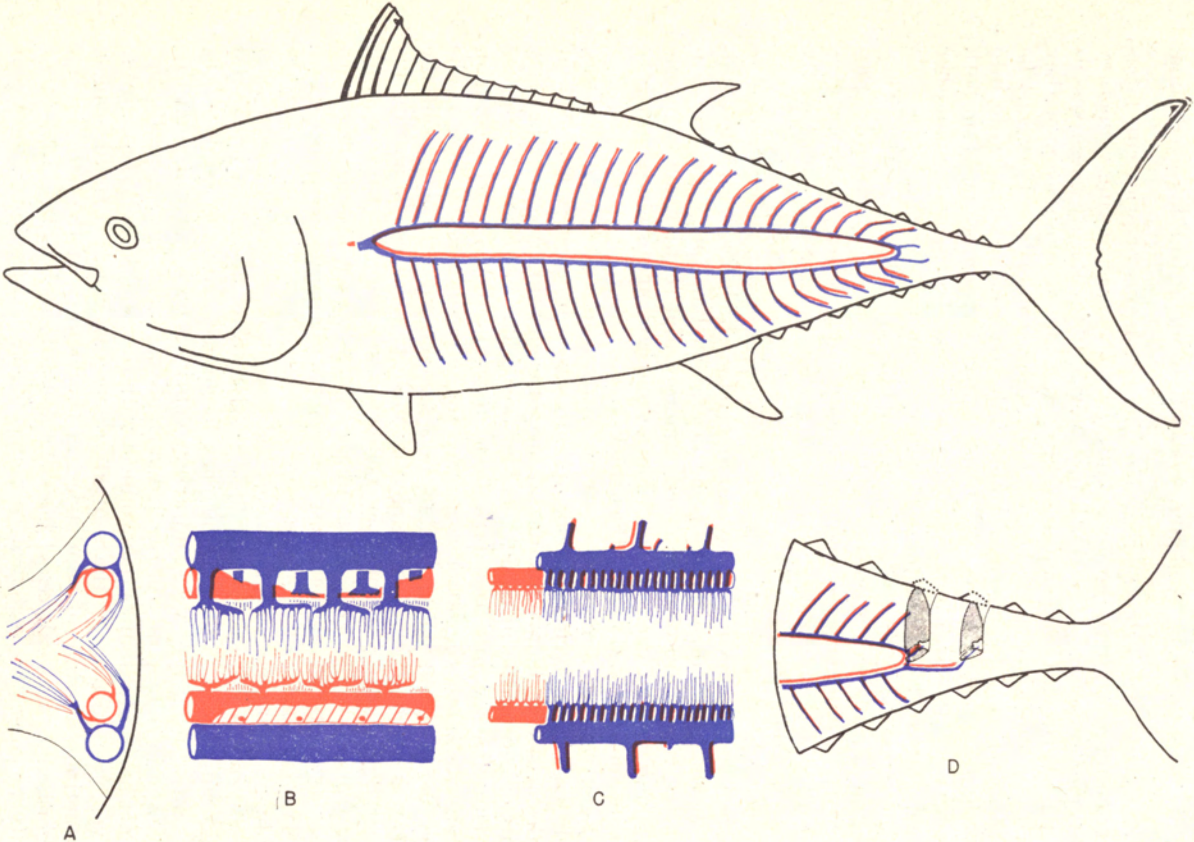

FIGURE 55. Bluefin tuna: Cutaneous system. Upper: Course of cutaneous vessels in superficial musculature. A: Enlarged transverse section. B: Enlarged partial view of C. with portions of the arterial walls cut away to show origin of arterioles and venules. C: Enlarged view of cutaneous vessels in central region. D: Posterior, terminal course of cutaneous vessels.

with a moderate horizontal trunk (derived mainly from the dorsal branch) connecting it with the 30th or 31st vertebra, and a large posterior continuation of the ventral vein and artery beyond the commissure, to the 32d vertebra, where these vessels turn in to enter that vertebra as separate horizontal trunks. The course of these vessels in the bluefin is thus intermediate between that of the yellowfin and the big-eyed tuna and suggests a transitional stage of evolution. It is therefore not surprising that considerable variation is found in this character. The extent of this variation is hard to define, and one can appreciate it only after a number of dissections. The course of the last segmentals was not followed in this species.

Despite this variation the cutaneous system of the bluefin is sufficiently distinct to separate it from the other species. The fact that the arteries and veins pass anteriorly between the third and fourth ribs, separates the bluefin from all species except the albacore, and the latter differs from it both in the terminal circulation and in the origin and course of arterioles and venules.

7.14. Post-Cardinal Vein

There is no post-cardinal vein in the bluefin, in which respect it resembles the albacore. The cutaneous veins (Fig. 52), after passing mesially between the third and fourth ribs, leave the arteries, turn anteriorly, and enter directly the Cuvierian duct on right and left side. This system is therefore comparable in all respects with that of the albacore and different from the remaining tunas.

In one specimen (L.C.-6) the cutaneous veins on one side were decidedly abnormal. Instead of fusing in an anterior commissure between the fourth and fifth intermuscular bones, the veins continued separately to the Cuvierian duct. The central branch, following a normal course, passed with the cutaneous artery between the third and fourth ribs and thence continued anteriorly to discharge into the Cuvierian duct. The dorsal branch, on the contrary, continued anteriorly near the surface and passed between the second and third intermuscular bones and thence between the first and second ribs, to enter the Cuvierian duct separately. This variation resembled the normal course in the skipjack.

7.15. Skeleton

The craniums and vertebral columns of seven Southern California fishes previously collected, and also the skeleton of a bluefin taken at Alijos Rocks, Mexico, were examined in addition to the specimens discussed above.

General appearance of the cranium: (Figs. 56, 57 and 58) Viewed dorsally, the lateral margins of the frontals are convex, giving the cranium a broad, heavy appearance. Viewed laterally, the angular margin of the parasphenoid and basioccipital, the deep ventral projections of the alisphenoids, and the frontal notch just anterior to the supraoccipital are distinctive. In the albacore the basioccipital resembles that of the bluefin, but these two species are easily separated by the extension of the alisphenoids into the interorbital opening. Viewed ventrally the wide, massive parasphenoid with only a slight taper is characteristic of this species.

Vomer (1): The dentigerous area is elliptical, with a narrow strip of bone running posteriorly. This strip resembles in some specimens the ridge of the albacore, but it is not as sharp and it is always covered with minute teeth, thus differentiating the bluefin from the skipjack.

Supraoccipital (8): The supraoccipital crest is broad at the tip in contrast to the narrowly acute crest of the albacore. In the yellowfin and big-eyed tuna this bone resembles the condition found in the bluefin, therefore, the albacore is the only species that can be identified by this

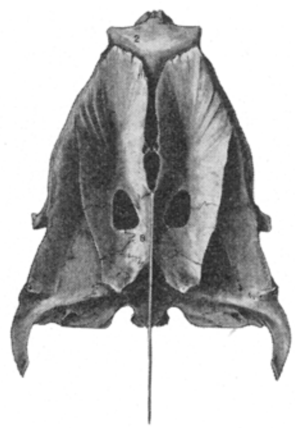

FIGURE 56. Cranium. Bluefin. Dorsal view

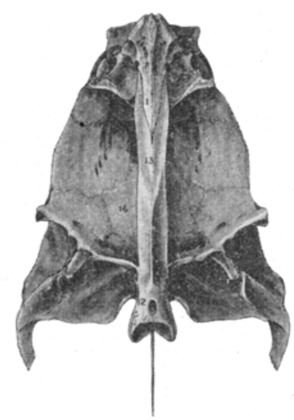

FIGURE 57. Cranium. Bluefin. Ventral view

character. Just anterior to the supraoccipital is a conspicuous depression in the frontals of the bluefin. While this depression is characteristic of the species, it is not equally developed in all individuals. An indentation at this point is found in all species, and in occasional specimens of yellowfin and albacore the maximum development of this indentation may approach the condition found in the bluefin (Fig. 58).

Basioccipital (12): In lateral view the posterior margin is prominently angular. The ventral limb of this angle is formed by that part of the posterior margin of the parasphenoid which joins the basioccipital. This angle was estimated as being approximately 90 degrees in 20 out of 30 cases and was greater than 90 degrees in 10 specimens. The greatest angle observed was estimated at 130 degrees and was beginning to approach the evenly convex marginal condition of the big-eyed tuna.

Parasphenoid (13): This bone is broad and massive in the bluefin. It was not tapered in 14 out of 30 cases, and was only slightly narrowed posteriorly in the remaining 16. In the other species this bone is proportionately narrower with a definite taper. However, in large and apparently old specimens of yellowfin a condition resembling that typical of the bluefin is found, *i.e.*, broad massiveness with uniform width. In the albacore and skipjack the bone reaches the opposite extreme, being exceptionally slender with a conspicuous taper as illustrated in figure 18.

Alisphenoids (16): The conspicuous ventral extension of the alisphenoids is a very good character in the bluefin and readily identifies the species. The bone projects below an imaginary line drawn from the prefrontal notch to the dorsal corner of the basisphenoid's anterior process.

The prefrontal notch is on the median line at the very anterior end of the interorbital opening. In old specimens of bluefin the alisphenoids may become fused to the parasphenoid by a column of bone.

Spinal Column: (Fig. 58) The first completely enclosed haemal arch was on the tenth vertebra in 26 of 30 specimens examined, on the ninth in one, and on the eleventh vertebra in three cases respectively. However, in the latter case one fish had the eighth and ninth vertebrae abnormally developed, fused together, and the combined vertebrae were no larger than one normal vertebra. This probably affected the position of the first haemal arch. In the bluefin the haemapophyses turn definitely downward beginning on the eighth vertebra in all 30 cases examined, whereas in the albacore all haemapophyses preceding the first haemal arch extend laterally. The haemal arches are narrow in the bluefin and

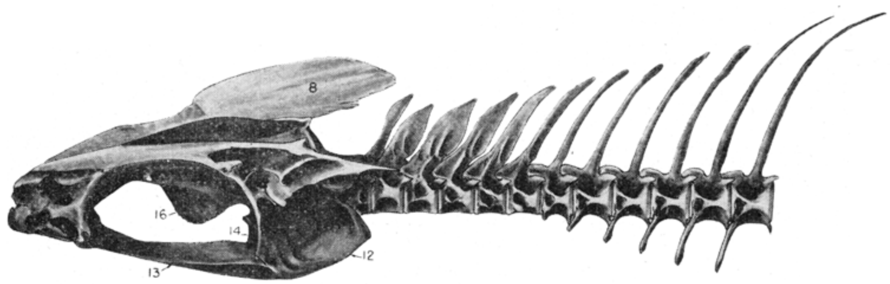

FIGURE 58. Axial skeleton. Bluefin tuna. Lateral view.

FIGURE 58. Axial skeleton. Bluefin tuna. Lateral view

in the big-eyed tuna rather than ovate as is the case with the yellowfin. In 23 out of 30 specimens of bluefin there were 18 precaudal and 21 caudal vertebrae counting the hypural. This count is normal for all the Thunnidae. The spines in six specimens were broken so that an accurate count was not obtainable, while in one abnormal specimen the count was 18 precaudal and 20 caudal, as one vertebra in the region of the hypural was absent.

Subopercle (26). (Fig. 74) The bluefin is easily recognized by the long straight margin which extends perpendicular to the upper edge of the anterior angular process. The length of this straight margin is variable, but it is definitely longer than the length of the angular process, while in the other species the margin is short and inconspicuous. In addition, the over-all height of the bone in relation to its width is distinctive. In this species the height is much greater than the width, while in the remainder of the Thunnidae the height is nearly the same as the width. The condition in the skipjack is reversed and the width is obviously greater than the height.

7.16. Conclusion

Because the fish from the two adjacent regions investigated are similar in all characters examined, it is apparent that they are of the same species, Thunnus thynnus. Hence the bluefin fishery of California is supported by a single species. This does not preclude the possibility that another extraneous species may occasionally enter our commercial catch. Fishermen and canners are at times puzzled by catches of tuna which in the opinion of the industry constitute a different species than T. thynnus. The fishermen sometimes referred to these fish as a cross between bluefin and yellowfin. We have examined several of these fish and pronounced them members of the genus Thynnus. The striations on the liver clearly separate them from the yellowfin. One specimen examined (but not described herein) differed significantly from all others.

The bluefin tuna common to the California fishery is very similar to Thunnus orientalis, as described by Kishinouye. Two characters however, appear to differ. In the local bluefin the cutaneous arterioles originate in two distinct, and diametrically opposite rows, whereas in his Plate 18, Kishinouye figures (for T. orientalis) these arterioles arising in a single row. Furthermore, he states on page 440: "This species (T. orientalis) is closely allied to the blue-finned tuna or leaping tuna of the California coast, but differs from it in the color of fins, and in the mode of ramification of canals of the cutaneous blood vessels."

Kishinouye figures and describes the air-bladder of T. orientalis, as short, broad and heart-shaped. The air-bladder of the local bluefin, however, is rudimentary and of a different shape in small fish, and so erratic in large specimens that no constant pattern is discernible. Despite the instability of the air-bladder, manifest in all tunas, we are of the opinion that these two differences will be substantiated by a direct and adequate comparison, and will therefore separate T. orientalis from T. thynnus.

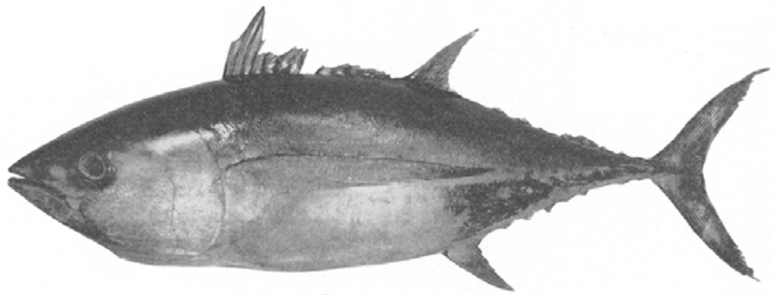

FIGURE 59. Big-eyed tuna, *Parathunnus mebachi*.

FIGURE 59. Big-eyed tuna, Parathunnus mebachi

8. BIG-EYED TUNA

Parathunnus mebachi (Kishinouye) 1923

While fishing tuna at the Galapagos Islands aboard the N. B. Scofield, on April 8, 1940, in the vicinity of Cape Berkeley, Albemarle Island, a tuna was caught which, while resembling the yellowfin, differed sufficiently so that it was set aside for later comparison with that species. Upon direct comparison, the body and head of this specimen appeared much deeper and the eye was conspicuously larger than in a yellowfin tuna of the same size. The pectoral fin was long and filamentous, reaching to the posterior end of the second dorsal base, resembling in this respect the albacore. The caudal fin was more open and appeared to have a greater spread, almost equaling the depth of the body. The lateral line was similar to that of the yellowfin, but the depression over the pectoral, characteristic of the tunas, appeared deeper. In body shape this specimen had more strongly convex dorsal and ventral outlines, suggesting those of the albacore, but it was less rotund than that fish; that is, it was deeper throughout but somewhat laterally compressed in comparison with the albacore. The coloration closely resembled that of the yellowfin. The fish possessed the same vertical white striations on the belly but lacked the white spots between these markings. Field notes made at the time of capture recorded that the white markings were not as conspicuous as in the case of the yellowfin.

This specimen was obviously different from the yellowfin, and the results of a cursory anatomical examination made later that day are included in this description.

Information subsequently gathered from fishermen indicated that occasional specimens of this species were taken at the Galapagos Islands, a few had been caught at Alijos Rocks, and others were caught spasmodically at Guadalupe Island. Through the courtesy of Captain Louis Massa, operating owner of the tuna boat "St. Mary," a second specimen was secured from Guadalupe Island. This fish, caught in the latter part of November, 1940, was undoubtedly of the same species as that taken at the Galapagos Islands, and accordingly the results of the separate examinations have been combined and the occurrence of this species in the eastern Pacific recorded on the basis of these two specimens.

The results of this work indicate that these two specimens belong to the genus Parathunnus, created and described by Kishinouye in his "Contributions to the Comparative Study of the So-called Scombroid Fishes." This genus includes only one species, P. mebachi, and there can be little doubt that the two local specimens belong to this species.

8.1. External Appearance (Fig. 59)

Outstanding characteristics of the species are the depth of the body and the head, the large eye, and the long pectoral fin, which, in the Guadalupe specimen reached to the end of the anal base. The vent is oval or slightly tear-drop in shape, and not round as in the albacore.

8.2. Proportional Measurements

See table 2.

8.3. Meristic Counts

See tables 3 and 4.

8.4. Viscera (Fig. 60)

The ventral appearance of the viscera is sufficient alone to identify the species and separate it from all other tunas. The most striking difference involves the relation of the intestine with the spleen. The latter is dorsal to the intestinal fold, and because this is relatively long, the spleen is hidden in this view except for a small portion seen at the anterior bend of the intestine. The absence of the spleen in this view separates the big-eyed tuna from all others with the exception of the skipjack, and the latter, having no fold in the intestine, is readily identified. The peripheral markings on the liver also distinguish the big-eyed tuna from all others, although these markings were not conspicuous in one of the two specimens.

8.5. Caecal Mass

This is moderately long, measuring 0.58 of the length of the abdominal cavity in the case of the Guadalupe specimen. In this fish the apex lay upon the left side. Its location was not recorded in the case of the Galapagos specimen. The enveloping membrane enclosing the caecal mass seemed to be tougher and less easily ruptured than in the other tunas, and the individual caeca or tubules appeared larger and coarser, giving to the whole mass the appearance of a looser texture. The caecal mass was connected to the duodenum by seven distinct ducts.

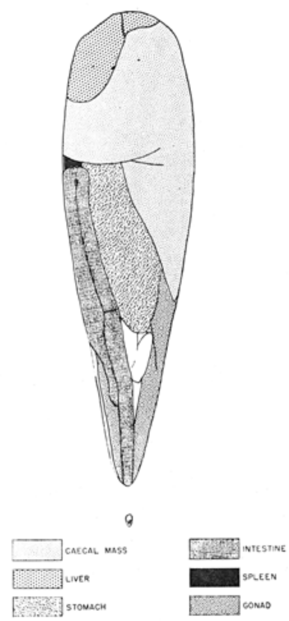

FIGURE 60. Big-eyed tuna: Ventral view of the viscera, in situ. A small portion of the spleen shows at the anterior bend of the intestine. The tip of the gall-bladder appears in outline at the posterior tip of the stomach

8.6. Liver

(Fig. 61). In size and general shape this liver resembles that of the yellowfin. In the Guadalupe specimen the center lobe was the longest, whereas in the Galapagos specimen the right lobe was slightly the longest.

The ventral surface of the liver is characteristically marked. In the peripheral zone on each lobe fine, short striations run perpendicular to the margins. These striations, which are in reality fine blood vessels derived from the visceral circulation, were conspicuous in the Galapagos specimen, but faint and barely perceptible in the Guadalupe specimen. In this case, however, a subsequent injection of the coeliac-mesenteric artery clearly demonstrated these peripheral striations.

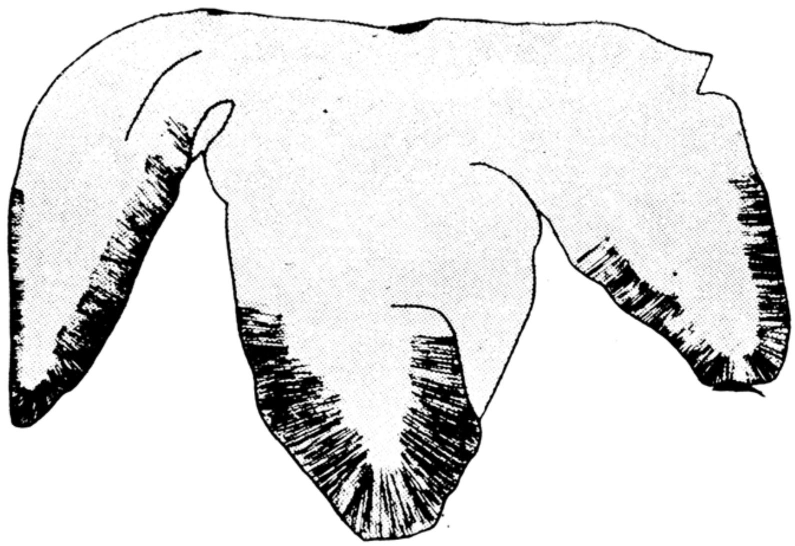

FIGURE 61. Big-eyed tuna: Ventral view of the excised liver, to illustrate shape and markings.

FIGURE 61. Big-eyed tuna: Ventral view of the excised liver,to illustrate shape and markings

The shape of the liver will separate the big-eyed tuna from all except the yellowfin, and the absence of surface markings in the latter will separate these two species.

8.7. Stomach

This is in no way distinctive and resembles that of the other tunas. In the Guadalupe specimen it lay mesially and measured 0.63 of the length of the abdominal cavity. In the Galapagos specimen the stomach extended nearly the full length of the body cavity.

8.8. Intestine

The course of the intestine is very similar to that in the yellowfin. However, the fold of the intestine, located on the right side, is considerably longer than that of the yellowfin, equaling half the length of the body cavity in the case of the Guadalupe specimen. Likewise, the loop of the duodenum seemed longer and more extensive in both specimens than in the other tunas. The rectum is separated from the remaining intestine by a slight constriction and a faint circular marking, and it is perhaps slightly larger in diameter. However, were it not for this superficial marking, the separation of the two regions would not be apparent.

8.9. Spleen

In the Guadalupe specimen the spleen did not show in ventral view, except for a small portion at the anterior bend of the intestine. The spleen is nevertheless long and quite large. It is located dorsal to the fold of the intestine and lies between this and the straight intestine. The anterior end extends far forward beneath (dorsal to) the caecal mass and the right lobe of the liver, while the posterior end reaches about midway between the bends of the intestine. In color and texture it resembles the spleen of the other tunas, and in shape it was somewhat indeterminate.

8.10. Gall-bladder

As in the other tunas, this is a long tubular sac. It follows the course of the straight intestine, and only its posterior portion is seen in ventral view. In the Guadalupe specimen the tip of the gall-bladder was bent anteriorly upon itself, as shown in figure 60, but was not held by membranes in this position. It could readily be straightened, but when this was done a permanent fold or crease at the bend could be detected.

8.11. Air-bladder

(Fig. 62). In both specimens examined the air-bladder was a long, narrow organ extending practically the full length of the body cavity. In both it was wedge-shaped, with a rounded anterior end, and tapering to a sharp point posteriorly. Anteriorly it resembles the bladder of the yellowfin tuna in that it is divided on its dorsal face by a central cleft into two pockets or horns. As in the yellowfin these horns project on either side of the dorsal aorta into a pocket or pit immediately beneath the vertebral column. The pit of the air-bladder is larger than in the yellowfin, and in both specimens examined was directly beneath the sixth and seventh vertebrae. However, the two horns are not as sharply separated and they are smaller than in the yellowfin, and in consequence they do not project as deeply into the corresponding pit. They are not as firmly attached to this as in the yellowfin. Figure 62 shows the presence and location of the circular orifice and internal septum. At the anterior end of the air-bladder, on the dorsolateral walls just posterior to the two horns, there is on either side a thickened area suggesting a vascular or specialized tissue. An injection of the Guadalupe specimen proved conclusively that the air-bladder receives arterial blood on its dorsal wall from the axial system, as in the other tunas, whereas the ventral wall is nourished by a branch from the coeliac-mesenteric artery. The shape of the air-bladder is sufficiently different to distinguish the big-eyed tuna from the other species.

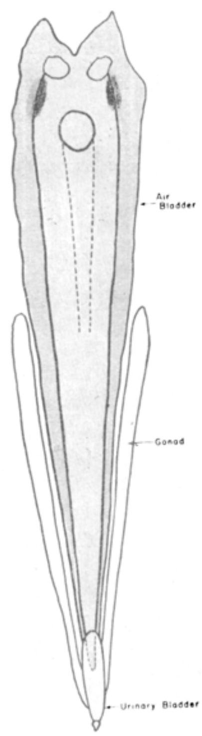

FIGURE 62. Big-eyed tuna: Ventral view of the air-bladder. The ventral wall has been opened to show the internal structure

8.12. Excretory System

Kidney: In shape and location the kidney (Fig. 63) closely resembles that of the bluefin. The posterior projection is short and extended to the eleventh and thirteenth vertebrae respectively in the Galapagos and Guadalupe specimens.

Ureter: The appearance of the ureters was similar in both specimens and is quite distinctive in this species. The ureter divides shortly after entering the kidney tissue, but the two branches continue together in the median line for a distance equal to the length of one vertebra. Thus in the Guadalupe specimen the ureter divided beneath the tenth vertebra and the two branches separated beneath the ninth vertebra. The two branches diverge rapidly. Each branch runs laterally and crosses the ventral face of the corresponding cutaneous vein and artery. It then turns anteriorly again. Beyond this it was not followed. The course of the uterers is thus very similar to that of the bluefin and quite different from that of the other tunas. In the big-eyed tuna, however, the ureters separate more abruptly and in a wider angle than in the bluefin.

Urinary Bladder: The urinary bladder was a relatively conspicuous organ in both specimens of this species. It was attached to the body wall in the posterior half of its length, and the anterior portion of the bladder projected freely into the abdominal cavity, attached only to the rectum. Laterally the bladder was loosely attached posteriorly to the membrane enveloping the gonads. The walls of the urinary bladder were heavy. In the Guadalupe specimen the bladder measured 56 millimeters, being equal to 0.17 of the length of the body cavity.

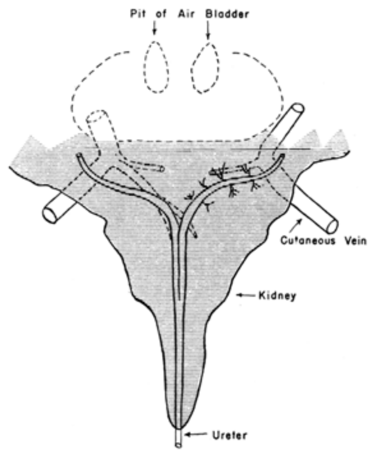

FIGURE 63. Big-eyed tuna: Ventral view of the posterior projection of the kidney and the two branches of the ureter. The pit of the air-bladder and the vertebral attachment of the pharyngeal muscles are dotted anteriorly, and the post-cardinal vein is shown running to the right cutaneous vein

The ureter in the Guadalupe specimen joined the bladder 22 millimeters from the anterior tip, thus near the middle of its length, and appeared to open into the bladder directly at this point.

Because the bladder in this species projects anteriorly freely into the abdominal cavity, it resembles only that of the yellowfin, and differs from the remaining tunas, in which the urinary bladder is attached throughout its length to the body wall. The bladder of the big-eyed tuna is more conspicuous than that of the yellowfin, but could be easily confused with the latter.

8.13. Circulatory System

1. *Anterior Arterial System* (Fig. 64): The arrangement in both specimens was similar. The "Y" of the aorta was beneath the second vertebra, and the posterior epibranchials joined the aorta beneath the third vertebra. In the Galapagos specimen this vessel was of appreciable length, as in the yellowfin, but in the Guadalupe specimen (fig. 64) it was extremely short and almost nonexistent. The coeliac-mesenteric artery arose beneath the fourth vertebra, and the small subclavians at the junction of the fourth and fifth vertebrae. (The latter were not observed in the Galapagos specimen.) The ligament crosses the aorta at

this point. The pharyngeal muscles were attached to the sixth vertebra, and the pit of the air-bladder was beneath the sixth and seventh vertebrae. In the Galapagos specimen the cutaneous arteries arose beneath the anterior end of the eighth vertebra, and in the Guadalupe specimen beneath the posterior end of the seventh vertebra. In both specimens the cutaneous arteries inclined posteriorly as in the albacore and bluefin. At a distance equal to the length of one vertebra a small artery was seen posterior to the cutaneous in both specimens. This small unpaired vessel arose from the ventral face of the aorta, and dividing immediately it sent a branch posteriorly on each side into the kidney substance. This vessel, which was quite conspicuous, was similar and distinctive in both specimens. There are no parallel arterial trunks in this species.

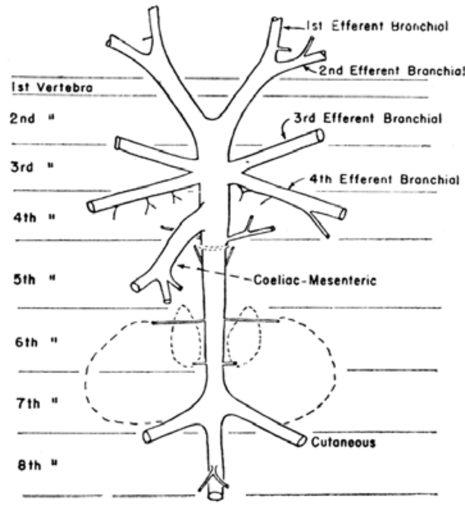

FIGURE 64. Big-eyed tuna: Ventral view of the anterior arterial system. The pit of the air-bladder and the vertebral attachment of the pharyngeal muscles are outlined

2. *Visceral Arterial System* (Fig. 65): The coeliac-mesenteric artery was injected and followed only in the Guadalupe specimen; hence this description is based upon only one specimen. The injection in this case was good, and the description is accurate insofar as this fish is concerned.

The coeliac-mesenteric artery divides into three major branches. The Number I branch, as in other tunas, is the smallest and least complex. It crosses to the left side of the fish in the dorsal wall of the oesophagus and continues posteriorly along the left dorsal face of the stomach, as in the yellowfin and skipjack, sending tributary branches to the adjacent wall. It is connected, as in the yellowfin, with the No. III branch.

The Number II branch, after entering the abdominal cavity, goes directly to the right lobe of the liver. Here it meets a tributary vessel (III-v.) from the No. III branch and with this gives rise to a large series of minute vessels, some of which enter the liver to contribute to the vascular plexus within the substance of the right lobe, and others converge to form a complex, divided vascular sac on the dorsal face of this lobe, from which the majority of the terminal vessels originate. This vascular sac has the appearance of being divided into two distinct but ill-defined and interconnected cones, and for convenience of discussion this interpretation will be assumed and the two cones will be designated II-A and II-B. It should be understood however that the terminal vessels to be described may have a more complex origin than indicated. often they are formed by small, converging arterial strands coming from both cones.

After giving rise to the above plexuses, the No. II branch continues as a distinct vessel into the substance of the spleen, wherein it gives rise to innumerable branches which nourish all parts of this organ. The other vessels originate in the vascular cones. The first, II-A, sends a large part of its supply through fine parallel vessels to the loop of the duodenum.

The injection failed at this point, and it is uncertain whether these terminate here or continue to the caecal mass or possibly to other visceral organs. A second bundle of parallel vessels (II-a.b.) runs from II-A to the ventral wall of the air bladder, and a larger bundle (II-st.) arising in this cone, runs to the right dorsal wall of the stomach. Here again the injection failed, but this vessel apparently continued posteriorly on this face of the stomach wall.

From the second cone, II-B, five distinct vessels originate. One, II-g.b., runs to and continues on the left face of the gall-bladder. A second, II-int.$_1$, nourishes the dorsal wall of the straight intestine as far as the posterior bend. The third branch, II-int.$_2$, crosses on the surface of the spleen to the ventral wall of the straight intestine. The fourth branch, II-rec.$_1$, likewise runs on the surface of the spleen and goes thence to the dorsal wall of the rectum (the descending portion of the intestine). It also sends a branch anteriorly on the dorsal wall of the ascending portion of the intestine. The last branch, II-rec.$_2$, runs on the margin of the spleen to the ventral wall of the rectum. In its course it nourishes also the anterior bend of the intestine.

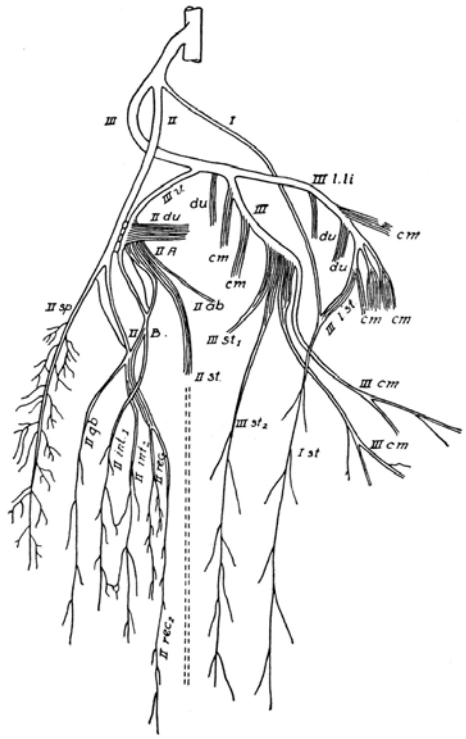

FIGURE 65. Big-eyed tuna: Diagrammatic ventral view of the coeliac-mesenteric artery and its branches

The Number III branch goes directly to the center lobe of the liver, where it divides into two major branches, III and III-l.li. in the figure. At or near the point of division, three or more series of minute parallel vessels arise and run to the caecal mass and to the duodenum. The branch (III) to the center lobe gives rise to a large number of small vessels which run into the substance of this lobe, and then it apparently breaks up into a single large vascular cone, from which four terminal vessels arise. One, III-st.$_1$, consists of a number of parallel vessels which run to the anterior ventral wall of the stomach. A second, III-st.$_2$, is composed of a large number of fine, parallel vessels which subsequently fuse into a single large vessel that runs the length of the stomach on its ventral wall, sending numerous tributaries to both sides. The two remaining vessels are large and both run into and presumably nourish the caecal mass throughout its extent.

The second main division, III-l.li., of the No. III branch runs on the dorsal surface of the left lobe of the liver. In its course it gives off numerous small vessels into the substance of this lobe, and three series of fine parallel vessels, two of which run to the duodenum and one to the caecal mass. Towards the distal end of the left lobe this branch divides into three. All divisions promptly break up into vascular sheets, two of which enter the left anterior portion of the caecal mass, and the third divides into two parts, one of which goes similarly to the caecal mass and the other to the left stomach wall. The latter part either joins the No. I branch or accompanies it posteriorly on the stomach wall. The injection failed at this point.

The No. II and No. III branches are connected as they join respectively the right and center lobes of the liver, by a vessel of moderate size. This vessel, III-v. arises in the No. III branch just prior to the first division of that branch and runs to the right lobe, meeting the No. II branch as that vessel gives rise to the first vascular cone. The appearance suggested that III-v. contributed as much, or more, to the cone formation as did the No. II branch. However, the two vessels are so inextricably connected at this point that it is impossible to evaluate the precise role of each separate vessel.

The coeliac-mesenteric system of the big-eyed tuna is thus intermediate in position between the condition found in the yellowfin and in the bluefin. As in the yellowfin and in the skipjack, there are three major branches to this artery in the big-eyed tuna, whereas there are only two in the bluefin and albacore; but unlike the yellowfin and skipjack, the vessels in the big-eyed tuna break up to a limited extent beneath the liver to give rise to conical plexuses similar to those found in the albacore and bluefin. The breakup in the big-eyed tuna is, however, less complete, and the plexuses less extensive. As in the bluefin, the No. II and No. III branches are connected in the big-eyed tuna by a moderate trunk, and the absence of this trunk differentiates the albacore. Thus the visceral arterial system of the big-eyed tuna is unique and different from the remaining tunas.

3. *Cutaneous System:* (Fig. 66) From their origin in the aorta the cutaneous arteries run laterally and pass between the fifth and sixth ribs. Approaching the surface each artery divides between the sixth and seventh intermuscular bones into a dorsal and ventral branch. Similarly the cutaneous veins, flowing anteriorly, join at this point in an anterior commissure. The big-eyed tuna resembles in this respect the yellowfin tuna.

The course of the vessels on the surface is not distinctive and resembles that of both the yellowfin and bluefin.

Each artery throughout its course on the surface gives rise to two continuous rows of arterioles. One row, in which the vessels are perhaps more numerous, originates on the proximal,[18] abaxial face of the artery, and the other arises almost directly opposite, that is, on the distal, axial face of the artery. The venules similarly arise in two rows. The more numerous series arises on the proximal, abaxial face of the vein, and these venules cross the abaxial face of the artery, thus obscuring its course, as in the bluefin and yellowfin. The second row originates on the proximal, axial face of the vein. Arterioles and venules immediately break up into capillaries, which together run into the dark flesh of the lateral median line as vascular sheets. In this species, as in the yellowfin and bluefin, these sheets run in at various angles. The origin and course of arterioles and venules in the big-eyed tuna is in these respects similar to that of the bluefin.

[18] See page 19 for a definition of terms.

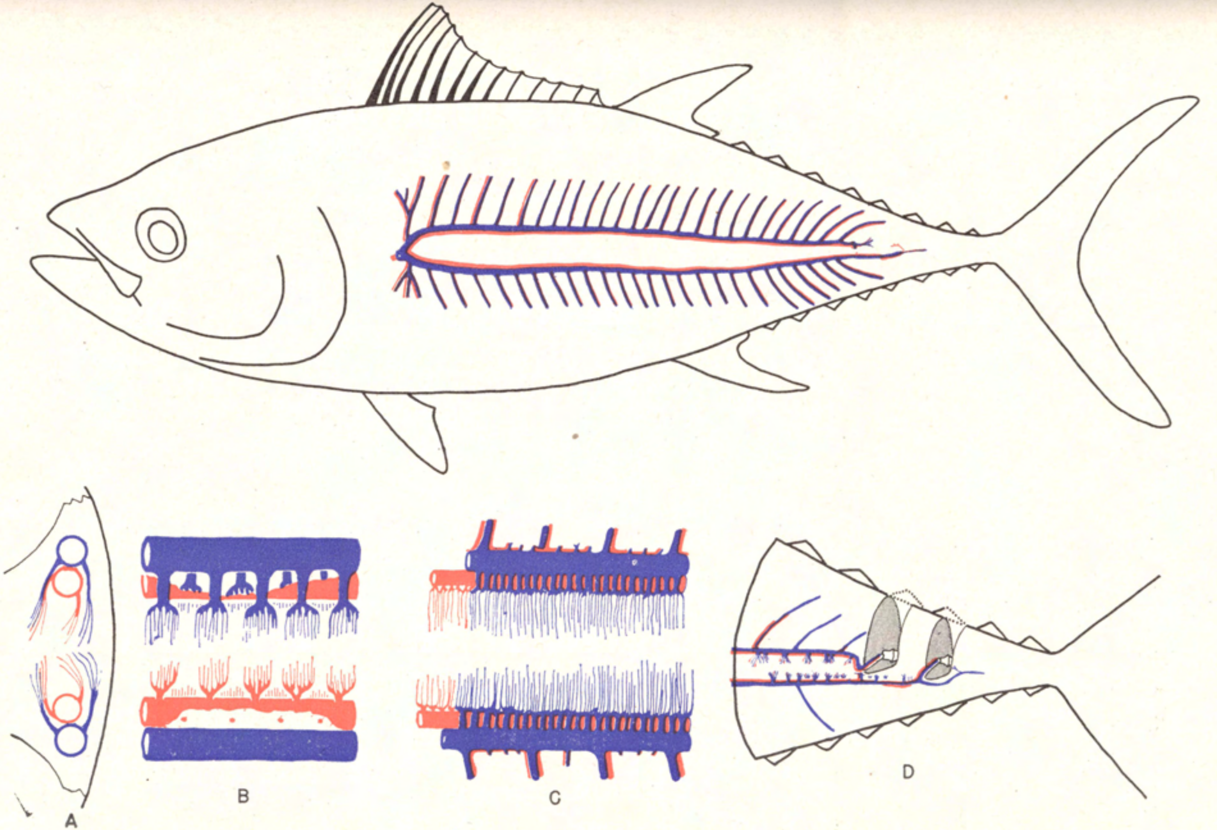

FIGURE 66. Big-eyed tuna: Cutaneous system. Upper: Course of cutaneous vessels in superficial musculature. A: Enlarged transverse section. B: Enlarged, partial view of C, with portions of the arterial walls cut away to show origin of arterioles and venules. C: Enlarged view of cutaneous vessels in central region. D: Posterior, terminal course of cutaneous vessels. See pages 112-114.

The posterior course of the cutaneous vessels in this species differs from that of the remaining species. Both specimens examined were essentially similar. Approximately beneath the fourth dorsal finlet, the dorsal branch of each cutaneous vein and artery turns proximally and then runs horizontally to enter the axial system through the 30th vertebra. This horizontal trunk is small, and on one side of the Guadalupe specimen was little more than a group of capillaries. The ventral branch of vein and artery continued posteriorly beyond this point for a distance equal to the length of two vertebra. Vein and artery then turned proximally and entered the axial system as horizontal trunks through the 32nd vertebra. These trunks were of appreciable size. A small branch of the ventral vein continued posteriorly beyond this in the surface musculature. A corresponding artery was not seen.

In the vicinity of the 30th vertebra, both vein and artery of the ventral branch give rise to a group of capillaries which run proximally at that point where the dorsal branch terminates. This suggested a commissure, but in neither specimen could we establish any direct connection between dorsal and ventral branch, and we therefore conclude that there is no posterior commissure in this species. Certainly there is nothing comparable with the commissure found in the yellowfin. It is quite possible that dorsal and ventral branches may meet in a weak commissure in occasional specimens, in which case the system would be exactly comparable with that of the average bluefin. The ultimate course of the last segmentals was not traced.

Details of this system thus distinguish the big-eyed tuna from all others. From the bluefin, albacore, and skipjack it is sharply differentiated by the fact that cutaneous arteries and veins pass anteriorly between the fifth and sixth ribs, as in the yellowfin. From the yellowfin, however, the big-eyed tuna differs in the lack of a posterior commissure and in other minor respects.

8.14. Post-Cardinal System

A post-cardinal vein is present in this species, but it is relatively small. It emerges from the haemal canal through the first haemal arch on the eleventh vertebra, where it is joined by a small renal vein from the posterior extension of the kidney. It then runs obliquely to the right of the fish and empties into the right cutaneous vein at the point where that vessel bends anteriorly as it approaches the Cuvierian duct. A different interpretation of this system would not change the essential facts. Thus it could be assumed that the small post-cardinal, after receiving the right cutaneous vein, increases considerably in size, and as a large vessel, empties directly into the Cuvierian duct (Fig. 63).

The cutaneous vein on either side, after passing mesially between the fifth and sixth ribs, crosses dorsal to the corresponding ureter; thereafter it leaves the cutaneous artery, turns anteriorly at an appreciable angle, and runs directly to and empties into the Cuvierian duct.

At the point where the post-cardinal vein joins the right cutaneous vein, another small vein enters the latter also. A comparable vessel enters the left cutaneous vein. These small vessels run laterally from the median kidney tissue, and their appearance suggests the transverse venous trunk which, in the yellowfin, joins the left cutaneous vein with the post-cardinal vein. In the case of the big-eyed tuna, however, these vessels were small and no connection between the pair was established.

8.15. Skeleton

The reader is asked to bear in mind that this discussion is based on only two specimens of the big-eyed tuna, and the authors make no claim that the differences described will survive the examination of a larger series.

While may bones of the big-eyed tuna differed in minor respects from the comparable bones in some of the other species, such variations were so subtle and unsatisfactory that it would require a combination of the differences in a number of bones to separate the species. Only these bones exhibiting major differences will be discussed herein.

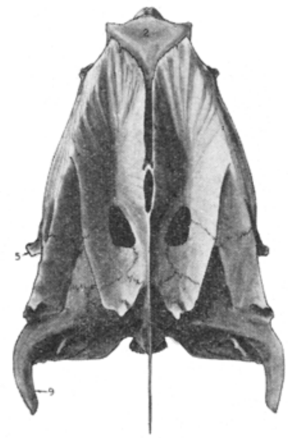

FIGURE 67. Cranium. Big-eyed tuna. Dorsal view

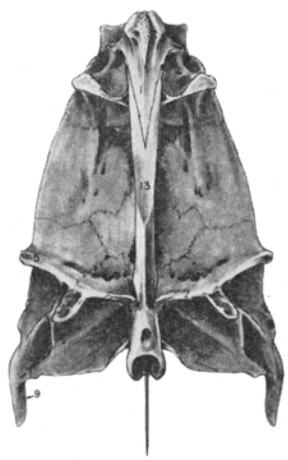

FIGURE 68. Cranium. Big-eyed tuna. Ventral view

Cranium (Figs. 67, 68 and 69): In the dorsal and ventral views the cranium of the big-eyed tuna resembles strikingly that of the yellowfin and to a less extent that of the remaining tunas. In the lateral view it is perceptibly deeper in the big-eyed tuna, but as the proportion of height to length is apparently a function of age, this proportion is significant only when expressed in relation to the size of the fish. The following table gives the proportional values obtained in three yellowfin and two big-eyed tunas, and a description of the methods adopted in making these measurements follows the table. The internal orbital length (measurement # 1) divided by its height (measurement # 3) equaled 3 in the small specimen of big-eyed tuna and 4.25 in the large, whereas this proportion in 42 specimens of yellowfin varied between 3.16 in a small fish to 6.66 in a large one. All measurements were taken in millimeters with a slide caliper.

TABLE 18

Proportional differences in the cranium of the yellowfin and big-eyed tuna.

Proportional measurements	Yellowfin tuna			Big-eyed tuna	
	Cocos Island 8	Japanese 5	Japanese 1	1	2
Total length—mm.	----------	970	1197	569	910
Height cranium / Length cranium	.59	.65	.63	----------	.69
Height sphenotic / Length cranium	.33	.33	.31	.37	.34
Height sphenotic / Exterior orbital Length measure No. 2	.58	.60	.57	.63	.60
Exterior orbital Length measure No. 2 / Length cranium	.53	.51	.54	.56	.52
Height 1st vertebra / Length cranium	.16	.14	.17	.23	.20
Interior orbital Length measure No. 1 / Interorbital Height measure No. 3	4.30	4.00	5.00	3.00	4.25

TABLE 18

Proportional differences in the cranium of the yellowfin and big-eyed tuna

1. Internal orbital length was measured on the median line from the prefrontal notch to the middle of the anterior edge of the basisphenoid.

2. External orbital length was taken from the outer, ventral corner of the prefrontals to the angle of the parasphenoidal groove at the base of the expanded wing.

3. Height of orbit was measured along the perpendicular from the dorsal face of the parasphenoid to the most ventral extension of the alisphenoids.

4. Cranial length was measured from the anterior tip of the vomer to the posterior basioccipital margin. This is at the junction of the first vertebra with the cranium.

5. Cranial height was measured with the vomer and parasphenoid bones resting on a table and the vertical axis of the skull perpendicular to the table top. The height was then measured perpendicularly from the table to the top of the supraoccipital crest.

6. Sphenotic height was measured from the table to the dorsal surface of the sphenotic process in a vertical line with the cranium in the above position.

7. Height of first vertebra was measured with the skull in the above position and was considered as the perpendicular distance between the table top and the anterior ventral edge of the first vertebra.

The most useful and distinctive difference discovered, which characterizes the big-eyed tuna concerns the postero-ventral margin of the cranium seen in the lateral view. This margin is smoothly rounded, with the convex margin of the parasphenoid and the basioccipital continuing in an unbroken curve to the insertion of the vertebral column. Although this character does not effectually differentiate the big-eyed tuna from the skipjack, there is in reality no difficulty in their separation, since the latter differs in numerous respects from the big-eyed tuna. Thus in this species the ventral projection of the alisphenoids between the orbitals is well developed, whereas in the skipjack these bones project very little, if at all, into the space below. Although the profiles of the parasphenoid and basioccipital are most distinctive of the big-eyed tuna, they may in cases of extreme variation prove inconclusive. In such cases they may be supplemented by the following characters, which, taken together, should yield a positive identification of the skull.

Basisphenoid (14): On the basisphenoid there are well developed processes on both the anterior and posterior margins. The anterior process is always present in the yellowfin, but the posterior processes are variable, being well developed in some specimens while scarcely visible in others. Furthermore, in the big-eyed tuna the basisphenoid slopes slightly forward, whereas in 60 specimens of yellowfin only 14 sloped forward, with the remainder perpendicular to the parasphenoid. The height-to-width ratio of the basisphenoidal shank was 2.3 and 2.5 in the big-eyed tuna, and ranged between 1 and 3 in the yellowfin.

Parietal Crest: In the lateral view the projection of the curve formed by the lateral margin of the prefrontals meets, or blends smoothly into, the parietal crest in this species. In the yellowfin the parietal crest extends farther forward (cf. page 68).

Vomer (1): The presence of vomerine teeth in this species separates it from the skipjack. The absence of a thin bony ridge posterior to the vomerine teeth in the big-eyed tuna separates it from the albacore in which this ridge is well developed.

Sphenotic (5): Viewed ventrally, the posterior margin of the sphenotic is straight for the greater part of its length in the big-eyed tuna, whereas in the albacore the margin is curved, particularly at the tip.

Prootic (15): In all the Thunnidae examined, the lateral wings of the prootic are attached to the sphenotic, while in the skipjack these lateral wings project free of the sphenotic. In lateral view of the cranium, the dorso-posterior process of the prootic is deeply arched on its ventral margin in the big-eyed tuna. The comparable curve in the bluefin and the albacore is very open and frequently flattened. Since this region is easily damaged in cleaning, too much emphasis should not be placed on this character.

Spinal Column (Fig. 69): In this species the first complete (entirely closed) haemal arch is on the eleventh vertebra. This statement disagrees with that of Kishinouye, but the discrepancy is possible due to the method of counting or to intraspecific variation. The haemapophyses are well developed on the tenth vertebra, but their ventral tips are not joined together. Kishinouye may have terminated his count at this tenth vertebra rather than at the first completely closed haemal arch on the eleventh vertebra.

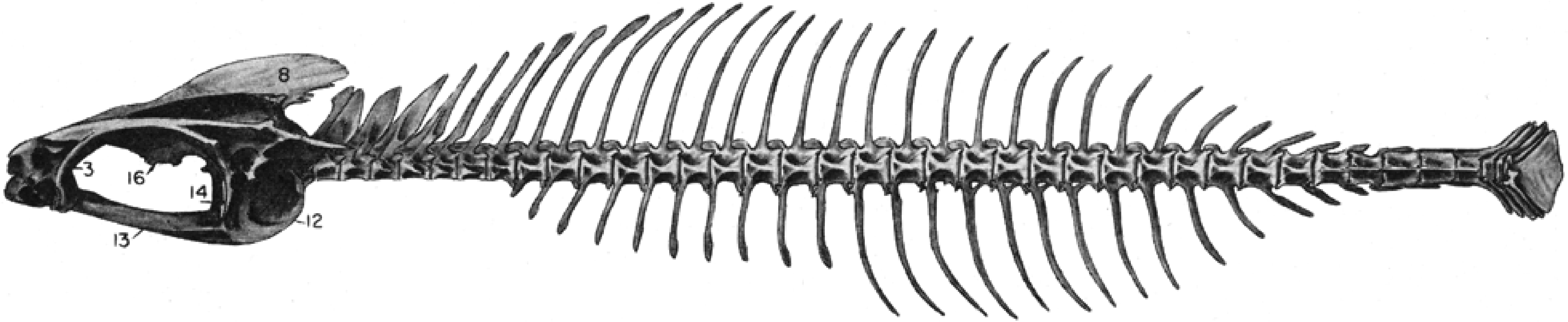

FIGURE 69. Axial skeleton. Big-eyed tuna. Lateral view.

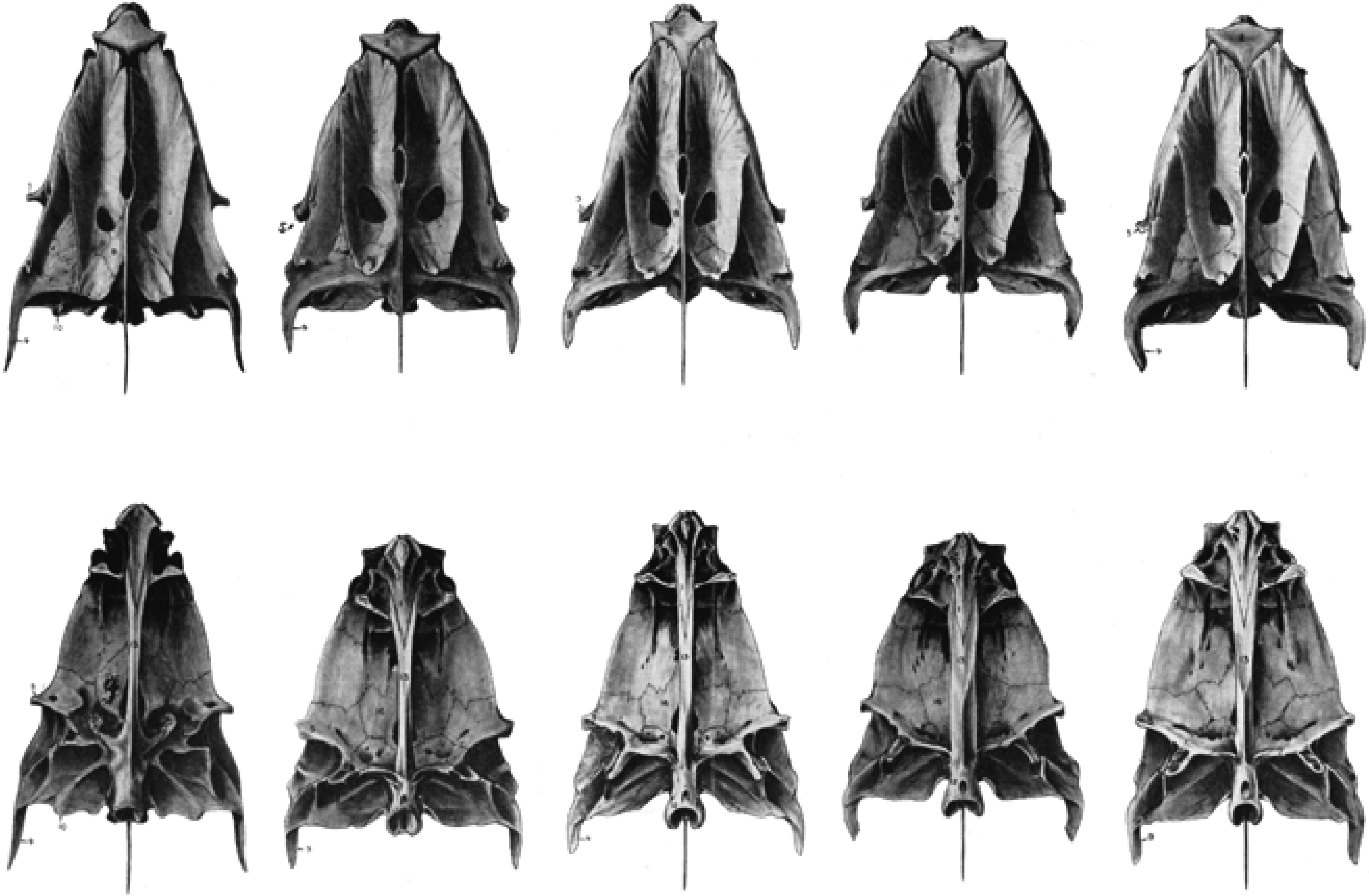

FIGURE 70. Above, dorsal view; below, ventral view of cranium. Left to right, skipjack, yellowfin, albacore, bluefin, big-eyed tuna.

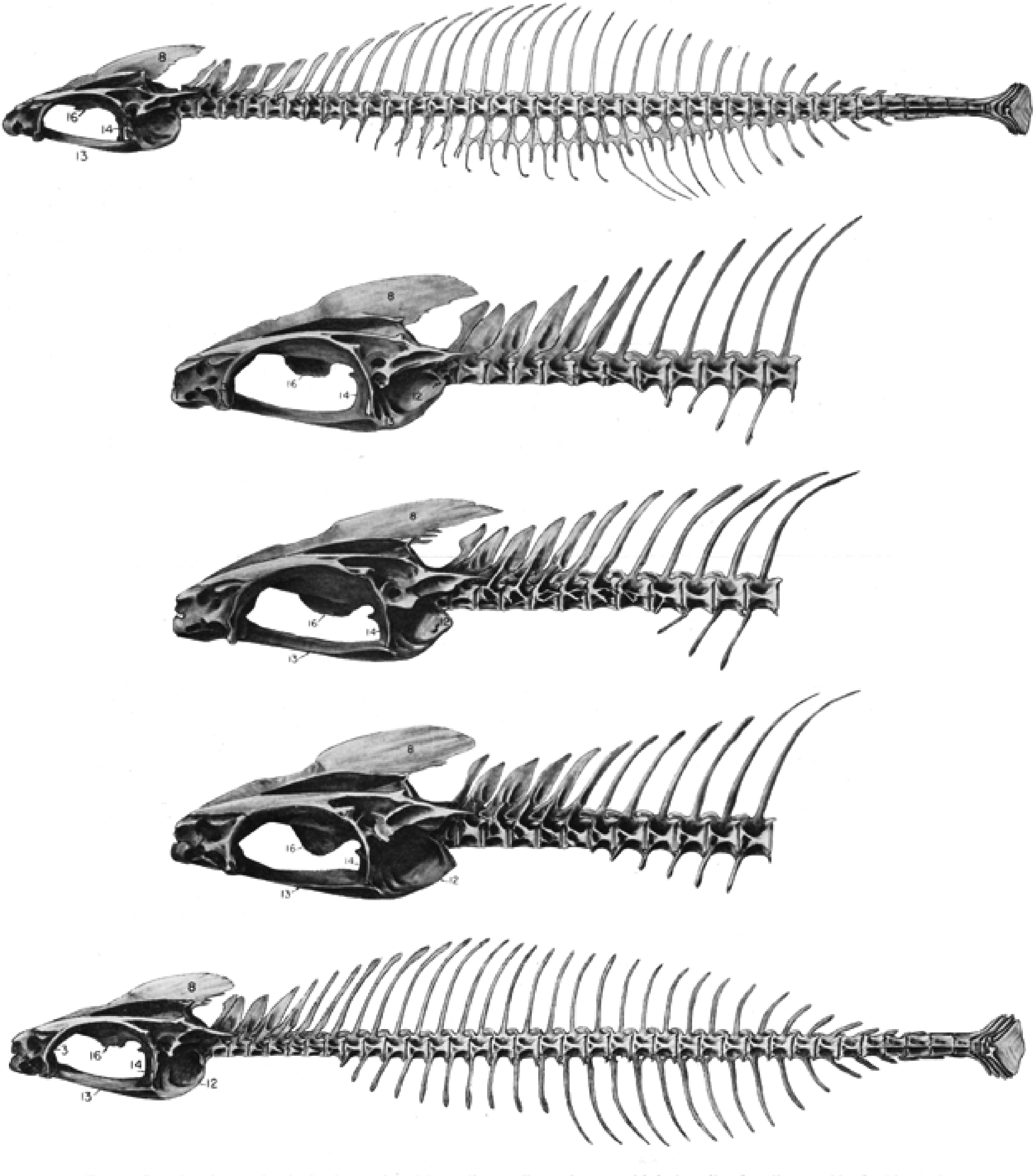

FIGURE 71. Cranium and spinal column viewed laterally. Top to bottom, skipjack, yellowfin, albacore, bluefin, big-eyed tuna.

Pectoral Girdle (55, 57, 58): A preliminary examination of the pectoral girdle and a comparison with that of the yellowfin indicated proportional differences in these bones, but a larger series of measurements and a more careful study demonstrated that specific differences did not exist. Viewed internally, the cleithrum has an isthmus in the region where it passes along the coracoid. The least width of the isthmus was measured and divided into the width of the coracoid measured from the narrowest portion of the isthmus to the dorsal articulating condyle. In the smaller specimen of big-eyed tuna a value of 3.7 was obtained, while in the larger the value was 3.1. In the yellowfin the range was from 1.9 to 3.7, so that this character is not suitable for the differentiation of these species. The mesially projecting flange along the concave anterodorsal border of the cleithrum is poorly developed in the big-eyed tuna. Its edge is smooth and straight and does not bear the wing-like expansion characteristic of the skipjack. In this respect it resembles the other species of the Thunnidae. (Fig. 76.)

Pelvic Girdle (62): The portion of the flaring plate ventral to the flange is much reduced and its area is approximately one-third that of the plate dorsal to the flange. This contrasts strongly with the condition found in the skipjack, in which the ventral portion of the plate is at least one-half the area of the plate above the flange. (Fig. 75.)

8.16. Conclusion

A comparison of the foregoing description with that of Kishinouye indicates that the big-eyed tuna is in reality Parathunnus mebachi. However a direct comparison of specimens will be required to reconcile two major discrepancies. On page 442, Kishinouye states: "At the margin of the exterior surface of the liver a few short venules are found. On the internal surface of the liver, conical masses of plexus of venules only are found, arteries not being divided in the masses * * *", and he defines this as a generic character. On page 369, Kishinouye figures the anterior course of the post-cardinal and cutaneous veins, and according to this the left cutaneous vein does not connect with the left Cuvierian duct. In these two instances his statements do not accord with our findings.

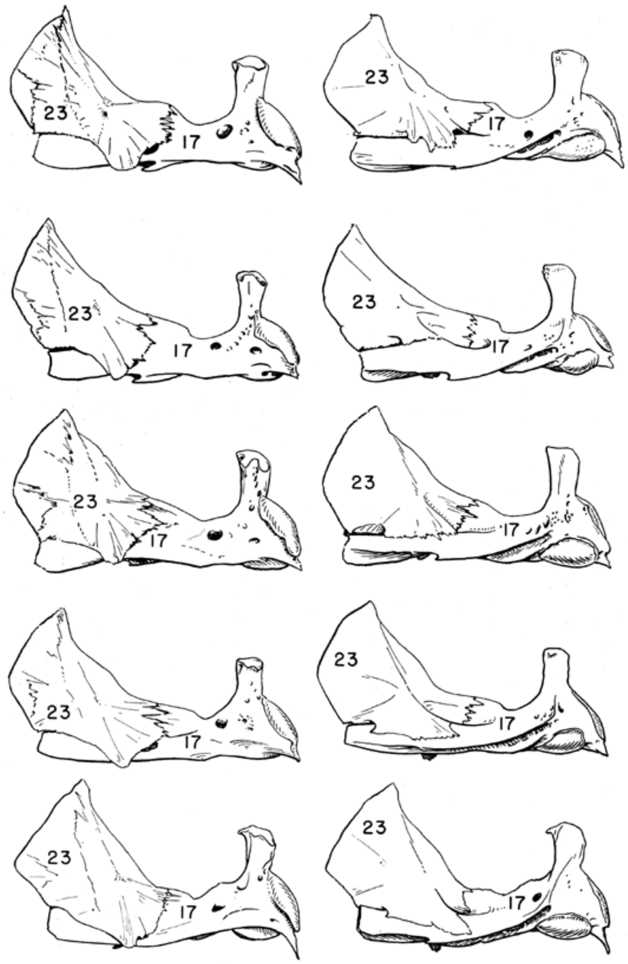

FIGURE 72. Hyomandibular and Metapterygoid. Top to bottom, big-eyed tuna, albacore, bluefin, yellowfin, skipjack. Left side viewed internally; right side viewed externally.

FIGURE 72. Hyomandibular and Metapterygoid. Top to bottom, big-eyed tuna, albacore, bluefin, yellowfin, skip-jack. Left side viewed internally; right side viewed externally

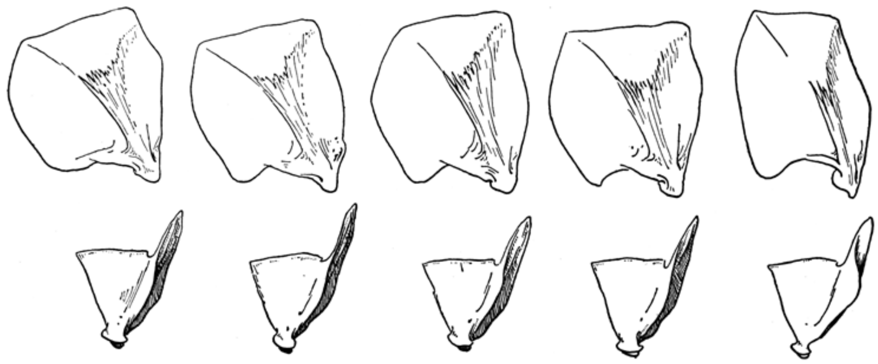

FIGURE 73. Opercle above; quadrate below. Left to right: big-eyed tuna, albacore, bluefin, yellowfin, skipjack.

FIGURE 73. Opercle above; quadrate below. Left to right: big-eyed tuna, albacore, bluefin, yellowfin, skipjack

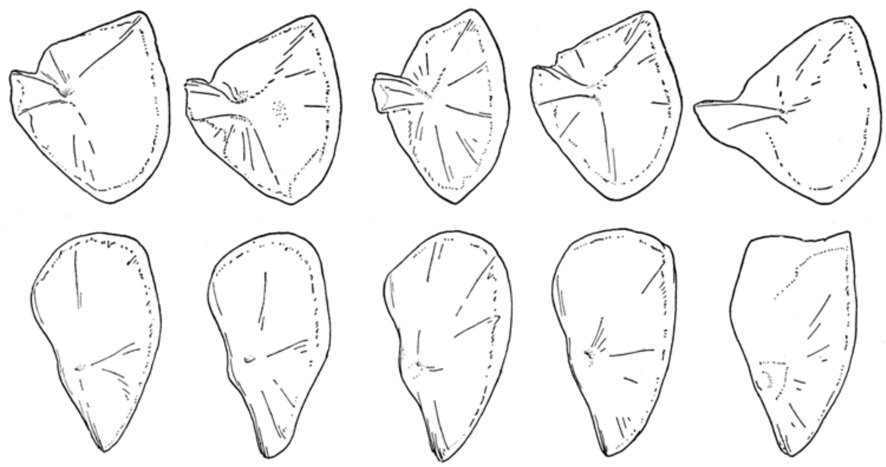

FIGURE 74. External views of Subopercle above; Interopercle below. Left to right, big-eyed tuna, albacore, bluefin, yellowfin, skipjack.

FIGURE 74. External views of Subopercle above; Interopercle below. Left to right, big-eyed tuna, albacore, bluefin, yellowfin, skipjack

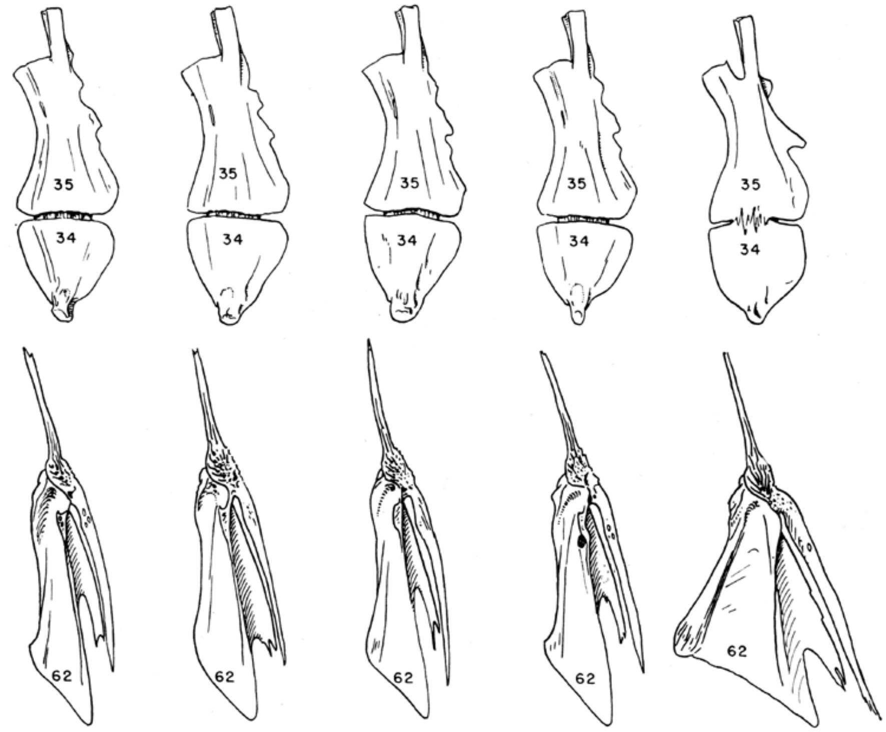

FIGURE 75. Epihyal and Ceratohyal above; external view. Pelvic girdle below; internal view. Left to right, big-eyed tuna, albacore, bluefin, yellowfin, skipjack.

FIGURE 75. Epihyal and Ceratohyal above; external view. Pelvic girdle below; internal view. Left to right, big-eyed tuna, albacore, bluefin, yellowfin, skipjack

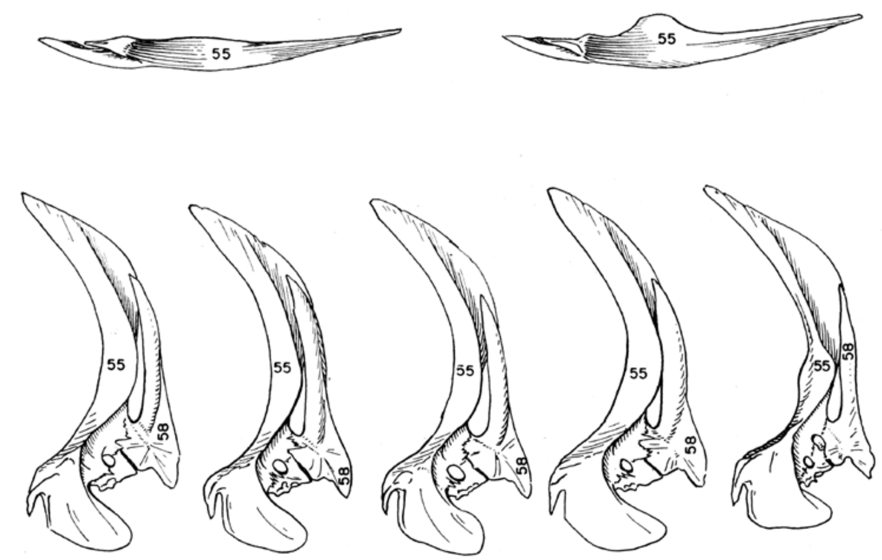

FIGURE 76. Cleithrum. Above, right, dorsal view showing the wing-like expansion on the cleithrum of the skipjack. Below, external view, left to right, big-eyed tuna, albacore, bluefin, yellowfin, skipjack.

FIGURE 76. Cleithrum. Above, right, dorsal view showing the wing-like expansion on the cleithrum of the skipjack. Below, external view, left to right, big-eyed tuna, albacore, bluefin, yellowfin, skipjack

APPENDIXES

Appendix I

Dissectional Blanks:

A specimen of the blank forms used to record the results of each dissection is reproduced below. It should be emphasized that these forms were designed to record only the routine observations and to serve as a guide in the dissection. Organ systems were adequately described in the case of two or more specimens of each species, and numerous sketches were made. Fish subsequently examined were referred to the various descriptions and sketches, and any departures from these were recorded and/or drawn.

Specimen:	Date of Dissection:
Code No.	
Sex:	
Measurements:	
Body length:	Dorsal-ventral distance: (from
Head length:	base of 1st dorsal ray to base of
Insert. 1st dorsal:	1st ventral ray)
Insert. 2nd dorsal:	Dorsal-anal distance: (from base
Insert. anal fin:	of 1st dorsal ray to base of 1st
Insert. ventral:	anal ray)
Diameter of iris:	Depth of caudal peduncle: (its
Maxillary length:	least vertical distance)
Greatest depth of body:	Length of 1st dor. base:
Location of above:	Length of 2nd dor. base:
Greatest width of body:	Length of pectoral:
Location of above:	Post. ext. of pectoral:
Height of 1st dorsal:	Height of anal:
Height of 2nd dorsal:	Spread of caudal:
Counts:	
1st dorsal spines:	Anal rays:
2nd dorsal rays:	Anal finlets:
Dorsal finlets:	Gill rakers:
Abdominal Cavity Measurements:	
Total length:	Caecal mass:
Stomach:	Liver, center lobe:
Teeth:	
Upper jaw:	
Lower jaw:	

Tongue: Smooth:
Lateral ridge each side:

Gill rakers:
Well developed on anterior side of first arch only:
No anterior rakers on remaining arches:
Inner margin of anterior rakers undulating:

Gall bladder:

Urinary bladder:

Liver: No venules on surface:
No plexus within:
Right lobe longest; attentuated:
Bile duct runs full length of right lobe:

Air bladder: None:

Intestine: Short, no loop:

Spleen:

Caecal mass:

Ureters: Nearly separate; Run parallel to vertebra, where they fuse in a Y:

Kidneys: Extend posteriorly to vertebra:
Bridge between pharyngeals present:

Circulatory System:
Post-cardinal joins right Cuvierian duct:
Post-cardinal leaves haemal canal through arch on vertebra:
Dorsal aorta enters haemal arch on vertebra:

Cutaneous:
No anterior commissure:
No posterior commissure:
Epaxial—vein and artery—pass to first rib.
Hypaxial—vein and artery—pass to first rib.
Veins do not enter Cuvierian duct directly—pass first through kidneys, break up there, and subsequently fuse and lead to duct.

Anterior arterial system:
Y of aorta is beneath:
Posterior epibranchials are:
and join aorta beneath:
Coeliac-mesenteric arises on right side beneath:
Pharyngeal muscles attached to:
Cutaneous arteries arise directly opposite
beneath:

Notes:

Appendix II

Measurements

All the measurements were made either with large slide calipers or with dividers. The latter were used only for a few small measurements, such as the diameter of the iris and the height of fins, etc. Most measurements were made with calipers. These instruments, of which there are two, were specially made for this work. The one used most has a range up to one meter, and the other, used only for large tuna, has a scale reading to 165 centimeters. Both are precision instruments of great strength, made of a noncorrosive aluminum alloy. The arms of both are approximately 14 inches long, made thus to allow for the great depth of large fish. All measurements are straight-line distances between reference points.

A. External Measurements

Body Length. The body length was measured with the tip of the fixed arm of the caliper resting on the table against the tip of the upper jaw of the fish. The sliding arm was moved until the anterior face made a firm contact over its entire width with the cartilaginous tissue in the fork of the tail.

Head Length. The tip of the fixed arm of the caliper was held with one hand against the tip of the upper jaw of the fish, and the sliding arm was moved until its anterior face rested squarely against the most distant point on the margin of the subopercle. The measurement was made to the bone rather than to the dermal flap, which often projects slightly.

Insertion of First Dorsal Fin. The dorsal fin was held erect with the fingers of the left hand, and the tip of the sliding arm of the caliper was placed firmly against the ball of the left thumb, which in turn was held against the face of the first spine at its insertion. The scale of the caliper was then moved with the free hand until the tip of the fixed arm touched the tip of the upper jaw. Using the sliding arm as a fulcrum, the tip of the fixed arm was then swung through a slight arc to insure that the caliper just touched the tip of the snout.

Insertion of the Second Dorsal Fin. The second dorsal fin was held erect and a mark made at its base to indicate its anterior extent. The point of insertion thus determined is subject to a slight error because the fin meets the outline of the body in an even curve, due to the inclination of the first short ray. The tip of the fixed arm of the caliper was held against the tip of the upper jaw and the sliding arm was then moved anteriorly until its forward face reached the above mark.

Insertion of the Anal Fin. The fin was held erect and its insertion marked. The location of this point is subject to the same slight error described in the foregoing measurement. The tip of the fixed arm of the caliper was then held in place against the tip of the upper jaw and the sliding arm moved anteriorly until it reached the insertion of this fin.

Insertion of the Ventral Fin. The fin was held extended with one hand and the sliding arm of the caliper was pressed against the thumb, which was so placed as to mark the insertion of the first ray. The scale was then moved until the tip of the fixed arm touched the tip of the upper jaw and the caliper was swung through a small arc to insure accuracy.

Greatest Body Depth. With the first dorsal fin depressed into its groove, the greatest body depth was measured perpendicular to the axis of the body. The point of greatest depth was recorded in terms of the spines of the first dorsal fin. This measurement was influenced to a large extent by the condition of the fish.

Greatest Body Width. This measurement was likewise influenced by the condition of the fish. The greatest width of body was measured transversely with the pectoral fins pressed firmly against the sides. The location of the greatest width was recorded in terms of the spines of the first dorsal fin, but frequently the two sides were almost parallel for some distance and in such cases the point selected was quite arbitrary.

Dorsal-Ventral Distance. This measurement was made with the fixed arm of the caliper resting firmly against the contour of the body and the lateral face of the arm against the anterior spine of the first dorsal fin, which was held erect. With an assistant holding the ventral fin erect and perpendicular to the body, the sliding arm was then moved inwards along the first ray of this fin until the face of the arm touched the outline of the body. The measurement was quite satisfactory except in the case of soft fish.

Dorsal-Anal Distance. This measurement was taken with the tip of the fixed arm of the caliper resting against the base of the anterior spine of the erect first dorsal fin and the contour of the body. The sliding arm of the caliper was then moved until it came in contact with the ventral body margin at the insertion of the anterior anal ray. Two slight errors affect this measurement. One is discussed under the heading of the anal fin, and the second is due to the width of the caliper arm, which is 6 millimeters. Held as in this measurement the inner face of the fixed arm does not touch the actual insertion of the first dorsal fin. Due to the width of the arm, its inner face in reality forms the hypotenuse of a small triangle of which the other two sides are the contour of the body and the face of the first dorsal spine, so that there is a constant error equal to the altitude of this triangle. Both these errors, however, are negligible in relation to the distance separating the two points of reference.

Length of First Dorsal Base. With the first dorsal fin held erect, the tip of the fixed arm of the caliper was placed against the contour of the body with the inner face against the anterior margin of the first spine. The sliding arm was then moved anteriorly until it reached the mark previously made to indicate the insertion of the second dorsal fin. This measurement is therefore the distance between the insertion of the first and second dorsal fins, and it was used because it can be measured more accurately than can the length of the fin itself.

Length of Pectoral Fin. The fixed arm of the caliper was held against the body of the fish at the anterior termination of the dorsal margin of the pectoral fin. Inspection of a tuna will show that this point is quite precise. The sliding arm was then moved until it touched the extremity of the pectoral fin. The posterior extent of the fin was also recorded in terms of the first dorsal spines in the case of the bluefin, with reference to the origin of the second dorsal fin in the case of the yellowfin, and in terms of the anal base and anal finlets in the case of the albacore and the big-eyed tuna.

Spread of Caudal. This was as a rule a very unsatisfactory measurement, because in the majority of specimens the caudal fin was either frayed or damaged. Moreover, repeated handling of the fish results in a diminished spread of the caudal because this fin is invariably used as a convenient handle. In those cases where it is recorded, the spread of caudal is the greatest vertical distance between the extremities of dorsal and ventral lobes.

Height of Fins. These measurements were made with dividers. One point of the dividers was inserted against the contour of the body at the insertion of the fin and the dividers opened until the other point touched the extremity of the longest ray, provided this was intact. No measurements were taken which involved the use of broken spines or rays, and doubtful measurements were recorded as such.

Length of Second Dorsal Base. Although this was measured as a routine, the measurement has, in our opinion, little value because the length of the base is really a matter of interpretation. In about half the cases examined, of all species, the first finlet was actually connected with the second dorsal fin by a slight continuation of the fin membrane. In view of this we adopted the following standard procedure. If, when the second dorsal fin was alternately raised and depressed, the first dorsal finlet moved slightly up and down with it, thus demonstrating a connection, then we counted such a finlet as an integral part of the second dorsal fin and the base of this fin was measured accordingly. Obviously this affected the count of the finlets as well as the measurement of the base of the fin. Every degree of variation was found, from a broad and unmistakable membranous connection at one extreme to a barely perceptible fold of tissue against the body contour at the other extreme. Under such circumstances some arbitrary rule was necessary, and the length of the second dorsal base was accordingly measured with one point of the dividers located at the insertion of this fin and the other point placed against the insertion of the last ray of the fin, or against the insertion of the ray of the first finlet if this was attached to the fin.

Length of Anal Base. The condition in this case was entirely comparable with that of the second dorsal base. The measurement was made in a similar manner and the discussion and conclusion above apply equally to this fin.

Diameter of Iris. By means of dividers a measurement was made of the greatest distance between the opposite external margins of the yellow iris, as that was delimited by the black surrounding tissue. This diameter, which is not parallel to the axis of the body but decidedly at an oblique angle to the axis, gives a good indication of the size of the eye and may be measured more accurately than the diameter of the orbit.

Maxillary Length. In taking this measurement one point of the dividers was inserted at the posterior margin of the maxillary and the instrument closed until the other point just touched the tip of the snout.

Depth of Caudal Peduncle. The least vertical depth of the caudal peduncle was measured with dividers. This measurement was suggested by its occasional use in systematic literature. Although continued as routine throughout the investigation, it is our opinion that in the case of the tunas it is worthless.

B. Internal Measurements

All abdominal cavity measurements were made as follows: The belly was opened and the side walls cut away sufficiently to expose the entire viscera without, however, disturbing any organs. The view thus obtained is that reproduced in all the visceral drawings. The length of the abdominal cavity was arbitrarily taken to be that distance between the posterior tip of the heart and the anterior margin of the vent. The majority of measurements were made and all were recorded with reference to the posterior tip of the heart. Thus, the length of the stomach, caecal mass, etc., or the extent of the kidney or the air-bladder is invariably that distance between the posterior tip of the respective organ and the posterior tip of the heart. The majority of measurements were made with the caliper, the fixed arm of which was held against the posterior tip of the heart and the sliding arm moved to the extent of the variable.

The measurements of the air-bladder and the kidney were generally made after removal of the viscera, and they were accordingly measured with reference to the vent. Such measurements were subtracted from the total length of the abdominal cavity, thus giving the extent of the organ from the tip of the heart. The urinary bladder was measured with dividers. One point was fixed at the external opening, located at the posterior margin of the vent, and the dividers opened until the other point reached the anterior tip of the bladder.

Appendix III

Meristic Counts

In making the fin-ray counts no distinction was made between rays and spines. Both terms are used synonymously in this report. Usually the components of the first dorsal fin are referred to as spines and those of the remaining fins as rays.

First Dorsal Fin. This count was fairly satisfactory and reliable. The only difficulty or uncertainty encountered concerned the last small spine in those fishes where the fin membrane was ruptured. In such cases the spines were frequently retracted into the groove, and if the last spine happened to be unusually short, it was at times difficult to raise it into view. This was particularly true of the skipjack and less so of the remaining tunas. Our rule was to count this last spine only if it could be clearly seen or its presence unmistakably established. The number of cases in which this difficulty was encountered was small, and the recorded counts are essentially accurate.

Second Dorsal Fin. In making this count the procedure followed was to cut the skin at the base of the fin and peel it back against the rays, thereby exposing their bases. It was moreover necessary to scrape the skin away from the first and second rays because the first one is relatively short and in some cases extremely so, making it easy to overlook.

After a few preliminary trials one becomes accustomed to the appearance and structure of the rays, and a reliable count may be readily obtained.

The identity of the first dorsal finlet was the greatest factor influencing this count. Where the finlet was attached to the fin by membrane it was counted with the second dorsal rays. For greater clarification on this point the reader is referred to the discussion of the method of measuring the length of the second dorsal base.

Dorsal Finlets. Despite the rule adopted in this work, by which the first finlet, when attached to the second dorsal fin, was considered as a part of that fin, the data show that this structure should be considered instead as a finlet. In the majority of such cases the number of finlets was one less than the modal number. The difficulty may be overcome by combining the second dorsal fin-ray count with the number of dorsal finlets, and this has been done in the various tables throughout this report.

Anal Fin. The method used in this count is similar to that described for that of the second dorsal fin. The same rule was adopted here regarding the first finlet.

Anal Finlets. The discussion under the heading of dorsal finlets applies equally to the anal finlets.

Gill-rakers. This is a rather unsatisfactory and at best only an approximate count, particularly in the case of the skipjack and the yellowfin. In the above two species there are short rudimentary gill-rakers at the upper end of the arch, and these rudiments vary between true short rakers and barely perceptible projections on the arch. Despite any arbitrary decisions as to the method to be followed, the possibility of an error on one, two, or even three rakers is frequently involved. To minimize this error, or rather to be more consistent, we established the following rule: We counted as a raker any rudiment that projected distinctly above the arch, ignoring all other protuberances that did not project freely and obviously as short rakers. This rule was unsatisfactory, but no better solution was apparent. Furthermore, in all species it was occasionally difficult to make a decision as to the allocation of the gill-raker at the angle of the arch. In such cases the gill-raker was included with the count of that limb of the arch with which it moved. For this reason the total number of rakers appears to be a better character than the partial number on each limb.

Appendix IV

Injection Technique

The majority of the tunas are caught on hook and line, and in all commercial loads the fish are somewhat roughly handled. The resulting rupture of blood vessels in many specimens, particularly in the region of the head, materially increases the difficulties of injection.

Throughout this work a 30 cc. all-metal gun was used, with a luer-lok adapter and, in most cases, a No. 18 needle. Occasionally, and particularly in the case of the skipjack, a No. 20 or No. 21 needle proved more suitable. A larger gun would have saved much time and trouble, because in the case of large fish it was necessary to refill the gun two or more times. It is likewise advisable to have two or more needles of each size, because it is often necessary to inject both branches of the cutaneous arteries separately.

For an injection mass a stock solution of "latex" was used, in two colors, blue and red. This proved superior to a cornstarch mass which failed to penetrate to the distal portions of small vessels. The only disadvantage to the "latex" was the difficulty it involved in cleaning the gun. In combination with the vaseline used as a seal on the plunger, the "latex" formed a sticky film which was hard to remove. No way was found, other than prompt cleaning of the gun, to obviate its formation.

After some preliminary difficulties it was discovered that the success of an injection could be materially increased by stroking the vessels in the direction of flow. Thus in the injection of the cutaneous vessels the skin over the vessel was stroked with considerable pressure, and in the case of the visceral injection it helped considerably to stroke the walls of the abdominal cavity.

The procedure followed varied with the species. In the case of the yellowfin, wich was the simplest to inject, the skin over the cutaneous vessels was cut away just posterior to the insertion of the pectoral fin and a No. 18 needle inserted anteriorly into one branch of the cutaneous artery. Entering at this point the injection mass flowed mesially to the dorsal aorta and thence to the cutaneous vessels of the opposite side, to the viscera through the coeliac-mesenteric artery, and to the anterior arterial system. In addition it also flowed posteriorly, via the anterior commissure, on the side of the injection, through the second branch of the cutaneous artery; and because there is in this species a posterior commissure, the "latex" under favorable circumstances would frequently flow anteriorly again and emerge at the point of insertion of the needle. Needless to say, complete success was seldom attained, and in many cases it was necessary to re-inject portions of the system.

The cutaneous veins were injected at the same point. The needle was inserted posteriorly into one branch of the cutaneous vein, and the injection mass flowed posteriorly in this branch to the posterior commissure. From this point it flowed anteriorly through the commissure into the second branch and also through the horizontal trunk to the cutaneous veins of the opposite side. Where leaks or obstructions existed, however, it was necessary to inject the cutaneous veins separately.

The same technique was followed in the case of the bluefin tuna, but because of the normal insignificance of the posterior commissure, it was generally necessary to make two or more separate arterial injections and to inject each cutaneous vein separately. In the case of the albacore and the big-eyed tuna this was invariably necessary.

In these three species the presence of conical vascular plexuses dorsal to the liver presented a serious obstacle to the injection of the coeliac-mesenteric artery. In all cases injections were made through the cutaneous arteries as usual, applying considerable pressure in an effort to force the fluid through the capillary vessels of the cones. In occasional specimens this was successful, and in such cases the several arteries were reinjected as they emerged from the cones and thus followed their distal course. In some instances the coeliac-mesenteric artery was severed at its origin in the aorta and injected separately. Although this produced a fairly complete injection of the coeliac-mesenteric system in a few specimens, the procedure was generally unsatisfactory. In the deep and somewhat difficult dissection involved in reaching the origin of this artery, the minute vessels nourishing the Cuvierian ducts were invariably ruptured and the ensuing leaks caused considerable difficulty. In fact, no effectual solution to the injection of this system was found and results were obtained only by persistent trials on each specimen.

The injection of the skipjack presented a different problem. In this species the cutaneous vessels are very small and the walls of both veins and arteries are delicate and fragile. In the majority of cases it was impractical to inject the arterial system through the cutaneous artery. Because no other suitable artery was accessible without destroying some essential structure, it was finally decided to inject directly into the dorsal aorta. This was done anteriorly at the origin of the aorta. Cutting through the ventral symphysis of the gill arches and thence dissecting through the dorsal wall of the pharynx, the "Y" of the aorta was exposed. Injection was then made through one of the anterior epibranchials. The procedure was crude but no alternative was found. Furthermore, the injection mass seldom penetrated into the terminal portions of the small cutaneous vessels, and to follow the course of these it was necessary to make a laborious injection of each separate branch. The cutaneous veins were similarly and separately injected. A No. 21 needle is best suited for this work.