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A PRELIMINARY ESTIMATION OF FISHING MORTALITY RATES OF BLUEFIN TUNA IN THE WESTERN ATLANTIC OCEAN, BASED ON TAGGING EXPERIMENTS IN 1975 TO 1981

T. Doi, Y. Kishimoto, Z. Suzuki
Far Seas Fisheries Research Laboratory

SUMMARY

The NMFS Laboratory at the Southeast Fisheries Center, Miami, U.S.A., provided us with a long series of tagging records for bluefin tuna. Unfortuantely, they contained some unusable records, but still served for evaluating the fishing mortality coefficient. Analyzed here are records for fish tagged in 1975 to 1981 at ages of five years or younger, and recaptured in the year of release or following two years.

A method is developed to estimate the fishing mortality coefficient of fish exploited in some limited seasons of the year. The fishing mortality can vary from year to year, but the fishing seasons must be common in duration and in time over the years under discussion.

The recapture ratio during this period showed fairly large variations among the five age groups. The resultant estimates of fishing mortality coeficients per year ranged from 0.008 for age-3 fish recaptured in 1977 to 0.167 for age-3 fish taken in 1978.

RESUME

Le laboratoire de Miami du NMFS nous a remis une série d'une bonne longueur de registres de marquages de thon rouge, qui comporte malheureusement quelques registres inutilisables, mais est utile pour l'évaluation du coefficient de mortalité par pêche. Nous analysons ici l'information correspondant à des poissons marqués de 1975 à 1981 à un âge de 5 ans ou moins, et repris la même année ou au bout de deux ans.

Une méthode est élaborée pour estimer le coefficient de mortalité par pêche du poisson exploité à certains saisons limitées de l'année. La mortalité par pêche peut varier d'année en année, mais la durée et l'époque de la saison de pêche doivent être les mêmes pour les années étudiées.

Le taux de recapture ces mêmes années montre des variations assez importantes entre les cinq groupes d'âge. Les estimations du coefficient annuel de mortalité par pêche qui en découlent vont de 0.008 pour les poissons d'âge 3 repris en 1977 à 0.167 pour les poissons de 3 ans repris en 1978.

RESUMEN

El laboratorio del NMFS, en Miami, facilitó una excelente y larga serie de registros de marcado de atún rojo. Desafortunadamente, algunos de estos registros no se pueden emplear, pero son útiles en la evaluación del coeficiente de mortalidad por pesca. En este documento se analizan registros de peces marcados de 1975 a 1981, con edades de 5 años o menos, y recapturados el mismo año que fueron marcados o bien dentro de los dos años siguientes.

Se desarrolla un método de estimación del coeficiente de mortalidad por pesca de peces explotados durante una temporada limitada. La mortalidad por pesca puede variar de año en año, pero las temporadas de pesca deben tener una duración y una época común en el curso de los años estudiados.

La tasa de recaptura, en los mismos años, mostraba variaciones bastante notables entre los grupo de edad de 5 años. Los coeficientes estimados de mortalidad por pesca anual se encontraban entre 0.008, para peces de 3 años recapturados en 1977 y 0.167 para peces de 3 años recapturados en 1978.

1. Introduction

The cohort analysis is widely used for stock assessment of commercially important species of long life span. A requirement for ensuring the validity of this method of analysis is that reliable estimate is available of the fishing mortality rate in the last year of the data series, which is called terminal-F. Such data are seldom obtained for bluefin tuna stocks in the western Atlantic Ocean. Tagging experiment continuously conducted by the Miami Laboratory of the U.S. National Marine Fisheries Service provides a rare opportunity for the estimation of fishing mortality rates of young bluefin tuna ranging between one and five years old in seven years from 1975 to 1981.

The manuscript was sent on 11 June 1984 to the Southeast Fisheries Center for review of the Center's scientists. They responded quickly to us and explained procedures of execution and data compilation of the tagging experiments on 31 July 1984. It is understood to take long time for elucidating the efficient series of tage and recaputure data. The present paper is submitted to the working group meeting at the first approach for the further cooperation in this field.

We would like to express our acknowledgement to Dr. J. Powers and Mr. M. Parrack of the Miami Laboratory for sending and explaining us the data file, on which this study was based.

2. Available tagging data

The available files comprise large data of approximately 35,000 tags of bluefin tuna released and reported in nearly 30 years from sometime in the 1950's to 1981. It should be noted that the data are enumerated in number of tags but not in number of individual fish, some of which brought two or more tags with them.

Inspection of data showed missing or erroneous reports. The errors are classified into six categories.

1) There were some fish with double tags but with report for only one of them.
2) Release records were not filed for some recaptured fish.
3) Data were missing or illogical for date, month or year. One example of illogical records is 1979.80.30.
4) No record was made available for fork length, body weight and age of fish. Size data were kept for only 216 fish among 1 795 that were tagged in 1981.
5) Contradiction occurred between age and size records for some fish. An extreme example is a fish which was aged 0 year, but measured 200 cm in fork length.
6) Contradictory records appeared between age at release and age at recapture for some fish.

It is very likely to assume that the correction for the voluminous files needs a quite long time. Nevertheless, there is an agreement among ICCAT scientists for that the U.S. scientists would provide more reliable tag data as soon as possible (ICCAT 1983).

Effort was paid in this study to make useful as many fish as feasible according to the following two criteria.

1) Undesignated date of release or recaputre was assumed 15th or midpoint of the month. June or midpoint of the year was given for the data without record of the month.
2) Recorded age was adopted for the fish with difference of one year between recorded age and estimated age from size record.
3) For fish with discrepancy between age data at release and recapture, the age at release is adopted as far as it is available. If this is not recorded, the fish is classified to the age at recapture.

Fork length, l, of fish recorded only in body weight, w, is

estimated with the use of length-weight relationship given in Equation 1 proposed by Parrack (1982). A similar calculation is adopted for converting measured or estimated fork length to age of fish lacking the chronological record by assuming a growth curve of Equation 2 (Parrack and Phares 1979).

Eq. 1 $\underline{W} = 2.86 \times 10^{-5} \times \underline{l}^{2.93}$

Eq. 2 $\underline{l} = 313 \left[1 - 0.9169 \exp(-0.0903\underline{t})\right]$

where, $\underline{l}$: fork length in cm,

$\underline{w}$: live weight in kg,

$\underline{t}$: age in year at the beginning of May.

Strictly speaking there is a minor bias in estimating age of fish, because a few fish were not determined either in live weight nor in fork length.

Through these treatments 12 729 release and recapture data sets are refiled for estimating the fishing mortality rates in the seven years from 1975 to 1981. The single tags made up of 10 682 released fish and 928 recaptured fish, and the multiple tags comprised 2 047 releases and 295 recaptures. The virtural recovery rates appear lower for the single tags or about 8 percent than for the multiple tags or about 14 percent. But chi-square test did not indicate significance for the difference at a probability of 5 percent, even if it appears reasonable to note that multiple tags were nearly twice as much discovered as single tags.

There are some fish which cannot be aged by any means. It is noted that the share of unaged fish was negligible from 0.2 percent in 1979 to 2.3 percent in 1975, but rose to 27.6 percent in 1980 and even 88.4 percent in 1981 (Table 1).

Determination of age becomes more difficult for older fish due to decrease of yearly increment of length and weight. Therefore, the present present survey covers only very young fish of zero (0) to five (5) years old.

Eventually 8 810 release data were used for the present analysis. It is not possible to evaluate the extent of possible bias in estimates of fishing mortality rates due to elimination of the non-aged fish, especially those in 1980 and 1981.

Appendix Tables 1 to 7 give counts of released and recaptured fish by age and by duration of liberty for the total of 12 729 fish. Table 1 summarizes the recaptures by groups of duration of liberty which may serve as the base of the present estimation.

3. Method of calculation

The present calculation is based on the conventional techniques of stock assessment. In detail, the natural mortality coefficient, M, stays constant, 0.18 per year throughout the period under consideration. Taking remarkable seasonality of bluefin tuna fishing into account, the calculation assumes that the fishing season lasts for a certain duration of T that occurs at the same time of year. Fishing mortality stays constant for a given fishing season in a year, but may change from year to year. It is also assumed that the fish are released at the beginning of the fishing season, T. Figure 1 represents fishing mortality for a tagged cohort at different level from year to year. In case that there is a single fishing season of T, number of fish with tags at a given time, t, during the fishing season, and number of recaptured fish in the first year of release are expressed Equations 3 and 4.

Eq. 3 $x = R \exp\left[-(M+F)t\right] \quad 0 \leq t \leq T$

Eq. 4 $r = \int_0^T FXdt$

where x: number of fish with tags at time of t,

R: number of fish released at beginning of T or t=0,

M: natural mortality coefficient,

F: fishing mortality coefficient,

r: number of fish recaptured during the first fishing season after release.

Equation 5 represents a ratio of number of recaputures to total release, based on Equations 3 and 4.

Eq. 5 $r/R = \frac{F}{M+F}\left[1-\exp(-(M+F))T\right]$

In Equation 5, T approximates to 4/12 = 0.3333, because the fishing season lasts usually for four months from June to September during the seven years under consideration. Assuming M be constant, the tagging data provides estimates of fishing mortality coefficient with the use of the Equation 5, in case that all the tags be attached to the fish which behave as the other untagged members, and be found and reported to the research institutes when the tagged fish be caught.

Actually tagging procedure may injure the fish and then could lead them into death, especially just after the operation. Tags could drop from body of the fish due to various causes. It is very likely that there are two types of loss of taggs. One occurs just after the tagging operation due to immediate effects of tagging operation on liveliness of fish and stability of tags on the body. The other loss can continuously occur at rather constant intensity. Baglin et al. (1980) estimated for bluefin tuna in the northwestern Atlantic Ocean, that the immediate loss is about four (4) percent of total fish tagged, and the following continous loss approximates 0.205 per year as instantaneous coefficient.

No direct measure is made available for counts of fish which were not found when they were captured in the fishing grounds, or brought to the markets. Taking these types of loss, real number of total tagged fish in Equation 5 be modified as (1-a)R insted of R, real number of total recaputre be r/(1-q), and total mortality coefficient be (M+F+p) but not (M+F), where,

p: coefficient of shedding of tags which may continue for long period of time at more or less constant intensity.

q: ratio of tagged fish which were not found or reported to the total recaputres,

and a: ratio of tagged fish which died or lost their taggs immediately after the tagging operations.

Therefore, Equation 5 is to be modified as Equation 6.

Eq. 6 $\frac{\frac{r}{1-q}}{(1-a)R} = \frac{F}{M+F+P}\left[1-\exp(-(M+F+P)T)\right]$

Furthermore, both Equation 5 and Equation 6 assume that all the fish be tagged simultaneously at the beginning of fishing season, To or 1st June. Appendix Tables 8 to 14 indicate that the tagging operation was not neccesarily conducted in June, but mostly in July as in 1975 through 1977, or in August as in 1978 and 1981, and last for two or even three months.

Such discrepancy in time of tagging requires correction for it. A calculation of average release date, T'mo, as calculated by Equation 6', serves for the required correction.

Eq. 6' $T'mo = \frac{\sum_i^n Ti}{n}$

where Ti: number of days from a fixed reckoning day to release day for i-th individual

n: number of fish released

However, for practical use, T"mo is converted to a calender date, T'mo.

Appendix Tables 8 to 14 show that the average release date extend from 25 June in 1980 to 20 August in 1978. These dates should replace the assumed 1 June for the years when the given cohort was released in calculating Equation 5 or Equation 6. The relative duration of tagged fish exposed for fishing, Tm, is calculated as a ratio duration from T'mo to 30 September in terms of month against 12 months. Values of Tm are also included in Appendix Tables 8 to 14, which vary from 0.114 in 1978 to 0.264 in 1980.

Treatment of data for each year of recapture needs modification for total size of tagged stocks in the next and following years after tagging operation. Namely, R in Equations 5 and 6 no longer represents number of tagged fish in the sea, because the tagged fish received fishing mortality in duration of Tm and natural mortality during seven months since 1st June. The denominator on the left term in Equation 6 is given by Equation 7'.

$$\text{Eq. 7'} \qquad R't = (1-a)R_{t-1} \cdot \exp\left[-(M+P)(1-T+Tm)-F_{t-1} \cdot Tm\right]$$

Likewise the denominator for the third year of tagging experiment is given by Equation 7".

$$\text{Eq. 7"} \qquad R"t = R'_{t-1} \cdot \exp\left[-(F_{t-1}T+M+P)\right]$$

Theoretically it is possible to calculated the fishing coefficient in following years with the data obtained then, but decrease of tagged stocks and size of recaputres may forbide estimation of mortality coefficients at high accuracy.

4. Results.

Table 2 gives counts of fish of zero to five years old released in 1975 to 1981, and number of fish recaputres in the seven years, together with Tm's or indices of average duration of fishing season for tagged stocks. It should be recalled that fishes suffer from fishing mortality not in whole year but only in fishing seasons which last Tm in the first year of tagging or T in the following years.
Fishing mortality coefficient per year is obtained by multiplying the value Tm or T.

Conversion of recapture ratio to fishing mortality coefficient was repeated for the recaptures in the second and third years after tagging operations as given in Tables 3 and 6 and Tables 4 and 7, respectively.

5. Discussion and conclusions

A comparison between Tables 5, 6 and 7 indicates discrepancy among estimates of fishing mortality coefficients in the fishing season depending upon sets of data. For instance, F for 2-age fish in 1978 was estimated 0.092 in Table 5, but 0.383 in Table 6. All the estimates for release number of 100 or more fish are given in Table 8. There are two possible common measures of F's for an age group in a year, for which two estimates were made available. The first is an arithmetic mean of F estimates. It is also possible to calculate another common estimate of F on the assumption that all 0- to 5-age fish were equally vulnerable to the fisheries.

Here is selected the arithmetic mean which is easy to calculate. The estimates ranged from 0.025 as for 3-age fish in 1977 to 0.500 as for 3-age fish in 1978 (Table 9). Since the mean duration differs among fish recaptured in the year of tagging operation and also between

them and fish in the second and third years of tagging operations, it is better to convert the relative coefficient to the conventional fishing mortality coefficient per year (Table 10). Using catch at age table (ICCAT 1984) and the terminal F's in Table 10, number of recruitment at the beginning of age 1 was calculated for the years 1974-1979 (Table 11, Fig. 2). It was indicated that the 1973 year class appeared quite strong, 110 x 10^4 fish in terms of geometric mean compared with low but relatively stable recruitment from 1976 to 1979 which ranged between 21 x 10^4 and 37 x 10^4 fish.

The aforementioned calculation bases on a number of assumptions. Considered here among them comprise two factors inclusive of a or immediate loss of tagged fish just after the operation and q or ratio of unreported fish after recaputres, both of them were neglected at the present study. Inserting possible values of 0.01 to 0.20 for both paramenters into Equation 6, the possible change of F values are calculated so that even moderate change in a and q may cause rise of F' values by about 20 percent. This indicates importance of measuring such additional parameters for ensuring the accuracy of fishing mortality. Moreover, the data would be revised at the Miami Laboratory. Re-analysis based on such revision would be very useful for evaluating the stock status of bluefin tuna in the area under discussion.

References

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3 ICCAT 1984 Report of working group on bluefin tuna (BFTWG/84)

4 Parrack M.L. 1982 Atlantic bluefin tuna resource update, ICCAT CVSP Vol, XVII, p 315-321

5 Parrack M.L. and P.L. Phares 1979 Aspects of the growth of Atlantic bluefin tuna determined from mark-recapture data, ICCAT, CVSP Vol, VIII, P 356-420

Table 2. Number of 0- to 5-age bluefin tuna tagged in 1975 to 1981 (denominators) and number of recaptures in the same year (numerators).

YEAR	1975	1976	1977	1978	1979	1980	1981
Tm	178	217	229	114	230	264	150
AGE							
0	0 / 14	0 / 7	0 / 51	0 / 27	0 / 11	0 / 16	0 / 6
1	10 / 145	25 / 750	4 / 192	11 / 839	2 / 94	1 / 46	13 / 124
2	7 / 65	112 / 1034	35 / 1631	5 / 489	0 / 64	120 / 1944	4 / 46
3	2 / 14	48 / 600	0 / 14	0 / 6	1 / 101	3 / 204	8 / 24
4	2 / 53	0 / 0	0 / 11	0 / 1	0 / 2	5 / 73	8 / 8
5	1 / 11	0 / 0	0 / 0	0 / 0	0 / 89	0 / 1	3 / 3

Indices of duration of fishing season are cited from Appendix tables 8 to 14.

Table 1. Number of tagged fish at different age released in 1975 to 1981, and number of fish recaptured therefrom.

Year of release	Number of released fish by age groups					Number of fish recaptured in 1975 to 1981				
	Total	0-5 years	VI-6 years	unknown	unknown o/o to Total	Total	Year of release	one year after	two years after	over there years after
1975	352	302	42	8	2.3	58	22	27	6	3
76	2469	2391	34	44	1.8	333	185	64	75	9
77	2139	1899	214	26	1.5	339	55	201	82	1
78	1688	1362	318	8	0.7	171	24	108	33	6
79	1125	361	762	2	0.2	47	6	30	11	
80	3161	2284	5	872	27.6	227	129	98		
81	1795	211	5	1579	88.4	48	48			
Total	12729	8810	1380	2539		1223	469	528	207	19

Table 3. Number of fish tagged in 1975 through 1980 and estimated to have lived at beginning of the second fishing season (denominators) and number of recaptures of the second fishing season (numerators).

YEAR	1976	1977	1978	1979	1980	1981
AGE						
1	1/10	0/5	0/36	0/20	0/8	0/11
2	16/97	38/515	15/133	63/613	6/65	5/31
3	9/42	5/653	179/1129	41/358	6/45	86/1271
4	0/9	20/391	0/10	0/4	4/71	3/140
5	1/37	0/0	1/8	1/1	0/1	0/47

Year and age are given for the second fishing season.

Table 4. Number of fish tagged in 1975 through 1979 and estimated to have lived at beginning of the third fishing season (denominators) and number of recaptures in the third fishing season (numerators).

YEAR	1977	1978	1979	1980	1981
AGE					
2	0/6	0/3	0/24	1/14	1/5
3	1/54	42/323	14/80	20/372	5/40
4	2/22	20/441	67/639	6/214	1/26
5	0/6	11/252	0/7	0/3	1/45

Year and age are given for the third fishing season.

Table 5. Fishing mortality coefficient in the fishing season based on recapture data taken in the first fishing season.

YEAR	1975	1976	1977	1978	1979	1980	1981
AGE							
0	.000	.000	.000	.000	.000	.000	.000
1	.416	.163	.096	.118	.098	.088	.762
2	.663	.552	.099	.092	.000	.254	.626
3	.897	.401	.000	.000	.045	.059	2.800
4	.224	-----	.000	.000	.000	.283	32.496
5	.555	-----	-----	-----	.000	.000	32.496

Table 6. Fishing mortality coefficient in the fishing season based on recapture data in the second fishing season.

YEAR	1976	1977	1978	1979	1980	1981
AGE						
1	.337	.000	.000	.000	.000	.000
2	.578	.245	.383	.347	.310	.564
3	.775	.025	.553	.390	.459	.224
4	.000	.168	.000	.000	.186	.069
5	.088	----	.428	.000	.000	.000

Year and age are given for the second fishing season.

Table 7. Fishing mortality coefficient in the fishing season based on recapture data taken in the third fishing season.

YEAR	1977	1978	1979	1980	1981
AGE					
2	.000	.000	.000	.237	.717
3	.060	.446	.617	.177	.428
4	.305	.149	.355	.091	.125
5	.000	.143	.000	.000	.072

Year and age are given for the third fishing season.

Table 8. Fishing mortality coefficient in the fishing season estimated for size of tagged fish of 100 or more, selected from Tables 5, 6 and 7.

YEAR	1975	1976	1977	1978	1979	1980	1981
AGE							
1	.416	.163	.096	.118			
2		.552	.099 .245	.092 .383	.347	.254	
3		.401	.025	.553 .446	.045 .390	.059 .177	.224
4			.168	.149	.355	.091	.069
5				.143			

In each cell, the upper, middle and low numbers denote the estimates based on data in the first, second and third year after tagging, respectively.

Table 9. The mean values of the fishing mortality coefficient in the fishing season.

YEAR	1975	1976	1977	1978	1979	1980	1981
AGE							
1	.416	.163	.096	.118			
2		.552	.172	.238	.347	.254	
3		.401	.025	.500	.218	.118	.224
4			.168	.149	.355	.091	.069
5				.143			

Table 10. Average fishing mortality coefficient per year

YEAR	1975	1976	1977	1978	1979	1980	1981
AGE							
1	0.074	0.035	0.022	0.013			
2		0.120	0.053	0.069	0.116	0.067	
3		0.087	0.008	0.167	0.070	0.038	0.075
4			0.056	0.050	0.118	0.030	0.023
5				0.048			

Table 11. Population numbers at the beginning of age one estimated from number of catch by age (ICCAT 1984) and starting F's in Table 10.

unit: 10^4 fish

YEAR	1974	1975	1976	1977	1978	1979
Recruitment at the beginning of age one	156	67	17	7	48	37
	110	27	57	20	13	36
	77	154	21	34	35	
		30	19	47	43	
Geometric mean	110	54	25	21	31	37

Appendix Table 1 Release-recapture number in each year

RELEASED YEAR = 1975

RELEASED AGE & NO.		RECAPTURED YEAR & NO. 1975	1976	1977	1978	1979	1980	1981
0	14	0	1	0	0	0	0	0
1	145	10	16	1	2	0	0	0
2	65	7	9	2	0	0	0	0
3	14	2	0	0	0	0	0	0
4	53	2	1	0	0	0	0	0
5	11	1	0	0	0	0	0	1
OD THAN 5	42	0	0	3	0	0	0	0
UNKNOWN	8	0	0	0	0	0	0	0

Appendix Table 2 Release-recapture number in each year

RELEASED YEAR = 1976

RELEASED AGE & NO.		RECAPTURED YEAR & NO. 1976	1977	1978	1979	1980	1981
0	7	0	0	0	0	0	0
1	750	25	38	42	3	0	0
2	1034	112	5	20	3	0	0
3	600	48	20	11	2	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
OD THAN 5	34	0	1	2	0	0	1
UNKNOWN	44	0	0	0	0	0	0

Appendix Table 3 Release-recapture number in each year

RELEASED YEAR = 1977

RELEASED AGE & NO.		RECAPTURED YEAR & NO. 1977	1978	1979	1980	1981
0	51	0	0	0	0	0
1	192	4	15	14	1	0
2	1631	35	179	67	0	0
3	14	0	0	0	0	0
4	11	0	1	0	0	0
5	0	0	0	0	0	0
OD THAN 5	214	16	6	1	0	0
UNKNOWN	26	0	0	0	0	0

Appendix Table 4 Release-recapture number in each year

RELEASED YEAR = 1978

RELEASED AGE & NO.		RECAPTURED YEAR & NO. 1978	1979	1980	1981
0	27	0	0	1	0
1	839	11	63	20	2
2	489	5	41	6	2
3	6	0	0	0	0
4	1	0	0	0	0
5	0	0	0	0	0
OD THAN 5	318	8	4	6	2
UNKNOWN	8	0	0	0	0

Appendix Table 5 Release-recapture number in each year

RELEASED YEAR = 1979

RELEASED AGE & NO.		RECAPTURED YEAR & NO. 1979	1980	1981
0	11	0	0	1
1	94	2	6	5
2	64	0	6	1
3	101	1	4	1
4	2	0	0	0
5	89	0	4	0
OD THAN 5	762	3	10	3
UNKNOWN	2	0	0	0

Appendix Table 6 Release-recapture number in each year

RELEASED YEAR = 1980

RELEASED AGE & NO.		RECAPTURED YEAR & NO. 1980	1981
0	16	0	0
1	46	1	5
2	1944	120	86
3	204	3	3
4	73	5	0
5	1	0	0
OD THAN 5	5	0	0
UNKNOWN	872	0	4

Appendix Table 7 Release-recapture number in each year

RELEASED YEAR = 1981

RELEASED AGE & NO.		RECAPTURED YEAR & NO. 1981
0	6	0
1	124	13
2	46	4
3	24	8
4	8	8
5	3	3
OD THAN 5	5	1
UNKNOWN	1579	11

Appendix Table 8 Release record by age by month, 1975

	AGE	0	1	2	3	4	5
JAN	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
FEB	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
MAR	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
APR	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
MAY	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
JUN	F	0	0	0	0	0	0
	M	5	13	11	0	0	0
	L	0	12	8	2	0	0
JUL	F	1	17	6	0	0	0
	M	2	17	15	9	22	0
	L	4	61	10	1	3	0
AUG	F	0	9	1	0	0	1
	M	0	5	3	0	0	5
	L	2	3	4	0	0	1
SEP	F	0	1	2	1	0	0
	M	0	2	4	1	0	0
	L	0	5	1	0	28	4
OCT	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
NOV	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
DEC	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
TOTAL		14	145	65	14	53	11

Fishing season .... 6/1 - 9/30
Average release date 7/27
Tm(1975) 0.178

Appendix Table 9 Release record by age by month, 1976

	AGE	0	1	2	3	4	5
JAN	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
FEB	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
MAR	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
APR	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
MAY	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
JUN	F	0	0	0	0	0	0
	M	0	2	4	6	0	0
	L	0	2	1	14	0	0
JUL	F	1	152	318	122	0	0
	M	2	572	711	458	0	0
	L	0	7	0	0	0	0
AUG	F	0	0	0	0	0	0
	M	4	12	0	0	0	0
	L	0	2	0	0	0	0
SEP	F	0	0	0	0	0	0
	M	0	1	0	0	0	0
	L	0	0	0	0	0	0
OCT	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
NOV	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
DEC	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
TOTAL		7	750	1034	600	0	0

Fishing season .... 6/1 - 9/30
Average release date 7/13
Tm(1976) 0.217

Appendix Table 10 Release record by age by month, 1977

	AGE	0	1	2	3	4	5
JAN	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
FEB	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
MAR	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
APR	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
MAY	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
JUN	F	0	1	0	0	0	0
	M	0	8	17	0	0	0
	L	0	25	40	2	0	0
JUL	F	5	147	1358	8	7	0
	M	0	9	205	1	1	0
	L	0	0	0	0	0	0
AUG	F	0	0	0	0	1	0
	M	0	0	0	0	1	0
	L	1	1	0	3	0	0
SEP	F	0	0	0	0	1	0
	M	10	1	11	0	0	0
	L	35	0	0	0	0	0
OCT	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
NOV	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
DEC	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
TOTAL		51	192	1631	14	11	0

Fishing season .... 6/1 - 9/30
Average release date 7/ 8
Tm(1977) 0.229

Appendix Table 11 Release record by age by month, 1978

	AGE	0	1	2	3	4	5
	F	0	0	0	0	0	0
JAN	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
FEB	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
MAR	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
APR	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
MAY	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
JUN	M	0	0	1	0	0	0
	L	0	12	32	0	0	0
	F	1	1	4	0	0	0
JUL	M	0	1	2	0	1	0
	L	7	24	13	2	0	0
	F	0	34	21	1	0	0
AUG	M	18	61	33	2	0	0
	L	0	705	377	1	0	0
	F	0	1	6	0	0	0
SEP	M	0	0	0	0	0	0
	L	1	0	0	0	0	0
	F	0	0	0	0	0	0
OCT	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
NOV	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
DEC	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
TOTAL		27	839	489	6	1	0

Fishing season .... 6/1 - 9/30
Average release date 8/20
Tm(1978) 0.114

Appendix Table 12 Release record by age by month, 1979

	AGE	0	1	2	3	4	5
	F	0	0	0	0	0	0
JAN	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
FEB	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
MAR	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
APR	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
MAY	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	1	0	0	0
JUN	M	0	4	6	1	0	8
	L	7	70	38	2	0	5
	F	4	6	3	0	0	26
JUL	M	0	8	1	94	1	50
	L	0	0	0	0	0	0
	F	0	4	4	2	0	0
AUG	M	0	1	9	0	0	0
	L	0	0	2	2	1	0
	F	0	0	0	0	0	0
SEP	M	0	1	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
OCT	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
NOV	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
	F	0	0	0	0	0	0
DEC	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
TOTAL		11	94	64	101	2	89

Fishing season .... 6/1 - 9/30
Average release date 7/ 8
Tm(1979) 0.230

Appendix Table 13 Release record by age by month, 1980

	AGE	0	1	2	3	4	5
JAN	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
FEB	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
MAR	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
APR	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
MAY	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
JUN	F	0	0	0	0	0	0
	M	1	13	17	49	1	0
	L	8	18	1925	152	66	0
JUL	F	0	3	0	0	0	0
	M	0	7	0	0	0	0
	L	0	0	0	0	0	0
AUG	F	1	0	0	0	0	0
	M	2	2	0	0	0	0
	L	1	1	1	0	0	0
SEP	F	0	1	0	0	3	1
	M	3	0	1	2	3	0
	L	0	1	0	1	0	0
OCT	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
NOV	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
DEC	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
TOTAL		16	46	1944	204	73	1

Fishing season .... 6/1 - 9/30
Average release date 6/25
Tm(1980) 0.264

Appendix Table 14 Release record by age by month, 1981

	AGE	0	1	2	3	4	5
JAN	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
FEB	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
MAR	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
APR	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
MAY	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
JUN	F	0	0	0	0	0	0
	M	0	0	7	9	2	3
	L	0	0	0	9	6	0
JUL	F	0	0	0	0	0	0
	M	0	3	3	1	0	0
	L	0	5	6	0	0	0
AUG	F	0	26	8	0	0	0
	M	3	29	6	1	0	0
	L	1	56	13	3	0	0
SEP	F	1	3	0	0	0	0
	M	0	0	2	0	0	0
	L	1	1	1	0	0	0
OCT	F	0	1	0	0	0	0
	M	0	0	0	1	0	0
	L	0	0	0	0	0	0
NOV	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
DEC	F	0	0	0	0	0	0
	M	0	0	0	0	0	0
	L	0	0	0	0	0	0
TOTAL		6	124	46	24	8	3

Fishing season .... 6/1 - 9/30
Average release date 8/ 7
Tm(1981) 0.150

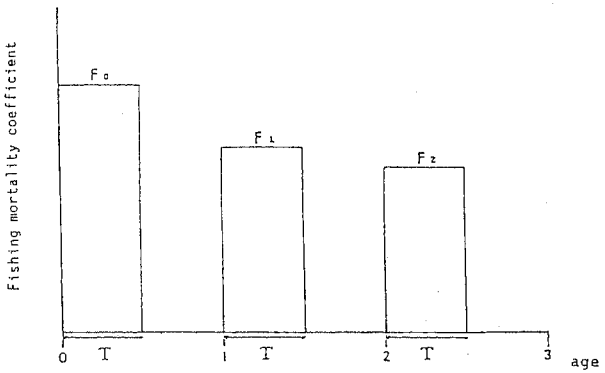

Fig. 1. Schematic presentation of occurrence of fishing.

Note that time and duration of fishing are constant over years while fishing mortality coefficients stay constant in a fishing season but can change between fishing seasons.

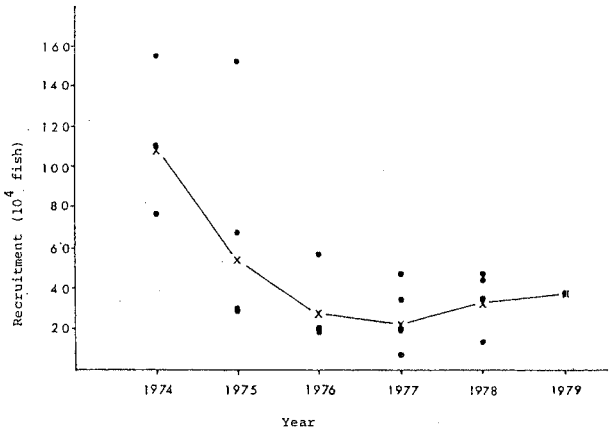

Fig. 2. Recruitment in number at the beginning of age one calculated from the F's in Table 10.

Cross marks denote annual geometric mean.