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A COMPARISON OF EASTERN AND WESTERN ATLANTIC BLUEFIN TUNA (*THUNNUS THYNNUS*) WITH REFERENCE TO STOCK DIFFERENCES

by

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INTRODUCTION

The Atlantic bluefin tuna (Thunnus thynnus) has been subjected to increased commercial and recreational exploitation during the past few years on both sides of the Atlantic. This has brought about the need to take immediate, preliminary measures to manage the fishery on an international basis. One of the basic requirements in managing a fishery, however, is to determine if more than one stock or population is involved. No definitive information on this subject is available for Atlantic bluefin.

The purpose of this study is to present information indicating that at least two independent populations of bluefin tuna occur in the Atlantic Ocean. Our conclusions are based on the analysis of meristic, morphometric, and other data collected since 1952. In that year, Mather began to obtain measurements and counts of bluefin from the New England area and Rivas did the same in the Bahamas. Additional morphometric data have been obtained from the Bahamas and the New York and New England areas since 1974.

In 1952, Rivas obtained measurements and counts of bluefin tuna in the Bay of Biscay and the North Sea. In 1974, these data were compared with similar data from the western Atlantic on the basis of 42 morphometric and 11 meristic characters. Admittedly, the European sample was small, only 28 fish, but the analysis gave strong indication that the eastern and western Atlantic samples differed in the number of pectoral rays and in the length of the second dorsal fin. In order to obtain a larger eastern Atlantic sample, Rivas spent part of the summer of 1975 measuring fish from various European fisheries.

This study is based on 691 western Atlantic specimens, 264 to 2700 mm fork length (FL), and 583 eastern Atlantic specimens, 124 to 2510 mm FL. Fork length was measured from the tip of the snout (upper jaw) to the margin of the middle caudal rays. The second dorsal fin was measured from its origin to its tip with the fin in its natural position. Measurements were taken in a straight line with slide calipers to the nearest millimeter.

In addition to the measurements and counts, other characters indicating stock differences are also discussed.

SPAWNING GROUNDS AND SEASONS

The known spawning grounds of the western Atlantic bluefin tuna are restricted to the Gulf of Mexico and the Straits of Florida and those of eastern Atlantic bluefin are in the Mediterranean and Black Seas (Richards, MS.). There is no evidence that bluefin tuna spawn between these areas. The eastern and western Atlantic spawning grounds, therefore, are separated by a distance of about 4000 miles and located at different latitudes; south of latitude 28° N on the western side and north of latitude 35° N on the eastern side.

In addition to their isolation from each other, the different latitudinal locations of the two spawning areas have different environmental conditions and overlapping spawning seasons. In the western Atlantic, spawning takes place in April, May, and June at ocean temperatures ranging from 25° C to 30° C (Rivas, 1954; Richards, MS.). On the other hand, in the eastern Atlantic, spawning occurs in June, July, and early August at temperatures ranging from 19° C to 26° C (Richards, MS). On August 14, 1975, Rivas collected nine young bluefin 138 to 169 mm FL off Castellón, Spain (Mediterranean). These specimens are estimated to be about 40 to 60 days old.

Nearly simultaneous widely separated spawning on each side of the Atlantic at different temperatures may be considered as an indication of two separate stocks. As a result of early growth in markedly different temperatures, it would be expected that eastern and western Atlantic fish would differ in a number of characters related to early developmental rate. This is shown and discussed below in the sections dealing with gillrakers in juveniles.

SIMULTANEOUS LATITUDINAL DISPLACEMENTS

It is now well established, as summarized by Mather et al (MS.), that bluefin tuna of similar size show a similar pattern of latitudinal displacement, at about the same time, on each side of the Atlantic. In the Atlantic, bluefin tuna migratory movements differ according to three distinctive size groups which are similar on both sides of the Atlantic. The giant size group comprises fish 200 cm FL or longer, medium size fish range from 135 to 200 cm, and the small fish measure less than 135 cm FL.

In the western Atlantic, giant bluefin tuna migrate northward after spawning (April-June) to New England and Canada. On the other hand, during July through November, the fish are present in the northern area but absent in the southern (Rivas, MS.). In the eastern Atlantic, a similar pattern of displacement takes place at about the same time. During November through February the giant fish are present in the Canary Islands (Santos-Guerra, 1975) but absent in waters to the north. In May through July giant fish are present off southern Spain and Morocco and in the Mediterranean (Sacchi, pers. comm.) but absent in the Canary Islands, the Bay of Biscay, the North Sea, and Norway. During August through October, however, the eastern Atlantic fish are present in the northern areas but absent in the southern. Mather et al (MS.) have shown by tag returns that an unknown number of giant fish migrate occasionally from the Straits of Florida to Norway In September 1975, Rivas examined 178 giant bluefin landed near Bergen, Norway, of which 53 were measured. All the fish, both males and females, were long spent and preliminary analysis of the morphometric data indicates that they may constitute a mixture of giants from the eastern and western Atlantic.

Medium size bluefin are not known to occur in the southern areas of their ranges on either side of the Atlantic at any time of the year. In the western Atlantic this group is apparently absent from northern waters in the spring but present in the summer, fall, and winter. Conversely, these fish are present off the North American east coast, between Puerto Rico and the area east of Cape Hatteras, in the winter and spring but apparently absent in the summer and fall (Rivas, MS.). In the eastern Atlantic, medium size fish are also absent from northern waters in the winter and spring but present in the summer and fall. Medium size fish are present in the Mediterranean throughout the year (Sacchi, pers. comm.).

The seasonal distribution pattern for the small fish is similar to that of the medium size fish for the western and eastern Atlantic. Young-of-the-year, however, occur in the Gulf of Mexico and the Straits of Florida northward to New England in the summer and fall and in the Straits of Florida in the winter (Rivas, 1954). Similarly, in the eastern Atlantic, young-of-the-year are found off the Atlantic coast of Morocco and in the Mediterranean Sea in the summer and fall (Mather et al, MS.) and in the Canary Islands in the winter (Santos-Guerra, 1975).

Simultaneous occurrence of similar sizes and similar seasonal displacements by size group on each side of the Atlantic is, in our opinion, another indication of two separate stocks. It would be difficult to accept the presence of only a single stock unless the rhythms discussed above occured in an alternating fashion or from east to west or west to east.

As to the giants off Norway, their gonad condition, the time of year, and the low water temperature would seem to preclude the possibility that these fish are breeding in that area. Whether they are all western Atlantic or eastern Atlantic fish, or a mixture of both, the likelihood of gene exchange is very remote.

GILLRAKERS IN JUVENILES

Young and adult bluefin tuna about 100 mm long and larger from both sides of the Atlantic, have the same total number of gillrakers which ranges from 34 to 43. The mean for the western Atlantic is 38.8 and that for the eastern Atlantic is 38.7. There is no ontogenetic variation in the young and adult. In juveniles up to about 100 mm long, however, the number of gillrakers increases with length as shown by Potthoff (1974). Although Potthoff had juveniles from both sides of the Atlantic they were all combined in his paper and no distinction was made between eastern and western Atlantic. He had noted, however, that juveniles of the same size from each side of the Atlantic differed in the number of gillrakers (pers. comm.). Potthoff has kindly turned over to us his original data and we are now able to verify his findings.

There is a total of 97 juveniles in Potthoff's material of which 27, 16.0 to 88.5 mm. long, are from the western Atlantic (Gulf of Mexico and Straits of Florida) and 70, 13.9 to 117.5 mm., are from the Mediterranean Sea. In order to make the two samples strictly comparable only 30 of the Mediterranean juveniles were used so as to obtain a mean length comparable to that of the 27 western Atlantic juveniles. This was done by selecting at random from the Mediterranean sample as many juveniles as possible equal to, or nearly equal in length to, each of the 27 juveniles in the western Atlantic sample. A comparison between the two samples follows.

	N	Length (mm)	$\bar{X}$	Gillrakers	$\bar{X}$
Western Atlantic	27	16.0 - 88.5	37.3	15-39	27.4
Eastern Atlantic	30	16.3 - 87.5	37.3	13-36	25.0

The difference between the means is 2.4 which is 8.76 percent of the highest mean and no statistical test is necessary to show that the difference is significant. It follows, therefore, that in eastern and western Atlantic juveniles with the same number of gillrakers, the western Atlantic specimens are significantly smaller. For example, in juveniles with 18 gillrakers the western Atlantic specimens have a mean length of 17.8 mm. and the mediterranean ones 20.8, a difference of 14.4 percent. If we consider juveniles with the same number of gillrakers as being at the same stage of development then the western Atlantic juveniles have a faster rate of gillraker development and attain their full complement at a smaller size than those in the Mediterranean. We interpret the above differences between eastern and western Atlantic juveniles as another indication of two separate stocks.

PECTORAL FIN RAYS

Analysis of pectoral fin ray counts shows that eastern Atlantic bluefin tuna have fewer pectoral rays than those from the western Atlantic. There is no ontogenetic variation in the number of pectoral rays at least in specimens larger than 100 mm. FL. The following comparison is based on 192 eastern Atlantic specimens 124 to 2510 mm. FL and 64 western Atlantic specimens 264 to 2534 mm. FL. The standard deviation (S.D.) and the standard error (S.E.) are given in addition to the frequency distribution and mean (Fig. 1).

	N	30	31	32	33	34	35	36	37	$\bar{X}$	S.D.	S.E.
Eastern Atlantic	192	7	32	73	61	17	1	1		32.3	1.02	0.07
Western Atlantic	64			10	18	18	11	6	1	33.8	1.26	0.16

On the average, western Atlantic bluefin tuna have 1.5 more pectoral rays than eastern Atlantic fish. The difference between the means (1.5) is more than twice three standard errors (0.21) of the eastern Atlantic mean plus three standard errors (0.48) of the western Atlantic mean (0.69). The difference between the means, therefore, is highly significant and there is a 99.73 percent probability that the samples were drawn from different populations. The difference in number of pectoral rays, therefore, is strongly indicative of two separate stocks.

SECOND DORSAL FIN LENGTH

The second dorsal fin is significantly longer in the western Atlantic bluefin tuna than in the eastern Atlantic bluefin. We have analyzed and expressed this difference in two different ways and both methods have produced the same results.

The linear regression and covariance analysis are based on 691 western Atlantic specimens 264 to 2493 mm. FL and 573 eastern Atlantic specimens 570 to 2510 mm. FL. Because the growth of the second dorsal fin relative to linear growth is positively allometric the relationship between fork length and second dorsal fin length is curvilinear. For this reason, we have used natural logarithms of the original measurements in order to obtain straight lines (Fig. 2). The regression equation for the western Atlantic fish is:

$$\ln SD = -4.20748 + 1.30960 \ln FL$$

where SD is sedond dorsal fin length in millimeters and FL is the fork length in millimeters. The regression equation for the eastern Atlantic fish is:

$$\ln SD = -4.15506 + 1.29435 \ln FL.$$

Analysis of covariance was conducted to determine if there was significant difference between the regressions for western and eastern Atlantic fish. There was no difference between the two regression coefficients: $F_{(1,1229)} = 0.71$. The test for adjusted means, however, showed a highly significant difference: $F_{(1,\ 1229)} = 202$.

The difference between the eastern and western Atlantic fish was slso analyzed in terms of the second dorsal fin length as the percent of the fork length. Because of the allometric growth of the second dorsal fin, as mentioned above, this method is only valid if the samples compared are of similar mean fork length. In order to eliminate this source of error and make the samples strictly comparable we used only 442 western Atlantic specimens 800 to 2298 mm. FL and 468 eastern Atlantic specimens 800 to 2250 mm. FL. For each side of the Atlantic this material was subdivided into four equivalent length intervals within each of which the mean fork length is similar in both samples. In the following comparison the standard deviation (S.D.) and the standard error (S.E.) are given in addition to the frequency distribution and mean (Fig. 3).

800-1199 mm FL

	N	$\bar{X}$FL	10	11	12	13	14	15	16	17	$\bar{X}$	S.D.	S.E.
W. Atlantic	123	987		11	36	47	21	4	2	2	12.9	1.16	0.11
E. Atlantic	160	933	1	50	77	27	5				11.9	0.79	0.06

1200-1399 mm FL

	N	$\bar{X}$FL	11	12	13	14	15	16	17	$\bar{X}$	S.D.	S.E.
W. Atlantic	92	1290	1	2	17	42	23	5	2	14.2	1.01	0.11
E. Atlantic	142	1290	1	27	75	36	1			13.1	0.71	0.06

1400-1899 mm FL

	N	$\bar{X}$FL	12	13	14	15	16	17	$\bar{X}$	S.D.	S.E.
W. Atlantic	140	1627	1	12	55	45	20	7	14.7	1.02	0.09
E. Atlantic	125	1583	12	49	44	18	2		13.6	0.91	0.08

1900-2299 mm FL

	N	$\bar{X}$FL	13	14	15	16	17	18	19	20	$\bar{X}$	S.D.	S.E.
W. Atlantic	87	2140		6	24	31	15	10		1	16.0	1.18	0.13
E. Atlantic	43	2030	3	18	10	9	2	1			14.8	1.14	0.17

In each of the size groups analyzed above the difference between the means is much greater than three standard errors of the western Atlantic mean plus three standard errors of the eastern Atlantic mean. The difference between these means, therefore, is highly significant and there is a 99.73 percent probability that the samples were drawn from different populations.

The two analytical approaches employed both indicate that the second dorsal fin is significantly longer in the western Atlantic bluefin tuna. This difference, therefore is strongly indicative of two separate stocks.

DISCUSSION

In the ICCAT working document prepared by Mather et al (MS.) data relevant to the identification of Atlantic bluefin tuna stocks were presented and discussed. Their comments were mainly concentrated on stock structure in the Mediterranean and eastern Atlantic and stock structure in the entire North Atlantic Ocean. Since, in this study, we are not concerned with comparisons between the Mediterranean and the eastern Atlantic, we will confine our discussion to stock differences between the eastern and western Atlantic.

Mather et al presented arguments for a single versus two stocks and following their discussion they concluded that the available evidence precluded clear cut conclusions. They stated, however, that the greatest weight of evidence favored the existence of two Atlantic stocks, one on each side of the Atlantic. To this they added that, for management purposes, it must be recognized that important interchanges between the two proposed stocks occur on an apparently erratic and unpredictable basis. We agree with this statement but hasten to point out that the evidence presented in this paper tends to weaken the importance of occasional interchange.

On the basis of the meristic, morphometric, and other data presented in this paper we are of the opinion that the eastern and western Atlantic bluefin tuna each represent a separate population or stock. No specimens for study are, as yet, available from the mid-Atlantic. As far as meristic and morphometric characters are concerned, if and when these specimens are available, three possibilities may be predicted. (1) The fish are intermediate between the eastern and western Atlantic; if so, this would indicate a clinal distribution and continuous spawning across the North Atlantic and the presence of only one stock. (2) The fish belong to either the eastern or western Atlantic group and no intermidiate specimens occur; in this case two separate stocks are indicated with little or no gene exchange between them. (3) The fish are a mixture of both groups in which case again two separate stocks are indicated. It is evident, of course, that the age, sex, sexual maturity, and season of occurrence will have to be considered, in addition to morphometric characters, to determine the status of these fish.

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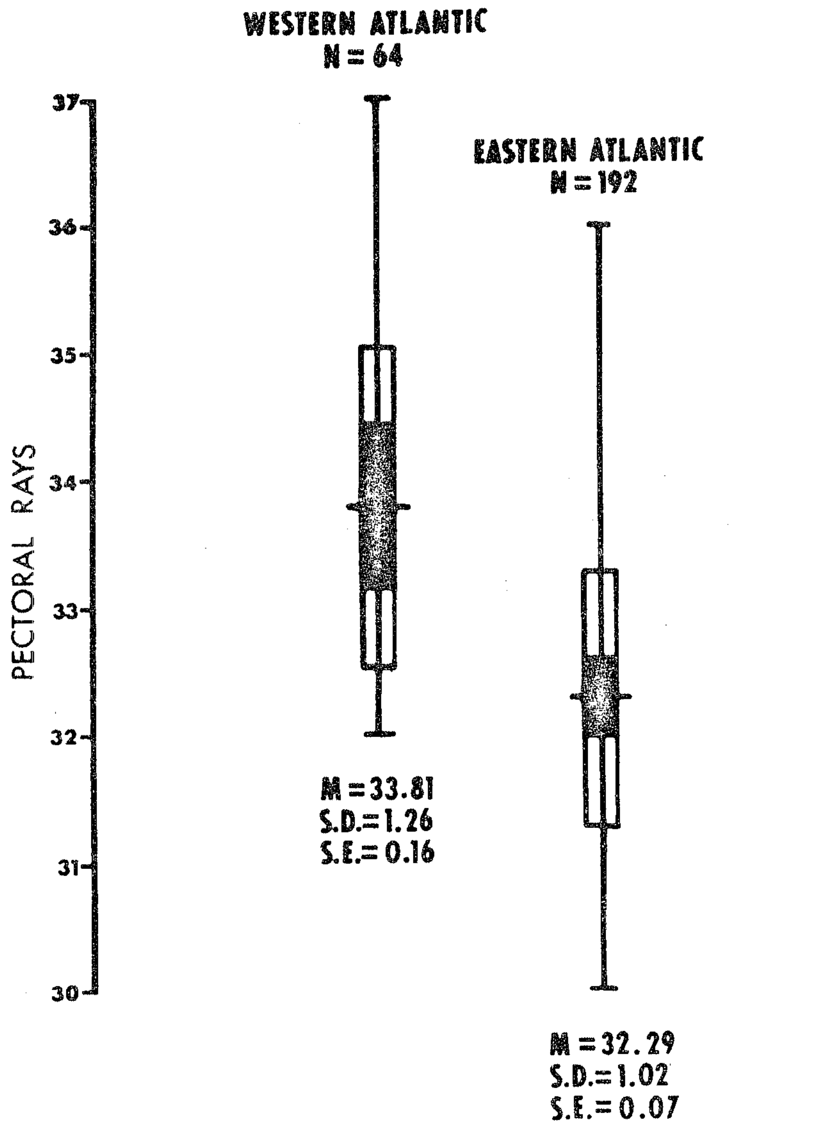

Figure 1. Comparison of number of pectoral fin rays in western Atlantic (left) and eastern Atlantic (right) bluefin tuna. Vertical line represents the range and the short horizontal line the mean. The white bar represents one standard deviation on each side of the mean and the black bar four standard errors on each side of the mean. See text for further explanation.

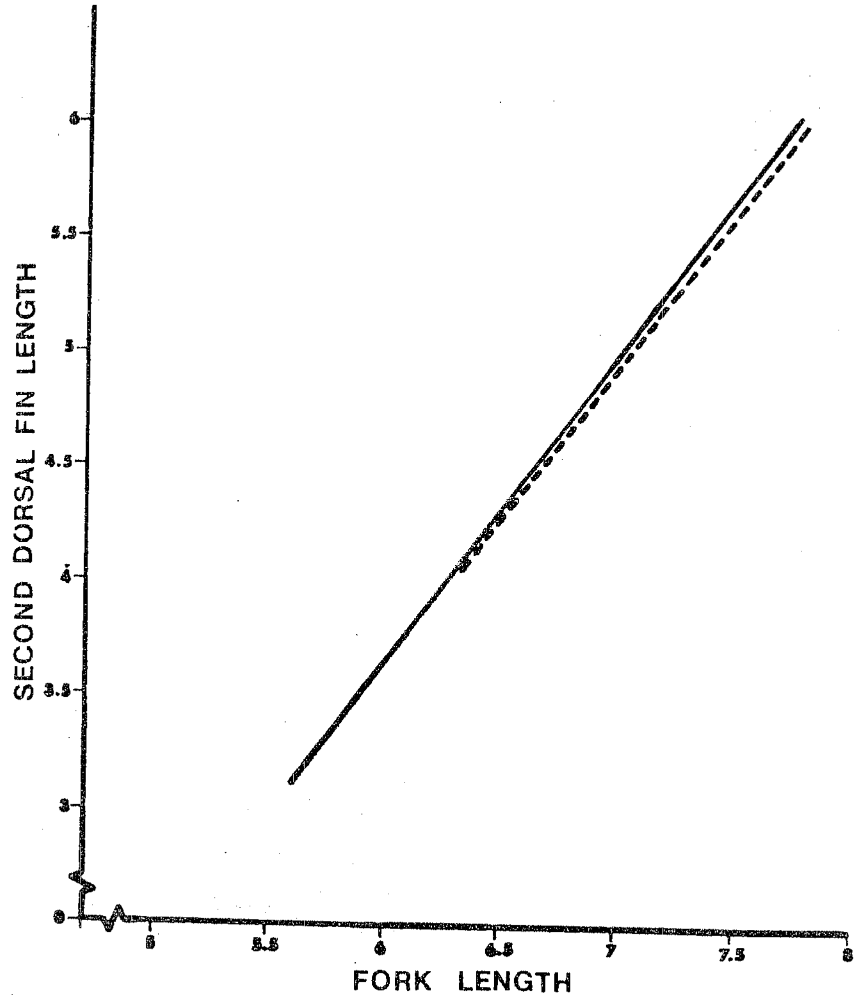

Figure 2. Regression of natural logarithm of second dorsal fin length against natural logarithm of fork length for western (solid line) and eastern (broken line) Atlantic bluefin tuna. See text for further explanation.

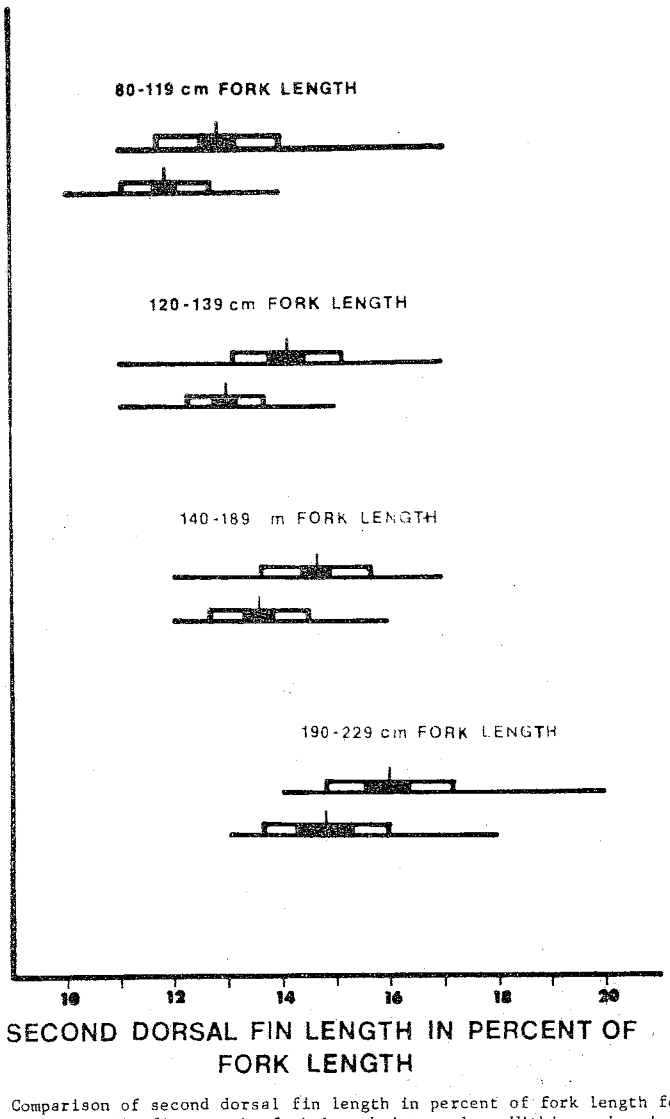

Figure 3. Comparison of second dorsal fin length in percent of fork length for western and eastern Atlantic bluefin tuna by fork length intervals. Within each pair of comparisons the western Atlantic data are above those for the eastern Atlantic. Horizontal line represents the range and the short vertical line the mean. The white bar represents one standard deviation on each side of the mean and the black bar three standard errors on each side of the mean. See text for further explanation.