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The 1982 Assessment of the Southern Bluefin Tuna (*Thunnus maccoyii*) Population and the Determination of Catch Levels which Stabilize the Parental Biomass

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THE 1982 ASSESSMENT OF THE SOUTHERN BLUEFIN TUNA *(THUNNUS MACCOYII)* POPULATION AND THE DETERMINATION OF CATCH LEVELS WHICH STABILIZE THE PARENTAL BIOMASS

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Abstract

The southern bluefin tuna population is assessed using cohort analysis. Four combinations of natural mortality and terminal fishing mortality parameters are used to see if their selection affects the assessment. Although the four cohort analyses provide quantitatively different results, the overall conclusions, which confirm the previously recognized critical state of the population, are not affected by the choice of these parameters. Recruitment for the period 1950-1976 was stable, but parental biomass underwent a significant decline (40%) from 1967 to 1975, then remained approximately constant until 1980. The 1980 parental biomass level is estimated to be 21-30% of the virgin parental biomass. Our major concern lay with the likelihood of further decline in parental biomass and the risk of recruitment failure which may result when the increased surface fishery catches of 1980-1983 begin to affect the adult population. The global catch which would stabilize the parental biomass at its 1980 level is calculated as 30 000-32 000 t per year, and is virtually unaffected by selection of cohort analysis input parameters. This catch level can be increased by 50% by postponing age-at-first-capture to 5 years. The relationship between catch and stable parental biomass is examined under different assumptions regarding recruitment.

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1. INTRODUCTION

Southern bluefin tuna are a highly migratory species. Spawned in an area between north-western Australia and Indonesia, juveniles (aged 1 to 8 years) inhabit, at least for part of the time, the continental shelf waters of southern and south-eastern Australia. Here they form large surface schools and are the basis of an Australian pole-and-line and purse-seine fishery. From an early age there is a gradual diffusion of fish to the waters of the Southern Ocean such that by maturity (8 years of age) most lead an oceanic, pelagic existence and have an almost circumpolar distribution between 30 and 50° S. This is disturbed only by a regular spawning migration during the southern summer (September-March). These oceanic fish are exploited by the Japanese longline fishery. Although the surface and longline fisheries are essentially geographically distinct, and the fish that they exploit are in different behavioural phases (surface schooling and deep water swimming, respectively), there is a substantial overlap in the age composition of their catches. Reviews of these aspects of the biology of southern bluefin tuna can be found in Shingu (1978) and Olson (1980).

Commercial exploitation of mainly juvenile southern bluefin tuna by Australian fishermen and tuna research by CSIRO date back to 1938 (Murphy 1979). The fishery developed from a small troll fishery off the south coast of New South Wales (NSW) to become Australia's most important fin-fish fishery. This was due primarily to the success of pole-and-live-bait fishing and the subsequent expansion of the fishery to areas of the coast of South Australia (SA) and Western Australia (WA). With the introduction of purse seining in 1974, the Australian catch was averaging around 10 000 t per year by the late 1970's (see Majkowski *et al.* 1981). In recent years (1980-1983), the harvesting capacity of the Australian tuna fleet has increased markedly, with corresponding increases in catches, particularly in SA and WA. After a total southern bluefin tuna catch of about 19 000 t in 1982, a catch in excess of 20 000 t is expected in 1983.

The Japanese fishery directed primarily at adult southern bluefin tuna began in the early 1950's (Shingu 1978). Following a rapid expansion, the Japanese catch peaked at about 77 000 t in 1961. Since then there has been a steady decline to 20 000-30 000 t per year. The history of surface and longline catches is shown in Table 1.

The critical biological state of the southern bluefin tuna population (i.e. continuous and significant decline in the parental biomass) has been identified by CSIRO scientists (Murphy and Majkowski 1981) and subsequently accepted by New Zealand and Japanese scientists. This, in addition to the recent expansion of the Australian fishery, the entry of New Zealand to the fishery, and the lack of any significant reduction in Japanese fishing effort, has prompted (i) further intensive studies (Majkowski 1982*a*; Kirkwood 1983; Majkowski and Hampton 1983, 1984*a,b*; Majkowski and Murphy 1983) to provide a scientific basis for future management of the southern bluefin tuna fishery and (ii) the first steps toward international management of the fishery to be taken.

The objective of this report is to present the 1982 assessment of the southern bluefin tuna population and to identify catch levels which would stabilize the parental biomass at selected levels. The methods used for these purposes have been developed and used on an *ad hoc* basis over the past two years (Murphy and Majkowski 1981; Majkowski and Hampton 1983, 1984*a,b*. The results presented in this report reflect the 'state of the art' in the refinement of these methods and the data holdings of the CSIRO Division of Fisheries Research to December 1982. The results may be subject to slight changes as new data become available and the analyses are further refined.

2. DATA AND PRELIMINARY METHODS USED FOR THEIR ANALYSES

2.1 Catch Data

Basic to most of the analyses presented in this report are statistics of global catches (in number of fish) by nation, geographical area and length class. Details of the methods for collecting and processing these data are presented in Majkowski (1982*b*). The global catch data used in this study refer to the calender years 1952-1980, inclusive (Japanese fishery: 1952-1980, Australian fishery: 1963-1980) and are assumed to represent the entire catches of southern bluefin tuna taken during that period. Australian catches prior to 1963 were not considered as no length frequency sampling took place at that time. More current data could not be used at the time of report preparation because of the unavoidable delay in receiving Japanese catch-by-length-class statistics (see Majkowski 1982*b*).

2.2 Age Determination

The method used to convert the catch length composition to age composition is based on the following age length relationship:

$$t = t_0 - 1/K\,[\ln(1 - L/L_\infty)] \qquad (1)$$

where t is age in years and L is fork length in centimetres. When this equation is used to estimate the age of a fish from a length class, L is assumed to be the midpoint of the length class. The parameters L_∞, K and t_0 are estimated as equal to 207.6 cm, 0.127 yr^{-1}, and -0.394 yr, respectively (Kirkwood 1983). Full details for deriving the age composition are given in Majkowski and Hampton (1983, 1984*a*.) Note that the growth parameters used in those papers had been preliminary estimates made by Kirkwood (unpublished data). Although by no means perfect, this is the only ageing method available to us at present. In this study the notation defining age classes is changed from that used in previous papers. Fish aged between 1.0 and 2.0 years are now referred to as belonging to class 1+ (previously age class 2). The results of applying the ageing procedure to the data are presented in Table 2*a* (catch age composition by cohort (e.g. the 1960 cohort includes all fish spawned during the 1959-1960 spawning season)) and Table 2*b* (catch age composition by calender year of capture).

2.3 Age-Length-Weight Schedule

The schedule of age, length and weight (Table 3) is required for a number of analyses described in this report. It is constructed first by converting age to length using a simple transformation of equation (1) and then converting this length to weight using one of the following equations:

$$W = 3.13087 \times 10^{-5}\ L^{2.9058} \qquad (2)$$

for $L < 130$ cm (Robins 1962)

$$W = 2.50470 \times 10^{-6}\ L^{3.4229} \qquad (3)$$

for $L \geq 130$ cm (modified from Warashina and Hisada 1970).

where W is whole weight (in kilograms) and L is fork length (in centimetres). A conversion factor (x 1.15) for gilled and gutted to whole weight has been incorporated into equation (3). Because the conversion of age to length is a transformation rather than a statistical estimation, it is thought appropriate to use the growth parameter values specified in the previous section even though they were derived using a regression of age on length. The two equations (2) and (3) are necessary because they were formulated on the basis of samples of fish of restricted length ranges. In previous studies (Murphy and Majkowski 1981; Majkowski and Hampton 1984*b*), equation (2) had been used for estimating weight from length of fish regardless of length.

3. POPULATION ASSESSMENT

3.1 Methods

Murphy (1965, 1966) described a method of estimating the instantaneous rates of fishing mortality and population abundances for age classes from a cohort when catch numbers by age class for that cohort are known. This technique, and its subsequent refinement by Tomlinson (1970), has come to be known generally as cohort analysis. Calculations associated with all cohort analysis results presented in this study are carried out using the computer programme COHORT developed by Dr William Fox (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, California) and which is based on the equations of Tomlinson (1970).

Cohort analysis requires two additional input parameters, namely M, the instantaneous rate of natural mortality, and F_t, the instantaneous rate of fishing mortality for the oldest age class considered in the cohort (terminal rate of fishing mortality). If the relevent information is available, M may be specified individually for each age class. In this study, however, M is assumed to be constant for all age classes.

The reverse solution option of program COHORT is used for all cohort analyses. This option takes advantage of the convergent properties of cohort analysis results (especially recruitment) over a range of F_t-values (Tomlinson 1970). Majkowski and Hampton (1983, 1984*a*) have shown that errors in catch by age class estimates are of acceptable magnitude up to age class 12+ only. For cohorts 1968 and older, the reverse solution of cohort analysis is applied using age class 12+ as the starting age class. For these cohorts, the same F_t-value is assumed. It is expected that Japanese fishing effort data will be available in the future, and weighting of F_t for different cohorts may then be possible. For cohorts more recent than 1968 (for which the most recently fished age classes with catch data available are 11+ or younger), the catch of the oldest available age class is used as the starting point and the average fishing mortality rate, F, for that age class from the three previous cohorts is used as F_t. This technique enables better estimates of recent recruitment levels than those made in the past (e.g. Murphy and Majkowski 1981). This is because recruitment estimates become more sensitive to incorrectly specified values of F_t for younger terminal age classes. By using values of F_t which are representative of the actual F's of those age classes (rather than arbitrarily specifying), our confidence in the recruitment estimates for those cohorts is increased. Initial (i.e. at the beginning of the year) population numbers for age classes $t + 1$ to the age class representing the cohort in 1980 (to a maximum of 20+) are calculated using the following equation:

$$N_{i+1} = N_i \exp(-M-F_t) \qquad (4)$$

where N_i is the inital abundance of age class i.

Because estimates of M and F_{12^+} (0.2 and 0.1 yr^{-1}, respectively (Hayashi *et al.* 1969; Murphy and Majkowski 1981), are uncertain to some degree, cohort and subsequent analyses are performed using four different combinations of M and F_{12+}, i.e. (i) M = 0.2, F_{12+} = 0.1, (ii) M = 0.2, F_{12+} = 0.15, (iii) M = 0.2, F_{12+} = 0.2, and (iv) M = 0.15, F_{12+} = 0.15 yr^{-1}. Such an examination is referred to as ordinary sensitivity analysis (see reviews in Majkowki 1982*c*, 1983). These combinations are chosen for the following reasons. Recent analysis of tagging data indicates that total mortality, Z, of adult fish is between 0.3 and 0.4 yr^{-1}. Therefore, the sum of M and F_{12+} values needs to be within this range. Because of increases in Japanese fishing effort and a large decrease in the adult stock during the developmental period of the Japanese fishery, it is considered that 0.1 yr^{-1} is probably the lower limit of likely values for F_{12+}. Accordingly, the first three combinations use different levels of F_{12+} (0.1, 0.15, and 0.2 yr^{-1}), and the best estimate of M (0.2 yr^{-1}). Tag return data show that southern bluefin tuna are very long lived: tagged fish have been recaptured at up to 21 years of age (J. Hampton unpubl. data). Because of this, we feel that if there is an error in the best estimate of M, it is one of overestimation, i.e. the real value of M may be somewhat less than 0.2 yr^{-1}. Therefore, the fourth combination is chosen with a reduced value of M (0.15 yr^{-1}) but which still satisfies the condition that $0.3 < Z < 0.4$ yr^{-1}.

The parental biomass is assumed to be the combined weight of all fish in the population of ages 8.0, 9.0, ..., 20.0 years at the beginning of the year [the midpoint of the spawning season (Shingu 1978)]. The age at first spawning is based on the observation of gonad indices by Shingu (1970) who noted that sexual maturity is reached at a length of about 130 cm (approximately 7.5 years of age). Given our previous assumption that spawning occurs at the beginning of the year, the first spawning opportunity would then be at age 8.0 years. The parental biomass for a particular year is obtained by multiplying the initial population numbers of classes 8+ to 20+ by the respective weights given in Table 3 and summing them. Because the parental biomass is assumed to include fish to age 20.0 years, the extent of the catch data allows calculations only for 1967 onwards (the oldest cohort being that of 1947).

3.2 Basic Results

The basic and most useful results from the cohort analyses described are estimates of initial population abundance of age classes 1+ to 20+ and estimates of fishing mortality rates of age classes 1+ to (t-1)+. This information is presented for the four cohort analyses in Tables 4*a*–*d* and Tables 5*a*–*d* respectively. For convenience, the tables are constructed by year rather than by cohort.

It is apparent from these results that the age structure of the population derived on the basis of cohort analysis is strongly dependent upon the choice of M and F_t. In general, increasing the value of M decreases the number of older fish and increases the number of younger fish in the population. For example, if M is increased from 0.15 to 0.2 yr^{-1}, the initial population of age class 20+ is reduced by approximately 30% and the initial population of age class 1+ is increased by approximately 25-70%. Increasing the value of F_t from 0.1 to 0.2 yr^{-1} results in a reduction in the initial population of age class 20+ of about 75% and a reduction in the initial population of age class 1+ of 12-30%. Similarily, increasing M from 0.15 to 0.2 yr^{-1} decreases F for all age classes but especially for the younger age classes (about 25% for age class 2+ and 7% for age class 10+). Increasing F_t from 0.1 to 0.2 yr^{-1} increases F for all age classes, particularly the older age classes (15-30% for age class 2+ and 50-65% for age class 10+).

3.3 Recruitment

Fish first became susceptible to capture in Western Australian waters towards the end of their second year of life. Because it is convenient to define recruitment to the fishable stock as the initial abundance of an age class, it is defined here to be the number of fish at age 1.0 years (i.e. the initial abundance of age class 1+). The number of recruits by year is presented in Tables 4*a*–*d* for the four different cohort analyses. Because of the convergent property of the reverse solution of cohort analysis, recruitment is relatively insensitive to the value of F_t chosen, at least for values not approaching zero. However, higher values of M yield significantly higher recruitment estimates. Increasing M from 0.15 to 0.2 yr^{-1} ($F_t = 0.15$ yr^{-1}) results in an increase in the recruitment estimate of 25-70%. Despite these quantitative differences, all four cohort analyses indicate that recruitment to 1976 had been relatively stable. Although on average, recruitment is slightly lower in the second half of the record, we do not believe that this constitutes a significant decreasing trend. Subsequent to 1976, recruitment cannot be reliably estimated by this method due to insufficient numbers of fished age classes within the recent cohorts.

For the stabilizing catch procedure considered later in this report, a constant level of recruitment must be specified. For this purpose, an average recruitment level is used, and is calculated for the second half of the data record (1964-1976), as it is thought that this period best represents the present situation regarding recruitment. The 1964-1976 average recruitment levels and their standard deviations for the four cohort analyses are presented in Table 6. The 1950-1963 averages and standard deviations are also presented in Table 6.

3.4 Parental Biomass

The 1967-1980 levels of parental biomass for each of the four cohort analyses are presented in Table 7. Changing M from 0.15 to 0.2 yr^{-1} produces only minor changes in parental biomass (increases of 1-6%). However, the effect of choosing different values of F_t is much more significant. Increasing F_t from 0.1 to 0.2 yr^{-1} results in decreases in parental biomass levels of approximately 40%. Regardless of these differences, the trend over time (a continuous reduction from 1967 to 1975 of 45 - 50%, then approximately stable to 1980) is essentially the same.

For comparative purposes, an estimate of the virgin (pre-exploitation) parental biomass is made for each cohort analysis by generating a 'cohort' from the 1950-1963 average recruitment level (Table 6), discounting successive age classes for natural mortality only. This recruitment level is assumed to be representative of that produced by the virgin parental biomass. The parental biomass for this 'cohort' is used as an estimate of the virgin parental biomass and ranges from 500 894 to 697 270t depending on the M/F_t parameter values used. The 1980 parental biomass, expressed as a percentage of the virgin parental biomass, ranges from 21 to 30%. These results also are presented in Table 7.

4. DETERMINATION OF CATCH LEVELS WHICH STABILIZE THE PARENTAL BIOMASS.

4.1 Methods

The following analyses were undertaken in order to estimate the stabilizing (sustainable) catches which could be taken from the population. The method used has been described (as method II) by Majkowski and Hampton (1984*b*). We regard this method as superior to their method I because stabilizing catches having a predetermined age structure which are estimated using method I may be difficult to harvest for practical reasons (the southern bluefin tuna fishery has limited control over the catch-age structure). This difficulty is eliminated in method II where the age structure of the stabilizing catch is compatible with the catchability coefficients of the fishery.

The estimation of stabilizing catch requires estimates of catchability coefficients by age class, average fish weights at the beginning and in the middle of the year, natural mortality rate(s), the level at which the parental biomass is to be stabilized, and the level of recruitment which is generated by that parental biomass. Because each of these parameters depends on the M/F_t values used in cohort analysis, the stabilizing catches corresponding to the four cohort analyses presented in Section 3 are estimated.

Estimates of catchability coefficients, q_i for the 1980 calender year are used. They are derived on the basis of the following equation:

$$q_i = C_i / [N_i \exp(-M/2)] \qquad (5)$$

where C_i is the 1980 global catch (in number) of age class i (Table 2*b*) and N_i is the initial abundance of age class *i* in 1980. Because the N_i's for 1980 estimated on the basis of cohort analysis are the most uncertain (they are derived directly from the estimated or chosen F_t's), an alternative method is used to obtain the 1980 N_i's. We assume that the initial population numbers for 1976 (Tables 4*a*–*d*) can be estimated with reasonable confidence on the basis of cohort analysis if M is accurately known. Using this population as a starting point, subsequent population numbers to 1980 are derived using the Pope (1972) catch equation,

$$N_{i+1} = N_i \exp(-M) - C_i \exp(-M/2) \qquad (6)$$

assuming that recruitment for the period 1977-1980 is constant at the 1964-1976 average level. Four sets of q_i's corresponding to each combination of M/F_t parameter values used in cohort analysis are presented in Table 8. The most recent estimate of parental biomass (1980) (Table 7), the 1964-1976 average recruitment (Table 6), and the weights-at-age presented in Table 3 comprise the remaining input parameter values required for the stabilizing catch estimations.

In addition to this basic analysis, we also examine the effect of postponing the age-at-first-capture, Tc, to various ages up to 5 years. This is accomplished by setting q_i's for age classes younger than Tc to zero (only integer values of Tc are considered). Also, the relationship between stabilizing catch and parental biomass level is examined assuming (i) recruitment is constant at the 1964-1976 average level for all parental biomass magnitudes, and (ii) recruitment is dependent upon parental biomass through a stock recruitment relationship. The relationship used is that of Shephard (1982) and takes the following form:

$$R = aP/[1 + (P/K)^{\beta}] \qquad (7)$$

where R is the number of recruits and P is the parental biomass which gave rise to those recruits. The parameters a, K, and β take the values presented in Table 9. They are calculated from the 1967-1976 parental biomass data and the corresponding recruitment levels as outlined in Hampton and Majkowski (submitted).

4.2 Results

Calculated catches stabilizing the parental biomass at its 1980 level are presented in Table 10. They appear not to be seriously affected by the selection of M/F_t values. This, as explained by Majkowski and Hampton (1984*b*), results largely from the offsetting effect of recruitment and natural mortality in the stabilizing catch procedure. The slight differences in the results presented in Table 10 and those derived by Majkowski and Hampton (1984*b*) are caused mainly by the different age-length-weight schedule used. Postponing Tc has the effect of increasing the stabilizing catch. The analysis indicates that the stabilizing catch may be increased by approximately 50% if Tc were postponed to 5 years.

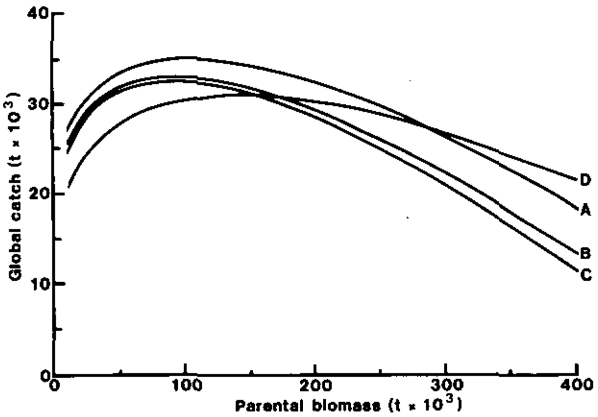

Figure 1. Global catch by stable parental biomass level assuming constant recruitment. Curve A is derived using data from cohort analysis in which M = 0.2 and F_t = 0.1 yr^{-1}; B - M = 0.2 and F_t = 0.15 yr^{-1}; C - M = 0.2 and F_t = 0.2 yr^{-1}; D - M = 0.15 and F_t = 0.15 yr^{-1}.

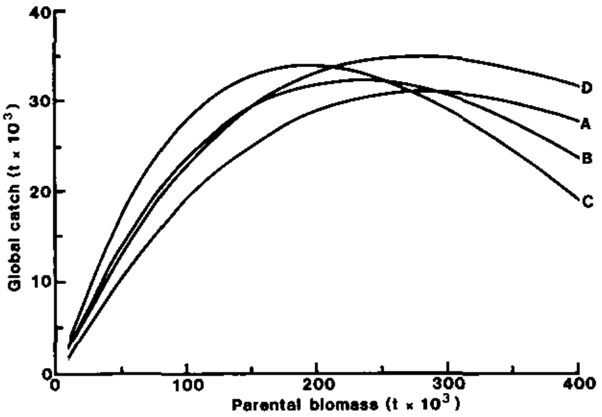

Figure 2. Global catch by stable parental biomass level assuming that recruitment is determined by a stock recruitment relationship. Curve A is derived using data from cohort analysis in which M = 0.2 and F_t = 0.1 yr^{-1}; B - M = 0.2 and F_t = 0.15 yr^{-1}; C - M = 0.2 and F_t = 0.2 yr^{-1}; D - M = 0.15 and F_t = 0.15 yr^{-1}.

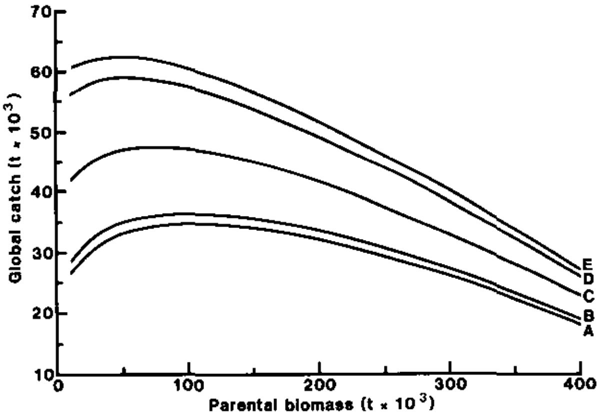

Figure 3. Global catch by stable parental biomass level assuming constant recruitment and showing the effect of (A) Tc=1, (B) Tc=2, (C) Tc=3, (D) Tc=4, and (E) Tc=5. The input parameters used for cohort analysis were M=0.2 and F_t = 0.1 yr^{-1}.

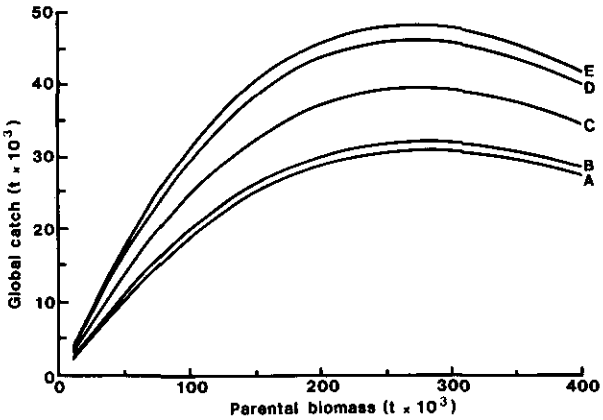

Figure 4. Global catch by stable parental biomass level assuming that recruitment is determined by a stock recruitment relationship and showing the effect of (A) Tc=1, (B) Tc=2, (C) Tc=3, (D) Tc=4, and (E) Tc=5. The input parameters used for cohort analysis were M=0.2 and F_t=0.1 yr^{-1}.

Possible combinations of stabilizing catch and parental biomass assuming a recruitment level independent of the parental biomass are depicted in Figure 1. The four curves reflect differences induced by the choice of M and F_t values in cohort analysis and the resulting M, q_i's, and R used in the stabilizing catch procedure. Figure 2 shows the same set of curves but with recruitment dependent upon parental biomass consistent with the stock recruitment relationships defined in Table 9. The level of stabilized parental biomass which maximizes catch ranges from approximately 190 000 to 250 000 t depending on which M/F_t parameters are used. In each case this level is substantially higher than the corresponding 1980 parental biomass. Stabilizing catch declines sharply at low stock sizes (cf. Figure 1) because of falling recruitment. This is probably a more realistic picture than that in Figure 1 in which recruitment is assumed to remain constant even at intolerably low stock levels.

The effect of postponing age-at-first-capture under assumptions of constant and stock-dependent recruitment is shown in Figures 3 and 4, respectively. The best estimates of M (0.2 yr^{-1}) and F_t (0.1 yr^{-1}) and the resultant cohort analysis outputs are used. Again, we believe stock-dependent recruitment to be the more realistic assumption and its effect is pronounced at low stock sizes where it forces convergence of the Tc situations depicted.

5. CONCLUDING REMARKS

The results contained in this report confirm the previously identified (Murphy and Majkowski 1981) critical state of the southern bluefin tuna parental biomass. However, there is no evidence from the population assessment in Section 3 that fishing activities have had any effect upon the level of recruitment until 1976. Because parental biomass appeared to be stable from 1975 to 1980, we can logically expect that cohort analysis estimates of recruitment to 1980 (when sufficient data become available) will behave similarly to those of pre-1976. However, we have no scientific basis for assuming that lower parental biomass levels will be able to sustain recruitment at this magnitude.

It is apparent that the activities of the global fishery have significantly decreased the parental biomass from its virgin level. The ratio of 1980 to virgin parental biomass level is sensitive to changes in input parameters for cohort analysis, but is likely to be in the range of 21-30%. No generalizations regarding what fraction of the virgin parental biomass represents a 'safe' (in terms of consistently providing adequate recruitment) level can be made; it is likely to vary considerably for different species. It is therefore impossible to specify a 'safe' level of parental biomass for southern bluefin tuna; it could only be determined by deliberately reducing the parental biomass until recruitment failure was observed. This approach is clearly unreasonable because recovery of the population could be slow and would require draconian restrictions on fishing. Therefore, it would seem imprudent to allow further significant decline in the parental biomass at the risk of recruitment failure. Hampton and Majkowski (submitted) have shown that the continuation of the 1982 fishing regime is likely to result in further significant reductions in parental biomass. We firmly believe that this fishing regime (1982) is not sustainable in the long term.

The stabilizing catch analyses in Section 4 give some indication of the sorts of fishing regimes which are likely to be sustainable on a long term basis. It is apparent that in order not to allow further long term reductions in parental biomass from the 1980 level, either

(i) global catch must be reduced, (ii) the age-at-first-capture increased, or (iii) a combination of actions (i) and (ii) introduced to allow more fish to survive to maturity.

The results provided in Section 4 are supported by observed data. The apparent stability of parental biomass during 1975-1980 was the result of levels of surface fishing from the early 1960's to the early 1970's (average catch approximately 8000t) and longline fishing from the early to late 1970's (average catch approximately 31 000t). This total catch (39 000t) can be interpreted as stabilizing the parental biomass in the same sense as the estimates provided in Section 4. This figure is in fact directly comparable to the estimated 1980 parental biomass stabilizing catch since the levels of stable parental biomass are about the same. The lower stabilizing catch calculated in Section 4 (31 784t) results because it refers to the 1980 catch age composition which is substantially younger than that of the 1960's and early 1970's. This comparision suggests that there is good agreement between empirical data and the stabilizing catch methodology.

Also, the simulation results of Hampton and Majkowski (submitted) show that, as would be predicted by the method used in Section 4 of this report, catches higher than the calculated stabilizing catch will cause further reduction in parental biomass. These consistencies make us confident that the stabilizing catch method is a valuable tool for fisheries analysis.

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Table 1. Annual southern bluefin tuna catches in tonnes and thousands of fish. Values enclosed in brackets are preliminary estimates.

Year	†NSW		*SA		WA		Aust Total		NZ		Japan		Total	
	t	no	t	no	t	no	t	no	t	no	t	no	t	no
1952							227	18			556	6	783	24
1953							435	34			3809	49	4244	83
1954							605	48			2183	27	2788	75
1955							435	34			2915	36	3350	70
1956							841	66			14948	186	15789	252
1957							982	77			21878	400	22860	477
1958							2024	159			12417	225	14441	384
1959							2008	158			63896	1032	65904	1190
1960							3072	242			75672	1188	78744	1430
1961							3402	268			77491	1209	80893	1477
1962							5136	404			40852	675	45988	1079
1963	2610	207	3589	225			6199	432			59200	1009	65399	1441
1964	2261	276	5517	379			7778	655			42718	743	50496	1398
1965	2246	160	4730	289			6976	449			40595	721	47571	1170
1966	2144	169	5994	417			8138	586			39607	683	47745	1269
1967	3672	362	3385	245			7057	607			59086	931	66143	1538
1968	5129	603	2926	263			8055	866			49482	828	57537	1694
1969	5885	691	3255	428	299	69	9439	1188			49644	844	59083	2032
1970	3611	393	3123	334	708	189	7442	916			40622	699	48064	1615
1971	5033	451	2817	344	600	121	8450	916			38120	697	46570	1613
1972	6133	340	4374	454	757	129	11264	923			39604	806	50868	1729
1973	1811	81	6835	696	308	69	9107	846			31205	651	40312	1497
1974	5276	297	6988	756	321	60	12585	1113			33924	672	46509	1785
1975	2466	225	4842	599	1236	218	8544	1042			24118	441	32662	1483
1976	308	32	6938	865	289	23	7535	920			33714	634	41249	1554
1977	4814	248	8789	1160	982	137	14589	1545			29595	536	44184	2081
1978	4332	224	4934	548	1999	495	11265	1267			22974	451	34059	1718
1979	3611	159	4338	632	2267	450	10216	1241			27715	520	37931	1761
1980	3427	138	6855	1083	2661	568	12943	1789	130	1	29474	521	42547	2311
1981	3267	117	9877	819	3327	727	16471	1663	173	2	(25000)	463	(41644)	2128
1982	1648	122	12748	1184	4345	734	18741	2040	257	4	(22000)	(407)	(40998)	(2433)

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† As the NSW season is concentrated at the end of the year, small portions of catches accredited to a year may have been taken early in the following year.

* As the SA season is concentrated at the beginning of the year, small portions of catches accredited to a year may have been taken late in the previous year.

Table 2a Global southern bluefin tuna catches (in number) by age class and cohort.

AGE	1947	1948	1949	1950	1951	1952	1953	1954	COHORT 1955	1956	1957	1958	1959	1960	1961	1962	1963
0+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2820	1336
2+	0	0	0	0	0	0	0	2	31	28	0	0	0	270	86380	232222	21324
3+	0	0	0	0	0	0	0	7046	3959	0	46	1135	5733	69179	235314	180064	229482
4+	0	0	32	0	0	13	47583	25686	5399	5337	15747	26621	53737	204626	224632	299711	164979
5+	0	96	0	9	62	65795	25765	30375	16560	46333	40252	90911	115071	121863	92763	67661	96957
6+	416	54	74	351	40850	21206	81833	42253	80183	50245	95562	67274	68611	79867	63541	66142	91098
7+	162	407	1713	39899	25677	176552	186988	121637	91449	121378	102810	113042	72080	110897	96694	91784	70547
8+	4568	18949	45803	37218	296621	373155	290666	154252	203209	183787	170305	150022	192569	137666	132987	89358	91775
9+	59360	63941	40779	240715	312719	321848	146238	203153	144473	128528	136565	216891	140795	144331	112584	111389	107320
10+	50233	26193	133892	162789	202947	87097	140385	91522	69140	74845	132187	116663	109674	87670	80247	73375	53333
11+	12443	48461	62200	88774	43609	65545	38008	36888	38021	70660	61769	61594	58111	47891	38975	32268	30559
12+	13688	18573	27882	19391	24246	14346	17309	19184	32463	33106	30942	32416	26408	19663	15891	15018	12826
13+	4722	7971	6261	5541	4064	8248	6605	12815	12994	12778	13907	11841	8646	6971	6014	4059	6528
14+	2896	2439	1619	1151	2363	2291	4219	5563	5832	7457	5580	3623	2904	2429	1406	2204	952
15+	554	390	651	784	668	1401	2350	2305	2483	2328	1404	1279	754	497	2033	219	346
16+	199	103	284	96	349	1156	695	1076	990	810	429	311	272	608	132	251	638
17+	30	84	15	249	601	522	374	278	424	164	103	94	53	116	129	180	210
18+	48	19	69	257	119	214	139	34	7	66	53	48	34	74	170	92	0
19+	53	226	286	123	86	143	181	46	54	39	46	149	172	260	32	0	0

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
0+	0	0	0	0	0	43	292	0	86	239	117	247	1888	6933	832	0	198
1+	5380	11851	0	23476	32039	60602	3179	17146	3623	94454	160866	139902	101964	223626	411934	192270	0
2+	56990	270795	477434	798261	702205	489475	278221	200721	480715	566031	393303	525096	496185	511552	928079	0	0
3+	134757	320721	277151	166167	337664	491844	218881	324244	318311	336399	456834	307551	283939	500366	0	0	0
4+	151052	128501	89869	125657	341050	482605	235035	111169	226151	271170	209698	170382	122025	0	0	0	0
5+	73636	104982	78717	141628	152054	227331	59445	56898	94047	149508	90149	93622	0	0	0	0	0
6+	54381	69589	99308	101055	119520	56529	44598	35879	76118	116677	52107	0	0	0	0	0	0
7+	59796	91664	78755	87845	57454	85153	59739	55806	61561	63246	0	0	0	0	0	0	0
8+	101260	75191	92057	71981	108545	134168	73129	73130	72833	0	0	0	0	0	0	0	0
9+	71758	86089	76261	102716	113454	75424	78508	96519	0	0	0	0	0	0	0	0	0
10+	62360	51194	73947	56168	41559	51147	74522	0	0	0	0	0	0	0	0	0	0
11+	24056	34073	23255	19345	28080	32720	0	0	0	0	0	0	0	0	0	0	0
12+	14880	10165	9337	13232	15339	0	0	0	0	0	0	0	0	0	0	0	0
13+	2804	3207	7922	6152	0	0	0	0	0	0	0	0	0	0	0	0	0
14+	1828	2430	2037	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15+	1240	1053	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16+	331	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2b Global southern bluefin tuna catches (in number) by age class and year of capture.

AGE	1952	1953	1954	1955	1956	1957	1958	1959	YEAR 1960	1961	1962	1963	1964	1965
0+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1+	0	0	0	0	0	0	0	0	0	0	0	2820	1336	5380
2+	0	0	0	0	2	31	28	0	0	0	270	86380	232222	21324
3+	0	0	0	0	0	7046	3959	0	46	1135	5733	69179	235314	180064
4+	0	32	0	0	13	47583	25686	5399	5337	15747	26621	53737	204626	224632
5+	0	96	0	9	62	65795	25765	30375	16560	46333	40252	90911	115071	121863
6+	67	416	54	74	351	40850	21206	81833	42253	80183	50245	95562	67274	68611
7+	101	1965	162	407	1713	39899	25677	176552	186988	121637	91449	121378	102810	113042
8+	160	4854	2105	4568	18949	45803	37218	296621	373155	290666	154252	203209	183787	170305
9+	1093	15200	8806	11760	59360	63941	40779	240715	312719	321848	146238	203153	144473	128528
10+	1671	14502	9299	11688	65214	50233	26193	133892	162789	202947	87097	140385	91522	69140
11+	1747	7987	4922	5178	28335	25906	12443	48461	62200	88774	43609	65545	38008	36888
12+	806	2769	1534	1784	9507	9436	4390	13868	18573	27882	19391	24246	14346	17309
13+	304	827	339	973	2961	3253	1483	3457	4722	7971	6261	5541	4064	8248
14+	132	150	21	182	735	787	279	565	1457	2896	2439	1619	1151	2363
15+	0	22	57	17	16	285	162	166	431	678	554	390	651	784
16+	0	12	25	3	3	81	26	46	377	257	111	199	103	284
17+	0	0	50	0	0	14	9	27	160	90	3	43	30	84
18+	0	0	0	4	0	0	1	37	0	58	9	12	36	48
19+	0	0	0	2	0	0	0	6	0	0	0	19	0	59

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
0+	0	0	0	43	292	0	86	239	117	247	1888	6933	832	0	198
1+	11651	0	23476	32039	60602	3179	17146	3623	94454	160866	139902	101964	223626	411934	192270
2+	56990	270795	477434	798261	702205	489475	278221	200721	480715	566031	393303	525096	496185	511552	928079
3+	229482	134757	320721	277151	166167	337664	491844	218881	324244	318311	336399	456834	307551	283939	500366
4+	299711	164979	151052	128501	89869	125657	341050	482605	235035	111169	226151	271170	209698	170382	122025
5+	92763	67661	96957	73636	104982	78717	141628	152054	227331	59445	56898	94047	149508	90149	93622
6+	79867	63541	66142	91098	54381	69589	99308	101055	119520	56529	44598	35879	76118	116677	52107
7+	72080	110897	96694	91784	70547	59796	91664	78755	87845	57454	85153	54739	55806	61561	63246
8+	150022	192569	137666	132987	89358	91775	101260	75191	92057	71981	108545	134168	73129	73130	72833
9+	136565	216891	140795	144331	112584	111389	107320	71758	86089	76261	102716	113454	75424	78508	98519
10+	74845	132187	116663	109674	87670	80247	73375	53333	62360	51194	73947	56168	41559	51147	74522
11+	38021	70660	61769	61594	58111	47891	38975	32268	30559	24056	34073	23255	19345	28080	32720
12+	19184	32463	33106	30942	32416	26408	19663	15891	15018	12826	14880	10165	9337	13232	15339
13+	6685	12815	12994	12778	13907	11841	8646	6971	6014	4059	6528	2804	3207	7922	6152
14+	2291	4219	5563	5832	7457	5580	3623	2904	2429	1406	2204	952	1828	2430	2037
15+	668	1401	2350	2305	2483	2328	1404	1279	754	497	2033	219	346	1240	1053
16+	96	349	1156	895	1076	990	810	429	311	272	608	132	251	638	331
17+	15	249	601	522	374	278	424	164	103	94	53	116	129	180	210
18+	19	69	257	119	214	139	34	7	66	53	48	34	74	170	92
19+	58	21	260	193	163	155	37	80	70	36	165	49	48	527	66

Table 3. Southern bluefin tuna age-length-weight schedule.

Age (yr)	Length (cm)	Weight (kg)	Age (yr)	Length (cm)	Weight (kg)
0.5	22.4	0.3	10.5	156.1	80.7
1.0	33.9	0.9	11.0	159.3	86.4
1.5	44.7	2.0	11.5	162.3	92.2
2.0	54.8	3.5	12.0	165.1	97.7
2.5	64.3	5.6	12.5	167.7	103.2
3.0	73.2	8.2	13.0	170.2	108.4
3.5	81.5	11.2	13.5	172.5	113.6
4.0	89.3	14.6	14.0	174.7	118.6
4.5	96.6	18.4	14.5	176.7	123.4
5.0	103.5	22.4	15.0	178.7	128.0
5.5	110.0	26.7	15.5	180.5	132.5
6.0	116.0	31.2	16.0	182.1	136.7
6.5	121.7	35.9	16.5	183.7	140.8
7.0	127.0	40.7	17.0	185.2	144.8
7.5	132.0	45.4	17.5	186.6	148.5
8.0	136.7	51.2	18.0	187.9	152.1
8.5	141.1	57.1	18.5	189.1	155.5
9.0	145.2	63.0	19.0	190.3	158.8
9.5	149.1	68.9	19.5	191.3	161.8
10.0	152.7	74.8	20.0	192.3	164.8

Table 4a Initial population numbers estimated on the basis of cohort analysis using $M = 0.2$ and $F_t = 0.1\ yr^{-1}$.

AGE	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
1	2232141	2903993	4742666	5446279	7472431	6884665	6226645	5414589	6488308	6771833	6911837
2		1827523	2410338	3882967	4458873	6117909	5636687	5097946	4433090	5312177	5544308
3			1496249	1973418	3179104	3650616	5008920	4614929	4173845	3629507	4349215
4				1225025	1615698	2602830	2988672	4100957	3778384	3417255	2965225
5					1002966	1322821	2130988	2447081	3357580	3093460	2754840
6						821159	1082948	1744706	2003492	2740898	2473306
7							671932	886594	1428377	1640004	2213716
8								549985	725514	1167909	1307418
9									446164	576892	914858
10										311808	414684
11											210056

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
1	7440325	6456493	5695624	5442442	5236972	4443695	4177689	4445876	4536880	5387846	6367928
2	5698934	6065424	5280756	4826929	4455894	4285125	3637149	3415477	3629271	3714484	4589990
3	4539270	4633143	4965949	4327856	3951711	3570176	3298803	2958585	2744973	2727127	2610970
4	3557260	3716440	3793255	4064750	3538172	3172916	2710713	2538342	2215295	2125776	1903733
5	2094521	2907561	3037943	3291431	3303891	2008282	2413146	2016750	1808107	1664911	1604173
6	2232202	1941223	2365552	2495415	2494698	2622917	2228106	1865739	1567452	1419275	1275627
7	2045819	1753701	1551186	1844364	1956766	1956225	2086721	1762276	1455450	1229967	1102309
8	1789298	1483911	1267247	1160290	1403880	1492549	1590841	1606453	1377768	1091591	916522
9	1036821	1197860	876927	770229	810991	494047	1056377	1031832	1179977	954550	769670
10	712217	632492	699814	431305	543930	481446	687860	749062	762672	770893	654709
11	315882	462629	371596	390791	274772	286533	311821	500838	545802	505434	526087
12	160752	214984	322731	224149	280045	160053	200350	222053	375756	383198	358150
13		119968	154261	239885	166276	207907	125019	148423	164581	278367	283880
14			88223	117984	177119	123180	154021	91132	109954	121865	206219
15				65357	87904	131213	91254	114102	67512	81456	90280
16					48418	64751	97205	67603	84529	50214	60344
17						35869	47969	72011	50081	62620	37051
18							26572	35536	53347	37101	46390
19								19685	26326	39520	27485
20									14503	19503	29877

AGE	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	6925029	5617100	5257408	5186967	6652813	4778284	4692981	3409553	5919152	8023737	
2	5184660	5614999	4596021	4288914	4243448	5361562	3766904	3715981	2699450	4604327	6197528
3	2875794	5612234	4155757	3511866	3330368	3040958	3879013	2729519	2569384	1763582	3341345
4	1887845	2204562	2652979	2954179	2677785	2430278	2202771	2872822	1823462	1826465	1188238
5	1475461	1464526	1691555	1864772	1488249	1980430	1892683	1599595	2107559	1303924	1341749
6	1246926	1115301	1128017	1257197	1389606	1422945	1567770	1498229	1224776	1590651	986235
7	962215	971813	648706	633987	938161	1029926	1113982	1243316	1194250	934084	1197064
8	819767	724157	741719	612233	611799	688891	791387	835243	968535	927402	709223
9	630608	590637	510193	516044	433496	417990	499126	550147	563032	727005	693332
10	500273	414960	383339	321188	357859	277539	273588	316250	348372	393019	524452
11	437293	330675	267538	247829	214950	236857	181158	157585	208370	247770	275693
12	375212	395670	227547	183937	173832	148460	172230	117659	108075	153159	177547
13	265320	277960	226445	168608	136264	128778	109982	127594	87164	80064	113463
14	210304	196557	205921	167755	124908	100947	95401	81477	94524	64573	59313
15	152771	155797	145613	152550	124276	92534	74783	70675	60359	70825	47837
16	66881	113176	115917	137873	113012	92066	68551	55401	52357	44715	51876
17	44709	49547	83842	85503	79914	83721	68204	50784	41042	38787	33126
18	27448	33118	36705	62112	63342	59242	62022	50527	37622	30405	28734
19	34367	20334	24534	27192	46014	40925	43858	45947	37431	27871	22524
20	20362	25460	15064	18175	20144	34080	34763	32491	34030	27730	20647

Table 4b Initial population numbers estimated on the basis of cohort analysis using $M \approx 0.2$ and $F_t = 0.15\ yr^{-1}$.

AGE	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
1	1770994	2327414	3816523	4799245	6663255	6403960	5649067	4775729	5410039	5672176	5883490
2		1449967	1905525	3124705	3929289	5455411	5243123	4625065	3910036	4429365	4643985
3			1187133	1560112	2558292	3217030	4466513	4292706	3786683	3201265	3626430
4				971942	1277312	2094552	2633881	3656872	3514570	3100274	2614610
5					795759	1045774	1714845	2156449	2993993	2877475	2495318
6						651512	856121	1403997	1765535	2451218	2296468
7							533037	700884	1149428	1445181	1969998
8								436268	573467	939525	1147913
9									353060	452409	727081
10										235621	312803
11											147734

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
1	6330792	5570385	5241352	4913440	4737069	4016923	3682865	4107143	4225378	4947108	5857149
2	4816994	5183214	4567196	4291256	4022784	3875837	3287575	3010415	3351939	3459447	4029144
3	3802148	3943821	4243657	3739304	3513139	3215578	2963732	2672370	2413358	2500097	2402254
4	2965493	3112936	3228806	3473387	3056304	2815846	2420420	2264028	1981002	1854272	1757922
5	2117463	2423064	2543835	2629365	2819724	2453764	2119194	1779122	1583600	1473115	1381913
6	2019724	1706200	1968879	2041876	2116391	2226522	1905116	1625087	1372909	1235471	1118610
7	1861036	1579740	1358768	1539606	1625561	1646504	1762186	1497841	1258429	1066694	951830
8	1509709	1364495	1124865	1002776	1178007	1221409	1255282	1340766	1161275	930388	780141
9	906232	1034617	782062	659843	682092	741546	834485	874309	962503	777400	637681
10	559141	525750	566462	352413	408743	376134	509861	567472	592847	593029	509765
11	232479	337440	284425	281955	210266	208822	225703	355150	397173	366529	380572
12	109733	146750	227303	153213	191570	113351	136763	151570	256498	261579	244460
13		77320	103413	155245	107967	135000	79877	96375	106815	180751	184332
14			54092	72874	109399	76003	95133	56288	67914	75271	127373
15				38400	51353	77092	53615	67039	39666	47859	53043
16					27960	36108	54326	37782	47242	27952	33725
17						19069	25501	38283	26624	33291	19697
18							13438	17970	26970	18762	23459
19								9469	12664	19011	13221
20									6673	8924	13397

AGE	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	6352519	4855274	4433115	4508195	5686845	4126272	4117910	3080519	5089401	7330735	
2	4766469	5146267	3972291	3614040	3687717	4570665	3233097	3245162	2364568	3965008	5630182
3	2580627	3270011	3772063	3041247	2777799	2586120	3232076	2292601	2184122	1489673	2785349
4	1717006	1962918	2372848	2645149	2259766	1982039	1830491	2342935	1466042	1511160	964150
5	1323548	1324664	1493730	1635523	1731332	1638255	1522441	1294886	1673831	1011406	1083660
6	1064964	988776	1013516	1095260	1201945	1212672	1287620	1195107	975326	1235595	746775
7	833670	822842	746764	740259	845600	876311	941832	1013960	946079	729872	906414
8	696608	618934	619764	528796	535078	580385	665628	694320	780763	724229	542049
9	523917	489819	420082	416249	365211	355216	410315	447239	447743	573295	527017
10	392327	327700	300887	250786	276201	221700	222245	243644	264236	298680	398648
11	318731	242385	196185	180406	157361	170068	135491	115659	148986	178915	198496
12	256127	208656	155362	125559	118661	101341	117571	80316	73774	104549	121197
13	172282	180490	147037	109482	88460	83619	71414	82851	56598	51908	73674
14	129896	121405	127189	103616	77150	62351	58925	50324	58384	39884	36635
15	89758	91536	85553	89629	73017	54367	43938	41524	35463	41143	28106
16	37379	63252	64585	60288	63160	51454	38312	30962	29261	24998	28093
17	23766	26340	44573	45456	42484	44508	36259	26998	21819	20620	17610
18	13881	16748	18562	31410	32032	29938	31364	25551	19025	15376	14531
19	16532	9781	11802	13080	22134	22573	21097	22102	18006	13407	10835
20	9317	11650	6893	8317	9217	15998	15907	14867	15579	12688	9448

Table 4c Initial population numbers estimated on the basis of cohort analysis using $M = 0.2$ and $F_t = 0.2\ yr^{-1}$.

AGE	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
1	1540459	2019197	3353426	4475244	6257944	6162972	5359808	4455995	4870961	5122373	5369200
2		1261221	1653179	2745553	3664020	5123571	5045814	4388240	3648261	3988005	4193845
3			1032601	1353508	2247869	2999846	4194825	4131163	3592787	2986941	3269075
4				845422	1108159	1840399	2456066	3434433	3382310	2941525	2439136
5					692173	907284	1506762	2010857	2811876	2769190	2365347
6						566703	742734	1233633	1646342	2302113	2207813
7							463602	608051	1009946	1347594	1447922
8								579419	497462	825327	1068016
9									306516	398183	634389
10										197540	261085
11											110085

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
1	5791874	4139212	4914001	4648728	4486934	3893275	3435410	3937586	4069395	4726567	5681594
2	4395929	4741986	4207631	4023244	3806957	3671043	3112654	2807816	3213118	3331739	3848581
3	3433604	3599083	3882409	3444917	3293709	3038139	2796079	2529165	2247465	2386457	2297745
4	2669641	2811197	2946638	3177623	2815281	2634194	2275167	2126774	1863770	1718477	1664919
5	1973797	2180840	2290793	2398280	2577574	2256452	1972126	1660224	1471275	1377150	1270751
6	1913312	1588578	1770564	1438617	1927196	2028270	1743563	1500687	1275566	1143511	1040848
7	1788451	1492625	1262468	1377245	1459967	1491611	1599874	1365576	1159859	987001	876545
8	1489762	1305080	1053562	923948	1045089	1085851	1128478	1207690	1052992	849621	720907
9	840820	952860	733523	601581	617593	672813	723566	770542	653748	688811	571650
10	482601	472314	499727	312931	361111	323461	420928	476721	507947	504125	437303
11	190798	274498	240794	227580	178002	169993	182677	282377	322909	297127	307869
12	84251	112673	169146	117635	147288	87039	105005	116380	196936	200837	187709
13		56475	75527	113382	78853	98596	58338	70387	78012	132010	134625
14			37856	50827	76002	52857	66091	39105	47182	52293	80489
15				25376	53936	50946	35431	44302	26213	31627	35053
16					17010	22748	34150	23750	29697	17571	21208
17						11402	15249	22891	15920	19906	11778
18							7643	10221	15345	10672	13344
19								5123	6052	10286	7153
20									3434	4593	6099

AGE	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	6085447	4470398	4087621	4282015	5686805	4126272	4117910	3000519	5089401	7330735	
2	4557259	4927609	3657180	3331174	3502537	4570665	3233097	3245162	2364568	3965008	5630182
3	2432950	3098800	3593078	2743266	2546224	2434571	3232076	2292601	2184122	1489673	2785349
4	1631468	1842022	2232709	2490471	2048593	1792507	1706460	2342935	1466842	1511164	964150
5	1247213	1254636	1394758	1520847	1611512	1465408	1367277	1193377	1673831	1011406	1083664
6	973959	976452	956187	1014246	1108076	1114614	1146117	1060074	892227	1235595	746775
7	769367	748338	695743	693333	739285	799476	861554	898104	842075	661847	906410
8	630984	566290	556772	487039	496669	526107	602727	628606	685915	639085	486364
9	470549	439386	381006	366350	331041	323794	365094	395778	393998	495657	457326
10	338356	280066	259661	215588	235381	193770	196553	207346	222189	254712	335117
11	259469	198266	160528	146717	128584	136702	112663	94708	119319	144514	168529
12	196651	160204	119285	96403	91107	77809	90269	61606	56643	80272	93054
13	125825	131819	107388	79959	64621	61071	52157	60509	41336	37969	53808
14	90242	84343	88361	71984	53598	43317	40937	34962	40560	27708	25451
15	59316	60491	56537	59230	48253	35928	29036	27441	23436	27189	18573
16	23497	39761	40548	37898	39703	32345	24083	19463	18394	15709	18225
17	14211	15750	26652	27180	25404	26614	21681	16143	13047	12330	10530
18	7895	9526	10558	17866	18220	17029	17840	14533	10821	8745	8265
19	8940	5292	6385	7077	11976	12213	11415	11958	9742	7254	5862
20	4795	5996	3548	4280	4740	8028	8187	7651	8016	6530	4862

Table 4d Initial population numbers estimated on the basis of cohort analysis using $M = 0.15$ and $F_t = 0.15\ yr^{-1}$.

AGE	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
1	1052973	1375759	2264782	2953168	4204744	4179915	3680698	3054044	3384554	3538462	3692793
2		906302	1184127	1949314	2541832	3619056	3597686	3168086	2628640	2913113	3045582
3			780062	1019187	1677790	2187775	3114951	3096557	2726728	2262490	2507311
4				671405	877223	1444087	1883036	2681063	2665231	2346917	1940813
5					577884	755033	1242908	1620744	2307612	2293974	1975919
6						497369	649774	1069781	1394979	1986123	1913482
7							427721	559215	920700	1200344	1671620
8								367993	480944	790066	996922
9									312501	396398	630285
10										214109	282058
11											137894

AGE	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
1	3992493	3559143	3479923	3377696	3318724	2770193	2492026	2960387	3084373	3656873	4357403
2	3178416	3436371	3063383	2495197	2907210	2853838	2303092	2139921	2537045	2654745	3125743
3	2621331	2735688	2957712	2636678	2577740	2422228	2241327	2031384	1789127	1933044	1843622
4	2154393	2256201	2354566	2544674	2264096	2154585	1867025	1762420	1536071	1415145	1367245
5	1646669	1649249	1436983	2012017	2165550	1698934	1665061	1394117	1239832	1169428	1078233
6	1676812	1389155	1576359	1624246	1694460	1779692	1527061	1320295	1118331	1004468	916774
7	1627297	1367448	1156517	1282518	1351450	1369931	1469473	1251468	1062424	903708	803304
8	1414982	1237239	1004002	682844	1019196	1050845	1083919	1160124	1010410	811802	688342
9	823560	943828	720710	595985	617269	689446	734565	775450	859736	691690	571445
10	511614	486791	524085	324343	377940	344006	459928	513425	541188	539740	465244
11	216524	316757	268929	264222	198820	195993	211613	331921	372685	343747	356782
12	107168	143320	215154	149632	187096	110702	133566	148035	250504	255465	238767
13		79342	106174	159390	110850	138604	82010	98948	109667	185578	189293
14			58815	78656	118079	82120	102680	60755	73303	81243	137480
15				43571	58270	87475	60836	76068	45008	54304	60187
16					32278	43167	64803	45068	56352	33343	40229
17						23912	31979	48007	33387	41747	24701
18							17715	23691	35565	24734	30927
19								13123	17550	26347	18323
20									9722	13002	19518

AGE	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	4724740	3327794	3076281	3324526	4255934	3234235	3299969	2454953	4157205	5868875	0
2	3720758	4014461	2861312	2588853	2858080	3575596	2634731	2710715	2018544	3371021	4669950
3	1953409	2553467	2998950	2275234	2042405	2015516	2554124	1903986	1847848	1279226	2428372
4	1330500	1527483	1885415	2126444	1695473	1458082	1440420	1887149	1216916	1386096	838756
5	1057853	1061953	1199363	1307532	1384086	1241897	1152053	1030650	1373469	853542	966542
6	859857	813336	641147	909409	984703	981441	1013849	936880	800032	1043796	651219
7	704757	689726	635621	632091	681474	736955	792381	831317	774864	618137	790431
8	606551	541295	538316	462301	471181	505281	581109	603203	664831	615258	475057
9	469557	439418	381046	369741	328381	320474	360520	399838	395247	504551	461891
10	358596	304186	275374	228941	251922	203247	205410	222231	239460	270483	361670
11	299159	227695	184306	169292	147796	154253	127672	108671	139420	167684	185534
12	250141	203780	151731	122624	115808	98973	114823	78439	72050	102106	118365
13	176883	185309	150964	112405	90842	85852	73321	85063	58109	53376	75642
14	140202	131038	137280	111837	83272	67297	63601	54318	63016	43048	39542
15	101847	103864	97275	101790	82851	61689	49855	47117	40239	46684	31891
16	44587	75450	76945	71915	75341	61377	45700	36934	34905	29810	34584
17	29803	33031	55845	57902	53276	55814	45469	33856	27361	25858	22084
18	18299	22078	24470	41408	42228	39468	41348	33685	25081	20270	19156
19	22911	13556	16356	18128	30676	31283	29239	30631	24954	18580	15016
20	13574	16973	10043	12117	13429	22725	23175	21660	22692	18487	13765

Table 5a **Fishing mortality rates estimated on the basis of cohort analysis using $M = 0.2$ and $F_t = 0.1\ yr^{-1}$**

AGE CLASS	1954	1955	1956	1957	1958	1959	1960	1961	1962
1+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0001
3+	0.0000	0.0000	0.0000	.0021	.0010	0.0000	0.0000	.0003	.0015
4+	0.0000	0.0000	0.0000	.0155	.0096	.0017	.0016	.0046	.0073
5+	0.0000	0.0000	0.0000	.0237	.0104	.0140	.0063	.0170	.0145
6+	.0001	0.0000	.0002	.0165	.0095	.0413	.0243	.0301	.0229
7+	0.0000	.0005	.0013	.0266	.0129	.1020	.1249	.0903	.0556
8+	0.0000	0.0000	.0292	.0442	.0319	.2013	.3232	.2902	.1502
9+	0.0000	0.0000	0.0000	.1301	.0504	.2942	.3375	.5119	.2320
10+	0.0000	0.0000	0.0000	0.0000	.0721	.2315	.3319	.3026	.2509
11+	0.0000	0.0000	0.0000	0.0000	0.0000	.1848	.1601	.3042	.1311
12+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.1000	.1000	.1000

AGE CLASS	1963	1964	1965	1966	1967	1968	1969	1970	1971
1+	.0006	.0003	.0014	.0029	0.0000	.0048	.0056	.0097	.0006
2+	.0216	.0616	.0065	.0185	.0858	.1525	.2230	.1614	.1009
3+	.0195	.0758	.0620	.0093	.0556	.1386	.1243	.0658	.1086
4+	.0169	.0737	.0957	.1392	.0856	.0815	.0756	.0539	.0649
5+	.0308	.0456	.0573	.0520	.0421	.0663	.0519	.0814	.0611
6+	.0432	.0287	.0345	.0403	.0457	.0527	.0820	.0493	.0714
7+	.0708	.0597	.0616	.0461	.0877	.0909	.0961	.0842	.0782
8+	.1082	.1456	.1327	.1085	.1670	.1494	.1739	.1278	.1502
9+	.3215	.1733	.1434	.1496	.2257	.1770	.2308	.2185	.2323
10+	.3646	.2544	.1173	.1166	.2114	.1021	.2036	.2140	.2389
11+	.3036	.1978	.1395	.0873	.1537	.1445	.1389	.1581	.1736
12+	.1000	.1000	.1000	.1000	.1000	.1000	.1000	.1000	.1000

AGE CLASS	1972	1973	1974	1975	1976	1977	1978	1979	1980
1+	.0036	.0008	.0158	.0378	.0334	.0335	.0425	.0583	0.0000
2+	.0690	.0530	.1332	.1236	.1221	.1690	.2257	.1293	.1800
3+	.1396	.0712	.1134	.1225	.1004	.2034	.1413	.1949	.1800
4+	.1525	.1977	.1017	.0517	.1200	.1098	.1354	.1084	.1200
5+	.0968	.0941	.1345	.0337	.0337	.0670	.0814	.0792	.0800
6+	.1020	.0927	.0995	.0448	.0319	.0268	.0709	.0843	.0600
7+	.1266	.1098	.1080	.0635	.0480	.0498	.0529	.0754	.0600
8+	.1628	.1452	.1009	.1222	.1636	.1944	.0869	.0909	.1200
9+	.2628	.1661	.2459	.2238	.2563	.2569	.1595	.1266	.1700
10+	.2362	.2016	.2127	.2766	.3517	.2172	.1408	.1546	.1700
11+	.1747	.1547	.1701	.1186	.2316	.1771	.1079	.1333	.1400
12+	.1000	.1000	.1000	.1000	.1000	.1000	.1000	.1000	.1000

Table 5b Fishing mortality rates estimated on the basis of cohort analysis using $M = 0.2$ and $F_t = 0.15\ yr^{-1}$

AGE CLASS	1954	1955	1956	1957	1958	1959	1960	1961	1962
1+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0001
3+	0.0000	0.0000	0.0000	.0024	.0012	0.0000	0.0000	.0003	.0017
4+	0.0000	0.0000	0.0000	.0171	.0109	.0020	.0019	.0054	.0085
5+	0.0000	0.0000	0.0000	.0255	.0115	.0159	.0076	.0203	.0178
6+	.0001	.0001	.0002	.0186	.0102	.0457	.0277	.0459	.0275
7+	0.0000	.0006	.0016	.0303	.0145	.1103	.1396	.1030	.0677
8+	0.0000	0.0000	.0371	.0552	.0364	.2295	.3566	.3334	.1834
9+	0.0000	0.0000	0.0000	.1690	.0637	.3445	.4024	.5971	.2709
10+	0.0000	0.0000	0.0000	0.0000	.0968	.3050	.4144	.4977	.3164
11+	0.0000	0.0000	0.0000	0.0000	0.0000	.2601	.2264	.4186	.1865
12+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.1500	.1500	.1500

AGE CLASS	1963	1964	1965	1966	1967	1968	1969	1970	1971
1+	.0007	.0004	.0016	.0032	0.0000	.0052	.0061	.0106	.0007
2+	.0240	.2683	.0072	.0211	.0932	.1647	.2455	.1768	.1106
3+	.0220	.0841	.0693	.0994	.0635	.1522	.1358	.0736	.1207
4+	.0196	.0835	.1078	.1574	.0962	.0940	.0840	.0594	.0732
5+	.0362	.0531	.0655	.0592	.0482	.0753	.0605	.0915	.0677
6+	.0511	.0339	.0405	.0557	.0524	.0608	.0949	.0579	.0807
7+	.0858	.0713	.0733	.0545	.1021	.1052	.1122	.0978	.0834
8+	.2103	.1809	.1617	.1315	.2013	.1777	.2058	.1522	.1781
9+	.3952	.2271	.1856	.1865	.2843	.2220	.2857	.2692	.2873
10+	.4716	.3107	.1616	.1568	.2809	.2436	.2696	.2816	.3130
11+	.4179	.2232	.1981	.1254	.2176	.2049	.1960	.2237	.2448
12+	.1500	.1500	.1500	.1500	.1500	.1500	.1500	.1500	.1500

AGE CLASS	1972	1973	1974	1975	1976	1977	1978	1979	1980
1+	.0043	.0009	.0185	.0439	.0382	.2382	.0497	.0639	0.0000
2+	.0803	.0632	.1548	.1465	.1438	.1960	.2620	.1531	.2000
3+	.1549	.0834	.1375	.1456	.1217	.2471	.1683	.2351	.2200
4+	.1721	.2238	.1216	.0638	.1462	.1363	.1712	.1325	.1500
5+	.1103	.1080	.1561	.0408	.0421	.0834	.1036	.1033	.1000
6+	.1142	.1072	.1168	.0528	.0389	.0337	.0899	.1098	.0800
7+	.1451	.1246	.1279	.0750	.1049	.0613	.0672	.0975	.0800
8+	.1981	.1701	.2097	.1068	.1976	.2387	.1869	.1179	.1600
9+	.3253	.2102	.2992	.2689	.3212	.3263	.2048	.1633	.2300
10+	.3115	.2861	.2849	.2924	.4531	.2919	.1899	.2086	.2300
11+	.2463	.2189	.2400	.1692	.3229	.2496	.1542	.1895	.2000
12+	.1500	.1500	.1500	.1500	.1500	.1500	.1500	.1500	.1500

Table 5c Fishing mortality rates estimated on the basis of cohort analysis using $M = 0.2$ and $F_t = 0.2\ yr^{-1}$

AGE CLASS	1954	1955	1956	1957	1958	1959	1960	1961	1962
1+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0001
3+	0.0000	0.0000	0.0000	.0026	.0013	0.0000	0.0000	.0003	.0018
4+	0.0000	0.0000	0.0000	.0180	.0117	.0022	.0021	.0059	.0093
5+	0.0000	0.0000	0.0000	.0266	.0121	.0171	.0084	.0225	.0187
6+	.0001	.0001	.0002	.0198	.0107	.0483	.0298	.0512	.0306
7+	0.0000	.0007	.0019	.0325	.0154	.1151	.1484	.1122	.0760
8+	0.0000	0.0000	.0429	.0631	.0392	.2469	.3762	.3604	.2028
9+	0.0000	0.0000	0.0000	.1987	.0735	.3767	.4454	.6519	.3104
10+	0.0000	0.0000	0.0000	0.0000	.1167	.3628	.4737	.5866	.3642
11+	0.0000	0.0000	0.0000	0.0000	0.0000	.3267	.2856	.5164	.2365
12+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.2000	.2000	.2000

AGE CLASS	1963	1964	1965	1966	1967	1968	1969	1970	1971
1+	.0047	.0064	.0017	.0433	0.0000	.0055	.0063	.0110	.0008
2+	.0253	.0723	.0076	.0226	.0974	.1716	.2585	.1857	.1158
3+	.0234	.0892	.0734	.1053	.0684	.1600	.1424	.0782	.1278
4+	.0213	.0895	.1151	.1665	.1026	.1018	.0889	.0626	.0761
5+	.0397	.0579	.0705	.0636	.0520	.0807	.0660	.0973	.0716
6+	.0562	.0373	.0440	.0603	.0565	.0659	.1015	.0635	.0864
7+	.0961	.0790	.0811	.0599	.1113	.1142	.1224	.1065	.0921
8+	.2464	.2059	.1815	.1470	.2244	.1962	.2266	.1602	.1963
9+	.4467	.2690	.2173	.2167	.3265	.2543	.3244	.3047	.3260
10+	.5534	.3710	.1992	.1896	.3562	.2931	.3219	.3345	.3707
11+	.5155	.2817	.2509	.1604	.2749	.2593	.2482	.2823	.3081
12+	.2000	.2000	.2000	.2000	.2000	.2000	.2000	.2000	.2000

AGE CLASS	1972	1973	1974	1975	1976	1977	1978	1979	1980
1+	.0046	.0000	.0185	.0439	.0382	.0382	.0497	.0639	0.0000
2+	.0875	.0687	.1637	.1465	.1438	.1960	.2620	.1551	.2000
3+	.1633	.0927	.1510	.1553	.1217	.2471	.1683	.2351	.2200
4+	.1839	.2386	.1350	.0708	.1576	.1363	.1712	.1325	.1500
5+	.1186	.1166	.1607	.0458	.0470	.0908	.1036	.1033	.1000
6+	.1214	.1162	.1264	.0575	.0438	.0377	.0987	.1098	.0800
7+	.1566	.1336	.1402	.0825	.1152	.0695	.0758	.1081	.0800
8+	.2222	.1861	.2278	.1632	.2206	.2672	.1249	.1346	.1800
9+	.3694	.2424	.3356	.2992	.3680	.3773	.2362	.1914	.2700
10+	.3709	.3168	.3434	.3423	.5301	.3526	.2301	.2493	.2800
11+	.3099	.2765	.3023	.2150	.4027	.3140	.1964	.2402	.2500
12+	.2000	.2000	.2000	.2000	.2000	.2000	.2000	.2000	.2000

Table 5d Fishing mortality rates estimated on the basis of cohort analysis using $M = 0.15$ and $F_t = 0.15\ yr^{-1}$

AGE CLASS	1954	1955	1956	1957	1958	1959	1960	1961	1962
1+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0001
3+	0.0000	0.0000	0.0000	.0034	.0017	0.0000	0.0000	.0004	.0023
4+	0.0000	0.0000	0.0000	.0221	.0144	.0027	.0026	.0072	.0113
5+	0.0000	0.0000	0.0000	.0314	.0141	.0201	.0097	.0261	.0218
6+	.0001	.0001	.0003	.0224	.0120	.0539	.0333	.0563	.0339
7+	0.0000	.0008	.0020	.0357	.0167	.1240	.1590	.1200	.0798
8+	0.0000	0.0000	.0433	.0643	.0410	.2549	.3904	.3715	.2078
9+	0.0000	0.0000	0.0000	.1903	.0712	.3758	.4383	.6483	.3055
10+	0.0000	0.0000	0.0000	0.0000	.1052	.3294	.4434	.5349	.3396
11+	0.0000	0.0000	0.0000	0.0000	0.0000	.2718	.2368	.4363	.1952
12+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.1500	.1500	.1500

AGE CLASS	1963	1964	1965	1966	1967	1968	1969	1970	1971
1+	.0009	.0005	.0023	.0043	0.0000	.0069	.0079	.0139	.0010
2+	.0325	.0916	.0097	.0290	.1219	.2146	.3201	.2265	.1406
3+	.0293	.1103	.0900	.1295	.0845	.1963	.1762	.0960	.1533
4+	.0259	.1077	.1385	.2017	.1227	.1219	.1066	.0754	.0926
5+	.0462	.0674	.0820	.0740	.3605	.0934	.0763	.1129	.0831
6+	.0626	.0415	.0495	.0673	.0631	.0735	.1130	.0705	.0965
7+	.1016	.0842	.0664	.3640	.1191	.1222	.1309	.1139	.0978
8+	.2409	.2081	.1849	.1497	.2290	.2011	.2325	.1723	.2010
9+	.4346	.2948	.2082	.2097	.3155	.2466	.3160	.2974	.3173
10+	.5067	.3359	.1762	.1704	.3039	.2640	.2916	.3042	.3378
11+	.4356	.2335	.2073	.1314	.2276	.2144	.2051	.2339	.2559
12+	.1500	.1500	.1500	.1500	.1500	.1500	.1500	.1500	.1500

AGE CLASS	1972	1973	1974	1975	1976	1977	1978	1979	1980
1+	.0061	.0012	.0242	.0550	.0467	.0457	.0596	.0785	0.0000
2+	.1134	.0871	.1993	.1864	.1748	.2332	.3061	.1700	.2400
3+	.1938	.1129	.1872	.1859	.1526	.2976	.1970	.2721	.2500
4+	.2160	.2791	.1613	.0856	.1847	.1677	.2047	.1511	.1700
5+	.1359	.1336	.1941	.0529	.0546	.1033	.1245	.1205	.1100
6+	.1357	.1286	.1398	.0640	.0485	.0420	.1079	.1280	.0900
7+	.1684	.1438	.1491	.0876	.1228	.0735	.0826	.1133	.0900
8+	.2256	.1920	.2351	.1662	.2239	.2727	.1259	.1367	.1000
9+	.3595	.2337	.3298	.2948	.3552	.3627	.2293	.1829	.2600
10+	.3365	.2876	.3086	.3150	.4867	.3162	.2063	.2270	.2500
11+	.2575	.2299	.2512	.1771	.3371	.2610	.1615	.1983	.2100
12+	.1500	.1500	.1500	.1500	.1500	.1500	.1500	.1500	.1500

Table 6. **Mean values of southern bluefin tuna recruitment and their standard deviations.**

Period		M/F_t combination used in cohort analysis			
		0.2/0.1	0.2/0.15	0.2/0.2	0.15/0.15
1950-1963	mean	6 199 916	5 419 609	5 029 191	3 477 226
	s.d.	851 866	775 884	761 748	507 955
1964-1976	mean	5 266 970	4 685 897	4 494 638	3 424 210
	s.d.	897 459	815 480	806 806	656 033

Table 7. **Southern bluefin tuna parental biomass (tonnes).**

Year	M/F_t combination used in cohort analysis			
	0.2/0.1	0.2/0.15	0.2/0.2	0.15/0.15
1967	358 816	266 053	220 594	251 731
1968	340 889	248 822	203 756	237 566
1969	321 478	232 537	189 054	224 628
1970	295 423	210 974	169 713	205 654
1971	272 253	192 549	153 734	189 762
1972	251 630	176 164	139 523	174 572
1973	228 852	158 589	124 687	158 420
1974	213 731	149 032	118 001	149 597
1975	201 892	140 878	111 726	141 064
1976	199 090	141 331	113 699	140 026
1977	193 994	138 042	111 422	134 952
1978	198 442	141 106	113 612	135 111
1979	209 703	149 805	121 702	141 750
1980	209 082	147 695	120 148	140 533
Pre-exploitation	697 270	609 513	565 605	500 894
$\frac{1980 \times 100}{\text{Pre-exploitation}}$	29.99%	24.23%	21.24%	28.06%

Table 8. **Southern bluefin tuna 1980 catchability coefficients.**

Age class	M/F_t combination used in cohort analysis			
	0.2/0.1	0.2/0.15	0.2/.2	0.15/0.15
1+	0.0403	0.0453	0.0473	0.0605
2+	0.2604	0.2961	0.3101	0.3900
3+	0.1906	0.2201	0.2319	0.2863
4+	0.0612	0.0715	0.0757	0.0905
5+	0.0773	0.0958	0.0958	0.1047
6+	0.0586	0.0775	0.0775	0.0866
7+	0.0585	0.0773	0.0773	0.0864
8+	0.1136	0.1488	0.1659	0.1656
9+	0.1571	0.2068	0.2383	0.2301
10+	0.1572	0.2069	0.2463	0.2224
11+	0.1316	0.1832	0.2242	0.1910
12+	0.0959	0.1411	0.1844	0.1407
13+	0.0602	0.0932	0.1282	0.0884
14+	0.0388	0.0644	0.0962	0.0575
15+	0.0217	0.0350	0.0507	0.0298
16+	0.0056	0.0089	0.0126	0.0072
17+	0.0052	0.0085	0.0124	0.0065
18+	0.0025	0.0041	0.0062	0.0030
19+	0.0023	0.0040	0.0060	0.0028

Table 9. **Parameter values for the southern bluefin tuna stock recruitment relationship.**

Parameter	M/F_t combination used in cohort analysis			
	.2/.1	.2/.15	.2/.2	.15/.15
a (recruits t^{-1})	34.88	43.03	54.73	32.24
	1.5	1.5	1.5	1.5
K (t)	345 935	250 322	182 748	247 927

Table 10. **Catches stabilizing the parental biomass at its 1980 level for a series of ages-at-first capture (Tc's).**

Tc	M/F_t combination used in cohort analysis			
	0.2/0.1	0.2/0.15	0.2/0.2	0.15/0.15
1	31 784	31 546	32 100	30 706
2	32 928	32 642	33 208	32 006
3	40 988	40 395	41 078	41 315
4	48 250	47 217	47 990	51 640
5	50 439	49 191	49 970	54 931

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