

ESTIMATION OF RATES OF TAG SHEDDING OF NORTHWEST ATLANTIC
BLUEFIN TUNA

by

W. H. Lenarz, F. Mather, J. Beckett,
A. Jones and J. Mason

SUMMARY

Results from a double tagging study on bluefin tuna off the east coast of the United States were used to estimate rates of tag shedding. The portion of tags retained after immediate shedding was estimated to be 0.971. The instantaneous rate of tag shedding was estimated to be 0.280 on an annual basis. These estimates were then used to correct the estimates of mortality rates of bluefin tuna for tag shedding. The average instantaneous rate of fishing mortality was estimated to be 0.459 and the average instantaneous rate of other mortality 0.821.

ESTIMATIONS DU TAUX DE REJET DES MARQUES DU THON ROUGE
DANS L'ATLANTIQUE NORD-OUEST

par

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RESUME

Les résultats d'une étude effectuée au moyen de double marquage de thon rouge au large de la côte Est des Etats-Unis ont servi à estimer le taux de rejet des marques. On estime que 0,971 des marques restent en place après les rejets qui ont lieu au moment même du marquage. Le taux instantané de rejet des marques sur une période d'un an a été estimé de 0,280. Ces calculs ont servi à corriger les estimations du taux de mortalité du thon rouge pour tenir compte du rejet des marques. On a estimé que le taux instantané moyen de mortalité due à la pêche était de 0,459 et celui de la mortalité due à d'autres causes de 0,821.

ESTIMACION DE INDICES DE DESPRENDIMIENTO DE MARCAS
PARA EL ATUN DEL NOROESTE DEL ATLANTICO

por

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RESUMEN

Se han utilizado los resultados de un estudio de doble marcado del atún frente a las costas orientales de los Estados Unidos para la estimación de índices de desprendimiento de marcas. Se calculó que la proporción de marcas retenidas después de producirse el desprendimiento inmediato era de 0,971. El índice instantáneo de desprendimiento de marcas se estimó en un 0,280 sobre una base anual. Dichas estimaciones fueron utilizadas para corregir las estimaciones de índices de mortalidad del atún teniendo en cuenta el desprendimiento de marca. El promedio de índice instantáneo de mortalidad de pesca se calculó en 0,459 y el promedio de índice instantáneo de otra clase de mortalidad en un 0,821.

ESTIMATION OF RATES OF TAG SHEDDING OF
NORTHWEST ATLANTIC BLUEFIN TUNA¹

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A joint experiment was initiated by FRBC, NMFS, and WHOI in 1971 under the leadership of F. Mather to estimate the rates of shedding of various types of tags by bluefin tuna. Five hundred eighty bluefin tuna were double tagged off the east coast of the U.S. during the 1971 fishing season. Several types of tags and personnel from the three participating agencies were used. The 1971 releases and returns in 1971 and 1972 are shown in Table 1 by major category. It is probable that more tags will be recovered for 1972. For this study it is assumed that the ratio of single tag return to double tag return will remain constant for the remainder of 1972 returns.

The notation and methodology follows Bayliff and Mobrand (1972) for this study:

$$n_{ddk} = F\tau N_D \pi \rho^2 e^{-(F+X+2L)t_k}$$

$$n_{dsk} = F\tau N_D \pi \rho (1 - \rho e^{-Lt_k}) e^{-(F+X+L)t_k}$$

where

$$t_k = \text{time at the middle of the } k\text{th period of length } \tau \quad (k = 1, 2)$$

Table 1. Tag releases and returns from east coast of U.S.
bluefin tuna double tag study, 1971

	Releases	First year returns			Second year returns		
		n _{dd1}	n _{ds1}	t ₁ (days)	n _{dd2}	n _{ds2}	t ₂ (days)
FRBC							
Plastic dart	140	16	1	24.4	6	6	373.0
Metal dart	128	9	1	19.4	8	7	373.6
WHOI							
Plastic dart	150	4	0	7.2	16	9	351.3
Metal dart	162	4	1	18.6	10	7	371.1
Total							
Plastic dart	290	20	1	19.8	22	15	358.8
Metal dart	290	13	2	19.1	18	14	372.4
Total	580	33	3	19.5	40	29	365.1

- n_{ddk} = number of returns of double tagged fish retaining both tags
 during the period centered at t_k
- n_{dsk} = number of returns of double-tagged fish retaining only one tag
 during the period centered at t_k
- N_D = number of fish released with double tags
- π = portion of tagged fish which remain alive after the Type-I
 mortality has taken place
- ρ = portion of the tags which are retained after Type-I (immediate)
 shedding has taken place
- F = instantaneous rate of fishing mortality
- X = instantaneous rate of other mortality (other includes natural
 mortality, Type-II tagging mortality and apparent mortality
 caused by migration from the fishery)
- L = instantaneous rate of shedding of tags

The formula used for estimating L and ρ is

$$\ln \frac{2n_{ddk}}{n_{dsk} + 2n_{ddk}} = -Lt_k + \ln \rho = Y_k$$

Since we have two estimates of Y_k the formula can easily be solved for L and ρ .

Estimates of Y_k are shown in Table 2. Estimates of L and ρ are shown in Table 3. Although some differences among categories are indicated the variability does not appear to be large enough to rule out the use of the estimates obtained from the combined data. These estimates of $\rho = 0.971$ and $L = 0.27974$ are close to the estimates of Bayliff and Mobrand (1972) of $\rho = 0.9$ and $L = 0.28$ for yellowfin tuna in the eastern Pacific.

We next used our estimates of ρ and L to correct the estimates of rate of exploitation and X made by Mather, Rothschild, and Paulik (MS). Let

$$\hat{U}_T = R/N$$

where

$$\hat{U}_T = \text{estimate of total exploitation of tagged bluefin over } n \text{ years}$$

$$R = \text{number of tag returns}$$

$$N = \text{number of tag releases}$$

and

$$\hat{U}_1 = \hat{U}_T / \sum_{i=0}^{n-1} \hat{S}^i$$

where

$$\hat{S} = \text{estimate of annual survival by Mather, Rothschild, and Paulik (MS)}$$

$$\hat{U}_1 = \text{estimate of single season exploitation of tagged bluefin}$$

and

$$\hat{F} = \hat{U}_1 (-\ln \hat{S}) / (1 - \hat{S})$$

and

$$\hat{X} = -\ln(\hat{S}) - \hat{F}$$

and

$$(F + X)^* = \hat{F} + \hat{X} - \hat{L}$$

Table 2. Intermediate results in estimates of shedding rates from 1971 U.S. east coast bluefin double tag study

	Y_1	Y_2
FRBC		
Plastic dart	-0.03077	-0.40547
Metal dart	-0.05407	-0.36291
WHOI		
Plastic dart	0	-0.24784
Metal dart	-0.11778	-0.30010
Total		
Plastic dart	-0.02469	-0.29335
Metal dart	-0.07411	-0.32850
Total	-0.04445	-0.30932

Table 3. Estimates of ρ and L from 1971 U.S. east coast bluefin double tagging study

	a	b	ρ	L (on annual basis)
FRBC				
Plastic dart	-0.00454	-0.0010749	0.995	0.39233
Metal dart	-0.03715	-0.0008719	0.964	0.31826
WHOI				
Plastic dart	-0.00519	-0.0007203	1.005	0.26289
Metal dart	-0.10816	-0.0005172	0.897	0.18879
Total				
Plastic dart	-0.00900	-0.0007925	0.991	0.28927
Metal dart	-0.06036	-0.0007200	0.941	0.26281
Total	-0.02950	-0.0007664	0.971	0.27974

where $(F + X)^*$ is an estimate of total instantaneous apparent mortality corrected for shedding rate.

$$\hat{S}^* = e^{-(F + X)^*}$$

where \hat{S}^* is an estimate of annual survival corrected for shedding rate.

$$\hat{U}_T^* = \hat{U}_T / \hat{\rho}$$

where \hat{U}_T^* is an estimate of total exploitation of tagged bluefin corrected for type I shedding.

$$\hat{U}_1^* = \hat{U}_1 / \hat{\rho}$$

where \hat{U}_1^* is an estimate of seasonal exploitation corrected for type I shedding.

$$\hat{F}^* = \hat{U}_1^* (-\ln \hat{S}) / (1 - \hat{S})$$

where \hat{F}^* is an estimate of F corrected for shedding.

$$\hat{X}^* = \ln(\hat{S}^*) - \hat{F}^*$$

where \hat{X}^* is an estimate of X corrected for shedding.

$$\hat{U}_1^{**} = \frac{\hat{F}^*}{\hat{F}^* + \hat{X}^*} (1 - \hat{S}^*)$$

where \hat{U}_1^{**} is an estimate of single season exploitation of tagged and untagged bluefin.

$$\hat{U}_T^{**} = \hat{U}_1^{**} \sum_{i=0}^{n-1} (\hat{S}^*)^i$$

where \hat{U}_T^{**} is an estimate of total exploitation of tagged and untagged bluefin.

The estimates are shown in Table 4. Estimates of \hat{X}^* (other mortality) range from 0.396 to 1.264 (average = 0.821). The values tend to decrease with time. This suggests that our implied assumption that L is constant over the period of the study may not be valid. It seems reasonable to expect that tag shedding has decreased as the taggers and investigators become more experienced. The value of \hat{U}_T^{**} ranges from 0.214 to 0.590 (average = 0.361) and tends to increase with time. Again our estimates of \hat{U}_T^{**} may be affected by undetected changes in L and thus the increase may be an artifact. The estimate of \hat{X}^* is considerably higher than expected values of M (natural mortality) for bluefin. Bluefin are a very long-lived fish and values of M of 0.1-0.2 seem reasonable. Thus, there may be significant amounts of Type-I and II tagging mortality and/or apparent mortality caused by migration. We also note that our estimate of L could change when the results of more years of recovery data are in. It is possible that L will increase with time because of deterioration of tags and growth of bluefin. If either L or Type-I and II tagging mortalities are underestimated the rate of exploitation will be underestimated. The estimate of mortality rates by Mather et al. (MS) are based on the assumption of constant mortality with respect to age. Results of a study by Sakagawa et al. (MS) indicate that mortality varies considerably with age. Thus the results shown in Table 4 are subject to question.

Table 4. Estimates of rates of exploitation and other losses from Table IV-3-A of Mather, et. al. (MS) and 1971 U.S. east coast double tag study

	1964	1965	1966	1967	1968
\hat{S}	0.128	0.160	0.407	0.244	0.201
\hat{U}_1	0.211	0.150	0.143	0.224	0.385
\hat{U}_T	0.242	0.178	0.225	0.292	0.478
n	1	2	4	3	2
\hat{F}	0.497	0.326	0.202	0.412	0.767
\hat{X}	1.558	1.506	0.697	0.999	0.838
$(F + X)$	2.056	1.833	0.899	1.411	1.604
$(F + X)^*$	1.776	1.553	0.619	1.131	1.324
\hat{S}^*	0.169	0.212	0.538	0.323	0.266
\hat{U}_T^*	0.249	0.183	0.282	0.301	0.492
\hat{U}_1^*	0.217	0.154	0.147	0.231	0.396
\hat{F}^*	0.512	0.336	0.223	0.431	0.795
\hat{X}^*	1.264	1.217	0.396	0.700	0.529
\hat{U}_1^{**}	0.240	0.170	0.166	0.258	0.441
\hat{U}_T^{**}	0.281	0.214	0.343	0.377	0.590

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