SCRS/1993/077 Col.Vol.Sci.Pap. ICCAT, 42 (1) : 250-254 (1994)

A REEXAMINATION OF THE STOCK STRUCTURE HYPOTHESES FOR ATLANTIC BLUEFIN TUNA

Hester, F.

East Coast Tuna Association

SUMMARY

The hypothesis that Atlantic bluefin tuna can be managed as two separate stocks, one in the eastern Atlantic and Mediterranean and one in the western Atlantic, is examined in the light of recent tag recovery information, changes in fishing patterns, and other information. The history of the line dividing the two putative stocks is reviewed. Alternative stock hypotheses for management purposes are developed.

RESUME

L'hypothèse que le thon rouge de l'Atlantique peut être géré en tant que deux stocks distincts, l'un dans l'Atlantique est et la Méditerranée et l'autre dans l'Atlantique ouest, est examinée à la lumière des informations récentes de marquage-recapture, les modifications des caractéristiques de la pêche et autres informations. L'évolution de la ligne délimitant les deux stocks supposés est examinée. D'autres hypothèses du stock pour les besoins de la gestion sont élaborées.

RESUMEN

A la luz de la reciente información sobre recuperación de marcas, cambios en los tipos de pesca y otro tipo de información, se examina la hipótesis de que el atún rojo del Atlántico puede ser ordenado como dos stocks separados: uno en el Atlántico este y Mediterráneo y otro en el Atlántico oeste. Se revisa la historia de la línea que divide los dos supuestos stocks. Se desarrollan hipótesis alternativas de stock con fines de ordenación.

INTRODUCTION

Present Management.

The last time the SCRS considered that there was a single stock of Atlantic bluefin tuna for management purposes was in 1982. Since that time the SCRS has considered only the two stock hypothesis with the line of separation as defined by ICCAT (1982). In fact, this separation of the ocean has become so ingrained in the assessment process that the SCRS has devoted separate meetings to the separate assessments.

There were several reasons for the separation of the stocks. These reasons include biological differences in the basic biology of the fish found on the two sides, in particular differences in growth rates and estimates of age at maturity (see for example Baglin, 1982, Cort and Liorzou, 1991), although recently these difference have become less apparent with the adoption of a new growth equation for the west (Turner, Restrepo and Eklund, 1991). Second, there are two widely separated spawning areas for Atlantic bluefin. Although there are records of trans-Atlantic migration based on mark-recapture experiments and opportunistic tagging, and other evidence, the rates of exchange have been thought sufficiently small and sporadic as not to separate the species into two stocks, at least for management purposes. Finally, there was the practical need to manage the fisheries. The quality of fishery data from east was not as complete as in the west, and the ability to make meaningful management recommendations that would be followed were less for the eastern fisheries, which include a number of non-ICCAT nations that fish bluefin. These reasons are less compelling today. New information indicates that the separation of stocks for management purposes should be reexamined to see if effective management can be achieved under the current hypothesis.

THE PROBLEM

The Division.

The division of the Atlantic into east and west for stock assessment first appears in Parrack (1980) who noted: "A separate analysis was required assuming a completely isolated West Atlantic population so that it was necessary to compile the catch under that assumption. Since longline catch per effort show a continuous distribution of fish across the Atlantic and mark-recapture data document frequent transatlantic movement (Brunenmeister 1979), the identification of catches from the hypothesized separate western stock was not obvious. Therefore, in order to define catches from a separate stock for analysis purposes, a geographical separation line approximately equidistant from eastern and western continents was arbitrarily defined as beginning at 40°W 60°N and proceeding to 40°W 10°N...".

The next reference to the line appears to be in the 1981 management recommendations by Panel 2 on Bluefin (ICCAT 1982). Here, and without explanation the northern segment of the line is move west 5-degrees to 45° west longitude.

Here the line has remained. It was originally placed arbitrarily, and without any biological basis or by reason of the location of fishing areas, at 40°W. It was then moved west to 45°W without a documented reason. Today, there are several reasons to reexamine the line. One is the recent shift in area by the Japanese winter bigeye/bluefin fishery (Suzuki, 1992). This fishery provides catch and effort data used as an index of abundance for medium and small giant by the SCRS. Substantial effort has shifted east of the line. In order to continue to use information from this fishery to develop an abundance index coverage for catch and effort data and length-frequency data should encompass the entire span of this fishery.

A second reason for a reexamination is that catches east of the line are not included in the analysis because of the tacit acceptance of the two stock hypothesis. The catches may be substantial and the effect of their exclusion should be examined.

Finally, the most important reason to reexamine the matter is not to decide on the placement of a dividing line *per se*, but rather to decide if current knowledge supports dividing the Atlantic into two stocks. Present ICCAT management recommendations place catch and some additional size limitations on fisheries to the west of the line whereas the management recommendations for the fisheries east of the line are only to cap fishing effort to pre-1975 levels and to observe a 6.4 kg minimum size. Neither recommendation has been followed to any degree. If, indeed there is a single stock in the Atlantic, or if there are two stocks with sufficient mixing between east and west, then the usefulness of imposing managing measures only in the west needs to be reviewed.

THE DATA

Spawning Areas

The occurrence of bluefin tuna larvae in plankton tows made it possible to document the existence of two spawning areas, the Gulf of Mexico, and the Mediterranean. Larvae also occur in the southwest Atlantic from Florida to the Carolinas (Berrien *et al*, 1978), but these are believed likely to be larvae produced in the Gulf of Mexico and swept out in the Florida Current. Despite speculation that other spawning areas exist, perhaps off the mid-Atlantic states of the US., no evidence has been found to support this speculation. Medium fish with well developed ovaries, but without hydrated eggs are take from time to time in the summer fishery off the US. Where and when these fish spawn is unknown., perhaps the Mediterranean, as extensive plankton samples have failed to show the presence of bluefin larvae in other than the previously mentioned areas, yet fish tagged off the US have been recaptured in the Mediterranean ((see below).

The situation in the Mediterranean is different than in the Gulf of Mexico. Because of the evaporative losses by this landlocked sea, high salinity surface water sinks and is replaced by surface water coming in from the Atlantic through the Strait of Gibraltar. This influx must, except under unusual circumstances, prevent fish larvae from leaving the Mediterranean for the Atlantic in significant numbers. Thus a situation such as is found in the Gulf of Mexico -Florida Strait does not exist in the east. Only older fish, as a rule, can move from the Mediterranean into the Atlantic, which may be one reason for the occurrence of large numbers of young fish there.

Spawning areas in the Mediterranean are widely scattered, which has lead some to suggest more than one spawning stock of bluefin occur there. Furthermore, in the past spawning also occurred in the Black Sea, although that "stock" appears" to have disappeared. Of more immediate interest is the localized distribution of tuna larvae in the east and the west Mediterranean (Piccinetti *et al., 1992).* The distribution of larvae suggests, as does the fishery data, that more than one spawning stock may occur there.

Fisheries.

There are two general types of fisheries for bluefin in the North Atlantic. These are the surface fisheries in the east and the west, and the fisheries for deep swimming bluefin throughout the area. The surface fisheries are nicely separated by some 5,000 km of ocean. Were is not for the recapture in a fishery on one side of the Atlantic of a fish marked in a fishery on the other side, it would be easy to postulate two separate stocks (Suzuki, 1989). Data from most of the surface fisheries are available and some provides useful information about stock identity.

Murphy (1991) reviewed the work of Cort and Rey (1984) on the distribution of young fish in the east Atlantic and the Mediterranean. He interprets their study as indicating young fish of unproven origin move eastward in the north Atlantic current to join juvenile fish already present along the eastern Atlantic seaboard. To Murphy (Ibid.) "the most logical source of these fish appears to be the Gulf of Mexico spawning ground".

His interpretation was that fish from the Atlantic enter the Bay of Biscay fishery early in the summer where they are supplemented by fish from the south. He did not believe these southern fish to be of Mediterranean origin, but subsequent tag returns proved him wrong. None-the-less, his hypothesis suggests there might be some relationship between catches of young fish in the Bay of Biscay, at least at the beginning of the season and catches of young fish off the Mid-Atlantic coast of the US. It is difficult to find data to test this hypothesis since the US. fishery for small fish is both subject to geographical changes in availability that the boats, which operate from home ports chiefly in the vicinity Cape Hatteras, have difficulty following (Brown and Lucy, 1991), and subject to changes in regulations that affect catches. On the other side, the most readily available information is found in the two indexes of abundance used by the SCRS in the 1991 assessment. These are for Spanish bait boats (SBB) in the bay of biscay, and French Purse Seiners (FPS) in the Gulf of Lyon. These indexes are on age-2 fish. Cort (1989) presents monthly CPUE estimates for the SBB. A comparison of the three data sources shows that for the years of overlap, 1982-1988, there is some correlation between the US. catch of age-2 fish and the Spanish bait boat index for July (R^2= 0.52 d.f..= 5), whereas the correlation between the French Purse seine index and the July SBB CPUE is R^2= 0.06 d.f. = 5. The relationship improves as the season progresses so that in August the FPS-SBB R^2= 0.28 and in September 0.43. None of the correlations are significant. The suggested support for Murphy's hypothesis would be more compelling if the 1973 year class, which was a good marker in the west, showed well in the east. The SBB index, however, indicates no remarkable occurrence in July that could be attributed to a large 1973 year class.

To examine this matter further I compiled a series for catch in numbers of age 2 fish in the west. I standardized the first part of the series from 1970 to 1982 to the catch at age for age 2 in 1975. I standardized the remainder of the series to catch of age two in 1992. I did this because regulatory changes in 1982 greatly reduced the catch of small fish in the west. I chose age 2 fish for the US. catch since selectivity is greatest on that age group in most years. I ignored the fact that US. purse seine catches of small fish were regulated beginning about 1977, which makes the part of the series from 1977 to 1982 not directly comparable to the earlier part of the series, or the latter part.

For the Bay of Biscay fishery I used catch of age 3 fish standardized to 1982, the year of highest catch. I did this on the assumption that most of the catch by the French and Italian purse seiners was on ages 0, 1 and 2, and the age 3 catch came mostly from the Bay of Biscay. I also developed a catch series for age 0 fish for the east standardized to the high catch year of 1985. These series are presented in Table 1, and plotted in Figs. 1 and 2.

In Fig.1 the catch of age 2 for the west is advanced one year to coincide with catch at age 3 in the east. In Fig.2. the catch at age 0 is advanced three years for the same purpose.

What is interesting in Fig. 1 is the coincidence of high catches in 1976 (the year refers to the east) from the 1973 year class on both sides of the Ocean. There also appears to be some synchrony of catches for other "strong" year classes, particularly since 1982. Such synchrony is not apparent in Fig. 2, which compares catch at age 0 to catch at age 3 in the east.

What is the explanation? Three come to mind: 1.) It is an artifact of the data and method. 2.) The is synchrony in spawning in the Gulf of Mexico and the Mediterranean with ages 2 and 3, (but not age 0 in the east) indexing spawning success. Or 3.), there is a shared component of young fish in the Atlantic, at least in some years.

In the fisheries for deep swimming bluefin, there were prior to 1982, four distinctive fishing grounds, the spring longline fishery for spawning bluefin in the Gulf of Mexico, the winter longline fishery for bigeye tuna and medium bluefin of the northeast coast of North America, the winter-spring longline fishery for giant bluefin in the east Atlantic and the late spring-early summer longline fishery for spawning bluefin in the Mediterranean Sea (Parrack, 1982).

Until recently, these fisheries indicated an apparent separation between east and west for the deep swimming fish as well. However, beginning about 1988 effort and bluefin catches in the winter fishery of the north west Atlantic expanded to the east. At present the distribution of catches links this fishery with the winter-spring eastern Atlantic fishery (See Miyabe, 1992 and Suzuki 1992), and there appears to be a continuous distribution of medium and large bluefin across the Atlantic.

Tagging.

The tagging information is difficult to interpret since tagging experiments have been carried out sporadically, or not for stock identification purposes. Several early reviews indicate interchange between east and west, c.f. Brunenmeister 1980. More recent data show similar patterns including sporadic crossings by groups of small fish. There is direct evidence of small fish large enough to be caught and tagged, crossing the Atlantic from one fishing ground to the other, e.g. Bay of Biscay to the mid-Atlantic coast of North America and between the Mediterranean and the Atlantic (Cort and Rey 1985). In this regard, it is interesting to note four more small fish tagged of the coast of North America in 1990 and 1991 were recaptured in the Bay of Biscay in 1992 and 1993 (NMFS, Miami communication).

Mark-recapture experiments are one of the most valuable methods of obtaining information on mixing and separation among fisheries. To be useful, the experiments need to be carefully designed. Analysis of existing data to determine mixing rates so far has been problematic. It may be there is sufficient information in the ICCAT data files to permit meaningful assessment. One difficulty is that current information is not always made available to the Secretariat in timely fashion. . The ICCAT data base still lacks records for the more recent years, and past records still require auditing for completeness, accuracy, and formatting.

Biochemical

Calaprice (1986) used nuclear activation chemical techniques to determine the ratios of element in tuna hard parts in an attempt to separate fish into geographical/geochemical "stocks". His results were inconclusive, but generally supportive of mixing rates in the order of 10-12 percent assuming regular mixing between east and west. Turner points out (pers. comm.) that if, fish move only once in its lifetime, the exchange rate must be prorated over the life span, which reduces these estimates to a few percent or lower.

DISCUSSION

Our present state of knowledge is complicated by several factors that may change in the next few years. One is the poor reporting by non-ICCAT nations fishing in the eastern Mediterranean. A second is the development of the Japan central Atlantic longline fishery in the past few years. It is not clear to what stock these fish should be assigned if the division of the Atlantic remains as it is at present. If catch from this area is significant in terms of total Atlantic catch, the implications for management become an matter of concern. Third is the under reporting of the recapture of marked fish. The situation is better in the Western Atlantic and the western Mediterranean. In fact, the western Mediterranean data base is sufficient now to permit meaningful analyses in combination with the Atlantic fisheries. Thus the SCRS could begin to explore various ramifications of the one or two stock hypothesis with the object of determining what degree of separate management can be allowed and still achieve the ICCAT goal of maintaining the stock(s) at MSY.

The available information is suggestive, but not conclusive, that there are exchanges of some magnitude at some times between east and west. What is known supports the idea that there are two, or possibly three spawning areas: the Gulf of Mexico and the Mediterranean, with the latter possibly being divide further into west and east. Fish from the Mediterranean move into the Atlantic an early age, and fish from the Gulf of Mexico appear off the east coast of North America in some years in quantity at age 0. After that their origins become difficult to separate. It is believed, but not proved, that fish spawned in the Gulf of Mexico return there to spawn, and fish from the Mediterranean there to spawn. Nor is the genealogy of fish taken by the Japan central Atlantic fishery clear. The distribution of catches suggests a western origin, but past tag recoveries show that fish tagged off Norway have been captured by the Iberian-Moroccan trap fishery. To date no tagged fish have been recaptured in the central area.

From a practical standpoint stock assessment of Atlantic bluefin has to be based on reasonable assumptions and a workable data base. In past it was more practical to provide a separate assessment for the west since at that time the data base for the east and Mediterranean was less well documented. The situation has improved, at least for the western Mediterranean eastern Atlantic. Thus, for stock assessment it is practical that two stock models be considered:

i. Two stocks, as at present, but with the separation line moved east to include the New Japanese central Atlantic winter fishery catches in the west.

ii. A single Atlantic and Mediterranean stock.

RECOMMENDATIONS.

Several questions need to be answered regarding the discreteness of the stocks. In particular more information is needed about interchange between in the eastern and western Mediterranean and the Mediterranean into the Atlantic by small fish and their movements in later life. To what degree do Mediterranean fish enter the North American fisheries? To what degree does the Gulf of Mexico supply fish to the Bay of Biscay surface fishery? Finally, what is the origin of the fish taken in the central North Atlantic? Are they of Gulf of Mexico or Mediterranean origin?

Perhaps the best way to answer these questions is through a major cooperative tagging effort in conjunction with the Bluefin Year, and beyond. Simultaneous tagging of small fish needs to be carried out in the Mediterranean Sea and of the coast of North America. Support for such work in US. waters is available, and it is to be hoped that similar support for work in the Mediterranean can be found.

REFERENCES

Baglin, R. 1982. Reproductive biology of western Atlantic bluefin. U.S. Fish. Bull. 80(1): 121-133.

Berrien, P., M.Fahay, A. Kendall, Jr., and W Smith. 1978. Ichthyoplankton from the *R.V. Dolphin* survey of continental waters between Martha's Vinyard, Massachusetts and Cape Lookout, North Carolina, 1965-66. Sandy Hook Lab., Northeast Fish. Cent., Tech. Ser. Rpt.(15): 152pp.

Brown, C. and J. Lucy. 1991. Standardized catch rates of small bluefin tuna in the Virginia (U.S.) offshore rod and reel fishery. ICCAT, Coll. Vol. Sci. Papers XXXV (2):308-316.

Brunenmeister, S. 1980. A summary and discussion of technical information pertaining to the geographical discreteness of Atlantic bluefin tuna resources. ICCAT, Coll. Vol. Sci. Papers IX (2): 506-527.

Calaprice, J. 1986. Chemical variability and stock variation in northern Atlantic bluefin tuna. ICCAT, Coll. Vol. Sci. Papers XXIV: 222-254.

Cort, J. 1989. Rendimiento de los cañeros españoles en la pesquería de atún rojo del Mar Cantábrico. ICCAT, Coll. Vol. Sci. Papers XXX: 343-345.

Cort , J. and J. Rey. 1984. Distribución geográfica de atún rojo (Thunnus thynnus, L.) juvenil del Atlántico este, Mediterraneo occidental y Adriático. ICCAT, Coll. Vol. Sci. Papers XVIII (2):298-318.

Cort , J. and J. Rey. 1985. Análisis de los datos de marcado del atún rojo (*Thunnus thynnus* L.) en el Atlántico este y Mediterraneo migración, crecimiento y mortalidad. ICCAT, Coll. Vol. Sci. Papers XXII: 213-239.

Cort, J. and B. Liorzou. 1991. Special Report of the IATTC No. 7. Deriso and Bayliff, Eds. p.148-151.

ICCAT. 1982. Recommendations by Panel 2 on bluefin management measures. Appendix 5 to Annex 5 ICCAT Report, 1980-81 (II), p.86-88. Madrid, 1982.

Miyabe, N. 1992. Standardized CPUE of Atlantic bluefin in the eastern Atlantic and Mediterranean Sea obtained form the Japanese longline fishery. ICCAT Working Document SCRS/92/169.

Parrack, M. 1980. Trends in abundance and age structure of Atlantic bluefin tuna. ICCAT, Coll. Vol. Sci. Papers XXVII: 563-568.

Parrack, M. 1982. Atlantic Bluefin Tuna resource Update. ICCAT, Coll. Vol. Sci. Papers XXIX: 315-321.

Piccinetti, C. and G. Piccinetti Manfrin. 1992. Distribution des larves de thonidé en Méditerranée. SCRS/92/93.

Suzuki, Z. 1989. Problems in the stock assessment of west Atlantic bluefin tuna. ICCAT, Coll. Vol. Sci. Papers XXX: 276-282.

Suzuki, Z. 1992. Critical review of the stock assessment of bluefin tuna in the western Atlantic. ICCAT, Coll. Vol. Sci. Papers XXXIX (3): 710-716.

Turner, S., V. Restrepo and A. Eklund. 1991. A review of the growth of Atlantic bluefin tuna, *Thunnus thynnus*. ICCAT, Coll. Vol. Sci. Papers XXXVIII : 358-367..

Walters, V. 1980. Ectoparasites of eastern and western Atlantic bluefin tunas. ICCAT, Coll. Vol. Sci. Papers IX (2): 491-498.

Table 1. East and West Catches and Standardized Catches

Year	East Age 3	East Age 3	Year	West Age 2 + 1 Year	West Age 2 + 1 Year	Year	East Age 0	East Age 0	East Age 3
1970	26881	0.08				1970	47310		0.08
1971	53183	0.17	1970	105084	0.69	1971	176316		0.17
1972	77235	0.24	1971	153364	1.00	1972	37774		0.24
1973	83721	0.26	1972	98578	0.64	1973	94175	0.08	0.26
1974	57043	0.18	1973	74311	0.48	1974	147154	0.30	0.18
1975	34843	0.11	1974	20056	0.13	1975	165497	0.06	0.11
1976	281023	0.89	1975	148027	0.97	1976	98361	0.16	0.89
1977	45387	0.14	1976	19781	0.13	1977	254810	0.25	0.14
1978	152611	0.48	1977	22419	0.15	1978	191316	0.28	0.48
1979	101914	0.32	1978	10863	0.07	1979	52881	0.17	0.32
1980	124017	0.39	1979	10552	0.07	1980	54015	0.43	0.39
1981	111212	0.35	1980	16183	0.11	1981	35240	0.33	0.35
1982	191496	0.61	1981	9616	0.06	1982	76175	0.09	0.61
						1983	342313	0.09	0.38
1983	121271	0.38	1982	3729	0.26	1984	1888	0.06	0.15
1984	48831	0.15	1983	2438	0.17	1985	389092	0.13	1.00
1985	316509	1.00	1984	7504	0.52	1986	588253	0.58	0.53
1986	167405	0.53	1985	5523	0.38	1987	94622	0.00	0.35
1987	109512	0.35	1986	5939	0.41	1988	29721	0.66	0.79
1988	249683	0.79	1987	13340	0.92	1989	19583	1.00	0.28
1989	89294	0.28	1988	9149	0.63	1990	171226	0.16	0.66
1990	209213	0.66	1989	12877	0.89	1991	101045	0.05	0.46
1991	146599	0.46	1990	4238	0.29			0.03	
			1991	14533	1.00			0.29	
								0.17