

## AN ANALYSIS OF RECAPTURES OF TAGGED BLUEFIN WITH RESPECT TO THE MIXING ASSUMPTION

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## SUMMARY

Recaptures of 1-3 year-old bluefin tagged from purse seines in 1962-1981 and recaptured in the recreational, purse seine and longline fisheries were analyzed to determine 1) whether the frequencies of recaptures were similar to what would be expected from the distribution of catches among those fisheries and 2) whether different experiments within a year showed similar results with respect to the recaptures by fishery. Analyses were performed on each age group separately and only on recaptures taken in the year (January-December) after release. It was found that different experiments within a year almost always showed similar patterns of recoveries among the fisheries. Most of the tests comparing the recaptures by each fishery with that expected from the catches indicated that the fish were mixing, but there were several experiments from which mixing was not indicated. However, the statistical results from many of the tests were highly sensitive to slight changes in the number of recaptures, so that reliability of the findings was uncertain. Several of the statistically significant results were associated with deviations from the expected number of recaptures for the recreational fishery, and it was suggested that imprecision in the estimates of the recreational catches provided additional reason to treat the results with caution.

## RESUME

Les recaptures de thons rouges de 1 à 3 ans marqués par des senneurs en 1962-81, et repris par la pêche sportive, la senne et la palangre, ont été analysées pour déterminer (1) si la fréquence des recaptures était semblable à celle qui serait escomptée selon la répartition des prises entre ces pêcheries, et (2) si différentes expériences menées dans le courant d'une même année montraient des résultats similaires en ce qui concerne les recaptures par pêcherie. Des analyses ont été effectuées séparément sur chaque groupe d'âge, et seulement pour les recaptures réalisées pendant l'année (janvier-décembre) suivant le marquage. On a observé que des expériences différentes menées au cours d'une même année montraient presque toujours un mode similaire de recapture par pêcherie. La plupart des tests comparant les recaptures de chaque pêcherie et celles auxquelles on s'attend vu les prises indiquent que les poissons se mélangent, mais plusieurs tests n'ont pas montré de mélange. Néanmoins, les résultats de nombre de ces tests sont très sensibles aux légères modifications du nombre de recaptures, d'où des incertitudes quant à la fiabilité des résultats. Plusieurs résultats significatifs du point de vue statistique ont été associés à des déviations du nombre escompté de recaptures par la pêche sportive, et il a été suggéré que le manque de précision des estimations sur les prises sportives fournissait d'autres raisons de traiter les résultats avec prudence.

## RESUMEN

Se analizan las recapturas de atún rojo de edades 1-3 marcado con barcos de cerco en el periodo 1962-1981 y recuperado por la pesquería deportiva, la de cerco y por la de palangre, para determinar: 1) si las frecuencias de las recapturas eran similares a los resultados esperados en base a las distribuciones de las capturas entre dichas pesquerías, y 2) si los diferentes experimentos llevados a cabo dentro de un año dado mostraban resultados similares con respecto a las recapturas por pesquería. Se efectuaron análisis de cada grupo de edad por separado, pero solo de las recapturas obtenidas durante el año siguiente al marcado (enero-diciembre). Se observó que en los diferentes experimentos realizados dentro del mismo año se observaban casi siempre pautas similares de recuperación entre las pesquerías. La mayoría de las pruebas de comparación de las recapturas de cada pesquería con las que se esperaba obtener en las capturas, indicaban que los peces se mezclaban entre sí, pero en alguno de estos experimentos no se observó tal mezcla. Sin embargo, los resultados estadísticos de muchas de estas pruebas eran muy sensibles a ligeros cambios en el número de recuperaciones, por lo que la fiabilidad de los resultados era cuestionable. Algunos de los resultados estadísticos importantes estaban asociados a las desviaciones en el número esperado de recapturas de la pesquería de recreo, y se sugiere que la falta de precisión en las estimaciones de las capturas de esta pesquería es una razón más que induce a considerar las conclusiones con cierta precaución.

## Introduction

Large numbers of juvenile bluefin tuna have been tagged in most years since the early 1960's. The releases and the recaptures from these marking experiments have been used to estimate abundance and mortality rates in the past, and most recently by Powers et al. (1983) and Doi et al. (1985). Some assumptions made in using mark-recapture information for those analyses are examined in this paper.

The primary assumption analyzed was that marked fish randomly mixed within the exploited population and thus had an equal probability of recapture as unmarked fish. A second assumption studied was that different experiments within a year showed similar results; this assumption is made if experiments within a year are combined to make one estimate of abundance and mortality rate. This latter assumption was investigated only in respect to the mixing assumption.

## Materials and Methods

The mark-recapture information at NMFS in Miami is maintained with one record for each release of a tag and another for each tag recaptured. These records were converted so that a single record contained all the information on each fish released and its possible recapture. These fish release records were used.

The analyses were limited to releases of 1-3 year old fish from purse seines and recaptures of those fish during the first year (January-December) after release. The recreational (RR) purse seine (PS) and longline (LL) fisheries accounted for almost all of the recaptures and only these were considered. Fish were aged from observed or estimated lengths, weights, or ages at time of release. Nearly all of the fish studied from 1962-1970 were

aged from estimated lengths. Measured lengths were used to age nearly all the fish released in 1971-1978. Estimated weights were used to age releases in 1980, and estimated ages were used for about 2% of the releases from 1971-1976. While significant numbers of recaptures were usually made both between tagging and the following January and between that January the next December (Table 1), only recaptures from the first calendar year (January-December) after release were used in the analysis.

Chi square tests were used to test the mixing assumption, and chi square tests of heterogeneity (Zar 1974) were used to examine the similarity of experiments. The expected frequency of recaptures for a fishery were derived for a year class in a year from the total number of recaptures and the total catch of that year class taken in that year by the fisheries analyzed. Each expected frequency of recaptures was calculated by multiplying the fishery specific percentage of the total catch by the total number of recaptures. If the expected frequency of recaptures for any fishery was less than 1, the analysis was not made. The heterogeneity tests, used to compare the similarity of experiments on a year class within a year, were made with 4 levels of grouping the data: comparisons were made for 1) different sets by a vessel on a day, 2) different vessels on the same day, 3) different days within a month and 4) different months within a year.

#### Results

There were enough recaptures of bluefin which were 1-3 year old at release to perform statistical analysis in 11 out of the 19 years in 1962-1981. There were 6 years in which recaptures of fish 1 year old at release could be tested, 8 years with tests on recaptures of 2 year olds at release, and 1 test on 3 year olds at release (Table 2). Recaptures from all 3 fisheries could be compared only in 4 cases in 1977-1980, only recreational

and purse seine recaptures could be compared in 1964-1971 and 1974, and only recaptures from the purse seine and longline fisheries were testable in 1973 and for 3 year olds in 1976. Recaptures of 1 year olds released in 1976 could not be compared across all fisheries, but recaptures from both pairs of fisheries (RR:PS and PS:LL) were possible.

There were 6 years in which the similarity of experiments within at least one of the levels of grouping the releases could be examined. These included 4 years with tests on 1 year olds at release and 2 years with tests on 2 year olds at release.

The heterogeneity tests usually indicated that experiments within a year showed similar patterns in the distribution of recaptures among the fisheries, though there was one test with statistical differences. There was at least one year in which comparisons could be made at each level of grouping (sets by a vessel in a day, vessels on the same day, days within a month or months in a year), and there were 2-4 observations to be compared within each of them (Table 3). In all years in which sets, vessels or months could be compared there were no statistically significant differences ( $P > 0.10$ ). There were 4 years when recaptures from releases on different days within a month were testable, and in 3 of these no statistical differences occurred. The single instance of significant differences was in August 1965 when there were 3 comparable days. The recaptures from two days early in the month showed very similar patterns of recaptures among the fisheries with 2% taken by recreational fishermen and 98% by purse seine (51 and 53 recaptures from each experiment), while on the third day later in the month 9% (7 fish) of the 81 recaptures came from the recreational fishery and 91% came from purse seiners. A decrease of 1 fish in the number of recaptures taken by the recreational fishery on that third day would have produced a nonsignificant result ( $P = 0.07$ ). Such sensitivity indicated that this result should be

treated with caution, and it was concluded that in general it was reasonable to combine recaptures of a year class from different releases in a year.

Most of the tests of the mixing assumption indicated that the numbers of recaptures by each of the three fisheries were not significantly different from what was expected, but there were several cases in which statistically significant differences did occur. Because the heterogeneity tests indicated that experiments within a year generally showed similar results, only the results of tests on the combined recaptures from all experiments in a year will be described, with the exception of recaptures of fish released as 1 year olds in 1966 which were not tested, because the results for August were found to be heterogeneous. Five of the fifteen tests clearly did not show significant differences between the observed and expected number of recaptures ( $P > 0.10$ ), 3 had probability values which were between 0.05 and 0.10, 1 was marginally significant ( $P = 0.04$ ), and 6 had highly significant results ( $P < 0.01$ ) (Table 4).

Many of the nearly significant and significant results were associated with relatively small deviations from the expected numbers of recaptures for the fisheries for which only a small number of recaptures were expected. Recaptures taken in the recreational fishery were involved in most of those analyses, and imprecision in the estimates of the recreational catch especially prior to 1975 may have had a strong influence on the results. The cases with nearly significant ( $P = 0.05-0.10$ ) and marginally significant ( $P > 0.04$ ) probabilities (1964, 1966, 1976 RR:PS and 1976 PS:LL) would have been insignificant ( $P > 0.10$ ) either if one additional or one less tagged fish had been recaptured by the fishery which caught the fewest tagged fish or if there had been a 10-20% decrease or increase in the number of recaptures from the fishery which caught the most tagged fish. The highly significant results for the tests on the 1965, 1967 and 1974 releases were heavily influenced by deviations from the expected frequencies of recaptures by the

recreational fishery of 3-6 fish (50-75% of observed), or they could have been due to much larger deviations from the expected frequencies for the purse seine fishery. The highly significant differences for the 1978 releases of age 1 fish was also heavily influenced by the recreational recaptures; an increase from 10 to 16 recaptures by the recreational fishery would have produced a probability of 0.05 and an increase from 10 to 19 would have produced a probability of 0.10. The result from the 1980 releases were strongly influenced by an unexpectedly small number of returns from the longline fishery but could not be fully explained by deviations from the expected number of recaptures for any one fishery.

#### Discussion

The frequent importance of small deviations from the expected number of recaptures for the recreational fishery in the outcomes of the tests of the mixing assumption could be due to different rates of reporting of recaptures from the fishery, due to inaccuracy in the estimated catches, or due to failure of the fish to mix. It seems reasonable to expect a higher rate of reporting recaptures from the recreational fishery than from at least the purse seine fishery, because of differences in the way catches are handled, but this was not observed. Therefore it was assumed that consistent differences in reporting rates for the various fisheries were not a major influence on the results. It seems improbable that the juveniles exploited by the recreational and purse seine fisheries came from different (not mixed) segments of the population, because the fisheries usually occurred in the same general area at about the same time. The most likely explanation for the highly significant results is that there were inaccuracies in the estimated catches. This explanation seems reasonable considering that the recreational catches were estimated (not censused), confidence intervals about such estimates were usually quite wide, and most of the deviations from the expected number of recaptures for the recreational fishery were within

75% and almost all were within 100% of the observed number of recaptures.

The sensitivity of most of the results to small changes in the numbers of recaptures means that a robust conclusion as to whether the recaptured juvenile bluefin had randomly mixed within the population cannot be made from this analysis. While many of nearly significant or marginally significant results would have been insignificant with small differences in the numbers of recaptures (or relatively small changes in the catch estimates) for the fisheries with small numbers of recaptures, it is also true that many of the insignificant results might have become significant with similarly small changes.

The results from these tests are similar to those reported by Powers, Conser, and Parrack (1983) for 1974-1978 for recoveries in the first year after release. The present analysis differs from the earlier work in that it covers a longer time span, it indicates that it is usually permissible (with respect to the mixing assumption) to combine data within a year for making estimates, and it identifies inaccuracies in the recreational catch estimates as a potential explanation for the statistical significance of the results.

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Table 1. Releases, and recaptures by years at liberty for 1-3 year old bluefin released from 1961-1981. 3+ refers to 3 or more years at liberty.

YEAR	AGE	RELEASES	-----RECAPTURES-----				
			TOTAL	YEARS AFTER RELEASE			
				0	1	2	3+
1964	1	235	79	52	27	0	0
1965	1	538	100	41	35	22	2
1966	1	2,285	775	353	367	44	11
	2	1,061	269	122	142	1	4
1967	2	551	168	90	55	12	11
1968	2	190	100	81	13	6	0
1971	1	140	30	2	25	3	0
	2	160	31	7	18	6	0
1972	1	47	23	5	18	0	0
	2	75	16	1	14	1	0
1973	2	165	43	31	10	1	1
1974	1	971	182	52	79	38	13
1976	1	581	90	20	31	37	2
	3	617	78	46	20	11	1
1977	1	124	27	4	11	11	1
	2	1,542	263	28	165	68	2
1978	1	653	81	2	55	18	6
	2	367	38	2	33	2	1
1980	2	1,899	221	127	86	3	5

Table 2. Recaptures by fishery of 1-3 year old bluefin tuna taken in the year after release which were used in statistical analyses and catches by fishery of those year classes in the year after release. A dash (-) indicates that recaptures by that fishery from those releases were not used in the analyses. Recaptures in parentheses were not included in the various analyses, because the expected number of recaptures was less than 1.

Year	Age	-----In The Following Year-----					
		Recaptures			Catches		
		RR	PS	LL	RR	PS	LL
1964	1	0	27	(0)	9,528	87,511	0
1965	1	8	27	(0)	34,594	41,250	0
1966	1	13	354	(0)	2,634	93,751	0
	2	3	139	(0)	249	32,559	0
1967	2	8	47	(0)	338	17,015	0
1971	1	2	23	(0)	8,156	88,599	12
	2	0	18	(0)	2,942	29,861	90
1973	2	(0)	10	0	1,174	16,601	3,789
1974	1	6	73	(0)	2,455	141,280	21
1976	1	1	27	3	3,849	17,761	616
	3	(0)	19	1	134	12,259	8,849
1977	2	4	151	10	232	16,145	1,234
1978	1	10	45	0	3,874	6,226	340
	2	0	33	0	501	12,396	1,128
1980	2	2	82	2	376	6,943	7,716

Table 3. Results from chi square tests of heterogeneity in which the recaptures from different releases or groups of releases were compared with respect to their observed and expected number of recaptures by gear. Recaptures from single purse seine sets by the same vessel within a day were compared as were recaptures from releases grouped to compare vessels releasing fish on the same day, different days within a month and different months within a year. P is the probability of obtaining a chi square statistic with the observed degrees of freedom (number of experiments -1).

Year	Age	Number of Experiments	Fisheries Included		P
			RR, PS	PS, LL	
Sets by a Vessel in a Day					
1977	2	2			0.83
1980	2	2			1.00
Vessels within a Day					
1977	2	2			0.45
1978	1	2			0.32
Days within a Month					
1966	1	3			0.02
1976	1	2			1.00
1977	2	4			0.38
1980	2	3			0.90
Months within a Year					
1965	1	2			0.13
1966	1	2			0.18

Table 4. Results of chi square tests by age and year of the number of recaptures of 1-3 year old bluefin tuna in the year after release compared to the number of recaptures expected from the total catch and total number of recaptures taken by the fisheries examined. P is the probability of obtaining a chi square statistic with degrees of freedom of (number of fisheries compared -1). Year refers to year of release and age to age at release.

YEAR	AGE	FISHERIES COMPARED		
		RR, PS	PS, LL	RR, PS, LL
1964	1	P= 0.09		
1965	1	P< 0.01		
1966 <sup>1</sup>	2	P= 0.06		
1967	2	P< 0.01		
1971	1	P= 0.94		
	2	P= 0.18		
1973	2	P= 0.13		
1974	1	P< 0.01		
1976	1	P= 0.05	P= 0.04	
	3		P< 0.01	
1977	2			P= 0.42
1978	1			P< 0.01
	2			P= 0.11
1980	2			P< 0.01

1) Results for releases of 1 year olds in 1966 are not shown, because the heterogeneity tests for August indicated significant differences.