STATE OF CALIFORNIA DEPARTMENT OF NATURAL RESOURCES DIVISION OF FISH AND GAME BUREAU OF MARINE FISHERIES

FISH BULLETIN No. 77

A Comparison of the Bluefin Tunas, Genus Thunnus From New England, Australia and California[1]

By

H. C. GODSIL

and

EDWIN K. HOLMBERG

1950

[1] Submitted for publication January, 1950.

CONTENTS

1. INTRODUCTION

The Bureau of Marine Fisheries has been fortunate in obtaining specimens of tuna from the Atlantic Coast and from Australian waters. In the fall of 1948 six specimens of Atlantic tuna, caught in September near Provincetown, Rhode Island, were frozen and shipped to us through the courtesy of the Terminal Island Sea Foods, Ltd., Terminal Island, California. To the officers of this company we express our gratitude. These fish ranged from 1,257 to 1,314 millimeters in body length, and in weight from 84 to 95 pounds.

In January, 1949, three specimens of the Australian southern bluefin, 920, 924 and 981 millimeters in body length, and averaging about 75 pounds each, were forwarded to us by the Australian Trade Commission, San Francisco. To Mr. Lynch and to Mr. Davies of that organization we express our sincere thanks. As far as we know the fish were caught off the north coast of Tasmania.[2]

The fish in both samples belong to the genus Thunnus. The Atlantic form is generally accredited to the species Thunnus thynnus, and the Australian southern bluefin is Thunnus maccoyii. The Australian northern bluefin, Kishinoella tonggol, does not enter into this discussion. The bluefin tuna of the Pacific Coast of the United States is also included in the species Thunnus thynnus. The Pacific Coast bluefin was extensively described by Godsil and Byers (1944), and the acquisition of the Atlantic and Australian specimens afforded an exceptional opportunity to make a thorough comparison of the three varieties. The present study was therefore modelled on the procedure outlined by Godsil and Byers, and the same characters were investigated. The measurements used, the technique and the nomenclature adopted throughout are identical. However, for the convenience of those who do not have access to the former publication, definitions of the terms used herein are listed in the appendix.

The present study was undertaken to clarify the systematic relationship of the various tunas. The classification of the tunas is confused, and has been based largely upon the examination of variable external

[2] After this paper had been submitted for publication, we obtained three more specimens of Australian southern bluefin. The results of the additional observations are incorporated on page 43, as an addendum to this paper.

characters in relatively few specimens. Such characters have led in some cases to unwarranted specific separations, while in others they have obscured more significant differences. Our particular purpose in this study was to determine whether positive, diagnostic differences exist between the Atlantic bluefin and our California bluefin, on the one hand, and between the Australian southern bluefin and the California bluefin on the other hand. Accordingly, we looked for characters, constant within the sample, which would enable one to distinguish fish from these three distinct geographical regions.

Unfortunately the dissections were not made at the same time. However the Atlantic and Australian specimens were examined within a relatively short interval, when the recollection of detail was still vivid. Because the dissections of the California bluefin had been made about seven years earlier, the authors repeated the entire routine examination upon three local specimens in the interval elapsing between the study of the Atlantic and Australian samples. Available data from the measurement and dissection of all California bluefin have been used in this report, and for this reason the number of fish and the size range shown in Table 1, and discussed in the text, varies in the different proportions. Complete measurements were not made upon all these fish.

The scope of the study was as extensive as time and circumstances permitted. Most of the Atlantic specimens had been damaged in one region or another and injections proved difficult. This is invariably true of commercially caught fish. The Australian specimens were in generally good condition, but each had been bled by cutting through the isthmus and severing the ventral aorta or the heart. This was a severe handicap in the visceral injections. All the material was frozen and stored for a period, and in consequence color notes and external markings were of little value. Each fish was necessarily thawed completely before examination. The amount of detail that could be observed was limited by the gradual softening and deterioration in the tissues.

Those characters were selected for examination which had been found in the earlier studies to differ most in the several species investigated. Where differences between the samples were discovered or suspected, particular care was thenceforth devoted to such characters. In the study of the bones comparisons were made of the entire skeleton: but only those elements are described which showed or suggested differences.

Because the three varieties were so similar, a complete description of each character in each sample would entail endless and unnecessary repetition. To avoid this, each character in the Atlantic bluefin is described in detail and the Australian southern bluefin is compared with this description. If it is identical, this fact is so stated. If differences exist, the features differing are described in detail. Finally both the foregoing descriptions are compared with earlier findings in the California bluefin. Similarities with either or both are noted, and differences emphasized.

Throughout the descriptive part we have arbitrarily selected a common name to designate each variety. Because two of them are generally known as bluefin, we have applied that name also to the Atlantic variety. A discussion of the specific relationship of the three varieties is given in the final section.

Both during the dissections and in the preparation of the manuscript the authors have received invaluable help from all members of this staff. The completed report is therefore the product of the group. To each we extend sincere thanks for the time and effort contributed. The original sketches were prepared for publication by Messrs. C. R. Clothier and E. C. Greenhood.

2. DESCRIPTION

2.1. EXTERNAL CHARACTERS

The color of all fish examined had faded, as the fish had been preserved in a frozen condition for some time. The Atlantic bluefin were black above and on the head and grey below, with longitudinal rows of spots on the belly. Two of the six fish had yellow finlets edged with black. The Australian fish were similar except that they lacked any distinct markings and were silvery grey ventrally. The California bluefin were colored much as described for the Atlantic form. The ventral markings in the former are described in the notes as oblique dark grey bars, each containing a row of lighter spots. The notes on coloration are given as observed. No attempt is intended at segregation on the basis of color.

The postero-ventral margins of the preoperculum and operculum were rounded in all three groups.

TABLE 1

RANGE IN RATIOS

The number and size of fish included in the California sample are shown for each proportion. In the Atlantic sample there were six fish throughout, ranging from 1,257 to 1,314 mm. in body length. In the Australian sample the three fish included ranged from 920 to 981 mm. body length.

Body proportion	Atlantic ratios	Australian ratios	California		
			Ratios	Number of fish	Range in size mm.
Body Length/Head Length	3.40– 3.52	3.28– 3.33	3.16– 3.43		628–1482
Body Length/First Dorsal Insertion	3.14– 3.27	3.03– 3.17	2.91– 3.23	2	628–1482
Body Length/Second Dorsal Insertion	1.79– 1.85	1.76– 1.79	1.68– 1.80	2	628–1482
Body Length/Anal Insertion	1.61– 1.65	1.60– 1.63	1.49– 1.61	32	628–1482
Body Length/Ventral Insertion	2.95– 3.18	2.82– 2.90	2.84– 3.12	32	628–1482
Body Length/Body Depth	3.51– 3.96	3.67– 3.71	3.30– 3.73	25	628–888
Body Length/Body Width	5.02– 5.67	5.19– 5.38	4.92– 5.69	25	628–888
Body Length/Dorsal-Ventral Distance	3.80– 4.08	3.76– 3.80	3.53– 3.85	25	628–888
Body Length/Dorsal-Anal Distance	2.54– 2.64	2.53– 2.64	2.32– 2.48	25	628–888
Body Length/Lg. 1st Dorsal Base	3.93– 4.07	3.91– 4.14	3.65– 4.01	25	628–888
Body Length/Pectoral Length	4.61– 5.08	4.38– 4.48	4.84– 6.02	30	628–1482
Body Length/Height First Dorsal	8.44– 9.40	8.07– 9.00	8.38–11.00	25	628–1418
Body Length/Height Second Dorsal	6.88– 7.57	7.43–(1 only)	7.20–10.16	17	628–1418
Body Length/Height of Anal	6.95– 7.76	7.66– 7.71	7.38–10.63	20	628–1418
Body Length/Lg. 2nd Dorsal Base	9.74–11.64	11.00–12.28	8.49–11.15	27	628–1418
Body Length/Lg. of Anal Base	6.61–13.98	11.86–14.21	9.23–13.85	24	628–888
Body Length/Spread of Caudal	3.38– 3.68	—	3.64– 3.93	19	628–888
Head Length/Diameter of Iris	9.27– 9.83	7.77– 8.75	6.93– 8.14	25	628–888
Head Length/Maxillary Length	2.50– 2.70	2.52– 2.61	2.42– 2.58	25	628–888
Body Length/Vent. Insert. to Vent	—	3.57– 3.74	3.06– 3.29	8	682–1482
Body Length/Body Cavity Length	2.70– 2.91	3.14– 3.22	2.37– 2.94	28	628–1533

TABLE 1 RANGE IN RATIOS The number and size of fish included in the California sample are shown for each proportion. In the Atlantic sample there were six fish throughout, ranging from 1,257 to 1,314 mm. in body length. In the Australian sample the three fish included ranged from 920 to 981 mm. body length

The vent was round in the three forms. A short groove extended posteriorly from the vent in the Australian form. The vent was large in both the Atlantic and California bluefin, but comparatively small in the Australian fish. Measurements were made on two Australian specimens. In one the vent was 3.25 mm. in diameter, with a 3 mm. groove posteriorly, while that of the other was 3.5 mm. in diameter with a 1.5 mm. groove. Unfortunately no comparable measurements were made upon the Atlantic and California bluefin, in which this aperture was approximately twice as large as that of the Australian fish.

2.2. PROPORTIONAL MEASUREMENTS

The body proportions given in Table 1 show that the three forms studied fell into definite size groups. The Atlantic bluefin were large; the Australian fish were of medium size, while most of the California fish were small. Because many proportions change with size of fish, a few measurements were subsequently made upon large California bluefin to render particular comparisons more valid.

Although Table 1 suggests differences in some proportions, many of these apparent differences can be correlated with the size of individual fish. For this reason it was necessary to supplement the discussion of the actual proportions with a rough regression analysis in which the several measurements of a given character were plotted against an independent variable, usually the body length. A free-hand line drawn through the points representing the California bluefin afforded a basis of evaluating the similarity or divergence of the other specimens. The method was adequate for judging the usefulness of a character in separating the three forms. A character was considered diagnostic when any single specimen could be distinguished by it. If, however, the difference was so slight that a series of specimens was required to make a group separation, the character was considered useful only in a biometrical study.

2.2.1. Diameter of the Iris

The diameter of the iris when compared to head length yielded a higher ratio in the Atlantic bluefin, suggesting a smaller eye than in the other two forms. Heldt (1927) reports that in the Mediterranean bluefin the size of the eye decreases proportionately with increased size of the fish. In view of this it is probable that no valid difference exists in this character, because the Atlantic fish were considerably larger than any of the other specimens.

2.2.2. Height of the Fins

The second dorsal and anal fins were higher than the first dorsal in the Atlantic and Australian bluefin, whereas in eight out of ten small California bluefin on which precise measurements of both fins were possible the first dorsal was higher than the second dorsal and anal fins. Subsequent measurements on two large California fish showed, however, that the condition agreed with that of the Atlantic and Australian forms. Thus the height of the second dorsal and anal fins increases proportionately with size, and the condition in all three groups of fish must be assumed comparable.

2.2.3. Insertion of the Anal Fin

The insertion of the anal fin was more anterior in the Atlantic and Australian bluefin than in the California variety. The ratio, body length ÷ anal insertion, averaged 1.63 in the six Atlantic fish. The range in this ratio in the Australian fish overlapped the Atlantic values and averaged 1.62. For the California bluefin the average was 1.54. A rough scatter diagram showed this difference to be too small to use as a diagnostic character. It suggested, further, in agreement with the findings of Heldt (1927), that the anal insertion was proportionately closer to the snout in large fish than in small ones.

Because the point of insertion of the anal fin, with respect to the end of the second dorsal base, has been used as a specific character by many authors, a test of this relationship was made upon the three groups of fish studied. The distance from the snout to the anal insertion was divided into the sum of the distances, snout to second dorsal insertion plus length of second dorsal base. The usefulness of this character was questionable because in many specimens a membrane connected the second dorsal fin with what would normally be the first dorsal finlet. In cases of such contiguity the first finlet was considered as an integral part of the second dorsal fin. For this reason the length of the second dorsal base was unduly variable. The actual value of the ratio under discussion encountered in the six Atlantic bluefin was from 1.02 to 1.06, averaging 1.050. The three Australian fish yielded values of 1.03 to 1.06, averaging 1.046. For the 23 California specimens the range was from 1.01 to 1.08, averaging 1.045. In agreement with the majority of authors discussing this character, the writers are of the opinion that it offers no valid justification for separating any species of Thunnus.

2.2.4. Dorsal-anal Distance

In the ratio, dorsal-anal distance to body length, the Atlantic and Australian bluefin are similar. The ratio in the California fish is smaller, indicating a greater dorsal-anal distance. Because the three samples fall into distinct size groups, and because no measurements on large California bluefin are available, it cannot be determined whether the suggestive difference in ratios is real or merely a function of the size of the fish. The value of this character is therefore indeterminate.

2.2.5. Abdominal Cavity Length

The length of the abdominal cavity differentiates the Australian bluefin from the Atlantic and California specimens. The cavity is measurably shorter in the Australian fish, with the result that the ratio, body length divided by abdominal cavity length, yields a higher value. The range in these values for the Atlantic, Australian and California fish is 2.70 to 2.91, 3.14 to 3.22 and 2.37 to 2.94 respectively. There is thus a clear differentiation, with no overlap.

These measurements are indicated by the solid symbols in Figure 1. Although there is a change in proportion with increasing size, the figure demonstrates the difference of the Australian specimens in this character, and the similarity of the Atlantic and California bluefin.

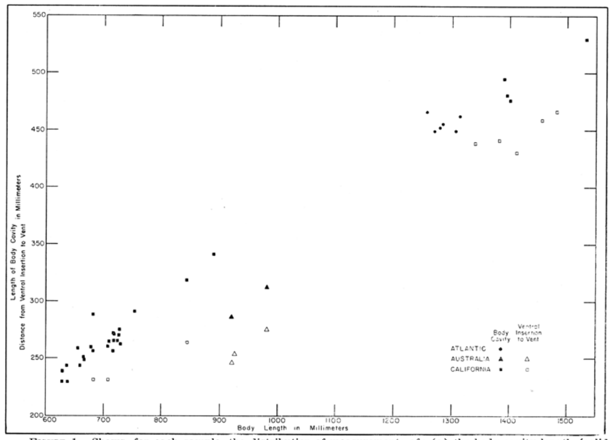

FIGURE 1. Shows, for each sample, the distribution of measurements of: (a) the body cavity length (solid symbols) plotted against the body length, and (b) a comparable distribution of the few measurements made of the ventral insertion to vent distance (open symbols), similarly plotted against the body length.

FIGURE 1. Shows, for each sample, the distribution of measurements of: (a) the body cavity length (solid symbols) plotted against the body length, and (b) a comparable distribution of the few measurements made of the ventral insertion to vent distance (open symbols), similarly plotted against the body length

Because this character was also found of value in an earlier population study of yellowfin tuna and albacore, a comparable external measurement was devised which could be conveniently made upon fish in the round. This is designated the ventral insertion to vent distance, and it is adequately described in the appendix. Briefly, it is the straight line distance between the base of the ventral fins and the anterior margin of the vent. The few available measurements of this character are shown by the open symbols in Figure 1, from which it is apparent that this measure, although not exactly similar to the foregoing, yields the same general results. Its use is advocated in any future study of the tunas.

2.3. MERISTIC COUNTS

A count of the gill rakers on the first arch, usually of the left side, was made upon each specimen. Such a count separates the Atlantic from the two remaining groups, which are similar in this respect. The Atlantic bluefin are characterized by a greater number of rakers upon both upper and lower limb of the arch (Table 2). In consequence the difference is accentuated when the counts are combined into a total count for each fish. When this is done the Atlantic and Australian fish are, in these small samples, clearly separated with no overlap in the sample frequencies. Between the Atlantic and California fish the difference is almost as great, but the larger sample of the latter demonstrated a slight overlap in the respective distributions.

TABLE 2

The Distribution of Gill Raker Counts on the Upper and Lower Limb, Separate and Combined

	Upper limb						Lower limb							
	10	11	12	13	14	15	21	22	23	24	25	26	27	28
Atlantic			1	1	3	1					2	2	1	1
Australian			3					2		1				
California	1	1	14	8	1	1	2	3	11	9	1			

Upper and Lower Limbs Combined

	32	33	34	35	36	37	38	39	40	41
Atlantic								3	1	2
Australian			2		1					
California	2	1	1	10	5	6		2		

TABLE 2 The Distribution of Gill Raker Counts on the Upper and Lower Limb, Separate and Combined

The California bluefin differed from the two remaining groups in the modal values of the second dorsal ray, dorsal finlet, anal ray and anal finlet counts. (See Table 3.) All are herein discussed together because the apparent differences stem from the same fact. In many specimens a membrane connected the fin with what would normally be the first finlet. This occurred both in the second dorsal and anal fins, but not necessarily in both fins on the same specimen. When the second dorsal ray and dorsal finlet counts were grouped together, and when, similarly, the anal ray and anal finlet counts were also grouped in each specimen, the apparent differences disappeared, showing that the total or over-all counts were the same and that the apparent differences depended upon the inclusion of the first finlet as a fin ray. The data indicate that such a connecting membrane between last fin ray and first finlet was relatively more prevalent in the California bluefin.

TABLE 3

Tabulation by Sample of the Various Ray Counts to Show the Distribution of Values

	First Dorsal Fin			Second Dorsal Fin		Dorsal Finlets		Sec. Dor. Plus Dor. Finlets			Anal Fin			Anal Finlets		Anal Fin Plus A. Finlets		
	12	13	14	14	15	8	9	22	23	24	13	14	15	7	8	21	22	23
Atlantic	--	3	3	4	2	2	4	--	6	--	--	6	--	--	6	--	6	--
Australian	--	1	2	3	--	1	2	1	2	--	1	2	--	--	3	1	2	--
California	1	5	19	--	25	23	2	--	23	2	--	3	21	21	4	1	21	2

TABLE 3 Tabulation by Sample of the Various Ray Counts to Show the Distribution of Values

2.4. VISCERA

Atlantic bluefin: Although in this variety there was considerable variation in the view of the viscera, *in situ*, a basic pattern was discernible. Anteriorly the center lobe of the liver covered a portion of the caecal mass. The liver was completely striated as in all members of this genus. The apex of the large triangular caecal mass was generally on the left side of the body cavity, though sometimes on the center line. In most specimens the spleen was large and conspicuous. Invariably it was on the right side of the body cavity, enclosed between the straight intestine,[2] laterally, and the ascending portion of the intestine, mesially. Invariably the anterior end, in this view, was hidden beneath the caecal mass, and typically the posterior end of the spleen reached the posterior bend of the intestine. The posterior portion of the stomach was generally seen in this view, its extremity reaching to or beyond the mid-length of the body cavity. In most specimens a portion of the air bladder showed between the left gonad and the apex of the caecal mass. The range of variation encountered in the six specimens is portrayed in the upper panel of Figure 2. The variability in the visceral view in this variety was probably due to the distension of the large air bladder.

Australian southern bluefin: The foregoing description applied equally to this form, except that in the three specimens examined there was less variability, and the basic pattern was more apparent. In no specimen was the air bladder seen in ventral view of the viscera. The individual tubules composing the caecal mass were finer in this variety than in the other two.

California bluefin: Specimens of this sample agreed with the description of the Australian southern bluefin, except that the tubules of the caecal mass were relatively large and coarse, as in the Atlantic bluefin.

[2] See appendix, p. 48.

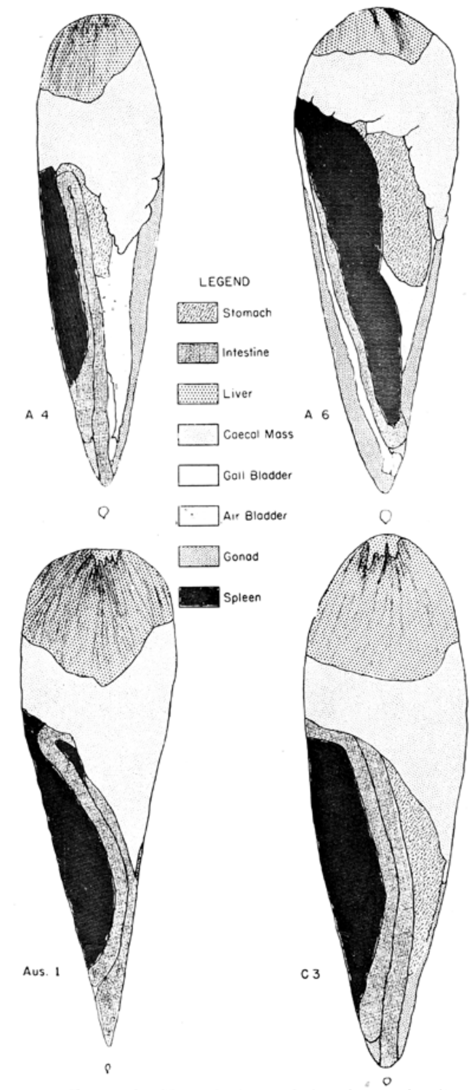

FIGURE 2. Ventral views of the viscera, *in situ*. In this and all other figures the code at lower left of individual sketches identifies individual specimens. A—, stands for Atlantic, Aus—, for Australian and C—, for California. Specimen A-6, illustrates the extreme of variation encountered in the Atlantic sample.

FIGURE 2. Ventral views of the viscera, in situ. In this and all other figures the code at lower left of individual sketches identifies individual specimens. A—, stands for Atlantic, Aus—, for Australian and C—, for California. Specimen A-6, illustrates the extreme of variation encountered in the Atlantic sample

2.5. CAECAL MASS

Atlantic bluefin: The caecal mass was a large conspicuous organ located at the anterior end of the body cavity. It was roughly triangular in ventral view, with the base abutting against the liver, and the lobulated margins tapering to a point posteriorly. Typically, the apex lay on the left side of the cavity, though in some specimens it lay on the center line. Measured from the tip of the heart the caecal mass extended in these specimens from 0.47 to 0.53 of the total length of the body cavity. The base of the caecal mass lay enfolded in and concealed by the lobes of the liver. It was connected to the duodenum by seven ducts, but inasmuch as five of these were bifurcated and complex, the number was a matter of interpretation. The tubules composing this organ were enclosed within an enveloping membrane, and appeared relatively large and coarse.

Australian southern bluefin: The caecal mass in this form was basically similar to the above description, except that the margins were less lobulated and in all specimens the individual tubules were relatively finer. In extent the caecal mass was relatively longer, approximating 0.63 and 0.67 of the length of the body cavity in the two measurable specimens. The proportions of this organ and the lobulations of the margin probably have no significance, in view of the variation encountered in other species. However, the fineness of the individual caeca contrasted with those of other members of this genus examined constitutes a distinguishing character when representative specimens are available for comparison.

California bluefin: The caecal mass in this form agreed essentially with that of the Atlantic bluefin. In extent, however, it was usually longer, ranging from 0.58 to 0.79 of the length of the body cavity. This may be associated with the size of the fish. The tubules in the California bluefin were coarse, as in the Atlantic form.

2.6. LIVER

Atlantic bluefin: The liver was composed of three lobes of which the center lobe was the longest. In ventral view of the viscera, *in situ*, only the center lobe was seen. The right and left lobes enclosed the anterior end of the stomach, dorso-laterally. All three lobes were completely striated on the ventral surface, although in some specimens the distal markings were faint. The right and left lobes were approximately the same in length and all margins were fairly regular and little crenulated. The typical shape and markings are portrayed in Figure 3. Attached to the dorsal surface of the liver were a number of large, conical, vascular sacs which are described with the visceral arterial circulation.

Australian southern bluefin: The liver conformed in general to the above description but differed in some respects. The right and left lobes were relatively longer than in the Atlantic form, and almost equalled the length of the center lobe. In all three specimens the shape of the liver was less regular, and all approximated the sketch shown (Figure 3). The surface of all lobes was heavily striated, and the substance of the liver was friable.

California bluefin: The liver in this form agreed fully with the description of that of the Atlantic bluefin.

FIGURE 3. Ventral views of the excised liver. That of the Australian specimen is remarkably similar to the liver of the albacore.

FIGURE 3. Ventral views of the excised liver. That of the Australian specimen is remarkably similar to the liver of the albacore

2.7. STOMACH

Atlantic bluefin: The apex of the stomach was generally near the center line of the body cavity, but varied in exact location so that no significance can be attached to its position. In extent it varied from 0.52 to 0.62 of the total length of the body cavity. In this respect it was relatively shorter than in either the California or Australian bluefin.

Australian southern bluefin: The observations of the stomach agreed with the foregoing, except that in extent the stomach varied between 0.61 and 0.70 of the length of the body cavity.

California bluefin: The stomach was relatively longer than in either of the above forms, varying between 0.66 and 0.81 the body cavity length.

2.8. INTESTINE

Atlantic bluefin: The intestine was always folded, and the length of this fold varied between 0.38 and 0.55 the length of the abdominal cavity. This fold was generally, though not invariably, apparent and conspicuous, lying predominantly on the right side of the body cavity. Occasionally it was concealed by the spleen. The latter invariably separated the straight intestine from the ascending portion which extended to or beyond the approximately transverse margin of the caecal mass, and thus the anterior loop of the intestine was sometimes concealed beneath the latter organ. Usually, however, the anterior loop and the entire fold of the intestine were visible in ventral view. The posterior bend of the intestine, in all these specimens, was located towards the posterior extremity of the body cavity. Its distance from the posterior tip of the heart in relation to the length of the body cavity varied between 0.77 and 0.89. The ascending and descending portions of the intestine were always adherent and parallel.

Australian southern bluefin: The foregoing description applies equally to this form. The fold of the intestine was 0.50 (in the one measurable specimen) and the posterior bend of the intestine was 0.82 and 0.83 the body cavity length.

California bluefin: The course of the intestine was as described above. The posterior bend of the intestine varied from 0.82 to 0.94 the body cavity length. No significant differences in this character were observed between the various forms.

2.9. SPLEEN

Atlantic bluefin: The spleen was a large, conspicuous, dark-red organ lying on the right side of the body cavity, separating the straight intestine from the ascending portion (see Figure 2). It was similar in the three forms discussed herein. Its anterior end was invariably hidden beneath the lateral margin of the caecal mass, and in this region the spleen tissue was diffuse and the margins of the organ were not distinct. The posterior end of the spleen generally reached the posterior bend of the intestine. The posterior extension of the spleen varied between 0.63 and 0.83 the body cavity length.

Australian southern bluefin: The foregoing description applies equally to this form. The posterior extension of the spleen in two specimens was 0.76 and 0.81 the body cavity length.

California bluefin: The above description is also applicable to this form. The posterior extension of the spleen varied between 0.75 and 0.88 the body cavity length.

2.10. GALL BLADDER

Atlantic bluefin: The gall bladder was a long, tubular sac extending, roughly, from the liver to beyond the posterior bend of the intestine. In the ventral view of the viscera *in situ*, only the posterior tip of the gall bladder showed, as a rule, and this was invariably doubled back upon itself in a fold. In the atypical view illustrated in Figure 2 (A-6), the gall bladder shows throughout its extent. This is exceptional and is probably due to the displacement of the visceral organs by the large distended air bladder. The distance of the posterior extension of the gall bladder from the tip of the heart varied between 0.82 and 0.93 the body cavity length. The gall bladder was of a deep green color and invariably on the right side of the body cavity, adherent to and running with the straight intestine. Occasionally in its posterior extent it crossed the dorsal face of the spleen and was attached in the enveloping membrane to the fold of the intestine. In all specimens the gall bladder was marked with three longitudinal marginal yellow stripes (as described for the albacore, Godsil & Byers, 1944), suggesting an equilateral triangular shape in cross section. These stripes were conspicuous in some and faint and regional in other specimens.

Australian southern bluefin: The condition was similar to the above description. The marginal yellow stripes were recorded in two of the three specimens.

California bluefin: The condition in the California bluefin was comparable with the other forms. The yellow, marginal stripes were, however, recorded in only two or three specimens.

2.11. DORSAL WALL OF BODY CAVITY

The roof of the body cavity was, in cross section, convex in all three varieties. The convexity began abruptly with the origin of the haemal canal and was greatest in this region, diminishing progressively toward the posterior portion of the cavity. The upper sketches, a, of Figure 4, depict diagrammatically the shape of the dorsal wall of the body cavity viewed in a longitudinal section cut through the vertical median plane of the fish.

Anterior to the ninth or tenth vertebra the roof of the body cavity was, in cross section, relatively flat. With the origin of the haemal canal on the tenth vertebra the roof of the body cavity sloped abruptly downward, and from this point posteriorly the depth of the haemal spines determined the level of the dorsal wall of the cavity. This ventral bulge was not confined to the median line. It extended transversely toward the belly wall, but was separated from the latter by a depression on either side (Figure 4, b and c). This depression was formed mesially by the side of the ventral bulge and laterally by the belly wall. It was in the shape of the bulge, and in the size and shape of the depression that the varieties differed.

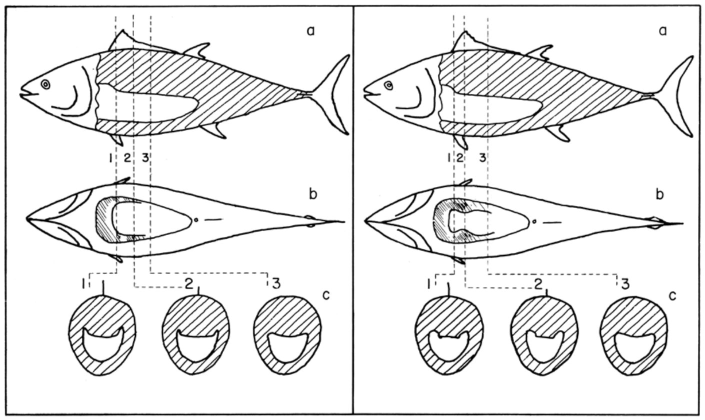

FIGURE 4. Diagrammatic sketches to illustrate the shape of the dorsal wall of the body cavity. The left hand panel depicts the condition found in the Atlantic and Australian specimens, and the right hand panel shows comparable views of large California bluefin. The sketches a, at top, represent a section cut through the longitudinal axis in the vertical median plane, with the viscera omitted to show the shape of the dorsal wall of the cavity. Sketches b, center, show a ventral view of the fish and the body cavity with the viscera removed. The shading in these figures is intended to show relative depth. Sketches c, bottom, show the view seen in transverse sections cut in planes indicated by the numbered dotted lines.

FIGURE 4. Diagrammatic sketches to illustrate the shape of the dorsal wall of the body cavity. The left hand panel depicts the condition found in the Atlantic and Australian specimens, and the right hand panel shows comparable views of large California bluefin. The sketches a, at top, represent a section cut through the longitudinal axis in the vertical median plane, with the viscera omitted to show the shape of the dorsal wall of the cavity. Sketches b, center, show a ventral view of the fish and the body cavity with the viscera removed. The shading in these figures is intended to show relative depth. Sketches c, bottom, show the view seen in transverse sections cut in planes indicated by the numbered dotted lines

Atlantic bluefin: (See left hand panel of Figure 4.) The ventral margin of the bulge forming the roof of the body cavity was slightly convex in cross section. The bulge covered nearly the full width of the body cavity, with the result that the lateral depression on each side was narrow and deep, constituting a pocket in the pectoral region. This pocket was deepest anteriorly at the origin of the bulge, and in this form was divided by a low transverse ridge into an anterior and posterior portion. The depth of the pockets decreased posteriorly as the bulge gradually merged into the slight convexity of the dorsal wall (shown by the unshaded portions of the pockets in Figure 4b). The air bladder extended into the full depth of, and filled these lateral pockets, but the kidney tissue did not enter them.

Australian southern bluefin: The foregoing description applies equally to this form. The lateral pockets, however, were not conspicuously divided into an anterior and posterior portion. In the one specimen in which a functional air bladder was present, this extended into and filled the lateral pockets, as in the Atlantic bluefin.

California bluefin: In small specimens, those up to about 80 cm., a conspicuous bulge was absent. Instead, the dorsal wall of the body cavity was, in cross section, slightly and uniformly convex. With increasing size, however, this convexity became progressively more pronounced, until in the largest fish examined, measuring 130 to 160 cm., there was a conspicuous bulge of characteristic shape. In approximately 30 specimens examined within this size range there were no major departures from the following basic pattern. (See right hand panel of Figure 4.)

In contrast with the Atlantic and Australian fish, the bulge in the California bluefin was relatively narrow. At its anterior end there was, on each side, a small bony protuberance projecting slightly into the body cavity. Posterior to these slight projections the bulge narrowed to form on each side the crescent-shaped margin of a lateral depression, which was analogous with, although different in shape and appearance from, the lateral pocket in the Atlantic and Australian bluefin. Instead of being a deep pocket as in these two varieties the depression in the California bluefin was saucer-shaped and relatively shallow in relation to its width (Figure 4b). Moreover it was not apparently divided, as in the Atlantic form, by a low transverse ridge into anterior and posterior portions. The air bladder extended into and filled these lateral depressions. Posterior to the depressions the bulge gradually lost its identity with decreasing convexity, and in the posterior portion of the cavity the roof was uniformly convex in cross section.

of the three varieties, the Atlantic and Australian were similar, and both differed from the California bluefin. The fundamental difference was in the width of the bulge. In the Atlantic and Australian forms this was broad, resulting in a narrow, deep lateral pocket. In the California bluefin the bulge was narrow and there was a broad, shallow oval depression on each side, rather than a pocket. In large fish this character is sufficiently constant to be diagnostic. Lacking small fish from the Atlantic and from Australia, no comparative discussion of these sizes is possible.

2.12. AIR BLADDER

Atlantic bluefin: There was a large, conspicuous air bladder in five of the six specimens examined. In the sixth specimen it was irregular in outline and more or less rudimentary (Figure 5). The following description is therefore based upon the five specimens.

The air bladder covered the full width and almost the entire length of the body cavity. It therefore had, in general, the shape of the dorsal wall of this cavity. It extended from the region of the oesophagus to and beyond the anterior tip of the urinary bladder. The rounded anterior end of the air bladder was traversed and divided internally by a ligament (found in other tunas) connecting the dorsal wall of the oesophagus with the dorsal wall of the body cavity. This ligament in some tunas, e.g. the yellowfin tuna, divides the anterior end of the air bladder into two "horns" which project separately into circular pits within the substance of the kidney tissue. Such was not the case in this bluefin. There were no pits and no separate horns anteriorly. Instead, the ligament, traversing the air bladder, connected with a septum which divided the anterior end or head of the air bladder into two internal compartments, no evidence of which was apparent externally. Just posterior to this ligament the ventral wall of the air bladder was attached to the viscera by a pair (one on either side of the median line) of blood vessels.

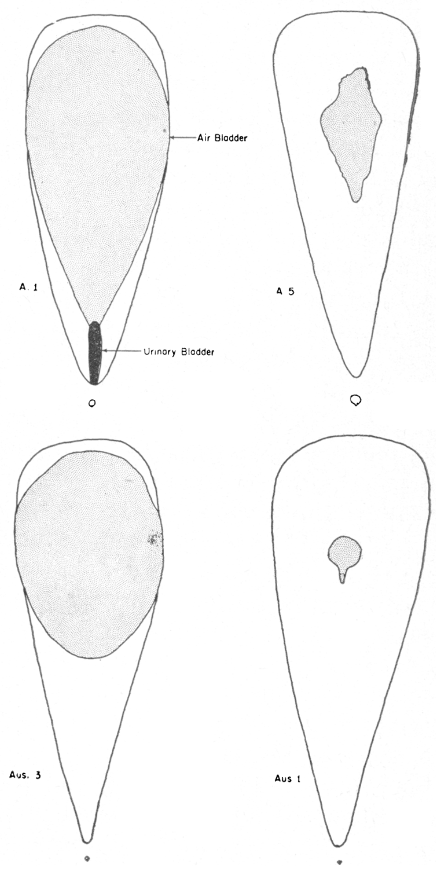

FIGURE 5. Illustrates for the Atlantic and Australian bluefin, upper and lower panels respectively, a functional (left) and a rudimentary (right) air bladder

Laterally, the rounded head of the air bladder ran to the lateral walls of the body cavity in the region of the pectorals. Its width included the deep pockets described in the foregoing section. The air bladder extended into these pockets, thus giving it two deep dorsal projections, the shape of which was determined by that of the pockets in the dorsal body wall. At this point the width of the air bladder was greatest, and posterior to this the air bladder tapered to a blunt point. In these five specimens the apex of the air bladder extended beyond the anterior tip of the urinary bladder, so that the tip of the air bladder was actually divided into two posterior projections by the ureter as this left the dorsal body wall to enter the urinary bladder.

Within the air bladder there was located near its mid-length the circular orifice and internal septum characteristic of other tunas. This orifice opened into a posterior projection which was separated by an extremely fine membrane.

In the sixth specimen the air bladder was small and collapsed. It measured only 156 mm. in total length and covered approximately one-third of the width of the body cavity. It was typical of the condition found frequently in the California bluefin.

Australian southern bluefin: Only one of the three specimens had a functional air bladder. In the remaining two it was vestigial, measuring respectively 19 and 35 mm. in greatest length. As in all such cases the rudimentary air bladders were collapsed. This description is therefore based on the single specimen with a functional air bladder. This extended from the region of the oesophagus to or slightly beyond the mid-length of the body cavity. Anteriorly its structure and appearance were identical with that described for the Atlantic bluefin (see Figure 5). It covered the entire width of the body cavity, and extended into the dorsal pockets in the pectoral region of the body wall.

Posteriorly the end of the air bladder was rounded, rather than pointed, and the posterior margin was 128 mm. distant from the vent. Internally the circular orifice and dividing septum were present at about the mid-length of the air bladder, but the posterior extension of this inner chamber was very short.

California bluefin: In the California bluefin the large majority lacked a functional air bladder. When present it was so variable as to preclude typical description. Structures similar to that of the one Australian specimen were observed.

The Atlantic bluefin differed from both the California and Australian in that five out of six possessed a functional air bladder, and in each case this was large, extending almost the full length of the body cavity. Because the air bladder in all the tunas has been found to be a particularly variable structure, the writers hesitate to consider it as a diagnostic character. The consistent shape and dimensions of the air bladder in five of the six Atlantic bluefin suggest, however, that if this is confirmed on larger numbers it might prove to distinguish the Atlantic from other varieties of Thunnus, because in no other form has such an air bladder been consistently found.

2.13. EXCRETORY SYSTEM

2.13.1. Kidney

Atlantic bluefin: The posterior extension of the kidney mass (Figure 6) was slight and roughly triangular in shape. The kidney mass extended to the 10th or 11th vertebra, or from 0.18 to 0.21 the body cavity length. The lateral margins were extensively lobulated in most specimens.

Australian southern bluefin: The shape of the posterior kidney mass differed in this form. It cannot be described as triangular, since the posterior margin ran more or less transversely across the body cavity. The posterior extension appeared to be slightly longer in this form, but through an oversight measurements were not taken.

California bluefin: The structure of the kidney mass was comparable with that of the Atlantic bluefin. Both differed slightly from the Australian bluefin.

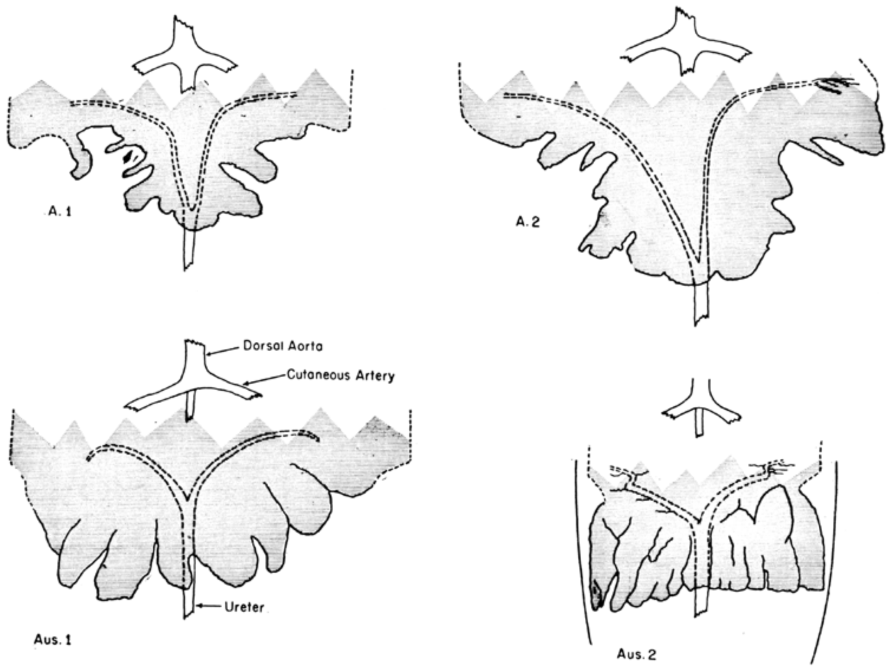

FIGURE 6. An outline of the posterior kidney mass in the Atlantic (upper) and Australian (lower) specimens, to show the extent of variation encountered and the course of the ureters.

FIGURE 6. An outline of the posterior kidney mass in the Atlantic (upper) and Australian (lower) specimens, to show the extent of variation encountered and the course of the ureters

2.13.2. *Ureter*

Atlantic bluefin: The single ureter divided into two branches as it entered the kidney mass. The point of division varied from 12 to 25 mm. within the substance of the kidney. Continuing posteriorly from the point of fusion of the two branches was a septum, which actually separated the single ureter into two tubes. The length of this septum varied, but approximated 5 to 10 millimeters in length.

The two branches diverged gradually and then bent sharply outwards towards the lateral kidney mass. Frequently the left branch continued anteriorly near the median line, to bend out abruptly at a right angle, whereas the right branch curved out more gradually from the point of division.

Australian southern bluefin: The single ureter divided at a considerable distance within the posterior margin of the kidney. In the three specimens the ureter continued as a single vessel a distance of 35, 51 and 56 mm., respectively, after entering the kidney mass. There was also a septum separating for a distance of several millimeters the single ureter into two tubes, as in other bluefin.

The course of the ureters differed in this variety. Because the point of division was more anterior, the two branches separated more abruptly. This was conspicuous in two of the three specimens, but less so in the third. (See Figure 6.)

California bluefin: The California bluefin was comparable with the Atlantic, and both differed from the Australian variety.

2.13.3. Urinary Bladder

Atlantic bluefin: The urinary bladder is a tubular sac opening externally through the vent. In length it varied between 0.15 and 0.17 the length of the body cavity. The bladder was embedded in the dorsal wall of the body cavity throughout the greater part of its length, but the anterior third, approximately, projected freely into the body cavity. The ureter joined the dorsal wall of the bladder at a distance which varied from 6 to 14 millimeters from the anterior tip of the bladder, and then ran within the dorsal wall of the bladder a distance of 6 to 15 millimeters before opening into it. As in the other tunas there was thus a tunnel, roofed by a delicate membrane, from the point of attachment to the actual orifice opening into the bladder.

Australian southern bluefin: The above description applies equally to this form. The extent of the bladder in two specimens was 0.17 and 0.19 that of the body cavity length. The length of the tunnel in the dorsal wall of the bladder was much shorter, however, varying between zero and three millimeters.

California bluefin: The condition here was comparable with the above description of the Atlantic bluefin.

2.14. CIRCULATORY SYSTEM

2.14.1. Anterior Arterial

Atlantic bluefin: The Y of the aorta was beneath the posterior half of the second vertebra or beneath the junction of the second and third vertebrae. The posterior epibranchials fused to form a short trunk which joined the aorta beneath the middle or anterior half of the third vertebra. The coeliac mesenteric artery left the aorta on the right side beneath the anterior half of the fourth vertebra, with the small subclavians arising laterally on each side at the same point. The cutaneous arteries arose opposite, or slightly staggered, forming an angle with the aorta of 60 to 70 degrees. Their origin was generally beneath the middle of the fifth vertebra. The aorta was somewhat constricted and reduced in size posterior

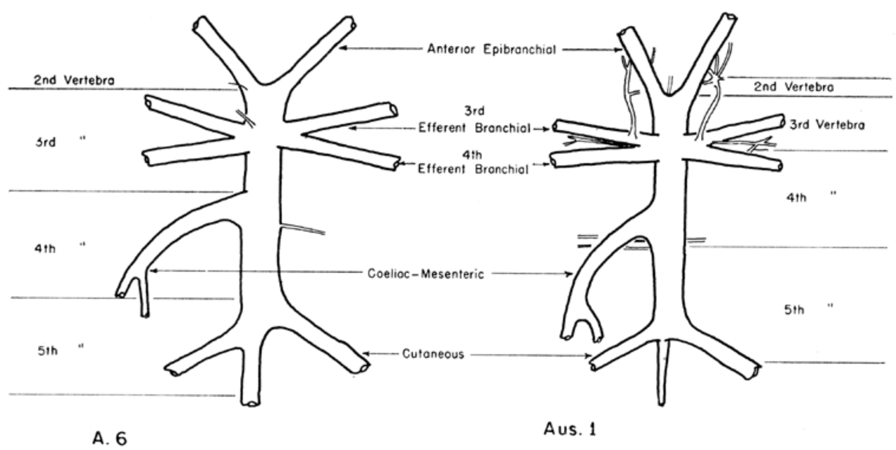

FIGURE 7. Comparable views of the anterior arterial system in the Atlantic (left) and Australian (right) specimens. Both sketches are reproductions of routine drawings made at the time of dissection. For this reason the scale is not comparable, and in some cases distorted.

FIGURE 7. Comparable views of the anterior arterial system in the Atlantic (left) and Australian (right) specimens. Both sketches are reproductions of routine drawings made at the time of dissection. For this reason the scale is not comparable, and in some cases distorted

to this point. The pharyngeal muscles were attached to the sixth vertebra and to the posterior portion of the fifth.

Australian southern bluefin: The condition in these fish was essentially as described above (Figure 7). There was one difference, however, in all three specimens. With the origin of the cutaneous arteries the dorsal aorta became conspicuously constricted. Furthermore in all specimens the appearance suggested that at this point the aorta divided equally to form the cutaneous arteries and gave rise, as a tributary vessel, to the continuation of the dorsal aorta from the dorsal face of the bifurcation. This impression was consistent and conspicuous, as indicated in the sketch.

California bluefin: The California bluefin resembled in all respects the Atlantic variety.

2.14.2. Visceral Arterial

In both the Atlantic and Australian forms the dissection was limited to the trunk and the main branches of the coeliac mesenteric artery. Its course was followed when possible to the break-up of these vessels in the substance of the liver. The condition of the fish precluded a successful injection of the entire visceral circulation.

Atlantic bluefin: The coeliac mesenteric artery arose from the right side of the aorta. It divided into two main branches, the No. II and No. III as used by Godsil and Byers. There was no No. I branch.

The No. II branch ran directly to the right lobe of the liver. It gave off numerous capillaries in its course to adjacent tissues, but no large vessels. In one specimen a small branch was given off to the lobule between the right and center lobes of the liver. Reaching the right lobe of the liver the No. II branch disintegrated into a complex capillary network, nourishing the entire lobe. On the dorsal face of this lobe were two moderate vascular cones. One connected with and apparently supplied blood to the right dorsal wall of the stomach, and the other to the anterior caecal mass, spleen, intestine and gall bladder.

The No. III branch ran in the diaphragm to the center lobe of the liver. In this course it gave rise to numerous capillary vessels to the adjacent tissue. Reaching the liver, it entered the substance of the center lobe and then divided into two approximately equal branches. The first branch ran into the center lobe and the second continued to the left lobe. Within these lobes the two branches rapidly broke up into a vascular network, ramifying throughout the liver substance. In one specimen a third small vessel arose at the final division of the No. III branch, and ran separately into the center lobe of the liver.

Beneath the center lobe was a large vascular cone connecting with and presumably supplying blood to the anterior viscera. The principal supply appeared to go to the caecal mass, although a connection with the straight intestine at its origin in the duodenum suggested that a portion of the intestine was nourished from this cone also.

Beneath the left lobe were three or four small vascular sacs arising from a common base but subsequently dividing into separate cones, and in addition one larger and separate cone. The latter invariably connected with the left dorsal wall of the stomach, whereas the majority of the smaller cones connected with the caecal mass.

In none of the five successful injections was any trace found of an artery connecting the No. II with the No. III branch. Failing to find this in the first dissection, particular care was taken in subsequent dissections to locate this vessel, and the writers are confident that it did not exist in these specimens. This connecting artery is characteristic of the California bluefin.

Australian southern bluefin: With one exception the foregoing description applies equally to this form. There was, however, in the one adequately injected specimen a connecting trunk joining the No. II and the No. III branch, as in the California bluefin. In a second specimen only the No. II branch was injected, and in this case a number of small to moderate branches arose from it, and, forming an anastomosing network, ran in the direction of the No. III branch. Although a connection with the latter could not be demonstrated, there was little doubt that this existed. All of the Australian specimens had been bled upon capture, by cutting the isthmus, and the blade of the knife had in each case severed the heart and in one case the liver.

California bluefin: The California bluefin possessed the connecting trunk between the No. II and the No. III branch, and thus conformed to the description of the Australian rather than the Atlantic bluefin. However, in other respects the three were similar, insofar as our observations went.

2.14.3. Cutaneous

Atlantic bluefin: The cutaneous arteries arose from the dorsal aorta beneath the fifth vertebra. Each cutaneous artery formed an angle of 60 to 70 degrees posteriorly with the aorta. With the veins, the arteries passed laterally between the third and fourth ribs, or occasionally between the second and third ribs.

Between the fourth and fifth intermuscular bones (in one fish between the fifth and sixth) both vein and artery divided into dorsal and ventral branches (see Figure 8). The vessels of the ventral pair (vein and artery) were invariably larger than the dorsal vessels. In the caudal region the vein and artery of each pair turned proximally and united in a posterior commissure characteristic of many tunas. The fused vessels ran axially as horizontal trunks to enter the vertebral column.

Frequently there were two posterior commissures and two horizontal trunks on each side. Typically the dorsal vessels turned proximally and in the center line were joined by branches of the ventral vein and artery to form the first posterior commissure and the first horizontal trunks. The ventral vessels continued—typically—posteriorly a distance of two vertebra and at this point turned axially to run into the vertebral column as the second pair of horizontal trunks. Generally a small branch of the dorsal vein and artery continued posteriorly beyond the first commissure and turned proximally to meet the ventral vein and artery, thus forming a second commissure. This was the basic picture obtained from repeated dissections, but a great deal of minor variation was found in individual fish. The horizontal trunk from the first commissure generally entered the 29th, 30th or 31st vertebra, while that from the second commissure entered the vertebral column two vertebra posteriorly. As often as not the comparable horizontal trunks from the two sides entered different vertebra, in which case there was one vertebra difference on the two sides.

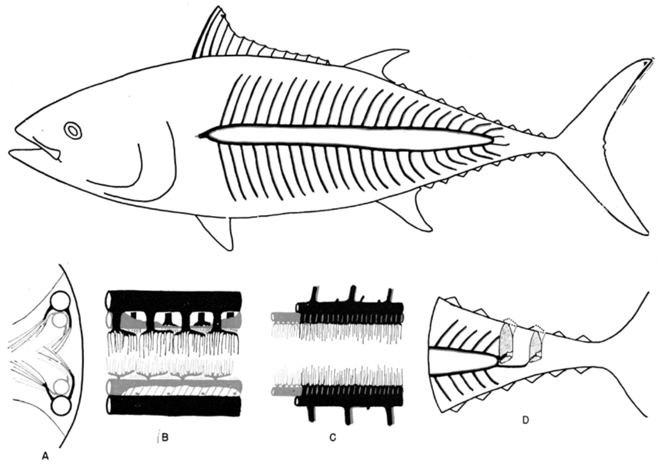

FIGURE 8. The cutaneous system in the California bluefin. This is a reproduction of figure 55, page 98, of Fish Bulletin No. 60. It shows the essential detail observed in the Atlantic and Australian specimens.

FIGURE 8. The cutaneous system in the California bluefin. This is a reproduction of figure 55, page 98, of Fish Bulletin No. 60. It shows the essential detail observed in the Atlantic and Australian specimens

Each dorsal and ventral vein gave rise to capillary sheets of venules throughout its course. There were two primary and regular rows of such venules arising in such manner as to surround the accompanying artery. Figure 8 portrays the detail. Similarly each branch of the cutaneous artery gave rise to two primary rows of arterioles, originating approximately on opposite faces of the artery. The proximal row was actually an irregular double row, and in some specimens could be so interpreted because the vessels were separated in origin by an arc of 5 to 10 degrees. The vessels in this row were more numerous, and larger than those of the second row arising on the opposite face of the artery.

Throughout the course of the vessels the venules and arterioles arising from the ventral branches of the cutaneous vessels were more regular than those originating in the dorsal branches. Moreover, regularity decreased towards the posterior end of the fish. Much detail has been omitted in this description because of excessive variability and therefore lack of significance.

Australian southern bluefin: The above description applies equally to this form, with the exception that the cutaneous vein and artery passed laterally between the second and third ribs more frequently than between the third and fourth. Furthermore in all cases the cutaneous vessels divided between the fifth and sixth intermuscular bones instead of between the fourth and fifth as was typical of the Atlantic form. The location of the posterior commissures was the same as in the Atlantic form.

California bluefin: A comparison of the California bluefin with the foregoing descriptions indicates that it is comparable with the Atlantic form and different from the Australian. Thus the cutaneous vessels passed between the third and fourth ribs, as in the Atlantic form, and divided between the fourth and fifth intermuscular bone. In both these respects the California and Atlantic forms agree.

2.14.4. Postcardinal Vein

Atlantic bluefin: There is no conspicuous postcardinal vein. The cutaneous vein on each side entered directly the Cuverian duct on its respective side. The actual opening of the vein into the duct was through a complex system of perforated membranes, the details of which were confusing.

Australian southern bluefin: The condition in this form is exactly as described above. The large first haemal arch suggested the possibility of a relatively large postcardinal vein, but a dissection of the tissues in this region failed to reveal any trace of a major vein.

California bluefin: In this character the California bluefin is comparable with both the above. There is no conspicuous postcardinal vein.

2.15. SKELETON

The entire skeletons of six Atlantic bluefin, three Australian bluefin, and four California bluefin were compared (see Figure 9). The following list enumerates the skeletal elements that were examined and studied for possible differences. The numbers refer to those used by Starks

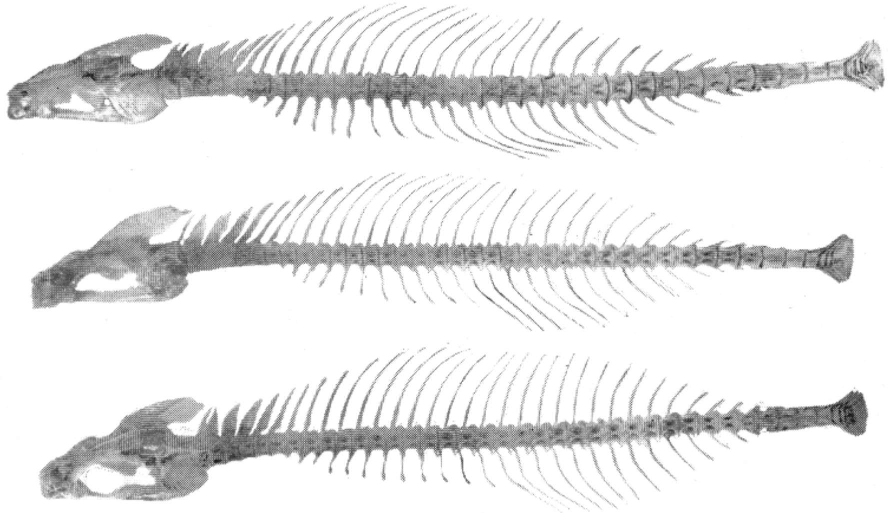

Photo by Al Johns for Vernon M. Haden, San Pedro

FIGURE 9. Cranium and spinal column viewed laterally. Top to bottom: Atlantic bluefin, Australian southern bluefin and California bluefin.

FIGURE 9. Cranium and spinal column viewed laterally. Top to bottom: Atlantic bluefin, Australian southern bluefin and California bluefin

(1901). of the remaining bones the majority were found to be unsuitable, for one reason or another, for such a comparison.

1.	Vomer	2.	Ethmoid	3.	Prefrontal
4.	Frontal	5.	Sphenotic	6.	Parietal
7.	Epiotic	8.	Supraoccipital	9.	Pterotic
10.	Opisthotic	11.	Exoccipital	12.	Basioccipital
13.	Parasphenoid	14.	Basisphenoid	15.	Prootic
16.	Alisphenoid	17.	Hyomandibular	18.	Symplectic
19.	Quadrate	20.	Pterygoid	21.	Palatine
22.	Mesopterygoid	23.	Metapterygoid	24.	Preopercle
25.	Opercle	26.	Subopercle	27.	Interopercle
28.	Articular	29.	Angular	30.	Dentary
31.	Maxillary	32.	Premaxillary	__.	Supramaxillary (Jugal)
33.	Interhyal	34.	Epihyal	35.	Ceratohyal
36.	Basihyal	37.	Glossohyal	38.	Urohyal
51.	Nasal	53.	Posttemporal	54.	Supraclavicle
55.	Clavicle	56.	Postclavicle	57.	Hypercoracoid
58.	Hypocoracoid	62.	Pelvic Girdle	64.	Abdominal Vertebrae
65.	Caudal Vertebrae	66.	Centra	67.	Neurapophyses
68.	Neural Spine	69.	Haemapophyses	70.	Haemal Spine
71.	Zygapophyses	72.	Parapophyses	79.	Hypural

The following list includes those elements in which differences were apparent and measureable.

- Vomer ·
- Frontal ·
- Basioccipital ·
- Metapterygoid ·
- Pelvic girdle ·
- Parapophyses ·
- Abdominal vertebrae ·
- Caudal vertebrae ·
- Centrum (of second vertebra) ·
- Haemapophyses ·
- Haemal spines ·

The three groups of fish studied fell into definite size ranges. The California bluefin were the smallest and the Atlantic bluefin were the largest, with the Australian bluefin intermediate in size. This complicated the study, and many differences noted were subsequently eliminated because they were considered to be a function of size.

2.15.1. *Cranium*

The general appearance of the cranium is the same in the three groups. All the bones of the cranium were compared, but no radical or constant differences were found. The cranium has been adequately described by Godsil and Byers, and by Kishinouye (1923). Dorsal and ventral views are shown in Figure 10a and 10b.

2.15.2. *Vomer*

On the ventral surface of the vomer in the Atlantic bluefin a ridge of bone extended ventrally and bore a dentigerous area over most of its length. This area varied in shape from long and narrow to broadly elliptical. The width to length ratio averaged 7.98 in the Atlantic fish, with a range of 4.73 to 13.52. In the Australian fish the dentigerous ridge was of moderate height. The width to length ratio averaged 9.12. The range was from 4.58 to 12.02. The vomerine ridge was of moderate height in the California bluefin. The ratio of width to length averaged 4.96, and the range extended from 4.32 to 5.50. In view of the overlap and the extensive variation in this character no significance can be attached to the apparent differences.

2.15.3. *Frontal*

The foramen on the dorsal median ridge between the frontal bones in the Atlantic bluefin was slightly elongate and elliptical in shape. Australian fish had a more broadly elliptical frontal foramen in all cases. California bluefin more closely resembled the Atlantic form. This character was not treated further because of its indefinable limits and because the margins of the foramen were occasionally damaged in cleaning individual skeletons.

2.15.4. *Basioccipital*

Viewed laterally, the posterior ventral margin of the cranium, formed by the basioccipital and the parasphenoid bones, was angular in some cases and rounded in others. These margins were angular in five of the six specimens of Atlantic bluefin. The Australian forms were angular in but one of the three fish. All four California specimens examined had angular margins. Because of the variability encountered the character was not studied further.

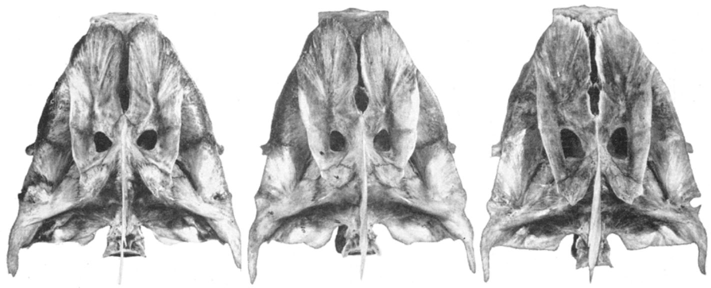

Photo by Al Johns for Vernon M. Haden, San Pedro

FIGURE 10a. Dorsal views of the cranium. Left to right: Atlantic bluefin, Australian southern bluefin and California bluefin.

FIGURE 10a. Dorsal views of the cranium. Left to right: Atlantic bluefin, Australian southern bluefin and California bluefin

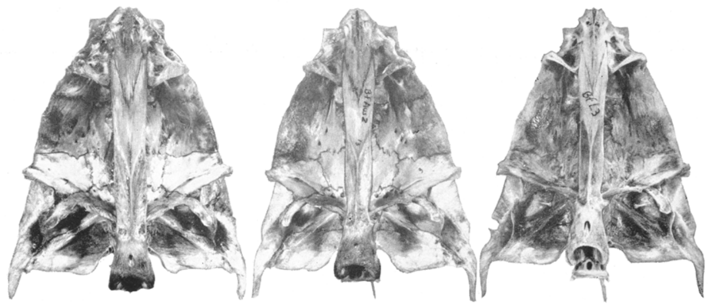

Photo by Al Johns for
Vernon M. Haden, San Pedro

FIGURE 10b. Ventral views of the cranium. Left to right: Atlantic bluefin, Australian southern bluefin and California bluefin.

FIGURE 10b. Ventral views of the cranium. Left to right: Atlantic bluefin, Australian southern bluefin and California bluefin

2.15.5. *Metapterygoid*

The width-length relationship was determined for this bone in the three groups. Atlantic fish gave a ratio of 1.7, Australian 1.7 and California bluefin 1.9. This structure was therefore narrowest in the California bluefin. However, the measurement was considered an unsatisfactory one, because the jagged sutures made it hard to determine the exact length of the bone.

2.15.6. *Pelvic Girdle*

The fact that this assembly was lost in all but one of the Atlantic specimens, and badly cut in the Australian fish, limits its use as a diagnostic character. It is discussed here because suggestive differences exist.

Kishinouye describes the pelvic girdle as being two paired bones each composed of three parts, an anterior external portion, an anterior internal portion and a posterior styliform portion. The anterior external portion is further composed of a thickened external wing which is folded along its external margin and is the longest anterior process, an internal wing joined to the external wing along its lower margin and lying in a plane approximately 90 degrees to that of the external wing, and a third, ventral wing which joins the external wing at its inner, ventral margin along approximately one-third the length of the external wing.

Atlantic bluefin: The suggestive differences observed concern the line of attachment of the internal wing with the external wing. In the

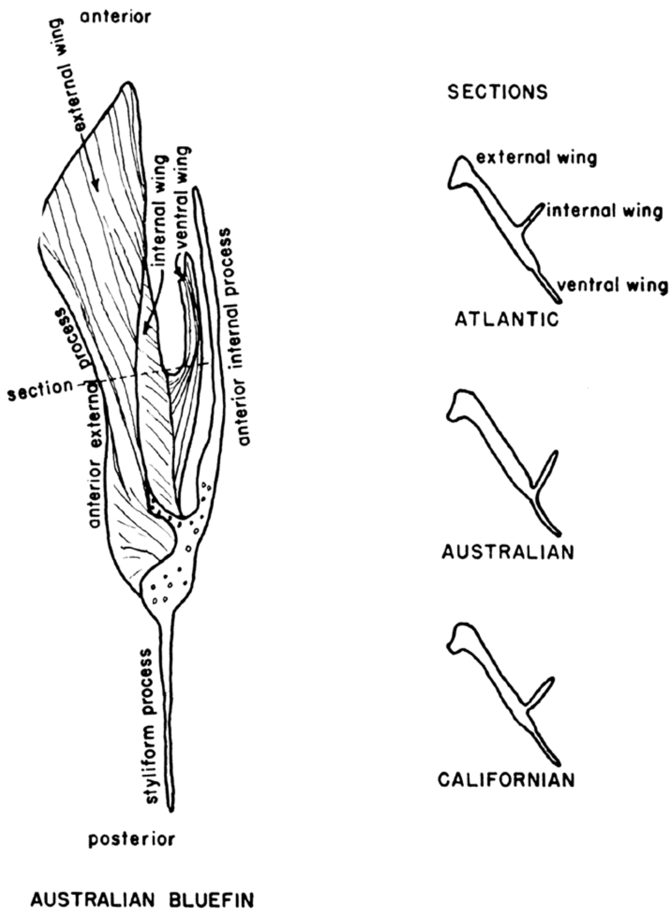

FIGURE 11. Diagrammatic dorsal view of the left half of the pelvic girdle, and three cross sectional views to show relative position of internal wing attachment

Atlantic bluefin this line of attachment was at some distance from the inner ventral margin of the external wing, being located approximately at one-third the width of the external wing, measured at the level of the anterior origin of the ventral wing, as indicated in Figure 11.

Australian southern bluefin: This group was characterized by the fact that the internal wing joined the external wing along the inner ventral margin of the external wing.

California bluefin: In the above character this form was intermediate between the Atlantic and Australian varieties. The internal wing joined the external wing along a line which was removed approximately one-sixth the width of the external wing, measured at the same point, namely, that shown by the section line in Figure 11.

2.15.7. *Spinal Column*

The vertebral counts were the same in all three groups, except for one California bluefin, in which the first haemal arch was on the eleventh vertebra. The counts for the three samples can be summarized as follows:

Number of vertebrae	39, omitting the hypural
First haemal arch	10th vertebra: on 11th in one California bluefin
First elongate haemal spine	19th vertebra
Number of precaudal vertebrae	18
Number of caudal vertebrae	21

Centrum: The anterior face of the second centrum was slightly elliptical in the Atlantic form. Dividing height of the centrum into the width gave an average ratio of 1.26 in the six Atlantic bluefin. The range was from 1.20 to 1.29. The same measurements in the Australian fish resulted in a range from 1.09 to 1.16, with an average of 1.13, showing a more rounded tendency. For the California bluefin the average ratio was 1.12, and the range from 1.02 to 1.26. The centrum was thus more rounded than in the Atlantic, but overlapped the Australian. Whether this character is a function of size is not known. The centrum may become more elliptical with increase in size. For this reason it cannot be considered diagnostic.

Parapophyses: Parapophyses are herein defined as the paired processes which extend from the anterior ventral or lateral angles of the vertebra and which do not join each other to form an arch. Where these processes do join to form the haemal arch they are known as haemapophyses.

Atlantic bluefin: The first ventrally extended parapophyses occurred on the eighth vertebra. The least distance between paired parapophyses on the ninth vertebra appeared to be less in this form than in the Australian. Measurements showed the least inside width to average 5.3 in the height of the parapophyses. The range was from 3.05 to 7.45.

Australian southern bluefin: The first ventrally extended parapophyses were on the ninth vertebra. The least width averaged 1.24 in the height, with a range from 1.10 to 1.41. In this character the Australian fish differed from both the Atlantic and California bluefin.

California bluefin: As in the Atlantic bluefin the first ventrally extended parapophyses were on the eighth vertebra. The least width into height of the parapophyses on the ninth vertebra averaged 6.73. The range was from 3.10 to 9.25. The overlap in the ranges of the Atlantic and California fish precludes its use in separating these two forms.

First Haemal Arch: With the single exception previously noted, the first haemal arch was located on the tenth vertebra in all three forms. A diagnostic difference was apparent in the shape of the arch. The Australian bluefin was typified by having a nearly 1:1 width to height ratio in the opening of the first haemal arch. This ratio in California and Atlantic bluefin was roughly 1 : 2. The relative size of the process forming the arch was smaller in the Australian specimens (see Figure 12).

Atlantic bluefin: The opening of the first haemal arch was triangular with a rounded apex. The greatest inside width divided into the height of the first haemal arch averaged 1.88.

Australian bluefin: The opening of the first haemal arch was more rounded in this form, and the greatest width averaged 1.23 in the height.

California bluefin: The opening of the first haemal arch was not distinguishable from that of the Atlantic bluefin. The greatest width of the opening of the arch into the height averaged 1.89. The shape of the first haemal arch separates the Australian from both the Atlantic and California bluefin.

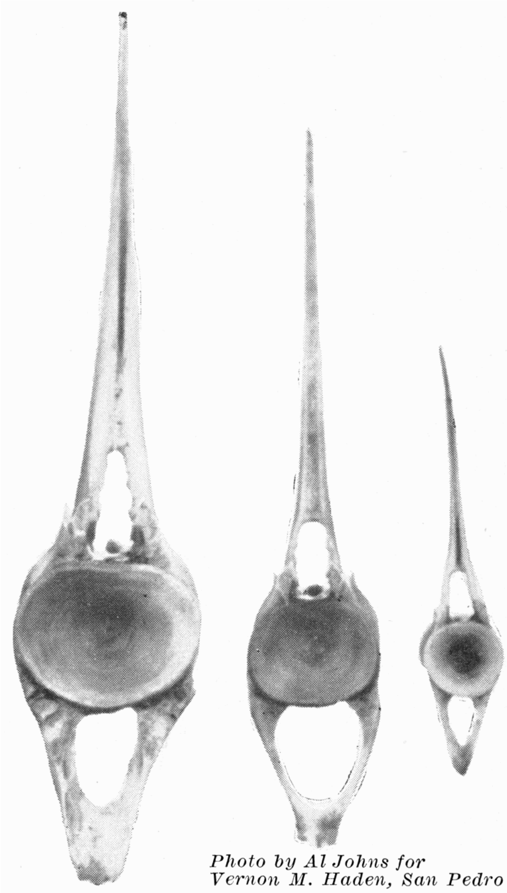

Photo by Al Johns for
Vernon M. Haden, San Pedro

FIGURE 12. The tenth vertebra showing differences in shape and structure of the first haemal arch. Left to right: Atlantic bluefin, Australian southern bluefin and California bluefin.

FIGURE 12. The tenth vertebra showing differences in shape and structure of the first haemal arch. Left to right: Atlantic bluefin, Australian southern bluefin and California bluefin

Size of first haemapophyses: In the Atlantic form the haemapophyses were broad. This is indicated by the fact that the least width into the height of the arch averaged 4.32.

Australian southern bluefin: The least width of the haemapophyses averaged 11.05 in the height, showing the relative weakness of the process in these fish.

California bluefin: Here again the California tunas were indistinguishable from the Atlantic form. The least width averaged 4.59 in the height.

Haemal canal: The haemal canal in the Atlantic bluefin was of moderate depth at the first haemal arch. It increased in depth in the next three or four arches, then decreased in depth gradually with each succeeding arch (see Figure 13). In the Australian bluefin the haemal canal was of moderate depth at the first haemal arch and diminished in depth at each succeeding arch. The California bluefin had a haemal canal similar to that described for the Atlantic fish.

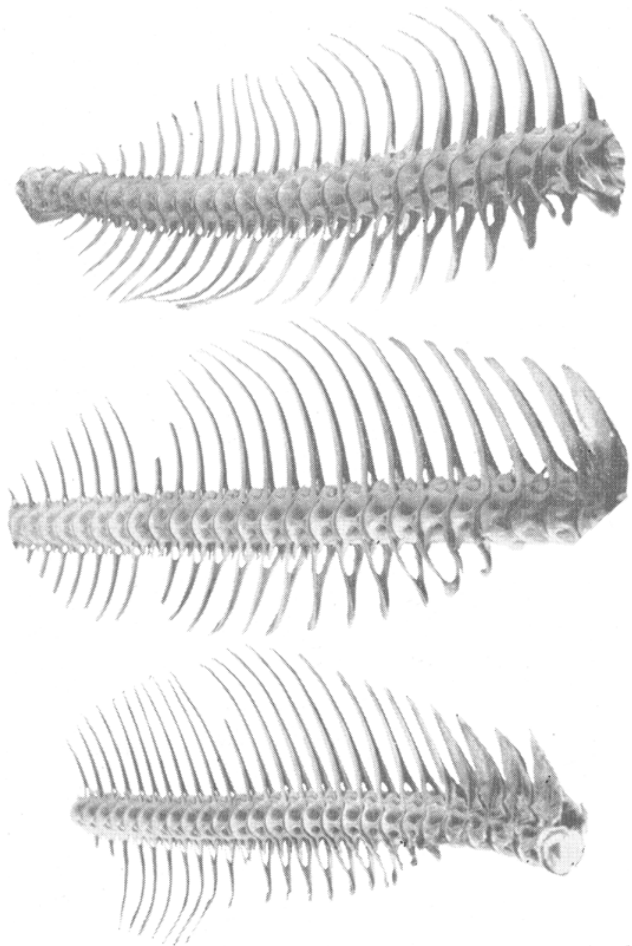

Photo by Al Johns for Vernon M. Haden, San Pedro

FIGURE 13. Oblique views of the spinal column to show the haemal canal. Top to bottom: Atlantic bluefin, Austrian southern bluefin and California bluefin.

FIGURE 13. Oblique views of the spinal column to show the haemal canal. Top to bottom: Atlantic bluefin, Australian southern bluefin and California bluefin

3. SUMMARY OF ANATOMICAL DIFFERENCES

A tabulation of the foregoing results, in terms of similarities and differences, will materially aid in the search for diagnostic characters and in the determination of degree of relationship. The first tabulation is a list of those characters in which no differences were observed, that is, in which the three varieties were indistinguishable. It must be emphasized that in their selection differences of a statistical nature are entirely disregarded. Thus the relative length of the stomach differs to some extent: and the length of the tunnel in the ureter as it enters the urinary bladder appears to be shorter in the Australian fish. The examination of a larger series, comprising fish of all size, might entirely change this result. Furthermore if these suggestive differences are valid, they would in all probability enable one to separate one group of fish from another, but not a single specimen of one variety from a specimen of a second variety. Such characters are not diagnostic and are irrelevant to this discussion. The selection is somewhat arbitrary, and some characters will bear further study.

Opercular margins	Postcardinal vein
Height of fins	Bones, as listed
Majority of external proportions	Basioccipital
Fin ray counts	Centrum
Stomach	Frontal Foramen
Intestine	Metapterygoid
Spleen	Vomerine teeth
Gall bladder	Vertebral counts
Urinary bladder	

of the remaining characters the following tabulation reveals the basic relationships and differences.

Character	*Similar in*	*Different in*
Size of vent	Atlantic and California	Australian
Length of trunk	Atlantic and California	Australian
Gill raker count	Australian and California	Atlantic
Visceral view	None	Atlantic, Australian and California
Caecal mass	Atlantic and California	Australian
Liver	Atlantic and California	Australian
Dorsal wall of body cavity	Atlantic and Australian	California
Air bladder	None	Atlantic, Australian and California
Kidney	Atlantic and California	Australian
Ureter	Atlantic and California	Australian
Anterior arterial	Atlantic and California	Australian
Visceral arterial	Australian and California	Atlantic
Cutaneous system	Atlantic and California	Australian
Pelvic girdle	None	Atlantic, Australian and California
Parapophyses	Atlantic and California	Australian
Haemal arch, first	Atlantic and California	Australian
Haemapophyses	Atlantic and California	Australian
Haemal canal	Atlantic and California	Australian

This tabulation suggests that the Australian southern bluefin differs in most characters from both the Atlantic and California bluefin, and that in a few characters the Atlantic form differs from the California bluefin. However, the characters are not all equally valid.

3.1. EXTERNAL CHARACTERS

For fish of comparable size, the vent in the Australian fish is approximately half the size of that in the Atlantic and California bluefin. When measurements of this character are available, related to the size of the fish, the size of the vent should constitute a useful diagnostic character within the genus.

The relative length of the trunk, in terms of the abdominal cavity length or of the distance from ventral insertion to vent, differs in the

Australian bluefin. It is possible that this difference may require biometrical methods to demonstrate, but present indications are that the difference separating the Australian bluefin, on the one hand, from the Atlantic and California bluefin on the other hand, is sufficiently large to enable the identification of a single specimen of the former.

On the basis of gill raker counts the Atlantic bluefin can be separated from the Australian specimens, and from most of the California specimens. This character is corroboratory rather than diagnostic. The Australian and California bluefin are similar, and individually indistinguishable.

3.2. INTERNAL CHARACTERS

The differences in visceral view are due in part to at least two structures. The view of the viscera in the Atlantic bluefin is materially affected by the large inflated air bladder. This inevitably crowds the viscera towards the ventral wall, and thus distorts the basic visceral pattern. With the air bladder collapsed one could not separate the Atlantic from the other bluefin by this character.

The Australian bluefin are distinguished by smaller tubules in the caecal mass, and the pattern of the latter is in consequence finer. But without specimens of the other varieties for comparison one could not identify a fish by this character alone. Hence the ventral view of the viscera, *in situ,* is not of itself a diagnostic character.

The liver is distinctly more lobulated in the Australian bluefin and the lateral lobes are noticeably longer. However, it will be necessary to examine a larger series of specimens before this can be accepted as a distinguishing character. The authors are of the opinion that it will prove valid, for they have never observed in California bluefin a liver that approached the Australian form.

The shape of the dorsal wall of the body cavity is an excellent diagnostic character in fish over 80 cm. (approximately) body length. By it one can separate positively any large specimen of California bluefin. The Australian and Atlantic forms are similar in this respect. In small California bluefin the entire dorsal wall of the body cavity is gently convex. The condition in comparable Atlantic and Australian bluefin is not known.

At best, the air bladder can be considered a diagnostic character in the Atlantic bluefin only. In the remaining two varieties its shape and degree of development were so variable as to limit its usefulness. of the three Australian specimens only one possessed a functional air bladder, and in the California bluefin all small fish had a vestigial or rudimentary air bladder. In the larger California fish, less than half had a functional air bladder, and this was extremely variable in shape and extent. Even in the Atlantic specimens one of the six possessed a small rudimentary air bladder. In the five remaining Atlantic specimens the air bladder was relatively constant in shape and extent, so that it may be used as a presumtive or corroboratory identifying character.

The kidney tissue and ureters may be considered as a single character. If the three Australian specimens examined are typical of the population, this character may be considered as distinctive, separating the Australian from the Atlantic and California forms between which there is no difference. In the Australian southern bluefin, the posterior extension of the kidney was extensively lobulated. Instead of being roughly triangular in shape its posterior margin ran more or less transversely across the body cavity. The ureters divided and separated laterally at a relatively wide angle, and the point of division was at a considerable distance within the posterior margin of the kidney. In the Atlantic and California bluefin the ureter divided shortly after entering the kidney mass and the two branches diverged gradually and then turned laterally somewhat abruptly.

In the anterior arterial system the prolongation of the dorsal aorta beyond the origin of the cutaneous arteries distinguished the Australian bluefin. In this form the picture suggests that the aorta divides into the two cutaneous arteries with the continuation of the aorta arising from the dorsal face of this bifurcation as a minor vessel.

In the visceral circulation the Atlantic bluefin is distinguished from the two remaining varieties by the fact that there is no connecting artery, nor a complex anastomosing network of small vessels, joining the No. II and No. III branches of the coeliac mesenteric artery.

The difference in the cutaneous system separating the Australian from the California and Atlantic bluefin is probably of a biometrical nature. Whereas in the Atlantic and California bluefin the cutaneous vessels passed laterally between the third and fourth ribs in the majority of cases, these vessels in the Australian specimens passed typically between the second and third ribs. Similarly in the Atlantic and California bluefin the cutaneous vessels divided between the fourth and fifth intermuscular bones, whereas they divided in the Australian bluefin between the fifth and sixth intermuscular bones.

The pelvic girdle differs in all three of the bluefin treated here. The difference is found in the position of the attachment of the internal to the external wing, as described in the text. This difference was quite conspicuous, but in view of the fact that only one assembly was saved for examination from the Atlantic sample, the conclusion must be accepted with reservations until it has been confirmed.

The shape of the first haemal arch is the most striking skeletal difference separating the Australian bluefin from the Atlantic and California specimens. In the former it was approximately round, whereas in the two latter varieties it was acutely triangular. Similarly, the structure of the haemapophyses in the Australian fish was characteristically weaker than in the other two varieties; and the shape of the haemal canal likewise separates the Australian bluefin. In all structures of the vertebral column the Atlantic and California bluefin are indistinguishable.

By one or more of the foregoing characters a single specimen of the Australian southern bluefin can be identified beyond any doubt. There can be no question about the validity of this species. Similarly at least one character, namely, the shape of the dorsal wall of the body cavity, will separate any large specimen of the California bluefin from the Atlantic variety. The gill raker count, the existence of the connecting artery between the No. II and No. III branches of the coeliac mesenteric artery, and the shape of the pelvic girdle constitute corroboratory characters. These observations indicate that the Atlantic and California bluefin should be considered as distinct species.

On the basis of the foregoing discussion a key for the identification of these three members of the genus Thunnus follows:

a. Bulge in roof of body cavity extends almost to belly wall, leaving a deep lateral pocket in pectoral region on each side. (This applies to medium and large fish. Condition in small specimens not known.)

b. Internal outline of first haemal arch broadly oval, with distal margin evenly rounded, so that width of aperture at distal end almost equals greatest width of aperture. Kidney extremely lobulated, with posterior margin truncated transversely. Ureter dividing far within kidney substance, with the two branches diverging laterally at relatively wide angle. Vent small, measuring about three millimeters in diameter. Gill rakers 34 to 36. Air bladder pear shaped, about half length of body cavity. When rudimentary, air bladder is approximately circular. Arterial trunk or network connecting the No. II and No. III branches of the coeliac mesenteric artery T. maccoyii

bb. Internal outline of first haemal arch distinctly triangular and narrow, with distal margin terminating in a rounded apex, so that internal width at apex less than half greatest width of opening. Kidney slightly lobulated, with posterior projection roughly triangular. Ureter divides near posterior margin of kidney, and the two branches diverge gradually and then turn abruptly outwards. Vent twice diameter of preceding species. Gill rakers 39 to 41. Air bladder elongated, covering entire width and length of body cavity. No arterial trunk or network connecting the No. II and No. III branches of coeliac mesenteric artery. T. thynnus (Atlantic)

aa. Bulge in roof of body cavity relatively narrow, leaving a lateral saucer-shaped depression in pectoral region on each side, in large specimens. Roof of body cavity uniformly convex in small specimens. First completed haemal arch twice as high as wide internally. Kidney slightly lobulated, with posterior projection roughly triangular. Ureter divides near posterior margin of kidney, and the two branches diverge gradually and then turn abruptly outwards. Vent twice diameter of that in T. maccoyii. Gill rakers 32 to 39. Air bladder rudimentary in small specimens, and such rudimentary air bladders narrowly elongate. Air bladder irregular in shape and size in large specimens. Conspicuous arterial trunk or network connecting the No. II and No. III branches of coeliac mesenteric artery T. thynnus (Pacific)

4. SYSTEMATIC RELATIONSHIPS

4.1. DISCUSSION

In an attempt to determine the systematic status and the relationships of the tunas discussed herein, the authors have compared their findings with those in the available literature. No claim, however, is made to a complete bibliographical search.

There can be little doubt concerning the generic identity of the three samples. All have the first completed haemal arch on the 10th vertebra. In all, the coeliac mesenteric artery divides into the No. II and No. III branches, with the No. I branch either missing or minute. In all, the liver is completely striated on the ventral surface of the three lobes, with conspicuous conical plexuses on the dorsal surface of each. In all, the cutaneous arteries originate beneath the fifth vertebra. The posterior extension of the kidney is short, and the single ureter divides far anteriorly. Reviewing these general, fundamental similarities in the course of dissection, makes one strikingly conscious of the inherent relationship, despite any differences in the length of fins or other external detail. The authors are thoroughly in accord with the conclusions of Kishinouye, that all belong in a single genus.

However, if all are to be retained within this genus, the inclusion of T. maccoyii necessitates one modification in the generic characters used by Kishinouye. The statement, "Anterior haemal arches of the precaudal region are turned forward and narrow," must be deleted. The haemal arches in this region of T. maccoyii, although turned forward, are wide.

Specifically, the Australian southern bluefin is clearly differentiated from the other forms. The bases for the separation are listed in the suggested key. It is significant that the anatomy of this tuna suggests throughout an affinity with the albacore, T. germo.

After this report was submitted for publication, the article by Fraser-Brunner (1950) appeared. Our findings, as reported herein, are in conflict with his classification. Fraser-Brunner synonymizes T. maccoyii with Thunnus (Parathunnus) obesus. This sub-genus is characterized, in his classification, by the lack of surface striations on the liver and by the fact that the cutaneous vessels originate beneath the seventh vertebra. T. maccoyii has, according to our observations, numerous, conspicuous, radiating striations on the surface of the liver; and the cutaneous vessels originate beneath the fifth vertebra. These, according to Fraser-Brunner, are characters defining the sub-genus Thunnus (Thunnus). Hence T. maccoyii must belong in the latter sub-genus. As it can be readily distinguished by both internal and external characters from Thunnus (Thunnus) thynnus, T. maccoyii must be accorded separate specific standing. Our conclusions remain, therefore, unchanged.

The relationship of the Atlantic and Pacific varieties of T. thynnus is infinitely closer. In by far the majority of characters they are identical and indistinguishable. In five, however, they can be differentiated.

1. In the Atlantic form the air bladder is normal (five out of six specimens) and covers almost the entire length of the body cavity, whereas in the large California specimens the air bladder is extremely irregular, and in the majority of cases where a functional air bladder is present, it is pear shaped, covering only the anterior half of the abdominal cavity. To this extent it resembles both T. maccoyii and Kishinouye's description of T. orientalis, of which the author states, "In immature tunies the air bladder is short, very narrow, and almost collapsed." This general description would fit the California variety also. In view of the instability of this organ throughout the order, one would hesitate to base a separation upon it alone.

2. In the Atlantic bluefin there is no arterial trunk connecting the No. II and No. III branches of the coeliac mesenteric artery, whereas in the California form this, or a connecting network, is present.

3. The pelvic girdle differs in the two forms, as described on pages 33 and 34. However, this bone from five of the Atlantic specimens was inadvertently lost, and the conclusion is based upon the examination of only one assembly. It must therefore be accepted with reservations.

4. The gill raker count differs in the two varieties. The total count in the Atlantic form was 39 to 41, compared with 32 to 39 in the California bluefin. The difference was mainly in the number of rakers on

the lower limb of the arch. In the Atlantic bluefin this number was 25 to 28, whereas in the California bluefin there were 21 to 25 rakers.

5. The last and most conspicuous difference occurs in the shape of the roof of the body cavity. In large fish the difference is striking and consistent. Unfortunately no small Atlantic specimens were available for comparison.

In view of these five differences, the writers are of the opinion that T. thynnus of the Pacific American coast should ultimately be separated specifically from T. thynnus of the American Atlantic coast.

A study of the published descriptions of the European tuna, T. thynnus, reveals in the anatomy a consistent and remarkable agreement with that of the American Atlantic specimens. All general descriptions could apply equally to both. Most detailed dissections, such as those of Eschricht and Mueller (1835), and Frade (1925, 1927, 1930) reveal comparable conditions. There is, however, one significant difference. This occurs in Frade's description of the cutaneous system. Frade (1925), speaking of the cutaneous system, states in loose translation that there are two rows of arterioles originating in each cutaneous vessel, one internal and the other external. The arterioles of the external row alternate with the corresponding venules.... those of T. thynnus give rise to capillary bundles which are above the bundles of venules. This description is illustrated in his Figure 1, of Plate 1.

This description and figure is entirely contrary to anything the present authors have observed in any of the tunas. In the three representatives of Thunnus described in this report, the arrangement of the cutaneous vessels was essentially identical, and different from the foregoing description of Frade. In all cases the venules were superficial to the arterioles, and in cases of a double venous and arterial injection, the arterial capillary bundles were more or less obliterated in surface view by the superimposed venous capillary bundles. There is a good deal of variation in this system, and the regularity of the basic pattern decreases posteriorly. It requires repeated dissections before one can perceive this basic pattern and recognize the variational departures from it. Inasmuch as Frade does not state the number of fish thus injected and dissected, one wonders whether the description might possibly have been based upon a single aberrant specimen. In view of the detailed similarity in the cutaneous vessels encountered in the three distinct samples investigated, such a radical difference in the European form is hardly to be anticipated, particularly as it would prove the exception in the entire family Thunnidae. The authors therefore suggest that this character be further investigated before any final conclusion is drawn.

There remain three characters which differed in the specimens studied, but for which there is no comparable description for the European variety. It has been shown that the dorsal wall of the body cavity differs in shape in the Atlantic and Pacific American specimens. The authors have not found a description in the literature of this character in the European form. The closest approach is contained in Frade, 1925 and 1927. Describing the air bladder, Frade states that there are two well developed lateral dilations, one on each side, posterior to which the air bladder narrows rapidly at first, and then more slowly. This description fits the condition found in the American Atlantic form, in which the lateral diverticula of the air bladder fit into a deep lateral pocket in the dorsal wall of the body cavity. To this extent the eastern and western Atlantic forms of T. thynnus appear to be alike.

No one has apparently investigated the existence of an arterial trunk or network connecting the No. II and No. III branches of the coeliac mesenteric artery. Likewise it has not been shown whether the pelvic girdle (as discussed in this report) is identical in the two varieties. These characters should be investigated. As the matter stands now the evidence is conflicting. The available descriptions of the European form agree in general with our findings in the western Atlantic specimens. Frade's description of the cutaneous system is the only positive difference observed, although additional characters which are discussed above should be investigated. In view of this uncertainty the writers suggest that no changes in nomenclature be made until the above questions are answered beyond dispute.

It is unfortunate that a direct comparison of T. thynnus of the Pacific with T. orientalis of Japan cannot be presented. A comparison of the authors' findings with the description of T. orientalis by Kishinouye reveals a remarkable agreement in most characters. In three, however, there appear to be differences. Kishinouye describes and figures the arterioles of the cutaneous vessels as arising in a single row, whereas the present authors describe for T. thynnus, two rows. In the numerous routine dissectional sketches and notes of this system it is quite obvious that both rows, particularly the distal row, are irregular, particularly in the posterior region of the body. It is therefore quite conceivable that the conditions in this system are identical in both species, and the differences can be attributed to errors of observation or description.

Kishinouye implies in various places that there is an abortive No. I branch of the coeliac mesenteric artery. The present writers have never found such a branch in T. thynnus. Occasionally a capillary-size vessel is present originating approximately where the No. I branch should be, and like it running to the oesophagus. This vessel is so small, and is moreover one of several originating in this region and nourishing the adjacent tissues, that it was not considered homologous with the No. I branch. This difference may therefore be an interpretative one.

Kishinouye states, on page 380, "In Thunnus orientalis the two ureters meet in a figure like U, and in the other forms of the Japanese tunnies they meet like the figure V." This description would not apply to T. thynnus. Unfortunately the author does not illustrate this.

Two of the foregoing differences could be attributed to personal interpretation. The third, the course of the ureters, cannot be so explained. If the description is correct, then the two species must be considered distinct. Before drawing a final conclusion, it would be desirable to check the three characters.

4.2. CONCLUSIONS

1. The Australian southern bluefin, T. maccoyii, is entirely distinct from the remaining members of the genus and can be identified positively by a number of characters.

2. The bluefin of the California coast is remarkably similar to that of the Atlantic coast. It can, however, be distinguished by at least four

internal characters and possibly by the gill raker count. The most useful character, in large fish, is the shape of the dorsal wall of the body cavity, which alone enables a positive identification. The condition of this character in small specimens from the Atlantic coast has not been determined.

3. Specimens of T. thynnus from the eastern and western Atlantic appear to be identical in most characters. However, additional comparisons should be made of three or four characters of which there is no record in the European literature. Likewise Frade's observations on the cutaneous system should be repeated before a conclusion is reached.

4. There is a striking similarity between T. thynnus of the California coast and T. orientalis of Japan. Only three characters in Kishinouye's description differ, and of these two might possibly be interpretative. The third, although it is not figured, suggests a positive difference. Until these differences are further investigated, T. orientalis must be considered as a species distinct from T. thynnus of the Pacific American coast.

5. A discussion or revision of the nomenclature is, at this time, premature. Although the results of this study suggest that the California and Atlantic bluefin should be considered distinct species, no present change in nomenclature is recommended. The relationship of both these varieties to the European bluefin, and that of the California bluefin to T. orientalis should first be determined.

5. ADDENDUM

After this manuscript was submitted for publication three additional specimens of Australian southern bluefin were obtained from a commercial shipment received in April, 1950. We are indebted to the officers of F. E. Booth Co., Inc., San Francisco, for these specimens. Each fish was measured and dissected according to the described routine. The findings are in essential agreement and conclusions are not materially changed. In fact the additional observations reinforce many of the separate conclusions. The additional specimens were all smaller than any of the original ones, and the measurements were therefore more directly comparable with those from California.

Externally, the appearance of these three fish was identical. The vent was small and rounded, as described, and definitely smaller than in comparable California bluefin. Only in one fish did the vent approach in size that of the California variety.

The insertion of the anal fin was slightly but consistently more anterior than in the California bluefin, and the dorsal-anal distance was less. Measurements of the abdominal cavity length and the corresponding ventral insertion to vent distance strengthen the conclusion that this region of the body is proportionately shorter in the Australian southern bluefin than in California bluefin.

The examination of these smaller fish revealed that the pectoral fin was consistently longer in the Australian southern bluefin than in California bluefin. This becomes apparent when the measurements are plotted.

The meristic counts are in agreement with those listed, except that the range in total number of gill rakers is extended from 34–36, to 32–36.

Internally, these three specimens agreed in all characters, except in minor detail, with the earlier descriptions. Tubules of the caecal mass

TABLE 4

The Distribution of Gill Raker Counts on the Upper and Lower Limb, Separate and Combined

Upper limb						Lower limb							
10	11	12	13	14	15	21	22	23	24	25	26	27	28
1	1	1	-------	-------	-------	-------	1	2	-------	-------	-------	-------	-------

Upper and Lower Limbs Combined

32	33	34	35	36	37	38	39	40	41
1	----------	1	1	----------	----------	----------	----------	----------	----------

Tabulation of the Various Ray Counts to Show the Distribution of Values

First Dorsal Fin			Second Dorsal Fin		Dorsal Finlets		Sec. Dor. Plus Dor. Finlets			Anal Fin			Anal Finlets		Anal Fin Plus A. Finlets		
12	13	14	14	15	8	9	22	23	24	13	14	15	7	8	21	22	23
--	2	1	2	--	1	2	--	2	--	--	3	--	--	3	--	3	--

TABLE 4 The Distribution of Gill Raker Counts on the Upper and Lower Limb, Separate and Combined

were fine in all, and this character distinguishes the Australian southern bluefin from both the Atlantic and California varieties. The lateral lobes of the liver were proportionately shorter than the description would imply, and in length were comparable with the California bluefin. The liver of one specimen was irregular, to the extent that the entire ventral surface of the center lobe was not typically striated. In this specimen there were zones of continuous radiating striations separated by broad zones without striations. This exception does not invalidate the character because the existing striations were characteristically and unmistakably of the Thunnus type.

Confirming the suspicion expressed in the text, the dorsal wall of the body cavity was relatively flat in these small fish, and lacking the characteristic bulge of the larger specimens. In cross section, the dorsal wall of the abdominal cavity was gently convex. The incipient bulge could be seen. In suggestive agreement with the developed structure, the convexity continued to the vicinity of the lateral wall of the body cavity. Here it sloped dorsal-ward, leaving a narrow groove on each side, which, according to the writers' interpretation, constitutes the *anlage* of the lateral pocket described for the larger fish. Thus, in both the Australian and California bluefin, and probably also in the Atlantic, this bulge develops progressively with increasing size of fish. While in large fish this character serves to differentiate the California bluefin from the Atlantic and Australian specimens, its absence in small fish limits its usefulness. In a final revision of a key, it should probably be subordinated.

The air bladder was rudimentary in these three specimens. In all, the rudiment was circular in outline, as opposed to the narrowly elongate rudiment in the California bluefin.

The recorded differences in the kidney of the Australian southern bluefin were confirmed by these additional observations. Differing from the Atlantic and California specimens, the posterior margin of the extension of the kidney, in T. maccoyii, is definitely transverse instead of roughly triangular. In all six specimens it was relatively long, extending to the level of the eleventh or twelfth vertebra. Likewise the ureters divided well within the substance of the kidney, at distances of 25, 27 and 40 mm., respectively, from the posterior margin of the kidney. The two branches separated immediately, including an angle between 25 and 45 degrees.

No contradictions were noted in the circulatory system. However, in one of the three specimens the continuation of the dorsal aorta beyond the origin of the cutaneous arteries was not conspicuously reduced in size, and was in fact, as large as the cutaneous arteries. In all specimens there was an arterial connection between the No. II and No. III branches of the coeliac mesenteric artery, as described. In two specimens it was large and conspicuous, while in the third it was moderate in extent.

The statement that, "... in all cases the cutaneous vessels divided between the fifth and sixth intermuscular bones ...," must be modified, because in one of the three fish they divided between the fourth and fifth intermuscular bones on both sides, and between the fourth and fifth on one side of each of the two remaining fish. To this extent they approached the condition in the Atlantic and California bluefin.

Complete skeletons of the three additional specimens were prepared, but only those structures were examined which had been shown previously to differ.

The pelvic girdle was in all cases saved intact. The differences noted in the text were confirmed, and this character serves therefore to differentiate the Australian southern bluefin from the California, and probably from the Atlantic variety.

The vertebral counts and characteristics agreed without exception with the table on page 33. The present material does not permit a more positive statement about the anterior face of the second centrum. It appears, however, that the shape of this centrum may prove to be an unsatisfactory character.

In agreement with the earlier findings the first ventrally extended parapophyses occurred on the ninth vertebra in all specimens. Also, the least width to height ratio of these parapophyses, although extended from 1.10–1.41, to 1.10–2.76 by this material, confirmed the conclusion that the Australian southern bluefin differed from the Atlantic and California specimens.

The shape and proportions of the first haemal arch are described in the text and used as a diagnostic character for separating the Australian southern bluefin. While this conclusion still remains valid, the description must be modified to include one aberrant specimen among the last three examined. In this fish, incidentally the smallest and normal in all other respects, the shape of the first haemal arch was transitional between the Australian type and the Atlantic-California type. In place of the typical and strikingly rounded arch illustrated, fish No. 5 possessed an arch that was triangular in external outline as in the Atlantic-California type. However, here the resemblance ceased, for this first arch was sufficiently wider than the subsequent ones so that looking anteriorly along the vertebral column, end on, one could see, not only the haemapophyses but the lateral portion of the enclosed canal of the first arch, which is impossible in existing examples of Atlantic and California fish. The shape of the aperture formed by this first haemal arch was quite different from the Atlantic-California type, and the writers had no difficulty in identifying this specimen in the collection. However, to include this extreme case, the description of this character should be modified as follows:

The opening of the first haemal arch is oval to round in outline, and relatively wide in the Australian southern bluefin, whereas it is triangular in outline and narrow in the Atlantic and California bluefin. In the Australian fish the distal margin (the apex) of the opening is broadly rounded, being nearly as wide at this point as at the base. In the Atlantic and California fish the triangular aperture of the first arch terminates distally in an apex that is sharply rounded and the width of the aperture at this apex is less than half the width at the base.

Measurements on these three fish yielded ratios for greatest width of opening to height of opening of: 1.26, 1.42 and 1.68, giving an average for the six Australian fish of 1.34, as compared with an average of 1.23 for the original three fish.

Additional observations upon the size of the first haemapophyses confirm and strengthen the conclusion that these structures in the Australian southern bluefin are noticeably weaker and measurably thinner than in the Atlantic and California bluefin. For the six Australian specimens the ratio of least width of the first haemapophyses to inside height of first arch averaged 10.44, with a range from 8.00 to 14.18.

One fish (again No. 5) of the last three necessitates a modification in the description of the haemal canal. Instead of having the greatest depth of canal within the first arch as in the five other fish, this one showed the greatest depth at the third arch as in the Atlantic and California bluefin. The value of this character is therefore lessened.

The various measurements and meristic counts made upon these three fish are recorded for reference.

Body length	687	674	710
Head length	211	204	219
First dorsal insertion	227	223	237
Second dorsal insertion	393	387	401
Anal insertion	433	422	443*
Ventral insertion	233	224	242
Greatest body depth	184	178	182
Greatest body width	124	123	136
Dorsal-ventral distance	178	174	180
Dorsal-anal distance	268	263	
Length, first dorsal base	173	171	177
Pectoral length	148	147	155
Height, first dorsal	81	66*	
Height, second dorsal	74*	72*	
Height, anal	82*	68*	
Length, second dorsal base	60	56	77*
Length, anal base	54	50	56*
Diameter of iris	30	31	32
Maxillary length	85	79	88
Ventral insertion—vent	206	201	
Body cavity length	237	232	242

* Approximate only.

6. REFERENCES

Castelnau, Francois L. 1873. Contributions to the ichthyology of Australia. R. Zool. Acclim. Soc. Victoria, Proc., vol. 2, p. 37–158.

Cuvier, Georges and Valenciennes, Achille 1831. Historie naturalle des poissons. Paris, vol. 8, p. 57–137.

Eschricht, Daniel Friedrich and Müller, Johannes. 1835. Uber die arteriösen und venösen Wundernetze an der Leber, und einen merkwürdigen Bau dieses Organes beim Thunfische (Thynnus vulgaris). Akad. Wiss., Abh., p. 1–32.

Frade, Fernando 1925. Sur l'anatomie de deux poissons scomberiformes: Thunnus thynnus (L.) et Auxis thazard (Lacép.). Soc. Portugaise Sci. Nat., Bull., vol. 10, p. 1–13.

1927. Sur la vessie natatoire du Thunnus obesus Lowe. Soc. Portugaise Sci. Nat., Bull., vol. 10, no. 7, p. 83–85.

1930. Anomalies chez le thon rouge. Soc. Portugaise Sci. Nat., Bull., vol. 11, no. 1, p. 1–5.

Fraser-Brunner, A. 1950. The fishes of the family Scombridae. Ann. Mag. Nat. Hist., vol. 3, no. 26, p. 131–163.

Godsil, H. C. and Byers, Robert D. 1944. A systematic study of the Pacific tunas. Calif. Div. Fish and Game Fish Bull. 60, 131 p.

Heldt, Henri 1927. Contribution à l'étude des races de thons (Thunnus thynnus L.). Charactéres biomètriques du thon tunisien et considerations sur sa croissance. Sta. Oceanogr. Salammbô, Ann. no. 4, p. 1–54.

1931. Le thon rouge et sa pêche: elements d'un nouveau rapport. Bibliographie du sujet. Sta. Oceanogr. Salammbô, Bull. 21, 165 p.

Jordan, David Starr and Evermann, Barton Warren 1926. A review of the giant mackerel-like fishes, tunnies, spearfishes, and swordfishes. Calif. Acad. Sci., Occ. Pap., no. 12, p. 8–25.

Kishinouye, Kamakichi 1923. Contributions to the comparative study of the so-called scombroid fishes. Tokyo Coll. Agric., Journ., vol. 8, p. 293–475.

Linnaeus, Carl 1758. Systema naturae. Editio decima, reformata, fasc. Brit. Mus. Nat. Hist. 1939, 297 p.

McCoy, Frederick 1885. Natural history of Victoria. Prodromus of the zoology of Victoria; or figures and descriptions of the living species of all classes of the Victorian indigenous animals. Melbourne, vol. 2, p. 21–25.

Malm, August W. 1877. Göteborg och Bohusläns fauna. Göteborg, p. 414–415.

Mastermann, Arthur T. 1894. On the skeleton of the tunny. Scotland Fish. Bd., 12 Ann. Rept., p. 272–283.

Moreau, Émile 1881. Histoire naturelle des poissons de la France. Paris, vol. 2, p. 418–430.

Sella, Massimo 1931. The tuna (Thunnus thynnus L.) of the western Atlantic. Inter. Rev. ges. Hydrobiol. u. Hydrogr. Bd. 25, heft 1–2, p. 46–67.

South, John Flint 1845. Zoology. *In* Encyclopaedia metropolitana. London, vol. 25, p. 620–622.

Starks, Edwin Chapin 1901. Synonomy of the fish skeleton. Washington Acad. Sci., Proc., vol. 3, p. 507–539.

Storer, David H. 1853. A history of the fishes of Massachusetts. American Acad. Arts, Sci., Boston, Mem., vol. 5, pt. 1, p. 143–145.

APPENDIX
DEFINITIONS

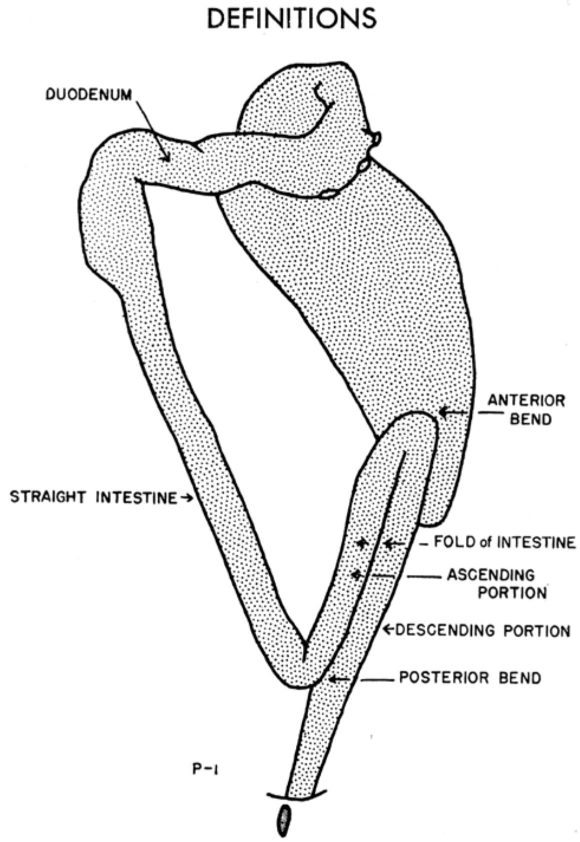

FIGURE 14. Explains the terms arbitrarily assigned in this publication to the various portions of the alimentary canal

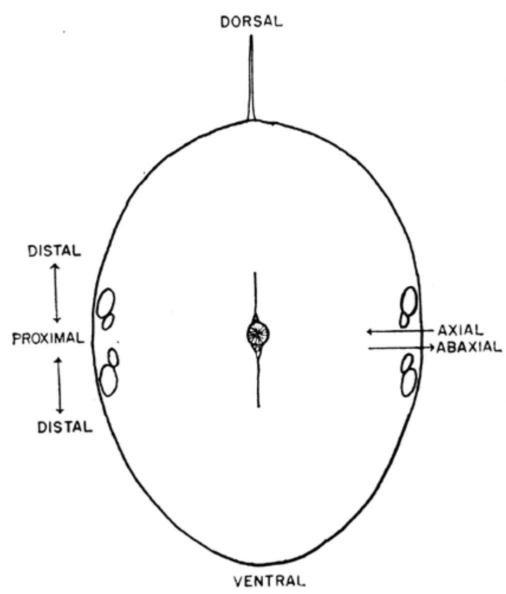

FIGURE 15. Defines the meaning of the terms used herein to describe the cutaneous blood vessels

DESCRIPTION OF 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.

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 six 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.

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.

Ventral Insertion to Vent Distance. This measurement was taken with the calipers. First, both ventral fins were held extended perpendicular to the body and a line of insertion was marked with the blade of a knife held flat against the extended first rays. The inside face of the fixed arm of the calipers was then placed against this mark, and the sliding arm was moved until its forward face coincided with the anterior margin of the vent. This gave a measure between two well defined points. It is a measure comparable with the internal body cavity length, and has the advantage that it can be made without dissecting the fish.

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.

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 percepitble 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.

ORIGINAL MEASUREMENTS

Body length	Head length	First dorsal insertion	Second dorsal insert.	Anal insertion	Ventral insertion	Greatest body depth	Greatest body width	Dorsal-ventral distance	Dorsal-anal distance	Lgth. first dorsal base	Pectoral length	Height first dorsal	Height second dorsal	Height anal	Lgth. second dorsal base	Lgth. anal base	Spread of caudal	Diameter of iris	Maxillary length	Ventral insert.—vent	Body cavity length
Atlantic bluefin																					
1270	367	393	694	774	400	331	*235	316	491	317	265	*140	....	179	109	192	....	38	136	....	449
1280	373	395	693	792	432	346	245	335	497	314	*269	142	....	*165	112	96	348	40	138	....	452
1285	376	401	706	781	415	366	256	338	505	327	266	*151	*170	*172	122	110	*368	39	140	....	455
1257	364	399	703	782	416	339	*236	325	489	318	*250	149	167	164	126	100	*365	37	140	....	466
1307	371	399	712	792	413	331	231	320	495	329	*257	*139	190	180	125	106	*377	40	141	....	449
1314	386	414	*725	814	446	357	250	343	507	*325	*285	144	183	189	*135	94	*389	41	149	....	462
Australian southern bluefin																					
*981	295	309	554	614	347	266	186	260	387	251	219	109	132	127	82	69	....	35.5	113	275	*312
920	280	304	515	564	322	248	171	242	348	222	206	114	....	....	75	71	....	32.0	108	246	286
924	280	301	524	572	319	252	178	246	356	229	211	109	....	*120	84	78	....	36.0	111	253	....

CALIFORNIA BLUEFIN

California bluefin

691	214	231	409	460	241	203	140	196	298	187	128	75	68	66	62	57	*151	28	84	------	------
723	229	246	421	470	250	210	143	199	305	189	------	83	------	*76	76	67	*205	30	90	------	265
716	213	238	417	*460	237	192	145	188	295	189	131	*78	------	------	78	------	------	*27	81	------	256
729	224	246	433	476	245	214	135	197	306	200	138	*79	------	------	79	79	------	30	91	------	262
727	219	236	421	483	246	202	146	190	305	191	143	79	*76	*79	*85	57	------	29	85	------	275
718	225	238	418	480	253	210	146	200	303	188	130	84	74	76	74	69	*241	30	90	------	271
638	197	207	370	421	219	179	*114	168	269	170	114	58	63	60	67	56	171	28	77	------	229
637	196	213	366	418	215	177	123	170	262	160	107	76	*70	65	75	47	171	27	77	------	243
628	194	206	370	412	214	171	117	164	262	171	*119	71	*63	62	62	55	*166	28	78	------	229
666	199	218	387	437	226	181	117	176	279	178	118	71	66	65	69	60	183	28	79	------	248
659	200	216	383	435	223	179	121	171	274	173	116	68	*67	64	71	49	*164	28	78	------	243
655	195	218	375	427	221	189	118	177	270	166	124	74	65	62	67	62	*156	28	78	------	258
665	206	226	385	437	226	180	118	176	272	168	117	72	68	------	65	48	*150	28	83	------	251
888	263	284	501	570	296	250	*161	233	358	225	176	*80	------	*91	99	80	*233	*33	106	------	341
716	222	233	412	472	249	208	133	194	304	184	148	------	*78	------	72	69	------	28	88	------	272
682	208	227	399	448	230	198	136	181	284	177	121	------	------	*73	75	63	------	*28	86	------	288
678	210	227	390	455	237	199	125	189	286	169	133	77	------	*71	69	62	*183	28	82	------	259
629	195	213	371	412	216	173	113	165	261	167	116	66	------	*56	68	61	160	27	79	------	238
726	225	245	429	480	253	204	133	201	298	192	142	81	*83	78	74	63	*192	28	88	------	270
753	228	253	431	489	253	215	144	208	309	188	145	*73	------	------	79	67	*180	28	89	------	291
717	226	246	420	469	250	217	142	203	297	182	139	*70	*80	*75	76	64	------	29	89	------	265
709	217	236	407	458	242	207	140	198	294	180	*134	79	------	------	69	*61	185	*29	85	------	264
844	255	282	491	540	286	245	166	236	347	223	163	*96	99	102	86	74	233	31	101	263	318
707	217	233	414	464	244	206	139	196	298	188	130	*85	*76	------	75	68	184	29	87	231	260
682	209	220	397	457	231	189	144	179	290	183	124	76	------	74	65	62	156	28	81	231	256
1382	415	433	773	869	454	------	------	------	------	------	------	------	------	------	------	------	------	------	------	441	------
1412	420	445	795	885	472	------	------	------	------	------	*267	------	------	------	------	------	------	------	------	430	------
*1341	*397	*419	*764	*854	*429	------	------	------	------	------	*263	------	------	------	------	------	------	------	------	438	------
1456	424	457	808	918	475	------	------	------	------	------	*292	------	------	------	------	------	------	------	------	458	------
1482	432	459	823	920	478	------	------	------	------	------	*246	------	------	------	------	------	------	------	------	466	------
1387	401	429	768	877	*464	------	------	------	------	------	*270	*145	*178	*185	149	------	------	------	------	------	------
1418	407	443	792	882	460	------	------	------	------	------	273	161	*184	*192	145	------	------	------	------	------	------
1391	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	494
1533	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	529
1401	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	476
1396	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	480

* Approximate only.

CALIFORNIA BLUEFIN