ESTIMATION OF SELECTIVITY AT AGE FOR BIGEYE TUNA IN THE INDIAN OCEAN

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ABSTRACT

In response to the recommendation made at the Meeting of the IOTC's ad hoc Working Party on Methods in April, 2001, the author attempts to provide the Selectivity-at-age information on bigeye tuna in the Indian Ocean. Separable VPA (Pope and Shepherd 1982) was separately applied to catch-at-age of the Japanese longline fishery and the total purse seine fishery after catch-at-size data were converted to catch-at-age with the use of growth equations (Tankevich 1982). The resulted selectivity for the Japanese longline fishery increases as the age becomes older. The selectivity for the total purse seine fishery (combined for all types of set) was somewhat high for ages 0 and 1, lower at intermediate ages and the highest for age 6. Since the latter observation is considerably different from our perception, further investigation and verification in data and estimation procedures might be necessary.

INTRODUCTION

The IOTC ad hoc Working Party on Methods met at Sete, France in last April to discuss the better ways in assessing bigeye tuna in the Indian Ocean. Among the recommendations made at that time, one of the most important recommendations is to use Age Structured Production Model (ASPM) which takes into account of the changes in selectivity on different size of fish, which has been encountered in the bigeye tuna in this Ocean since the mid 1980s by the introduction of purse seine fishing which sets on both free swimming and log (floating objects) schools. In the application of this model, the selectivity-at-age is a key element among those input parameters. The purpose of this paper is to provide this information from the available data at least for the major fishery that takes bigeye tuna in the Indian Ocean.

DATA AND METHOD

Selectivity-at-age was estimated by Separable VPA (Pope and Shepard 1982) for longline and purse seine fisheries using catch-at-age data for each type of fishery. This method was used to estimate selectivity-at-age at the ICCAT for bluefin tuna when selectivity-at-age in the most recent years were required as an input to the VPA calibrations (Conser 1987, ICCAT 1995). This method is a variant of VPA method which assumes the separability ($F_{ij}=f_i\ S_j$, , i=year, j=age). Apart from the ordinary VPA calculation, log catch ratio ($D_{ij}=\ln(C_{i+1,j+1}/C_{ij})$ of the same cohort from the successive years can be expressed by the annual fishing intensity, selectivity-at-age and total mortality (Z). By improving the f_i and S_j, the residuals between observed D_{ij} and predicted D_{ij} is minimized. Input data to the model are terminal F in the most recent year, natural mortality (constant over ages), reference age, selectivity at oldest age relative to the reference age. This method is generally insensitive to the input parameters such as reference age and selectivity at oldest age relative to the reference age. Fishing mortality in the terminal year was selected so as not to apart from the fishing mortality in the previous years.

Length-Age Conversion

Length-age conversion was conducted by the Von Bertalanffy Growth Equations by sex (Tankevich 1982) as shown in Fig. 1. All conversion was done on quarterly time frame. Up to 14 quarterly ages, the equation for female was used as the male curve indicates unrealistically fast growth during the early life stages less than 8 quarterly ages. Sex specific length-at-age is very similar between 8 and 14 quarterly ages, and became divergent since then. Therefore, the average length-at-age was used for fish older than 14 quarterly ages. In this process, it was assumed that spawning takes place at the beginning of each quarter, and that catch-at-size data represents those at the middle of each quarter. The cut-off length for each quarterly age was determined this way (upper length limit of i-th quarterly age is equal to the length at i-th quarterly age calculated from the growth equation.

After all length was converted to quarterly ages, annual age composition was calculated. Annual age 0 means fish born in the same calendar year when the catch was made. Similarly, annual age 1 is the fish born in one calendar year before the catch took place . Catch-at-age was created from age 0 to 9+.

Longline fishery

Only Japanese longline length (2 cm length interval) and catch data since 1965 were used. As it was already mentioned many times, the coverage of length data was generally very low compared to the other oceans. This coverage was shown for total Indian Ocean (Fig. 2) and for smaller areas (Fig. 3) on an annual basis. The overall

coverage was relatively high at 5-24 % during 1965 to 1992, and then declined to less than 3 %. Fig. 3 indicates Area 2 (20ºS-20ºN, east of 80ºE) has been covered better but not covered well in other areas. The recent low coverage prevails in all areas.

Catch in number and number of length data were aggregated by quarter, and 10 degrees (latitude) by 20 degrees (longitude) rectangle. The number of catch and length data were matched and judged if data substitution is required or not. When coverage is larger than 5 % or there is more than 100 fish measured, no substitution was made. In other cases, data substitution was undertaken following to the priorities shown below.

Substitution scheme used to develop catch-at-size.

Level 1: neighboring area of same latitude in the same quarter (priority: east, west, or two next east, two next west, select whichever the sample is larger).

Level 2 : neighboring area of 1) north or south, 2) south (north)-east or south (north)-west, latitude priority is 0º-0º(10º), 10º-0º(20º), 20º-30º(10º), 30º-20º(40º), 40º-30º of the same hemisphere, parentheses is the second priority, selection between east and west is made on the number of samples.

Level 3: same as Level 1 but neighboring quarter (only between 1st and 4th quarter, or 2nd and 3rd quarter)

Level 4: same as Level 2 but neighboring quarter (only between 1st and 4th quarter, or 2nd and 3rd quarter)

Level 5: 12 large areas (10º latitude by 20ºE-80ºE and by 80ºE-140ºE), use all data up to level 4.

Level 6: 6 large areas (20º latitude by 20ºE-80ºE and by 80ºE-140ºE), use all data up to level 4.

Even after these procedures, there are still some cases where no length data were found. When this occurred, totally combined length frequency was simply applied.

The estimated catch-at-size averaged for 5-year time frame was shown in Fig. 4. These data indicate typical length frequency between 90 to 170 cm in fork length for this species as seen in other oceans. The size of fish appears to be declining in more recent years. The average catch-at-size by area for the overall years (Fig. 5) showed that the size of fish caught is the largest in area 1, which is the area north of Equator and west of 80°E. In the temperate areas, the size of fish were smaller especially in the area of 40ºS-20ºS and west of 80ºE.

Catch-at-age was converted from catch-at-size by the method described above. The estimated catch-at-age for fish caught by the Japanese longline fishery is shown in Table 1. The largest component is age 4 fish followed by age 3 or age 5 fish. Age 6 and age 2 fish also accounted for significant components.

Then, the selectivity-at-age was estimated with the SVPA. Input data and parameters were shown in Table 2. The time frame (1965-1999) was divided into three periods taking consideration of the different catch trend by area in the Indian Ocean as shown in Fig. 3. These three periods corresponds to when catch was high in all areas (1965-1976), high mostly in the tropical areas (1977-1991), and high in the southern areas (1992-1999). The last period is appeared to relate to the management measures imposed on southern bluefin tuna (SBT) coupled with the slow economic situation surrounding the longline industry. As competition on higher valued-fish became stronger, more boats were attracted to this fishing. These fleets concentrate on SBT fishing and operate in near but the outside of the SBT fishing grounds while it is closed.

Purse seine fishery

Two data sets were available. One is catch-at-size for total purse seine fishery by country and type of sets for the years between 1991 and 1999 obtained from Fonteneau (*Pers. Com*). The other is catch-at-age data by type of sets developed by Nishida (1999) for 1982-1995. Average catch-at-size in the first data set is given by set type in Fig. 6. In log sets (includes all floating object sets), the majority of catch is composed of fish between 40 and 70 cm in fork length and nearly no fish larger than 100 cm. On the other hand, however, free swimming set catch contains significant amount of large fish between 80 cm and 150 cm. Catch-at-age (Table 3) was developed applying the method described in section 2.1. The age range in the catch are from age 0 to 6 but the majority is ages 0 and 1. It should be noted that the catch of age 3 is nearly equivalent to the catch by the Japanese longline fishery. Since there is no data before 1991 and no good catch estimate by set type, the average selectivity-at-age was estimated for aggregated purse seine catch-at-age (combined catch-at-age for all set type). Although it is not undertaken, the alternative way to estimate selectivity by set type is to utilize catch-at-size by set type and calculate weight of those catch-at-size with the use of length-weight conversion factor. Then, total catch for purse seine fishery can be prorated according to the weight estimated. Regarding the second data set, the age range (age 0 to 5) is much narrower than the first data set, possibly due to the different method used to develop catch-at-age.

SVPA was applied to these two data sets with input parameters shown in Table 2.

Results and Discussion

The estimated selectivity-at-age for the Japanese longline fishery is given in Fig. 7. The selectivity increases monotonically as age increases. Selectivity is higher for younger ages in more recent years.

The purse seine selectivity-at-age is shown in Fig. 8. It is very interesting to note that selectivity for younger ages such as 0 to 2 estimated from the first data set appears to be much lower than expected and the highest value was on age 6. The effect of natural mortality seems to be very minor within the range applied (0.4 – 0.8). As it is very difficult to perceive that purse seine fishery targets older ages such as ages 5 and 6 than younger ages, careful examination on the methods used to produce the catch-at-size and thorough verification of SVPA input parameters may be necessary. The results of the second data set shows log set put more fishing on ages 0 and 1 than others while free swimming set exerts more effort on older ages (3 and 4) than younger ones.

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Age/Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
0	0	0	-	0	0	0	0	0	0	3	0	0
1	2	12	1	3	3	11	7	2	1	3	5	1
2	39	55	49	47	49	25	56	18	4	18	21	13
3	77	87	120	96	84	102	44	52	27	24	29	21
4	100	118	147	156	105	87	80	65	56	66	50	16
5	100	106	132	160	87	78	70	51	37	57	50	13
6	53	70	57	66	46	33	30	19	13	19	29	8
7	19	30	13	20	13	7	7	5	4	5	16	2
8	4	10	3	4	3	1	1	1	1	1	4	0
9+	0	1	0	0	0	0	0	0	0	0	0	0
Total	**395**	**490**	**520**	**553**	**390**	**345**	**295**	**213**	**143**	**196**	**206**	**74**

Age/Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	2	1	2	2	3	7	4	1	1	1	1
2	10	15	7	27	34	23	48	36	53	33	14	13
3	21	51	34	37	46	65	92	85	91	98	84	55
4	41	110	42	50	42	63	114	96	115	102	124	90
5	29	99	33	36	38	57	85	63	87	81	99	69
6	15	48	16	16	21	36	46	38	43	42	40	45
7	7	17	6	5	8	22	23	12	15	18	15	17
8	1	5	1	1	2	12	11	9	4	6	4	4
9+	-	1	0	0	0	1	2	1	0	1	1	1
Total	**126**	**349**	**141**	**174**	**191**	**283**	**428**	**345**	**410**	**382**	**381**	**295**

Age/Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
0	0	0	0	0	0	-	-	0	0	-	-
1	2	0	1	1	0	-	2	1	1	3	0
2	14	15	21	9	9	13	77	33	69	51	24
3	37	54	41	36	67	97	67	91	115	75	68
4	46	54	69	39	59	123	76	99	111	107	75
5	38	43	55	35	44	89	76	86	62	98	72
6	27	20	14	10	23	51	51	40	38	45	29
7	14	9	5	2	8	15	26	22	21	14	11
8	3	2	2	1	3	3	13	8	8	3	2
9+	0	0	0	-	0	1	3	2	2	0	0
Total	**182**	**199**	**208**	**133**	**214**	**393**	**393**	**382**	**429**	**395**	**281**

Table 2. *Input data for SVPA. Longline data covers only Japanese fishery, while the purse seine (PS) covers all purse seine fisheries. Free and Log denote those catch made by free swimming school set and log (floating objects) set, respectively.*

Gear	Longline			PS Combined			PS Free	PS Log
Years Covered	65-76	77-91	92-99	91-99	91-99	91-99	91-99	91-99
Natural Mortality	0.4	0.4	0.4	0.4	0.6	0.8	0.8	0.8
No. of Iterations	30	30	30	30	30	30	30	30
Reference Age	5	5	5	2	2	2	2	2
Terminal F	0.8	0.6	0.5	0.5	0.5	0.5	0.5	1.0
Selectivity at oldest Age relative to Reference age	1.3	1.2	1.0	0.3	0.3	0.3	0.3	0.2

Table 3. *Catch-at-age in thousand of fish for the total purse seine fishery.*

Age/Year	1991	1992	1993	1994	1995	1996	1997	1998	1999
0	794	502	701	745	655	2202	2754	835	2428
1	741	666	722	1000	2122	1424	4271	2269	3251
2	110	126	72	156	437	153	222	360	405
3	62	23	57	35	73	123	39	137	128
4	42	8	45	18	21	46	14	52	35
5	34	10	33	22	25	16	14	16	23
6	5	4	9	14	9	4	4	2	8
7	0	1	1	2	1	1	0	0	1
8	0	0	0	0	0	0	0	0	0
9+	0	0	0	0	0	0	0	0	0
Total	**1788**	**1340**	**1638**	**1992**	**3344**	**3969**	**7318**	**3670**	**6280**

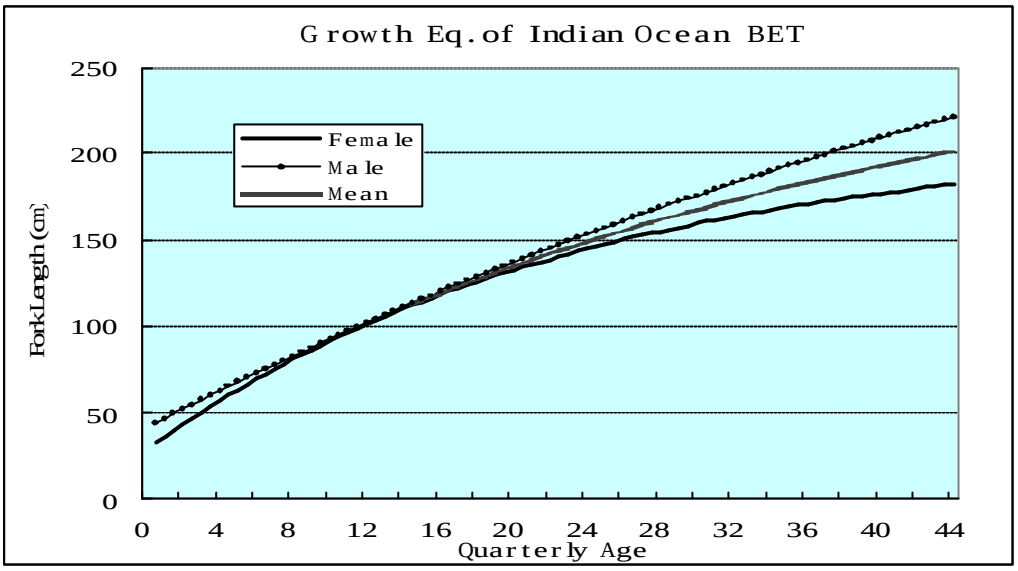
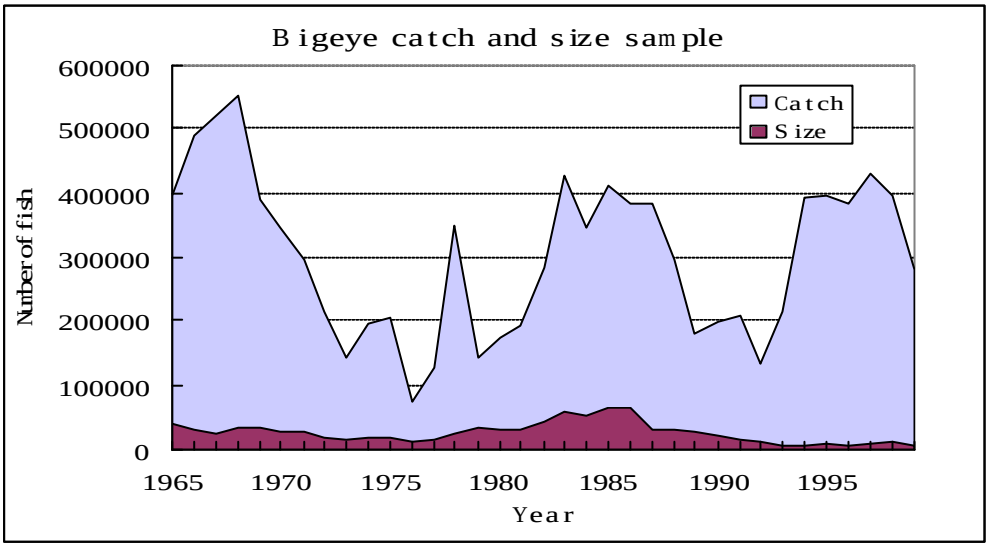


Fig.1. *Von Bertalanffy growth equation curves for age conversion. Thick line and thin line with solid circles indicate growth curves by sex obtained from Tankevich (1982). Shaded line indicates average length between the two curves by sex.*



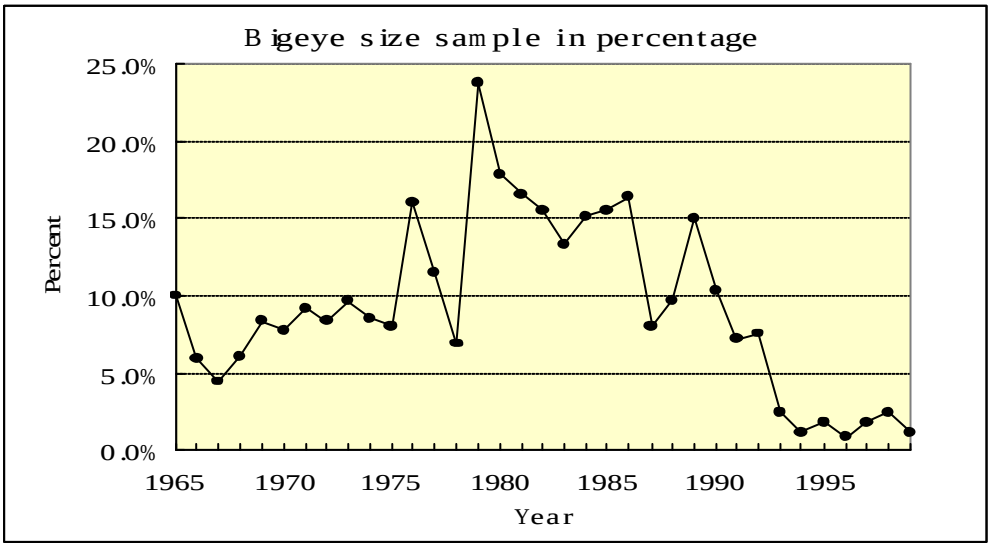


Fig. 2. *Availability of length data for the Japanese longline fishery in the Indian Ocean.*

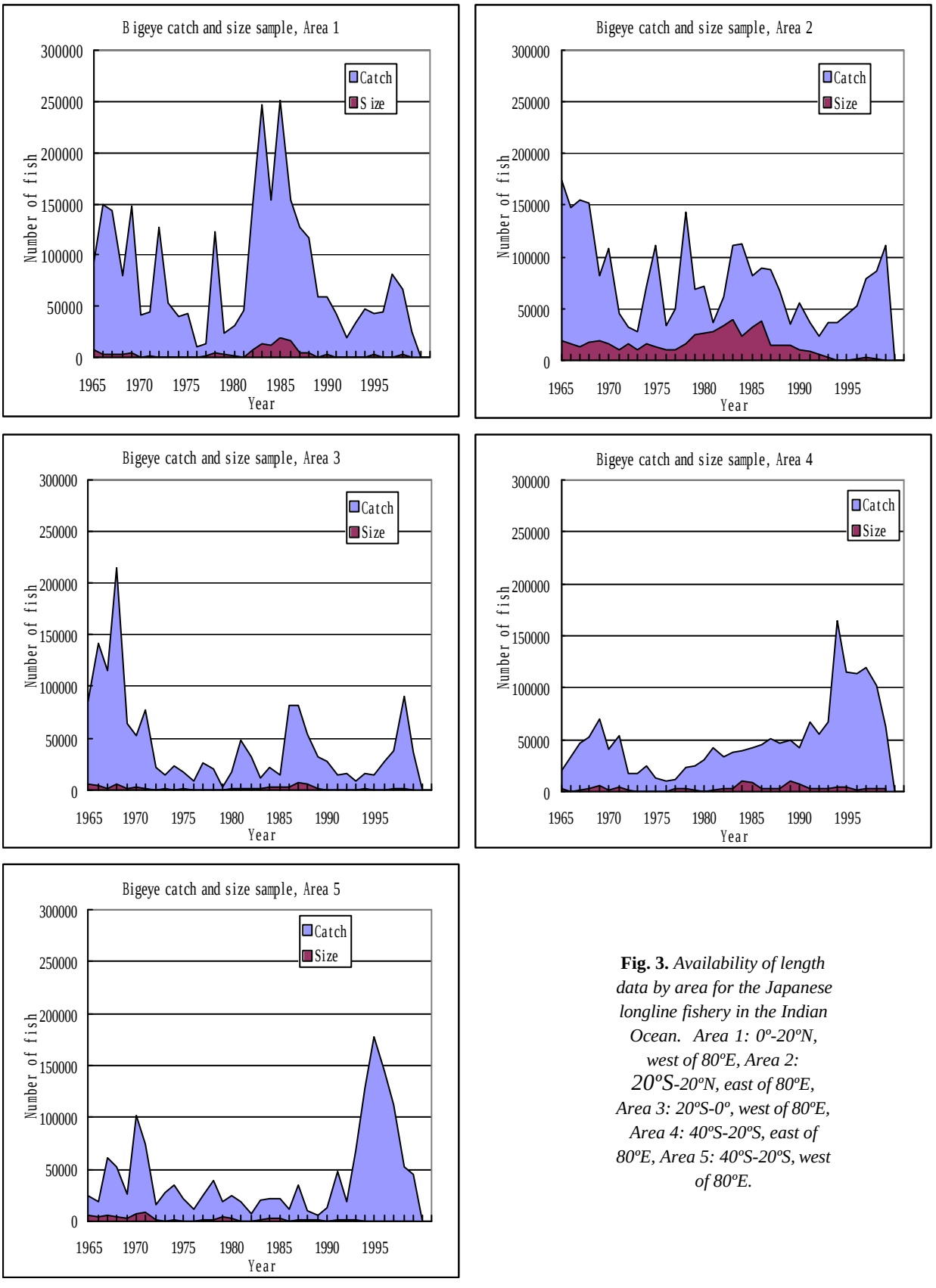
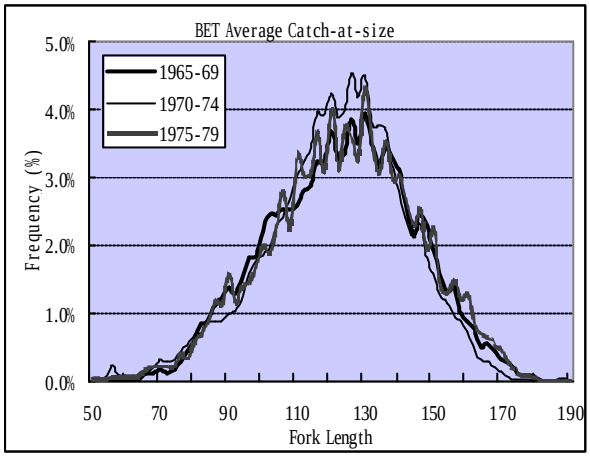
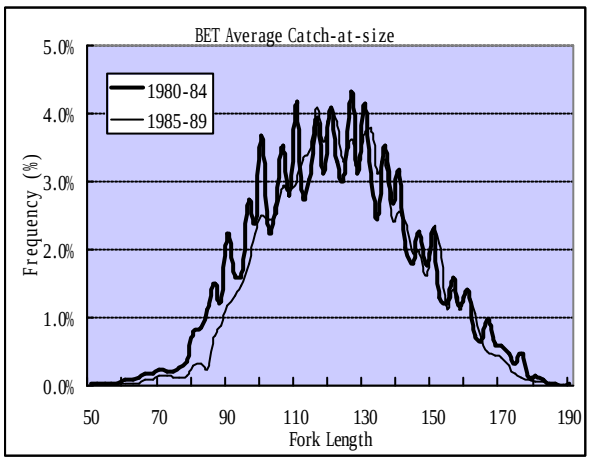


Fig. 3. *Availability of length data by area for the Japanese longline fishery in the Indian Ocean. Area 1: 0º-20ºN, west of 80ºE, Area 2: 20ºS-20ºN, east of 80ºE, Area 3: 20ºS-0º, west of 80ºE, Area 4: 40ºS-20ºS, east of 80ºE, Area 5: 40ºS-20ºS, west of 80ºE.*





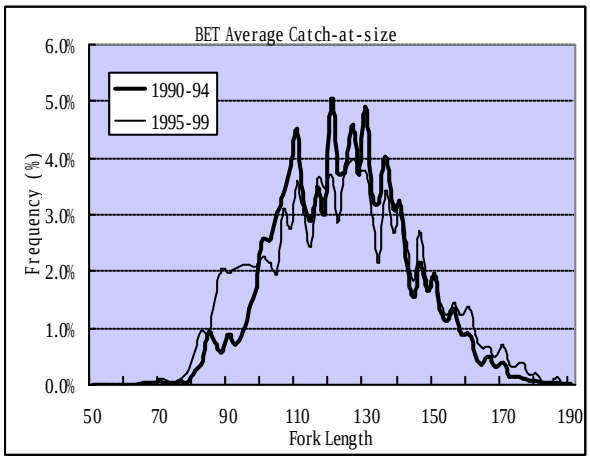
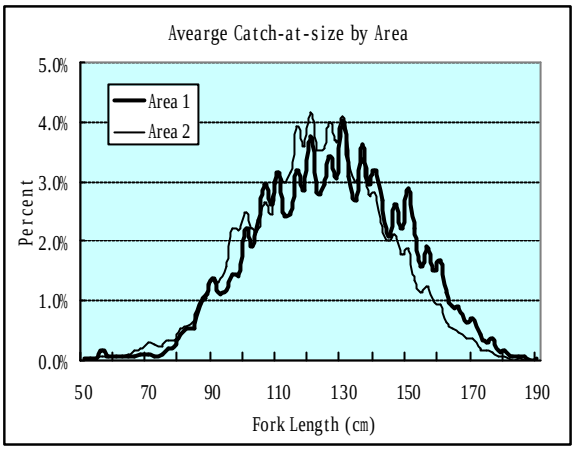


Fig. 4. *Catch-at-size for the Japanese longline fishery. Averaged for 5-year period.*



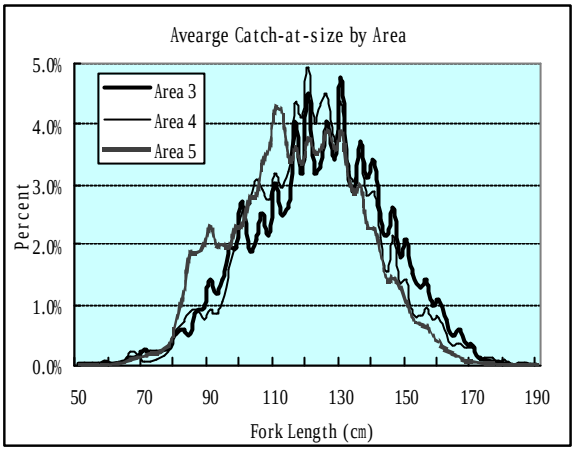


Fig. 5. *Catch-at-size by area for the Japanese longline fishery, averaged for all years. Area 1 : 0º-20ºN, west of 80ºE; Area 2 : 20ºS-20ºN, east of 80ºE; Area 3 : 20ºS-0º, west of 80ºE; Area 4 : 35ºS-20ºS, east of 80ºE; Area 5 : 40ºS-20ºS, west of 80ºE.*

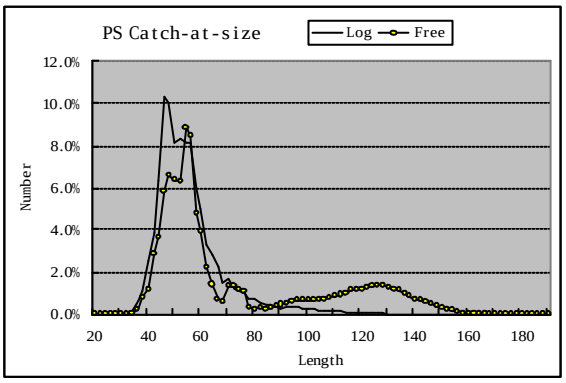


Fig. 6. *Average catch-at-size for the total purse seine fishery by type of set (Free and Log set) for 1991-1999.*

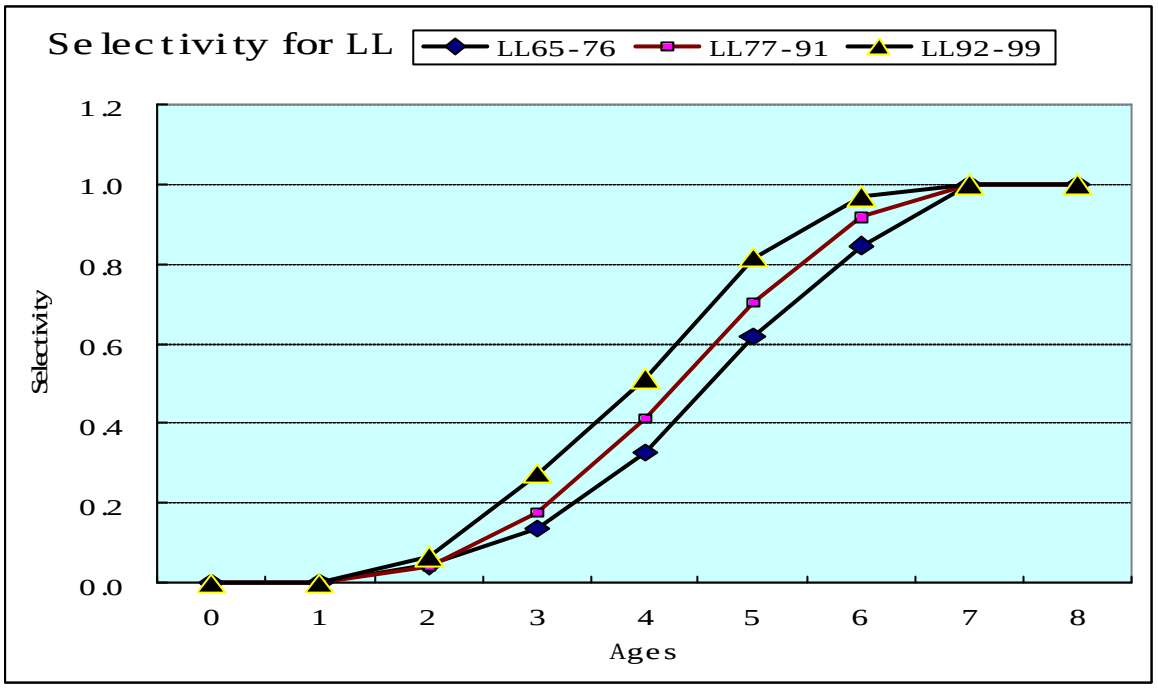


Fig. 7. *Selectivity-at-age for the Japanese longline fishery for the three periods; 1965-1976, 1977-1991, 1992-1999.*

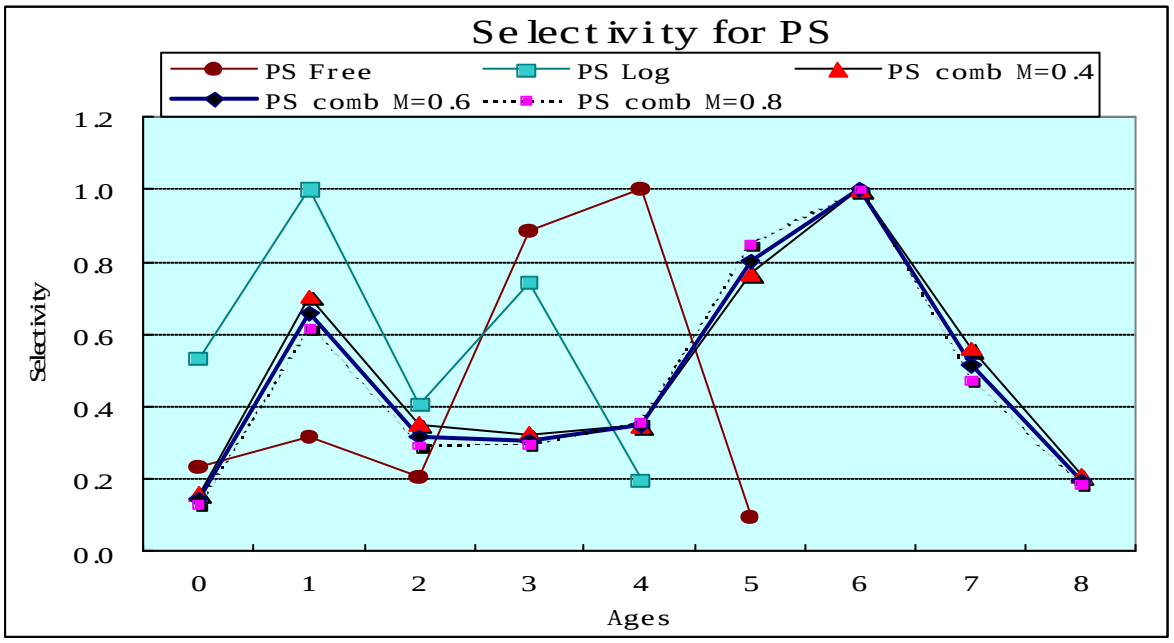


Fig. 8. *Selectivity-at-age for the total purse seine fishery in the Indian Ocean. PS Free and PS Log indicate selectivity estimated by separate catch-at-age for free swimming sets and log sets by purse seine (from Nishida 1999). All other PS combined selectivity is obtained from total purse seine data shown in Fig. 7 (Fonteneau Pers. Com.) with three different values of natural mortality.*