

AN APPROACH TO ESTIMATION OF TOTAL ALLOWABLE CATCH OF ATLANTIC BLUEFIN TUNA

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SUMMARY

Based upon the analyses of the Atlantic bluefin tuna size data revised at the SCRS Intersessional Bluefin Tuna Workshop held in May and September, 1983, provisional projection of the stock was conducted together with its possible allowable catch, taking into consideration the best estimates of fishing intensity in recent years and the effects of the regulations imposed on the stock.

RESUME

Sur la base des analyses effectuées sur les données de taille du thon rouge de l'Atlantique, révisées lors des Journées d'étude sur le thon rouge qui se sont tenues en mai et en septembre 1983, une évaluation provisoire du stock a été faite, ainsi que le calcul des éventuelles prises permises, en tenant compte des meilleures estimations de l'intensité de pêche des années récentes et des effets des réglementations imposées sur le stock.

RESUMEN

Se efectuó una previsión provisional del stock, basándose en los análisis de los datos de talla del atún rojo del Atlántico, y posible captura asignada, que habían sido revisados en las Jornadas de Trabajo sobre el Atún Rojo, del SCRS, celebradas en Mayo y Septiembre de 1983. Se tuvieron en cuenta las mejores estimaciones de intensidad de pesca en años recientes, y los efectos de las regulaciones sobre el stock.

1. Introduction

The stock appraisal of Atlantic bluefin tuna has been recently confused a great extent. At the 1982 SCRS meeting held at Madeira, diverse interpretations on the past stock behavior and its expected future stock status were presented, and concerns were expressed in various aspects of the data base itself and analytical methods (ICCAT 1983). In the course of two intersessional workshops on bluefin tuna since then, the data base was thoroughly reviewed by scientists of main bluefin fishing countries, and at the same time discussed were considerations on better biological information and analytical technique of the stock.

At this moment, though many subjects to be investigated are still unsolved and in progress, an attempt was made in this report to re-estimate future stock behavior by follow-up of the previous stock projection made by Kume and Suzuki 1983, based on revised catch-at-age data and re-estimated fishing mortality. The projection was made for only "western stock", as an example, the data of which are now revised to repletion by the review of the workshops (Nagai 1983 a).

2. Data and estimation procedures

The basic data used in this analysis were stock number at age in 1981, estimated catch-at-age data in 1982 and 1983, and population parameters needed in the projection model.

(1) Stock number at age in 1981.

The numbers of fish at age of the stock in the western Atlantic were referred to the estimation by Nagai 1983 b, which was based on separable virtual population analysis (VPA) for the ages 8-20 and conventional VPA for the ages 1-7. For the ages of 21 and older, the numbers at age were estimated using fishing mortality coefficient at age 20 (F_{20}) in 1981. In

this report, two sets of data were employed, which were obtained by applying separable VPA for the years 1975-81 and .15 and .20 of F_{20} . The latter F_{20} estimated less stock abundance.

(2) Estimation of catch-at-age data in 1982 and 1983. (Table 1)

Japan : After 1982, no longline operation was made in the Gulf of Mexico, and the fishing pattern in other areas was not changed since then. Catch-at-age data in 1982 and 1983 were assumed to be similar to those in 1981 exclusive of the catch in the Gulf of Mexico, under the monitoring quota of both years.

USA : The catch-at-age data in 1982 were estimated using reported catch and biological sampling data. For 1983, the size composition of the catch were assumed to follow 1982 data, according to which the 1983 catch-at-age data were estimated by gear under the monitoring catch scheme by gear.

Canada : The 1981 catch-at-age data, excluding purse seine catch, were applied to estimate 1982 and 1983 data according to the monitoring quota in each year.

(3) Fecundity (spawning potential) by age. (Table 2)

Age-specific spawning potential, expressed by number of eggs, was referred to from Suzuki and Hisada (1983).

(4) Natural mortality coefficient (M).

Employed was 0.18, which has been used in most of the bluefin studies.

(5) Growth equation and length-weight (L-W) relation (Parrack 1982).

i) Growth equation:

$$L_t = 313 (1 - .9169 \exp^{-.0903t})$$

ii) L-W relation :

$$W = .2861 \times 10^{-4} \times L^{2.929}$$

(6) Projection of the stock under two levels of allowable catch

i) 1982 and 1983 stock sizes and fecundity were calculated by catch-at-age

data and age-specific fecundity as above described using catch equation.

ii) Average fishing pattern (age-specific F-pattern) during 1979-1981, which was obtained from Nagai (op. cit.), was assumed for the years 1984-1990, as shown in Table 3.

iii) Recruitment at age 1 after 1982 was assumed three alternatives:

As shown in Table 4, average number of recruitment (N_1) was estimated to be 610,000 for the case $F_{20} = .15$ in separable VPA and 460,000 for $F_{20} = .20$. First alternative for N_1 was 500,000. The second was 200,000 which is close to the minimum estimate of 230,000 in all estimated N_1 . The third alternative was in-between value of other two N_1 .

iv) Allowable catch after 1983

Annual catches of 3,000 and 5,000 MT were assumed under the average fishing pattern aforementioned. The latter amount is close to average catch in late 1970's.

v) Projection

The changes in stock size and spawning potential were projected for 9 years up to 1990.

3. Results

The computed results on numbers and fishing mortality at age of the stock were shown in Table 5, as an example. All the results are illustrated in Figs. 1-3, as indicated by the change in stock size and fecundity by age groups.

The followings outline the results by two cases: the one describes the case for stock number at age estimated under $F_{20} = .15$ in separable VPA and the other under $F_{20} = .20$.

Case 1: Stock size estimated by setting $F_{20} = .15$ in separable VPA.

Regardless of the amount of allowable catch assumed, the projected stock

size and its trend would not change substantially. As shown Fig. 1, stock abundance of ages 1-4 (N_{1-4}) decreases from 1.48 million at 1981 to some extent until 1983, and two years later the abundance becomes stabilized, because the constant recruitment was assumed. The level of stabilization is different depending on the amount assumed for recruitment strength: if 500,000 recruitment at age 1 (N_1) is assumed, the level is a little higher than that of 1981, whereas under 350,000 and 200,000 of N_1 recruitment, the stock abundance of N_{1-4} would become much lower than the 1981 level. The level of N_{5-9} would maintain the same level of 1981 until 1984, but it turns to downward trend until it attains stabilization in 1988. The above projection is a deduction of the computation, and the level of stabilization after certain year is only dependent upon assumed recruitment strength. The projected stock level for ages older than 10 (N_{10+}) indicates gradual increase by two times in abundance until 1988 and then turns on the decrease, most likely reflecting the dominant year classes in early 1970's. It is noted that the projected stock size of N_{10+} until 1990 is not influenced by assumed recruitment amount. The projected spawning potential continues to increase and becomes 1.6 times as much of 1981 level, but it turns to decreasing trend since 1988 for the cases of assumed recruitment of 200,000 and 350,000.

Case 2: Stock size estimated by setting $F_{20} = .20$ in separable VPA

It is again noted that there would be only minor change in the projected stock size between two assumed allowable catches. In this case, as shown in Fig. 3, the stock abundance of N_{1-4} shows continuous increase for the case N_1 500,000 since the beginning, whereas under other two alternatives of recruitment, N_{1-4} decreases once until 1983 and then stabilizes since then. As to the stock size of N_{5-9} would not change much until 1984, but after 1985 it would level off at certain level depending on the amount of recruitment

assumed. The stock size of N_{10+} would be on the increase until 1988 when it becomes more than twice as large, which will not be influenced by the amount of recruitment assumed. The spawning potential would increase 1.4-1.6 times as much in 1988 compared to that of 1981, and if more than 350,000 recruitment is assumed, the level of the potential would not be lowered below the 1981 level even after 1988.

4. Discussion

The present projection may be summarized as follows:

(1) The stock size of N_{1-4} would be dependent upon the amount of recruitment strength assumed. In the pessimistic case, it would become even below the 1981 size.

(2) The present projection for N_{5-9} would level until 1984 at 1981 level, but since then in many cases, the level would be lower than that of 1981, especially being remarkable in case of case 1. This is attributed to the assumption made about recruitment strength that was adopted to be less amount than the average of 610,000 for the case 1.

(3) The stock size of N_{10+} , which represents the principal abundance of the size of spawning stock, would increase regardless of the cases and recruitment amount assumed, and its size would become 1.4-1.6 times as much as that of 1981. Similarly, the fecundity of the stock follows the same trend. It is mentioned that this trend is ascribed to the recruitment of the dominant cohorts of early 1970's to the spawning stock.

In conclusion of this study, it should be remembered that among the base figures of stock size at age in 1981, the estimates for ages 1-7 are less in its reliability due to the nature of VPA and, that the robustness of the model is affected by the reliability on biological elements such as sexual dimorphism, growth, natural mortality rate, age structure and stock structure

etc., and estimation procedure of VPA. It is, however, noticeable that the difference in allowable catch here assumed such as 3,000 or 5,000 MT would be compatible and negligible in projecting the trend of future stock size or fecundity.

References

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Table 1. Estimated catch at age data of bluefin tuna in the western Atlantic in 1982 and 1983.
(See text for explanation)

Year	AGE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1982	3947	2603	2892	1776	891	570	445	381	235	303	398	519	481	290	221						
1983	4336	2845	4898	3785	1915	1225	926	813	511	590	694	836	674	429	394						
1982	156	130	154	171	130	137	136	96	83	71	53	37	26	18	10						
1983	308	300	365	431	310	333	327	207	186	156	126	91	61	47	24						

Table 2. FECUNDITY BY AGE IN MILLION OF EGGS, ESTIMATED BY SUZUKI USING SOCKS/76/66

AGE	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
AGE	0.00	0.15	1.06	2.70	5.12	8.25	10.15	12.00	13.90	15.75	17.65	19.50	21.40	23.25	24.50	25.95
EGG	21	22	23	24	25	26	27	28	29	30						
AGE	21.20	28.35	29.45	30.50	31.45	32.35	33.20	33.95	34.70	35.35						

Table 3. INPUT DATA OF F AT AGE PATTERN FOR PROJECTION, 1984 ON (1979-1981 AHERABEX (after Nagai, 1983)).

(F_{81,20} = 0.15)

AGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AGE	.0104	.0379	.0336	.0278	.0329	.0124	.0175	.0194	.0271	.0333	.0304	.0361	.0463	.0735	.1161
IMP-F															
AGE	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
IMP-F	.1332	.1560	.1667	.1580	.1667	.1667	.1667	.1667	.1667	.1667	.1667	.1667	.1667	.1667	.1667

(F_{81,20} = 0.20)

AGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AGE	.0135	.0501	.0462	.0388	.0457	.0178	.0236	.0286	.0391	.0470	.0422	.0489	.0617	.0962	.1502
IMP-F															
AGE	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
IMP-F	.1713	.2000	.2136	.2025	.2136	.2000	.2000	.2000	.2000	.2000	.2000	.2000	.2000	.2000	.2000

Table 4. Estimates of population number at age 1 (after Nagai, 1983).

Year	1975	1976	1977	1978	1979	1980	1981	Average	S.D.
F _{81,20}	81.20	59	73	90	67	77	34	30	61
	0.15	46	55	66	49	57	26	23	46
	0.20								16

Unit: 10⁴ fish

Table 5. Matrices of projected stock number and fishing mortality for bluefin tuna in the western Atlantic, 1981-1990.

(For the case TAC= 5,000 MT, Recruit at age 1 = 500,000, $F_{81,20} = 0.15$)

Stock number at age											Fishing mortality at age										
AGE\YEAR	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	AGE\YEAR	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	301093	500000	500000	500000	500000	500000	500000	500000	500000	500000	1	0.0207	0.0061	0.0079	0.0079	0.0077	0.0070	0.0067	0.0063	0.0059	0.0056
2	279764	246342	415099	414355	414350	414508	414713	414887	415029	415151	2	0.0727	0.0096	0.0062	0.0287	0.0281	0.0256	0.0244	0.0229	0.0217	0.0204
3	526886	217293	203796	344564	336281	336744	337481	338164	338728	339205	3	0.0524	0.0121	0.0217	0.0254	0.0249	0.0227	0.0217	0.0203	0.0192	0.0181
4	374979	417625	179320	166572	280555	274147	274964	275939	276804	277528	4	0.0401	0.0039	0.0191	0.0210	0.0206	0.0188	0.0179	0.0168	0.0159	0.0150
5	411899	300898	347481	146950	136227	229678	224730	225652	226660	227548	5	0.0306	0.0027	0.0050	0.0249	0.0244	0.0222	0.0212	0.0198	0.0188	0.0178
6	261103	333679	250653	288788	119715	111113	187630	183891	184785	185782	6	0.0187	0.0016	0.0045	0.0094	0.0092	0.0084	0.0080	0.0075	0.0071	0.0067
7	154907	214051	278277	208433	238956	99102	92035	155493	152407	153252	7	0.0189	0.0019	0.0030	0.0132	0.0130	0.0118	0.0113	0.0106	0.0100	0.0094
8	137933	126967	178451	231732	171800	197084	81805	76025	128518	126029	8	0.0175	0.0027	0.0041	0.0147	0.0144	0.0131	0.0125	0.0117	0.0111	0.0105
9	123521	112720	105761	148437	190729	141502	162477	67493	62765	106159	9	0.0171	0.0019	0.0044	0.0205	0.0201	0.0183	0.0175	0.0163	0.0155	0.0146
10	92436	101424	93973	87951	121460	156220	116050	133397	55463	51617	10	0.0182	0.0027	0.0057	0.0252	0.0247	0.0225	0.0215	0.0201	0.0190	0.0180
11	30717	75817	84486	78045	71629	99040	127586	94905	109212	45450	11	0.0380	0.0048	0.0075	0.0230	0.0226	0.0206	0.0196	0.0183	0.0174	0.0164
12	19293	24700	63025	70043	63701	58529	81045	104532	77835	89645	12	0.0598	0.0190	0.0123	0.0273	0.0268	0.0244	0.0233	0.0218	0.0206	0.0195
13	8937	15179	20243	51998	56923	51898	47711	66161	85436	63680	13	0.0960	0.0285	0.0299	0.0350	0.0344	0.0313	0.0298	0.0279	0.0265	0.0250
14	9176	6782	12322	16409	41932	45982	41966	38697	53743	68491	14	0.0985	0.0383	0.0313	0.0556	0.0546	0.0497	0.0474	0.0443	0.0420	0.0397
15	8977	6945	5451	9975	12962	33213	36548	33455	30924	43037	15	0.0809	0.0286	0.0623	0.0879	0.0862	0.0785	0.0748	0.0700	0.0663	0.0626
16	8374	6916	5637	4278	7629	9955	25651	28359	26058	24166	16	0.1297	0.0204	0.0486	0.1008	0.0989	0.0901	0.0859	0.0803	0.0761	0.0719
17	8877	6144	5659	4484	3230	5787	7600	19688	21862	20164	17	0.1045	0.0191	0.0472	0.1181	0.1158	0.1055	0.1005	0.0941	0.0891	0.0842
18	8254	6679	5034	4508	3327	2410	4351	5750	14971	16698	18	0.1069	0.0208	0.0640	0.1262	0.1237	0.1127	0.1074	0.1005	0.0952	0.0899
19	7610	6195	5463	3943	3318	2464	1799	3269	4344	11364	19	0.1126	0.0249	0.0695	0.1196	0.1173	0.1069	0.1018	0.0953	0.0903	0.0852
20	6347	5680	5047	4256	2921	2472	1850	1359	2483	3314	20	0.1285	0.0207	0.0545	0.1262	0.1237	0.1127	0.1074	0.1005	0.0952	0.0899
21	7333	4662	4646	3991	3132	2163	1845	1390	1027	1885	21	0.1500	0.0265	0.0639	0.1262	0.1237	0.1127	0.1074	0.1005	0.0952	0.0899
22	4062	5272	3792	3642	2937	2319	1614	1386	1050	779	22	0.1500	0.0233	0.0757	0.1262	0.1237	0.1127	0.1074	0.1005	0.0952	0.0899
23	5400	2920	4302	2936	2680	2175	1731	1213	1048	797	23	0.1500	0.0295	0.0430	0.1262	0.1237	0.1127	0.1074	0.1005	0.0952	0.0899
24	4344	3882	2368	3442	2161	1985	1623	1301	917	795	24	0.1500	0.0193	0.0692	0.1262	0.1237	0.1127	0.1074	0.1005	0.0952	0.0899
25	1988	3123	3160	1845	2593	1609	1481	1220	983	696	25	0.1500	0.0205	0.0438	0.1262	0.1237	0.1127	0.1074	0.1005	0.0952	0.0899
26	3279	1429	2555	2542	1358	1876	1194	1113	922	746	26	0.1500	0.0333	0.0440	0.1262	0.1237	0.1127	0.1074	0.1005	0.0952	0.0899
27	1283	2357	1154	2042	1871	1005	1400	897	841	700	27	0.1500	0.0142	0.0694	0.1262	0.1237	0.1127	0.1074	0.1005	0.0952	0.0899
28	1581	922	1941	899	1503	1385	750	1052	678	638	28	0.1500	0.0254	0.0283	0.1262	0.1237	0.1127	0.1074	0.1005	0.0952	0.0899
29	407	1137	751	1576	662	1113	1034	564	795	515	29	0.1500	0.0143	0.0555	0.1262	0.1237	0.1127	0.1074	0.1005	0.0952	0.0899
30	4868	293	935	593	1160	490	891	777	426	603	30	0.1500	0.0307	0.0231	0.1262	0.1237	0.1127	0.1074	0.1005	0.0952	0.0899
TOTAL	2815030	2758030	2790800	2809230	2797640	2787900	2781490	2777970	2776710	2777430											

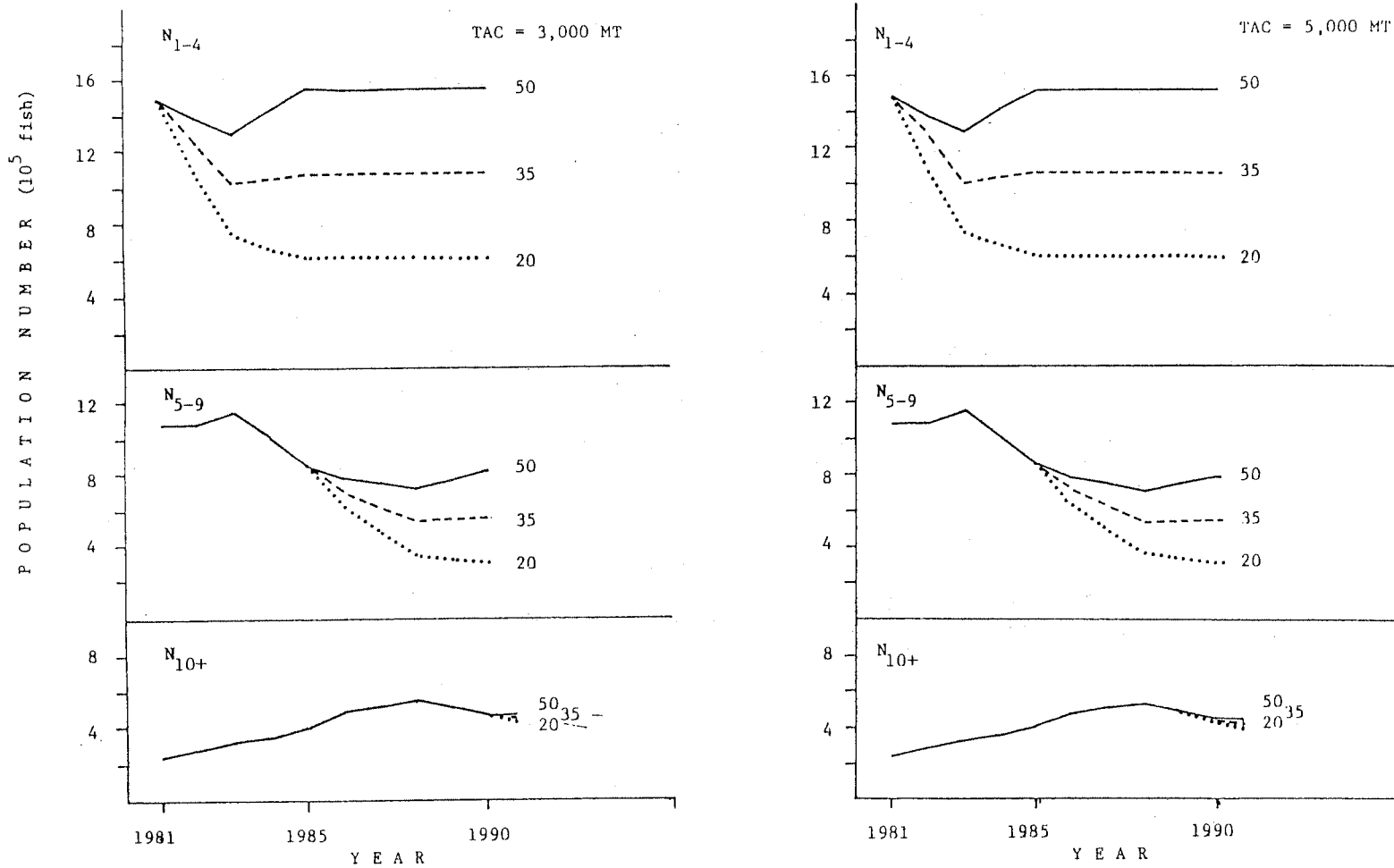


Fig. 1. Projected stock size for the years until 1990 in the case where $F_{B1,20}$ is assigned at 0.15 in the separable VPA.

The numerals in the figures indicate the number of recruits at age 1 in 10 thousands of fish.

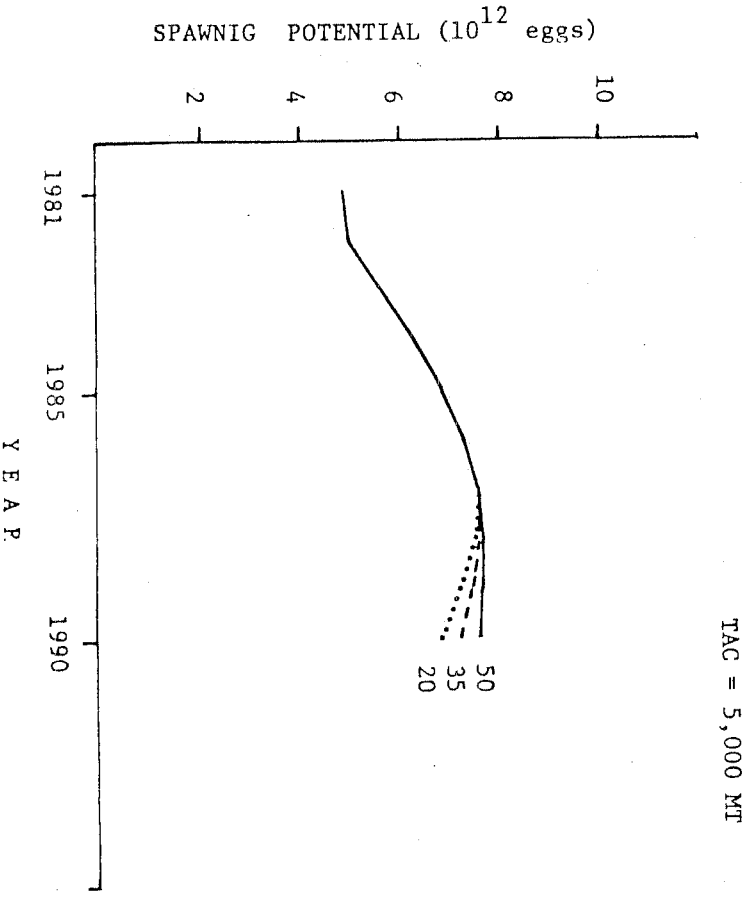
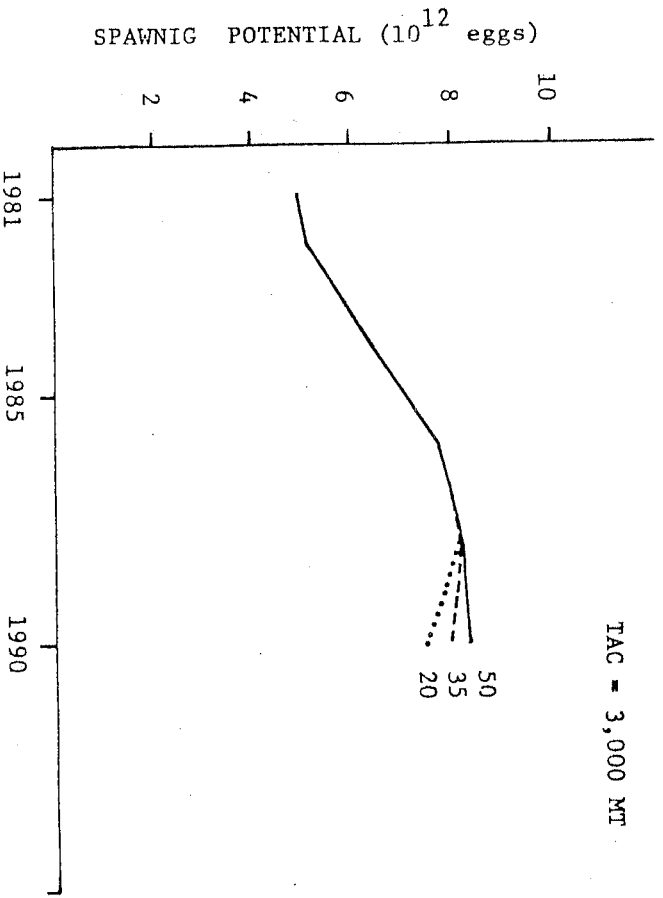


Fig. 2. Projected spawning potentials for the years until 1990 in the case where $F_{81,20}$ is assigned 0.15 in the separable VPA. The numerals in the figures indicate the number of recruits at age 1 in ten thousands of fish.

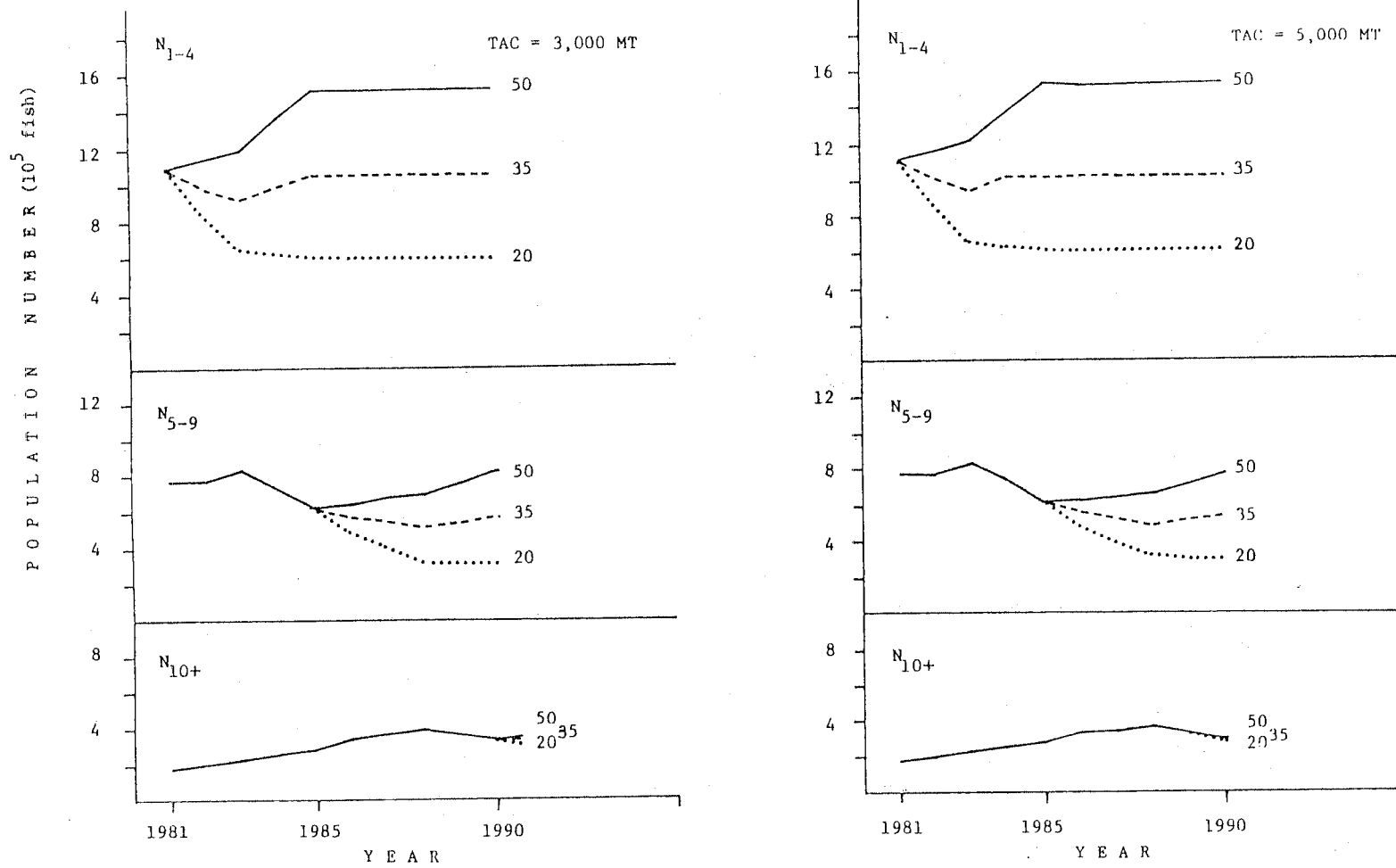


Fig. 3. Projected stock size for the years until 1990 in the case where $F_{81,20}$ is assigned at 0.20 in the separable VPA.

The numerals in the figures indicate the number of recruits at age 1 in ten thousands of fish.

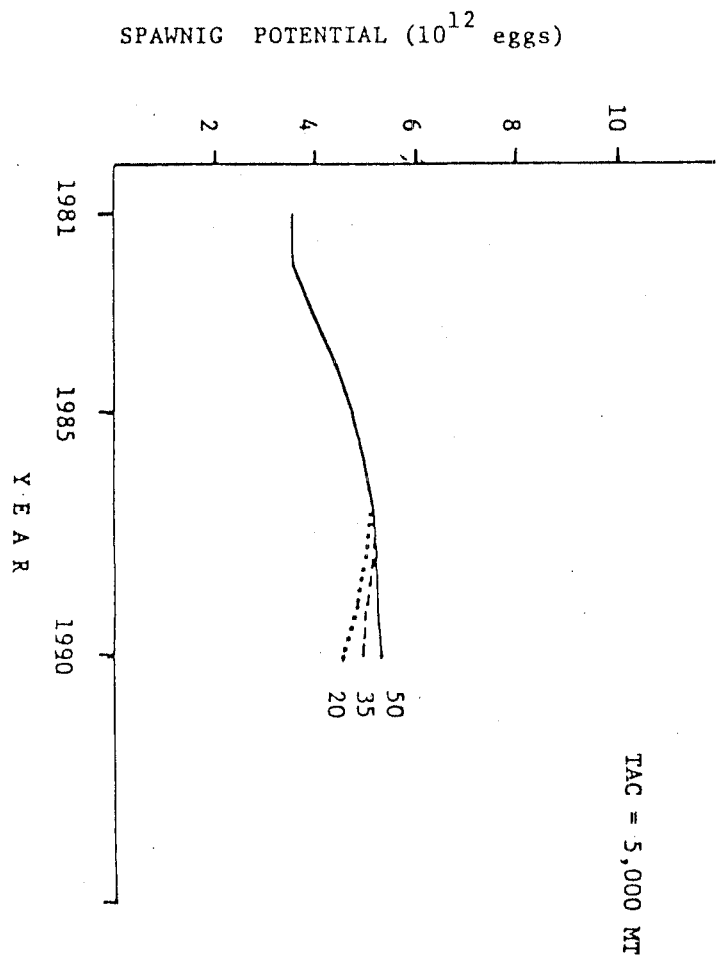
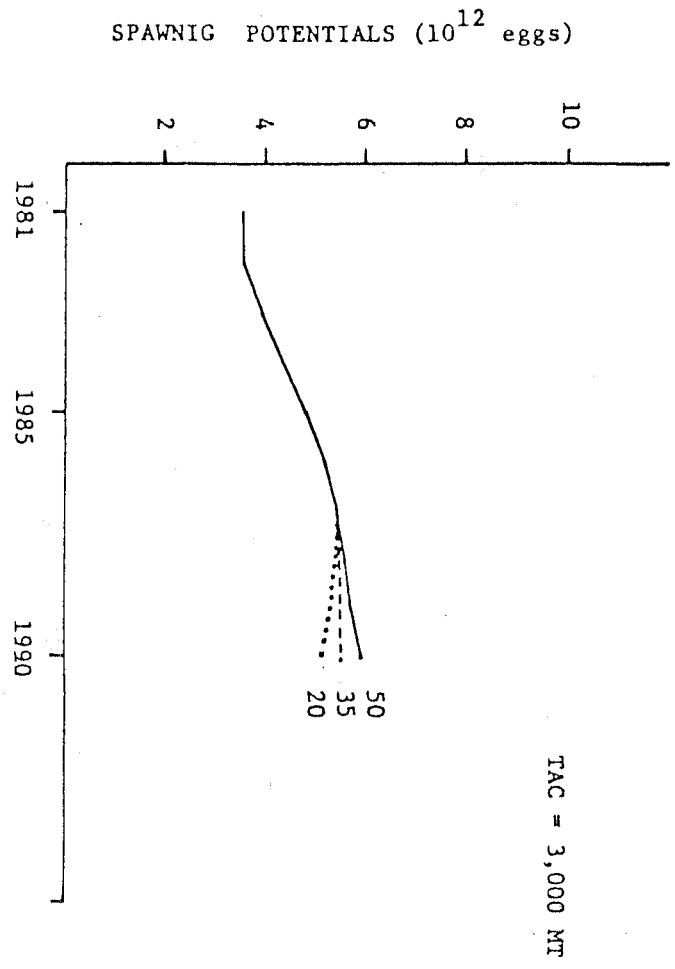


Fig. 4. Projected spawnig potentials for the years until 1990 in the case where Fig. 20 is assigned 0.20 in the separable VPA. The numerals in the figures indicate the number of recruits at age 1 in ten thousands of fish.