

# TIME-AREA COINCIDENCE OF YEAR-CLASSES FOR ATLANTIC BLUEFIN TUNA

SCRS/1994/104

Col.Vol.Sci.Pap. ICCAT, 44 (1) : 349-352 (1995)

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## SUMMARY

The hypothesis that Atlantic bluefin tuna can be managed as two separate stocks, one in the eastern and Mediterranean and one in the western Atlantic assumes there is a very low rate of mixing of fish between the western Atlantic and the eastern Atlantic and Mediterranean. A comparison of the coincidence of weak and strong year-classes on widely separated fishing grounds suggests this assumption may be violated.

## RESUME

L'hypothèse selon laquelle le stock de thon rouge de l'Atlantique pourrait être géré comme deux stocks distincts, l'un constitué de l'Atlantique Est et de la Méditerranée, et l'autre, de l'Atlantique Ouest, suppose que le taux de mélange entre les poissons de l'Atlantique Ouest et ceux de l'Atlantique Est et de la Méditerranée est très bas. Une comparaison de la coïncidence des classes d'âge fortes et médiocres dans des zones de pêche totalement distinctes indique que l'on pourrait déroger à cette hypothèse.

## RESUMEN

La hipótesis que el atún rojo del Atlántico puede ser gestionado como dos stocks separados, uno en el Atlántico este y Mediterráneo y otro en el Atlántico oeste, establece el supuesto que la tasa de mezcla de peces entre el Atlántico oeste y el Atlántico este y Mediterráneo, es muy baja. Una comparación de la coincidencia de clases anuales débiles y fuertes en caladeros muy distantes unos de otros, sugiere que este supuesto podría ser infringido.

## INTRODUCTION

The SCRS uses two hypotheses in assessing Atlantic bluefin tuna: A single stock comprising all the fish in the Atlantic and Mediterranean, or two separate stocks, one in the western Atlantic and the other in the eastern Atlantic and Mediterranean. In recent years the two-stock hypothesis has been used exclusively. This hypothesis depends on an assumption that the exchange of fish between the east and west Atlantic is sufficiently low the two areas can be managed separately. Butterworth and Punt, 1993 show that interchange of more than a few percent are sufficient to violate the assumption. Another study reported in SCRS/94/68 finds that on the basis of re-analysis of the ICCAT tagging data base exchange is likely greater than 1% to 3%, and cannot be ignored in the VPA.

Other estimates of exchange rates are higher 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. Depending on the samples and year of analysis he found mixing between 4.2 and 100%, but generally supportive of mixing in the order of 10-12 percent between east and west.

Walters, 1980 suggests mixing rates on the order of 15% based on the prevalence of ectoparasites, but his assumptions have been questioned.

Hester, 1993 reported a marked synchrony in year class strength in fisheries in the Bay of Biscay and off the U.S. East Coast, and offered three explanations: 1.) It is an artifact of the data and method. 2.) There 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. This paper makes some additional comparisons.

## Material and Methods.

Information on relative year class strength is assumed to be contained in CPUE series that target the same age groups. Year class strength also may be presumed to be reflected in catch-at age data, although they may be difficult to separate from effects of regulations, environmental influences, and the availability of other age fish to the same gear. In theory, these difficulties can be resolved by using VPA output.

For the purposes of this paper, the following CPUE series Table 1. were used:

Table 1. CPUE Series from SCRS Reports 1992 and 1993

Gear	Bait Boat	Purse Seine	Purse Seine	Rod and Reel
Country	Spain	France	France	U.S.A.
Area	E. Atlantic	W.Med.	W.Med.	Coastal W. Atl.
Age Range	2	2	3	1-5
1980	22.6			78.529
1981	33.8			9.132
1982	31.5	245.7	143.7	99.850
1983	44.2	124.3	109.4	25.605
1984	140.0	332.9	35.9	-
1985	67.9	114.7	172.7	13.791
1986	48.5	85.7	86.0	39.791
1987	86.0	245.3	60.9	55.690
1988	59.8	52.2	142.4	34.774
1989	63.2	280.5	54.0	56.712
1990	33.7	201.5	62.2	34.761
1991	63.8	253.6	53.9	70.356

VPA outputs were taken from the same SCRS Reports (1992 and 1993). It should be noted that SCRS/94/ indicates the CPUE series used in the 1993 assessment are likely to be modified, and the VPA stock estimates for the west will have to be revised. What effect these revisions will have on the conclusions of this paper are not clear. The Catch-at-age estimates (Table 2.) should remain unchanged.

Regression analysis was used to compare apparent year class strength patterns among areas. For graphical presentation of the VPA stock size comparisons (Figure 1), the estimates were divided by the mean of the stock size over the period under consideration to assist in the presentation.

## Results.

The results of the regression analysis are presented in Table 3. A graphical presentation of the VPA comparisons is given in Figure 1.

Table 3. Regression Analysis of Pairs of Year Class Abundance Indicators

Spanish BB age 2 vs. French PS age 2	R = 0.49 d.f. 8 R <sup>2</sup> = 0.24 Slope 1.46
Spanish BB age 2 vs. French PS age 3 1 year lag	R = 0.77* d.f. 7 R <sup>2</sup> = 0.61 Slope 0.56
French PS age 2 vs. French PS age 3 1 yr. lag	R = 0.69* d.f. 7 R <sup>2</sup> = 0.48 Slope 1.45
U.S.R&R age 1-5 vs. Spanish BB age 2	R = -0.14 d.f. 9 R <sup>2</sup> = 0.02 Slope -0.11
U.S.R&R age 1-5 vs. French PS age 2	R = 0.68* d.f. 7 R <sup>2</sup> = 0.47 Slope 2.23
U.S.R&R age 1-5 vs. French PS age 3	R = -0.40 d.f. 6 R <sup>2</sup> = 0.16 Slope -0.24
VPA age 1, 1980-1991	R = 0.59* d.f. 10 R <sup>2</sup> = 0.35 Slope 0.53
VPA age 1, 1980-1989	R = .73* d.f. 8 R <sup>2</sup> = 0.53 Slope 0.53
VPA age 2, 1980-1989	R = .65* d.f. 8 R <sup>2</sup> = 0.42 Slope 0.04
VPA age 3, 1980-1989	R = 0.25 d.f. 8 R <sup>2</sup> = 0.06 Slope 0.47
VPA age 5, 1980-1989	R = 0.74* d.f. 8 R <sup>2</sup> = 0.55 Slope 0.12

## Discussion.

Table 3. indicates a number of significant relations. Given the current stock model a relation might be expected between the French purse seine fishery for age 2 fish and the Spanish bait boat fishery, but such a relation is lacking. Instead, there is a significant relation between the Spanish bait boat fishery and the French Fishery for age 3 fish the following season. The CPUE index for French PS age 2 is high for the last three years of the index, which has been attributed to an operational change by the fleet (Ref.). It may be that the age 3 index provides a better indication of year class strength for the western Mediterranean.

The relation between the U.S. rod and reel index for small fish is negative except with French PS age 2, which is positively correlated and significant. This U.S. index is a new index (Ref) incorporating a greater range of ages and fishing area and is perhaps too broad to correlate with a single year class.

Another way to look at the east-west relation is to compare year class strength as estimated by VPA. Depending on the years included in the analysis, there is significant correlation between east and west for recent years. Including the last two years, or years prior to the mid-1970's usually results in lower correlation. Since VPA is highly uncertain for the most recent years, and more prone to error and bias in the earlier years, this tendency is not fatal to the argument that there is mixing between east and west. However, there is a danger with this type of analysis of interpreting a significant spurious correlation as indicative of a relationship between variables.

Graphical presentation of these relations are made in Figure 1a through 1d. The Age 4 VPA is not shown, but closely resembles Age 5. In all cases, stronger than usual '82, '85, and '87 year classes appear in both east and west, although their presence becomes more obscure in the east for the older age runs. The latter is perhaps due in part to the fact that

over 90% of the catch in the east is fish younger than age 4 during the period 1980 to present (Figure 1c). The VPA contains little reliable information on catches for the older fish. This will be less of a problem for the west where the average catch-at-age is somewhat more uniform and the catches of older fish are better documented. However, this observation is tempered by the fact that recruitment in the west has declined in relation to the east. From VPA the relative abundance of age-1 fish in the east has changed compared to the west from about equal to that in 1970 to about thirty-six fold that in the west in 1900 (Fig. 11).

The relation between east and west is quite striking for the Age 1 fish. Three year classes, '82, '85 and '87, make good showings and they generally continue to show well in catches as older fish. Why this should be is not clear. For the east much of this catch takes place in the mid-Mediterranean Sea and the Adriatic where sampling and reporting of catches is unreliable. The catch of Age 1 fish in the east is thus likely to be considerably in error, and that error may change from year to year.

Current thinking confines young fish to the Mediterranean (Ref) until they are in their second year. Thus one might speculate the good correlation with the west VPA is a result of transatlantic movement from east to west of fish age 2 and older. Table 2 appears to support this view since catches of Age 1 fish are small and the "strong" year classes do not appear until Age 2., except, perhaps for the 1987 YC. Regulations in the west make it difficult to evaluate the actual abundance of young fish from catch records, and sampling of these catches is incomplete.

(Addendum) During discussion of SCRS/94/104, the question was asked why does the 1973 year class not show up in the east? The answer is, it does, but did not using the data series I had available before the meeting. Figure 2 shows a plot of the VPA age 1 in the west vs. the Spanish bait boat index for age two the following year. I took this index from SCRS/94/91 (Cort 1994). He provides a slightly different index from that I had from the 1992 SCRS. The difference lies in the re-computed 1975 point, which is higher than it was in the earlier reference. The new index makes the 1973 pulse obvious.

A difficulty with this comparison is I cannot use the whole west time series since regulations greatly reduced the catch of small fish in the late '70's and the VPA stock size estimates drop an order of magnitude, or recruitment in the west dropped. Either way, one would have to break the scale from 1978 forward to make the full series comparable. Evidently the relation between east and west extends back into the earlier part of the period. However, the Spanish bait boat index has been divided into two segments, one from 1970-1977, the other from 1978 on. Therefore this difficulty disappears for the comparison.

The next question is where did the fish come from? Table 4 shows the estimated catch-at-age for several cohorts in the east. Catch at age 1 for the 1973 cohort in the east was similar to catches from the two preceding cohorts (1971 and 1972) but much less than for the 1974 cohort. The pattern changed at age 2 and older. Since the age 0 catches and much of age 1 catches (at least in the Mediterranean) can be presumed to come from fish spawned in the Mediterranean Sea, the increased strength of this cohort as age 2 in the fisheries, as indicated by the raw catch data, may be indicative of fish moving in from the west. The 1973 cohort continues a strong showing in catches for the east and contributes 121-thousand pieces to the east from age 4 to 14, whereas the 1974 cohort, which was much more abundant as young fish, contributes only 80-thousand pieces. One can argue the 1974 cohort was fished down, but it is difficult to account for the continuing strong showing of the 1973 year class in the eastern catches over so many years unless these fish were part of a very strong year class that did not all originate in the Mediterranean.

Table 4. Catches in the East from the 1973 1974, 1975, 1976 and 1977 Year Classes

Age/Year	1973	1974	1975	1976	1977
0	37774	94175	147154	165497	98361
1	142935	187116	696771	96878	217545
2	130118	289275	188236	289457	194104
3	34843	281023	45387	152611	101914
4	39694	64050	19182	50033	30598

(from SCRS 1992)

Additional support for the notion that fish spawned in the west contribute, at least on occasion to catches in the east comes from the recovery of three fish tagged as age 1 off the east coast of the U.S. in 1990 and recovered as age 4 in the Bay of Biscay in 1993 (Cort 1994). These fish may have been precocious migrants from the Mediterranean, but it seems more likely they were spawned in the Gulf of Mexico.

#### Conclusions.

Based on VPA stock size estimates there appears to be a degree of synchrony between Atlantic bluefin tuna year classes in the east and west. The most plausible explanation is that transatlantic movement of young fish occurs on a regular basis. The degree of correlation between east and west VPA stock size estimates indicates that this movement is considerably greater than was believed previously. This synchrony persists through at least fish Age 5.

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Table 2. Catch-at Age, Thousands of Fish

Age	Cohort East												Cohort West											
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1	111	150	700	707	173	217	624	280	818	482	529	307	3	68	3	4	1	1	1	2	5	1	2	3
2		339	226	170	643	359	274	445	170	421	368	416		10	4	2	8	6	6	13	9	13	4	14
3			191	121	49	316	167	110	250	89	209	146			2	3	2	12	7	9	12	2	18	11
4				25	36	32	75	30	29	64	57	38				1	2	3	3	5	4	4	2	3
5					20	13	8	10	9	38	27	19					2	4	1	4	4	2	3	2
6						9	6	8	10	7	8	6						4	2	2	4	2	2	2
7							3	8	11	12	6	4							1	2	2	3	2	2
8								4	6	7	9	5								1	2	2	2	2
9									5	4	10	10									2	1	15	2
10										5	9	14									2	2	2	2
11											4	9									2	1	1	1
12												2									2	1	1	1

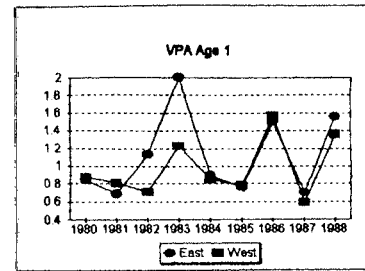


Figure 1a

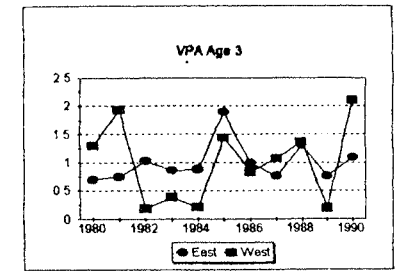


Figure 1c

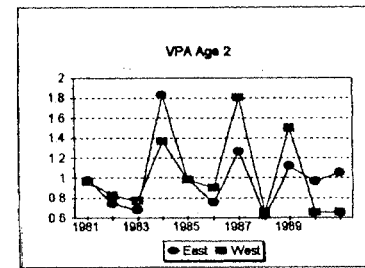


Figure 1b

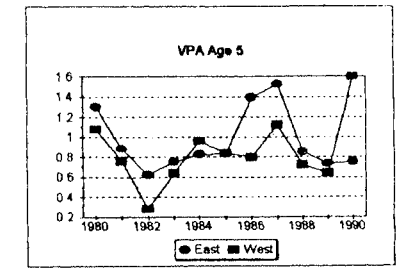


Figure 1d

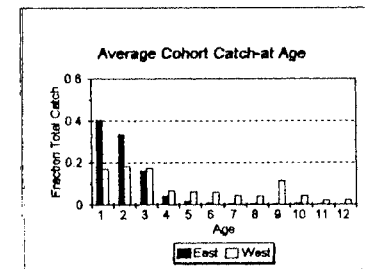


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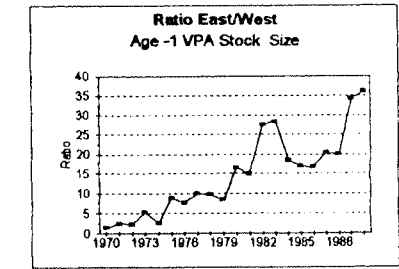


Figure 1f

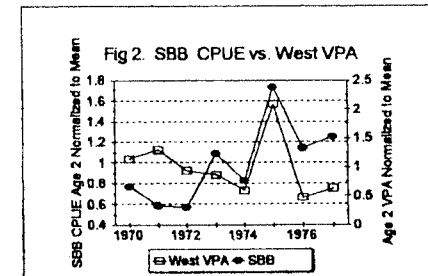


Fig 2. SBB CPUE vs. West VPA