PRELIMINARY STOCK ASSESSMENT OF BIGEYE TUNA IN THE INDIAN OCEAN BY A NON-EQUILIBRIUM PRODUCTION MODEL

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SUMMARY

Stock assessment of bigeye tuna was examined using ASPIC based on Japanese longline standardized CPUE and total catch by longline and purse seine fisheries in the Indian Ocean.

Two options were settled: first, B_1 ratio was fixed at 2.0, and second, CPUE during the first five years (1952-56) is excluded, because CPUE during 1952-56 is higher than the following years and shows large fluctuation. Therefore, four combinations were used for calculation. One of the four combinations, 1000 bootstrap trials were carried out to estimate confidence intervals.

As a result of ASPIC, the estimates of MSY ranged between 45 thousand and 74 thousand MT. Estimated CPUE showed declining trend. B-ratio is approaching 1.0 in recent years and F-ratio has already exceeded 1.0.

The value of MSY closely agreed, but B-ratio was a little smaller and F-ratio was higher than those by Okamoto and Miyabe (1996) in which catch and CPUE data until 1994 were included.

Considering these results, the present catch level seems to be excessive and it is necessary to reduce the catch and monitor the stock more carefully.

It is necessary to include purse seine catch in the stock assessment as well. Age composition of purse seine catch is quite different from that of longline catch, so the increase in purse seine catch changes the selectivity of the entire fishery. These change causes of large bias in a simple stock assessment such as production model. So analyses by using age-structured model are desired in the future study.

INTRODUCTION

There are several studies about stock assessment of bigeye tuna in the Indian Ocean using production model (Miyabe and Suzuki, 1991; Okamoto and Miyabe, 1996). But no report is observed in the last three years probably because of the difficulty in the standardization of CPUE. In this paper updated standardized Japanese longline CPUE and all catch including the catch of purse seine fishery were used for the stock assessment by a non-equilibrium production model (ASPIC).

MATERIALS AND METHODS

Standardized CPUE

Standardized CPUE of bigeye tuna by the Japanese longline fishery in the Indian Ocean was used, because this time series is the only available one that may reflect the change of abundance (Fig. 1, Table 1). Standardized CPUE from 1952 to 1999 was cited from Matsumoto (2000). The model used in the standardization in Matsumoto (2000) is as follows,

Log(CPUEijkl +const)=μ+YR(i)+MN(j)+AREA(k)+NHFCL(l)+MN(j)*AREA(k)+AREA(k)*NHFCL(l)+e(ijkl....)

Where Log : natural logarithm,

CPUE : catch in number of bigeye per 1000 hooks,

Const : 10% of overall mean of CPUE μ : overall mean,

YR(i) : effect of year,

MN(j) : effect of fishing season (month),

AREA(k) : effect of area,

NHFCL(l) : effect of gear type (class of number of hooks between floats),

MN (j)*AREA (k) : interaction term between fishing season and area,

AREA (k)*NHFCL (l) : interaction term between area and gear type,

e(ijkl..) : error term.

Area definition used in Matsumoto (2000) is shown in Fig. 2. The number of branch lines between floats (NHF) were divided into 3 classes (class 1: 5-9, class 2: 10-15, class 3: 16-21), though the NHF was fixed to 6 before 1974 because of the rack of information about NHF.

Catch data

Updated bigeye tuna catch weight data from 1952 to 1999 was taken from IOTC database (catch in IPTP area). Catch of longline and purse seine of all countries was used (Table

1). 1999 data was not included in the analysis, because the data are preliminary (including missing data).

Fitting the ASPIC model

ASPIC (A Surplus-Production Model Including Covariates, ver. 3.82), which is a non-equilibrium model was used for the present analysis (Prager, 1994). One series of data set (year, CPUE and total catch in MT) was inputted. For the present analysis, two options were settled: first, biomass ratio at the beginning of the fishery (B_1) was fixed at 2.0, and second, CPUE during the first five years (1952-56) is excluded, because CPUE during 1952-56 is higher than the following years and shows large fluctuation. Therefore, four combinations were used for calculation as shown in

Table 2. Of the four combinations, 1000 bootstrap trials were carried out to estimate confidence intervals for one case with full CPUE series and non-fixing of B_1 ratio.

3. RESULTS AND DISCUSSIONS

The summary of the results of ASPIC is shown in

Table 2. The estimates of MSY ranged between 45,740 and 74,930 MT; greatest when CPUE during 1952-56 was excluded and B_1 is not fixed and smallest when CPUE during 1952-56 was included and B_1 is fixed at 2.0. The tendency of F_{MSY} (F which gives MSY) and Ye(1998)(current replacement yield in 1998) is similar to that of MSY. The opposite tendency was observed in K (maximum stock biomass), B_{MSY} (biomass which gives MSY) and relative fishing mortality (ratio of current F to F at MSY: F-ratio). As to relative biomass (ratio of current biomass to biomass which gives MSY: B-ratio), though the difference was not so large, it was highest when CPUE during 1952-56 was included and B_1 is not fixed and smallest when CPUE during 1952-56 was included and B_1 is fixed. Bias corrected estimate and lower and upper limits of 80% confidence interval based on 1000 bootstrap trials are shown in Table 3. There is small difference between ordinary and bias-corrected estimates.

Compared these results with estimation by Okamoto and Miyabe (1996) which catch and CPUE data until 1994 were included (Table 4), the value of MSY (between 32 and 77 thousand MT in Okamoto and Miyabe, 1996) closely agreed, but B-ratio was a little smaller and F-ratio was higher than those by Okamoto and Miyabe (1996), though these are some overlap of range of the values. The reason of the differences is probably based on recent increase of catch and decrease of CPUE.

The trend of observed (standardized) CPUE and CPUE estimated from ASPIC (without excluding 1952-56 CPUE and without fixing B_1) are shown in Fig. 3. The MSY estimated in the present study is similar to the total catch around 1990 and lower than the recent catch, and it seems to be rather overfishing in recent years. Fig. 4 shows trends of B-ratio and F-ratio with their 80% confidence intervals with the same case as those of Fig. 3. Relative biomass (B-ratio) is continuing to decrease since 1952 and the speed of decrease accelerated since 1991. Relative fishing mortality (F-ratio) is increasing with small fluctuations and exceeded 1.0 in 1993, when purse seine catch started to increase rapidly.

In this study standardized CPUE was available only for Japanese longline fishery. For more accurate estimation, standardized CPUE for Taiwan longline fishery is also necessary, because its catch is increasing sharply and the amount is larger than that of Japan.

In recent years catch amount of purse seine fishery is also increasing (Fig. 1), so it is necessary to include purse seine catch in the stock assessment as well. But, as for purse seine fishery, besides its difficulty in standardizing CPUE, that is, age composition is utterly different from that of longline catch, so the increase in purse seine catch changes the selectivity of the entire fishery. These change causes of large bias in a simple stock assessment such as production model. So analyses by using age-structured model are desired in the future study.

Table 1 shows that the latest longline and purse seine catch have become approximately twice and three times as much as that of 10 years ago, respectively, and 2.3 times as to whole catch, and that abundance index (mainly for spawning stock) has decreased by over 30% as far as Japanese longline is considered. Referring the results of the present study of ASPIC, the present Biomass is approaching B_{MSY} and F-ratio is more than twice as much as F_{MSY}. So the present catch level seems to be excessive and it is necessary to reduce the catch and monitor the stock more carefully.

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Table 1. Standardized CPUE (by Japanese longline catch in the tropical area) and catch weight of bigeye tuna in the Indian Ocean.

Year	Standardized CPUE of Japanese longline	Catch in MT		
		Longline	Purse seine	Total
1952	11.37	702		702
1953	11.79	1,778		1,778
1954	12.43	4,627		4,627
1955	13.74	5,860		5,860
1956	13.63	9,482		9,482
1957	10.94	7,271		7,271
1958	10.63	6,407		6,407
1959	9.44	5,706		5,706
1960	11.17	9,754		9,754
1961	8.89	9,146		9,146
1962	10.41	14,169		14,169
1963	9.36	3,954		3,954
1964	9.27	14,000		14,000
1965	7.98	15,600		15,600
1966	9.09	17,527		17,527
1967	7.72	23,310		23,310
1968	9.41	34,551		34,551
1969	8.18	27,757		27,757
1970	8.04	24,832		24,832
1971	6.59	20,381		20,381
1972	7.85	18,759		18,759
1973	7.71	15,667		15,667
1974	7.47	26,163		26,163
1975	6.48	35,654		35,654
1976	7.41	27,297		27,297
1977	11.92	33,785		33,785
1978	11.46	48,146		48,146
1979	8.76	32,793		32,793
1980	8.72	33,704		33,704
1981	8.42	34,276	10	34,286
1982	9.01	43,019	8	43,027
1983	9.58	47,293	247	47,540
1984	6.65	36,493	3,561	40,054
1985	7.28	41,685	6,160	47,845
1986	8.93	45,192	9,951	55,143
1987	10.33	49,147	12,682	61,829
1988	8.63	54,428	13,862	68,290
1989	7.81	49,412	10,897	60,309
1990	7.61	54,775	11,332	66,107
1991	6.78	51,841	15,057	66,898
1992	6.40	52,662	11,222	63,884
1993	6.02	76,051	13,268	89,319
1994	5.58	75,935	17,860	93,795
1995	6.04	85,262	24,961	110,223
1996	5.53	97,402	23,396	120,798
1997	4.83	96,888	32,213	129,101
1998	5.21	109,139	32,070	141,209

Table 2. Summary of the results of ASPIC.

Parameter	Explanation of parameter	CPUE used	Value 1952-98	1952-98	1957-98	1957-98
		B_1 value	Not fixed	Fixed at 2.0	Not fixed	Fixed at 2.0
B_1 ratio	**Biomass ratio at the beginning of the fishery to current biomass**		2.948	2.000	8.972	2.000
MSY	**Maximum sustainable yield in MT**		61,040	45,740	74,930	61,150
r	**Intrinsic rate of increase**		0.1664	0.1106	0.2889	0.1838
q	**Catchability coefficient of fishery**		6.36E-06	6.08E-06	8.92E-06	7.19E-06
K	**Maximum stock biomass in MT**		1,467,000	1,655,000	1,037,000	1,331,000
B_{MSY}	**Biomass which gives MSY**		733,500	827,300	518,700	665,300
F_{MSY}	**F (fishing mortality) which gives MSY**		0.0832	0.0553	0.1445	0.0919
B-ratio	**Ratio of current biomass to B_{MSY}**		0.9846	0.8507	0.9623	0.923
F-ratio	**Ratio of current F to F_{MSY}**		2.230	3.404	1.841	2.354
Ye(1998)	**Current replacement yield in 1998**		60,890	45,290	74,790	61,050

Table 3. Bias corrected estimate and lower and upper limits of 80% confidence interval based on 1000 bootstrap trials. CPUE for 1952-98 was used and B1 value was not fixed.

Parameter	Bias -corrected estimate	Ordinary estimate	Relative bias (%)	80% confidence interval Lower limit	Upper limit
B_1 ratio	2.821	2.948	4.50	2.454	3.447
K	1,445,000	1,467,000	1.54	915,200	2,482,000
r	0.1664	0.1664	0.01	0.07048	0.3137
q	6.44E-06	6.36E-06	-1.21	3.49E-06	1.06E-05
MSY	60,040	61,040	1.66	39,880	75,730
B_{MSY}	722,300	733,500	1.54	457,600	1,241,000
F_{MSY}	0.08321	0.08322	0.01	0.03524	0.1569
B-ratio	0.9825	0.9846	0.22	0.817	1.248
F-ratio	2.247	2.23	-0.78	1.649	3.194

Table 4. Comparison of the result of ASPIC with that of Okamoto and Miyabe (1996). The values in Okamoto and Miyabe are of 1994.

Parameter	Present study	Okamoto and Miyabe (1996)
MSY	45700-74930 MT	32000-77000 MT
r	0.111-0.289	0.0057 and 0.058-8.50
q	6.08E-06 - 8.92E-06	1.00E-04 - 8.10E-02
K	1,037,000-1,655,000 MT	20-32 and 812,000-3,100,000 MT
B-ratio	0.85-0.98	0.90-1.72 and 6.24
F-ratio	1.84-3.40	0.46-2.28 and 3.04

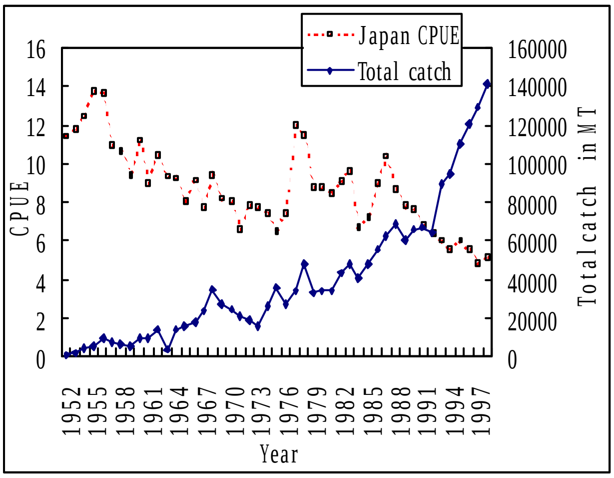

Fig. 1. Trend of total catch (catch of longline and purse seine of all countries) and standardized CPUE (by Japanese longline fishery in the tropical area) of bigeye tuna in the Indian Ocean.

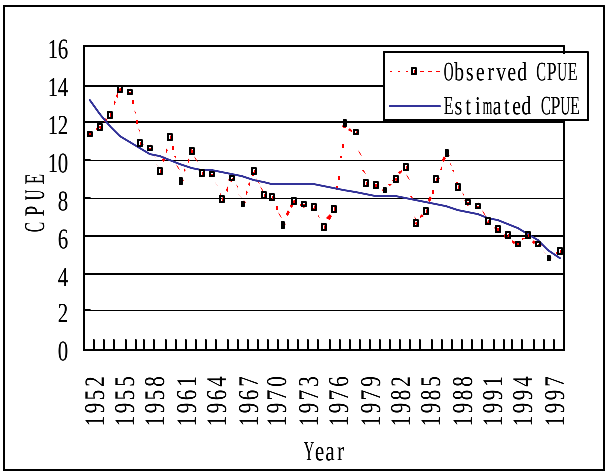

Fig. 3. Comparison of trend of observed (standardized) CPUE and estimated CPUE by ASPIC.

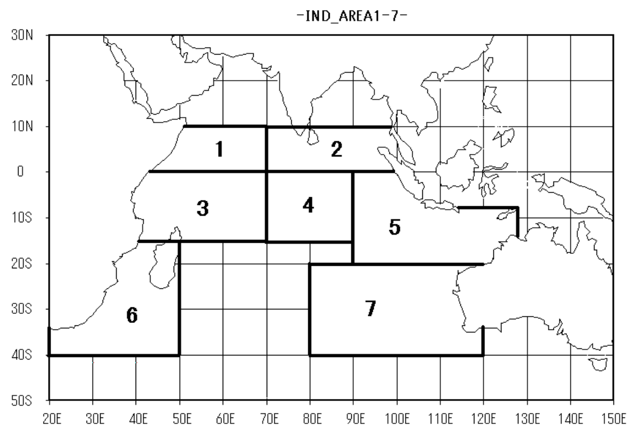

Fig. 2. Area definition used in standardizing bigeye CPUE of Japanese longline fishery.

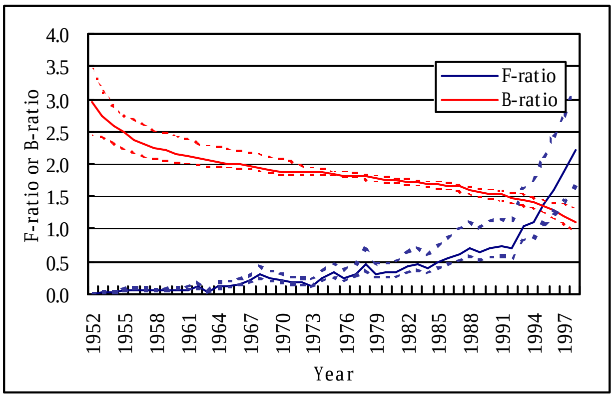

Fig. 4. Trend of relative biomass (ratio of biomass to biomass which gives MSY, B-ratio) and relative fishing mortality (ratio of F to F at MSY, F-ratio). Dotted lines show upper and lower 80% confidence intervals based on 1000 trials.