PRELIMINARY STOCK ASSESSMENT OF SWORDFISH (*XIPHIAS GLADIUS*) IN THE INDIAN OCEAN

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SUMMARY

Standardization of swordfish catch per unit effort (CPUE) caught by Japanese and Taiwanese longliners in the Indian Ocean were attempted to evaluate the influence of the current drastic increase of swordfish catch amount on the stock status. Two series of standardized CPUEs series showed opposite trend especially in 1990's when the catch amount of swordfish increased rapidly. The main reason of this cause was likely to be lack of information about the shift of target species from tunas to swordfish that was believed to be the case of the Taiwanese longliners.

Attempt an attempt was made to fit of standardized CPUE of Japanese longliners and total catch amount data to the non-equilibrium surplus production model, reliable parameters could not be estimated. This could be attributed to the uneven contrast between the sudden increasing trend of total catch amount and slower decreasing trend of CPUE of Japanese longliners in 1990's.

MATERIALS AND METHODS

DATA

Catch and effort statistics of Japanese longliners (1953 – 1999), and Taiwanese longliners (1967 – 1998) were used. As for the Japanese longline fishery, dataset from 1975 to 1999 were aggregated by month, 5-degree square and the number of hooks between floats (NHF). Similar data set without information about NHF was used in this study for Japanese longliners in the period between 1953 and 1975, and for Taiwanese longliners.

All the analyses in this study were conducted by using catch data (in number). This is because of following reasons: (a) the number of size data of swordfish were not enough to estimate catch weight, and (b) Prager and Goodyear (2000) indicated that the estimates of management benchmarks such as B-ratio and F-ratio differed only in the low level when numbers rather than biomass based indices of abundance were used in fitting to the non-equilibrium production model, all the analysis in this study were done by using catch number data.

MODEL CONFIGURATION OF CPUE STANDARDIZATION

Japanese longliners

a) Treatment of interaction term between year and area factor

Swordfish is an oceanic species and usually make long distance seasonal migration. Mejuto *et. al*. (1998) indicated the distribution pattern of swordfish in the Atlantic Ocean varied by size and sex. If behaviors of swordfish in the Indian Ocean were similar to those in the Pacific and Atlantic, the value of swordfish CPUE would be affected by these behaviors, and as a result of this, the trend of CPUE would vary by area and season.

Though the above discussion indicates it that interaction terms among year, area and quarter should be included into the analysis of the generalized linear model (GLM), interaction term between year and area (year*area interaction) could not be included into the model because of many missing data.

One of the way to incorporate year*area interaction which has some missing data into the standard linear model type analysis is to make it into a random factor and put into the generalized linear mixed model model. Although the statistical preferable of this modeling was not investigate, it was decided to use in this study as no alternative way available at now.

b) Generalized linear mixed model

Statistical model used to standardize CPUE data is standard linear mixed model with lognormal error. Fixed factors used in the model were year, area, quarter and NHF for the data set of 1975-99. The sub-area defined for the analysis of the data set before 1976 and after 1974 were shown in Fig. 1. NHF was categorized into 6 classes (3-4, 5-6, 7-9, 10-11, 12-15, 15<). The interaction terms of year*quarter and area*quarter were also included in the model. In addition, year*area interaction term was included in the model as random effect. For the data set before 1976, factor of NHF term was not included in the model. Analysis was conducted using the MIXED procedure available in the SAS statistical computer software.

Taiwanese longliners

a) Targeting effect

Although no information about the operational patterns of Taiwanese longliners was available, recent sudden increase of swordfish catch by Taiwanese longliners could be attributed to the shift of targeting from tunas to swordfish. If this were the case, this shift of targeting would affect on standardization results of swordfish caught by Taiwanese longliners. Although this effect can be represented by the NHF, no NHF information was available for Taiwanese longliners.

Instead of using NHF information, catch proportion of swordfish (number of swordfish catch to the sum of catch number of southern bluefin tuna, bigeye tuna, albacore, yellowfin tuna and swordfish) might be able to represent the shift of targeting to some extent. Data series of swordfish catch proportion was incorporated into the model as random factor because it must be robust to the temporal change of the abundance of species other than swordfish.

b) Generalized linear mixed model

The basic method to standardized CPUE data was same as that of Japanese one. Fixed factors included in the model were year, area, quarter, and as the interaction terms of year*quarter and area*quarter. Random factors were year*area interaction term and proportion of swordfish catch. The definition of sub-areas used in the analysis was shown in Fig. 2.

Non-equilibrium production model

Non-equilibrium surplus-production model was fitted to the estimated abundance indices and total catch amounts (in weight) of swordfish in the Indian Ocean. The model fitting to the data was implemented by the ASPIC software (Versoin 3.82).

RESULTS AND DISCUSSIONS

CPUE OF JAPANESE LONGLINERS

Standardized CPUE values of swordfish caught by Japanese longliners for 1953-99 was shown in Fig. 3 and their contrast to the nominal CPUE were shown in Fig. 4. Standardized CPUE showed the gradual increasing trend from 1954 to mid 1980's with some fluctuations. After the mid 1980's, it showed the decreasing trend with two small peaks in 1993 and 1997. The value of 1999 was about the same as that in 1954. Figure 5 shows the distribution of standard residuals, which close to the normal distribution.

Trend of the standardized CPUE of swordfish caught by Japanese longliners in this study was different from the previous study by Uozumi (1998), especially for the periods between 1967-1973 and after 1990. In the previous study, highest level of CPUEs was observed in the period between 1967-73. They dropped to the historical low level in 1990-91 and they increased rapidly after that.

The reason of these observed differences between the present and previous study was not clear. One of the possibilities is the different area stratification between two studies. In the previous study, analysis was conducted by using the data of 5X5 block with no missing, and the data from the inside of 200 miles zone was excluded from the analysis. As a result, the area coverage became rather smaller than that in the present study. Biological information such as life history, migration pattern and stock structure would be necessary to evaluate the difference of two observed CPUE trends, the amount of information was not enough by now.

In addition, the treatment of year*area interaction term in the model of CPUE standardization was different between two studies. In the previous study, year*area interaction was incorporated as a fixed factor while it was incorporated as a random factor in the present study. The difference of these two methods should also be evaluated from the statistical point of view.

Standardized CPUEs in five regions in the Indian Ocean (Northeast, Northwest, Central-east, Southeast, and Southwest) for 1975-99 were shown in Fig. 6. Standardized CPUE for each region was obtained by applying the same method as total CPUE (1975-99) on the data of the sub-areas in that region. General decreasing trends after mid 1980's with two peaks in 1993 and 1997 were observed in the Northwest and southwest Indian Ocean. In the Central-east and South-east Indian, CPUEs showed the gradual decreasing trend from the mid of 1980's to 1995 and then they increased slightly. In the Northeast Indian, CPUE increased rapidly from 1977 to 1982 and decreased from 1982 to 1984. After 1984, it became relatively stable until 1999 except for 1993 when a notable peak was observed.

CPUE OF TAIWANESE LONGLINERS

Standardized CPUE values of swordfish caught by Taiwanese longliners for 1967-98 were shown in Fig. 7. Figure 8 shows their contrast to the nominal CPUE. Standardized CPUE showed gradual decreasing the end of 1960's to mid 1970'. After that, it started to increase slowly until the beginning of 1990's when the trend of increasing became steep. The level of CPUE in 1998 was roughly the same as in 1967. Figure 8 shows the distribution of standard residuals, which seemed to be slightly skewed, but not far from the normal distribution.

Standardized CPUEs in five regions (Northeast, Northwest, Central-east, Southeast, and Southwest) for 1967-98 were shown in Fig. 10. Standardized CPUE for each region was obtained by applying the same method as total CPUE on the data of the areas in that part. In the southeastern and southwestern Indian, CPUEs dropped to the bottom in the mid 1980's and showed increasing trend thereafter with some fluctuations. The average levels of CPUE in 1990's were higher than those of before 1990's, especially in the southwest Indian, the average value of CPUE in 1990's was about two times higher than that in 1975-85. In the northwest and northeast Indian Ocean, CPUEs showed increasing the trend from 1975 to 1988, and dropped remarkably until the beginning of 1990s when they started to increase again. The values in 1998 were higher than those in 1975-85.

In comparing to the Japanese CPUE by large area, the general trends of Taiwanese CPUE showed completely different trends in the southwest Indian Ocean in 1990's.

CPUEs of Japanese longliners in the southwest Indian showed decreasing trend while Taiwanese CPUE stayed at historical high level. In the northwest Indian, Japanese CPUE decreased after 1993 while Taiwanese CPUE increased in the same period. In the southeast Indian, Japanese CPUE showed the steady and slow decreasing trend from 1978 to 1992 while Taiwanese CPUE showed the increasing trend after 1985 with some fluctuations.

Figure 11 shows the comparison between total Japanese and Taiwanese CPUE. Two series showed opposite trend for the periods of 1967-72 and 1989-98. One possible reason of this is the effect of swordfish catch proportion term. If the catch proportion did not represent the shift of targeting properly, then the trend of standardized CPUE of Taiwan would become different from the actual one, especially in the period when the shift of target species occurred.

The period of 1989-98 roughly coincide with the period when the catch amount of Taiwan increased drastically. Because this drastic increase of the catch amount could be attributed to the shift of target species from tunas to swordfish, the value of Taiwanese CPUE might be biased in this period. For the period between 1971 and 1989, two CPUE series showed same trend.

Non-equilibrium production model

Because the reason of difference of CPUE trend in 1990's between Japanese longliners and Taiwanese longliners was not clear, only the Japanese CPUE series was applied to the non-equilibrium production model (ASPIC) as abundance index of swordfish. As reliable number of total catch data was available only since 1970, analysis was conducted by using data after 1969..

Figure 12 shows the first fit of the data to the model (data for 1970-99 and no input parameters was fixed initially). Although the run of ASPIC ended normally and the estimated values of CPUE well fitted to the observed one, it produced unrealistic small value of K (62360 ton) and large value of r (20.9). The main reason of these values should be attributed to the differences of the magnitude of change of values between standardized CPUEs and total catch in 1990's, and also the low catch level (1000 – 3000 tons) during the period before 1985 when values of CPUE stabilized at higher level.

Because ASPIC try to explain the trend of abundance by using information of catch amount and CPUE, low catch level before 1985 would be the reason of very low level of estimated B1-ratio (6000 ton). In 1990's, the annual catch amount increased to more than 10,000 tons., ASPIC could not increase the level of biomass in 1990's because of decreasing trend of CPUE in that period, ASPIC had to set the value of r at very high level to explain such a large amount of annual catch with only less than 6000 tons of biomass.

Tables 1 and 2 show estimated values of parameter by ASPIC when one parameter (r or B1-ratio) was fixed at variety of levels. Two data series (1970-99 and 1985-99) were used for this analysis. Later data series begin with the year when the amount of catch started to increase consistently. The results of these sensitivity runs of ASPIC fluctuated, some were pessimistic and some were optimistic. The estimated values of B-ratio (Biomass level of 2000 to the MSY level) were above 1.0 and most of the estimated values of MSY were roughly close to the current catch level (20,000 – 30,000 tons).

CONCLUSION

The present study could not estimate the current stock status of swordfish stock in the Indian Ocean. This is because no correct abundance index was available in the present study. Both Japanese and Taiwanese CPUE could not explain the drastic increase of catch amount in 1990's.

Sudden increase of swordfish catch amount in 1990's can mainly be attributed to the catch increases of Taiwan (Fig. 13). During 1990's, majority of Taiwanese swordfish catch were made at the southwestern and northwestern Indian Ocean (Fig 14) where notable increase of Taiwanese CPUE and opposite trend of Japanese CPUE were observed in the same period. Figure 15 shows the simple mean values of standardized CPUEs of the eastern regions and the western regions by fleet. The mean trend of CPUE in the eastern regions were not so different between Japanese and Taiwanese longliners, while the mean trend of CPUE in the western regions were completely different between two fleet in 1990's.

If trend of CPUE of Taiwanese longliners were closer to the actual status of stock than that of Japanese longliners, then the swordfish stock in the Indian Ocean is still in a safe condition. The stock may have a large capacity or the stock may have had the recruitment of strong year class for many times in 1990's. If the actual trend of the stock were closer to the CPUE of Japanese, then the sudden increase of catch in the western Indian Ocean would cause the local depression of swordfish stock in this region. Right panel of Fig. 15 is strongly indicating that thing.

The discrepancy of observed trends between Taiwanese and Japanese CPUEs should be clarify as soon as possible to obtain correct index of swordfish in the Indian Ocean. For this purpose, following three points need to be implemented; (a) to collect information about NHF for the Taiwanese longliners, (b) to develop the adequate model of CPUE standardization which can incorporate year*area interaction in to the model with many empty cells in a data series, and (c) to collect information about biology of swordfish in the Indian Ocean such as life history, migration pattern, stock structure as well as catch at size. Further increase of catch amount of swordfish in the Indian Ocean, especially in the western side, would not be a wise option before correct information about stock status can be available.

REFERENCES

HINTON, M AND H. NAKANO 1996: Standardizing catch and effort statistics using physiological, ecological, or behavioral constrains and environmental data, with application to blue marlin (*Makaira nigricans*) catch and effort data from Japanese longline fisheries in the Pacific. IATTC Bull. Vol. 21(4): 171-200.

MEJUTO, J., J. M. DE LA SERNA AND B. GARCIA 1998: Some consideration on the spatial and temporal variability in the sex ratio at size of the swordfish (*Xiphias gladius*). ICCAT Col. Vol. Sci. Pap. 48(1): 205-215.

PRAGER, H. M. AND C. P. GOODYEAR. 2000: Fitting a Surplus-Production model with numbers- vs. weight based indices of abundance together with removals data in weight: An evaluation on simulated fisheries similar to blue marlin in the Atlantic Ocean. ICCAT SCRS/00/52, 15pp.

UOZUMI, Y. 1999: Standardization of CPUE for swordfish and billfishes caught by Japanese longline fishery in the Indian Ocean. IOTC/WPTT/99/???, 18pp.

Table 1. Estimated parameters of fitting procedure of non-equilibrium production model by using total catch amount of swordfish and standardized CPUE of Japanese longliners for the period of 1970-1999. Fitting procedure was implemented by ASPIC (version 3.82). Bold and italic values indicate the fixed ones.

r	MSY	K	B1-ratio	q	B-ratio	F-ratio
0.05	5,740	45,920	1.97	2.53E-06	1.05	4.37
0.20	14,980	299,500	1.91	3.86E-06	1.06	1.67
0.40	21,190	211,900	1.89	5.41E-06	1.10	1.15
0.60	24,640	164,300	1.89	6.95E-06	1.12	0.98
1.00	28,140	112,600	1.91	1.01E-05	1.17	0.84
5.55	33,220	23,940	***1.00***	4.76E-05	1.35	0.64
0.02	2,603	520,500	***2.00***	2.22E-06	1.06	9.56
3.68	32,740	35,620	***3.00***	3.17E-05	1.31	0.67
5.23	33,440	25,570	***4.00***	4.41E-05	1.36	0.63

Table 2. Estimated parameters of fitting procedure of non-equilibrium production model by using total catch amount of swordfish and standardized CPUE of Japanese longliners for the period of 1985-1999. Fitting procedure was implemented by ASPIC (version 3.82). Bold and italic values indicate the fixed ones.

r	MSY	K	B1-ratio	q	B-ratio	F-ratio
0.05	168,700	13,490,000	6.28	3.55E-08	2.93	0.02
0.20	28,240	564,900	3.71	1.51E-06	1.63	0.59
0.40	28,340	283,400	3.37	3.45E-06	1.40	0.69
0.60	29,310	195,400	3.30	5.25E-05	1.33	0.70
1.00	30,870	123,500	3.31	8.63E-06	1.29	0.69
no answer	no answer	no answer	***1.00***	no answer	no answer	no answer
0.03	3,775	472,100	***2.00***	2.37E-06	1.08	6.43
1.97	20,760	421,400	***3.00***	2.20E-06	1.44	0.90
0.12	24,560	836,500	***4.00***	8.90E-07	1.86	0.59

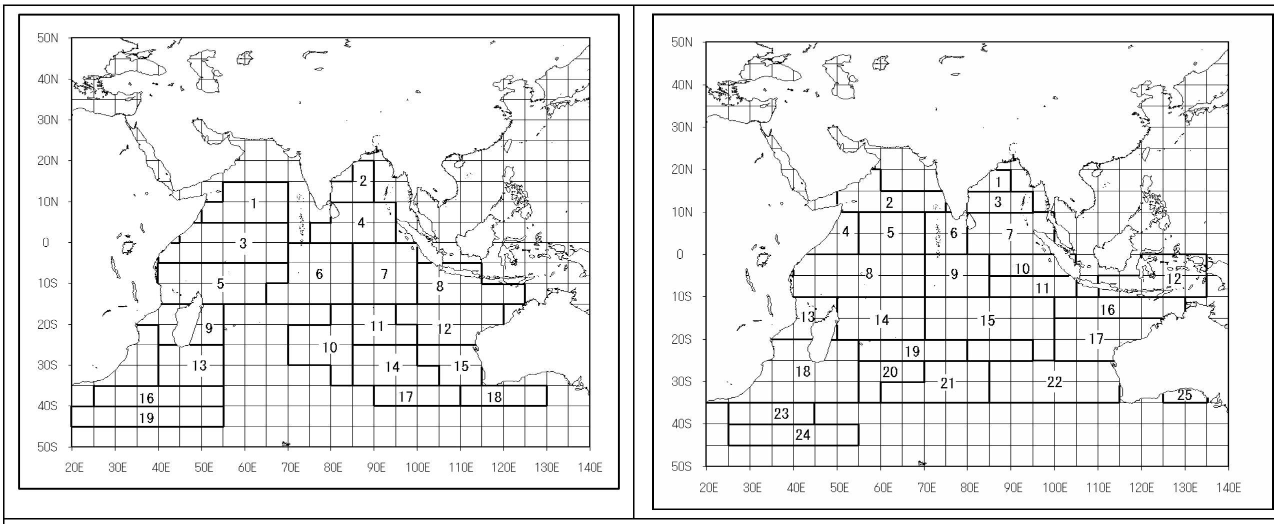

Fig. 1. Sub-area designations for the CPUE standardization of swordfish caught by Japanese longliners in the Indian Ocean for the period between 1975-99 (upper) and 1953-75 (lower).

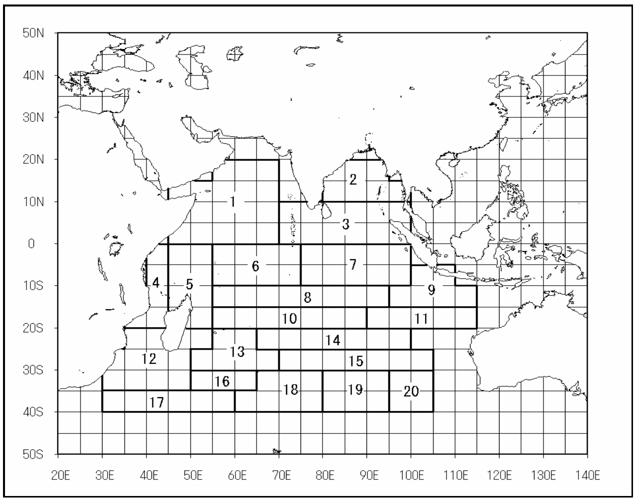

Fig. 2. Sub-area designation of the CPUE standardization of swordfish caught by Taiwanese longlinersin the Indian Ocean for the period between 1967-98.

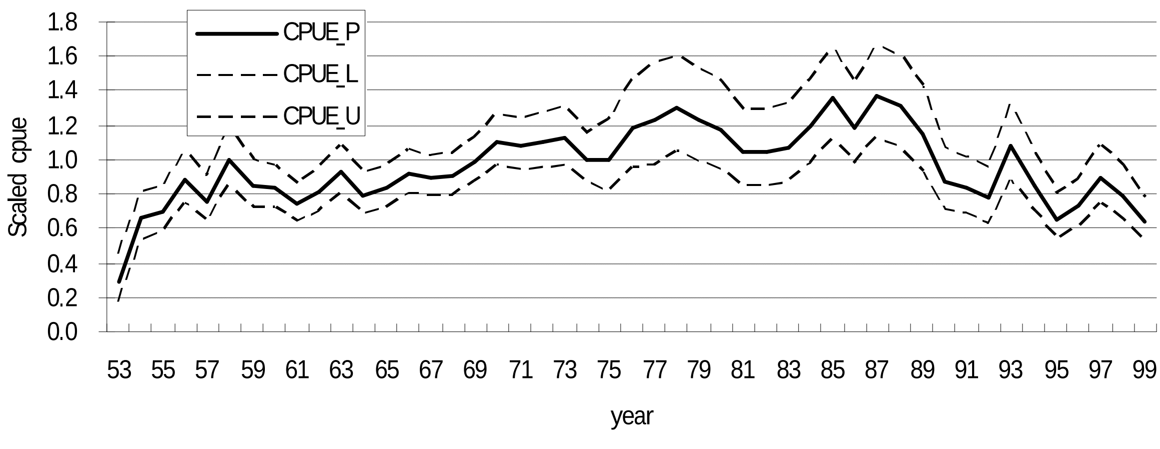

Fig. 3. Standardized and nominal CPUE of swordfish caught by Japanese longliners for 1953-99in the Indian Ocean. All the value of CPUE were scale to the one in 1975 which set at 1.0.

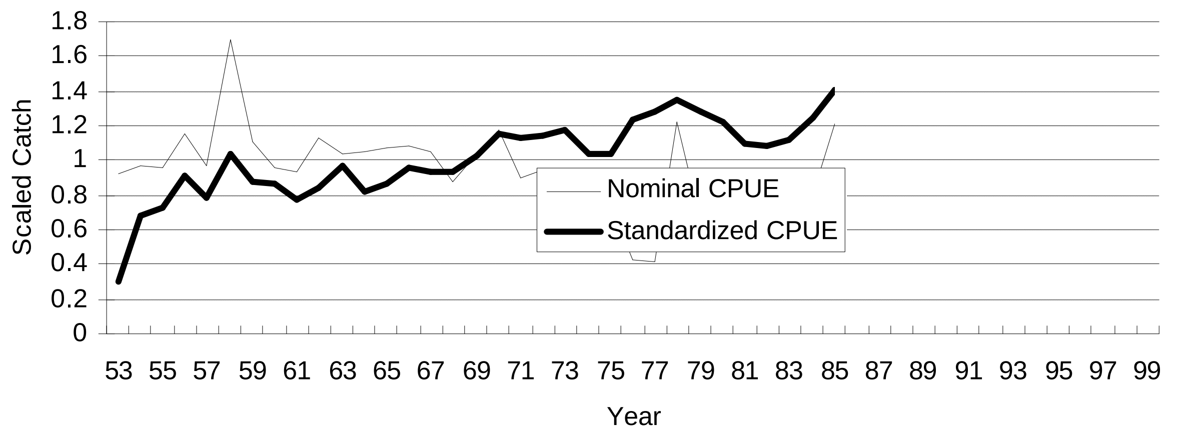

Fig. 4. Standardized and nominal CPUE of swordfish caught by Japanese longliners in the Indian Ocean. All the value of CPUE were scale to the average value of time series whichset at 1.0.

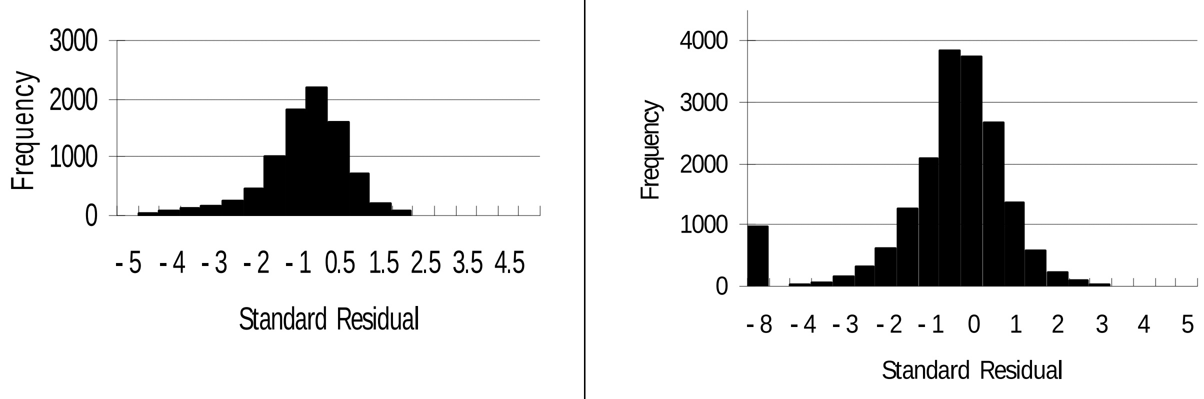

Fig. 5. Distribution of residuals for Japanese longliners in the period of 1953-75 (right) and 1975-99 (left).

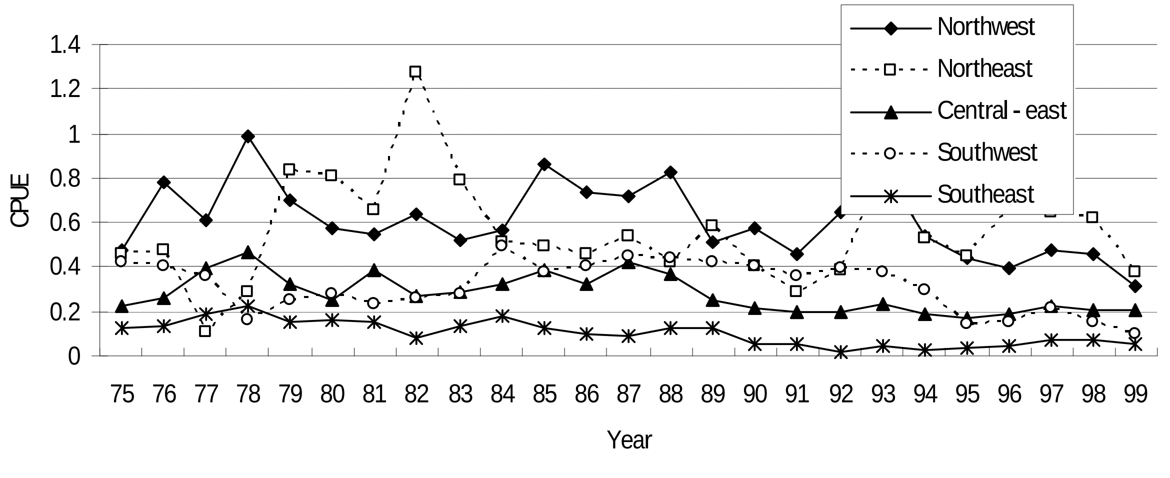

Fig. 6. Standardized CPUEs (after 1975) of swordfish caught by Japanese longliners by five regions in the Indian Ocean. Standardized CPUE of each region was obtained by using the data of main sub-areas in that region. Sub-areas selected to calculate the regional CPUE were as follows; northwest (areas 1, 3), northeast (areas 2, 4), central-east (areas 6, 7), southwest (areas 9, 13, 16), and southeast (areas 14, 15, 17, 18).

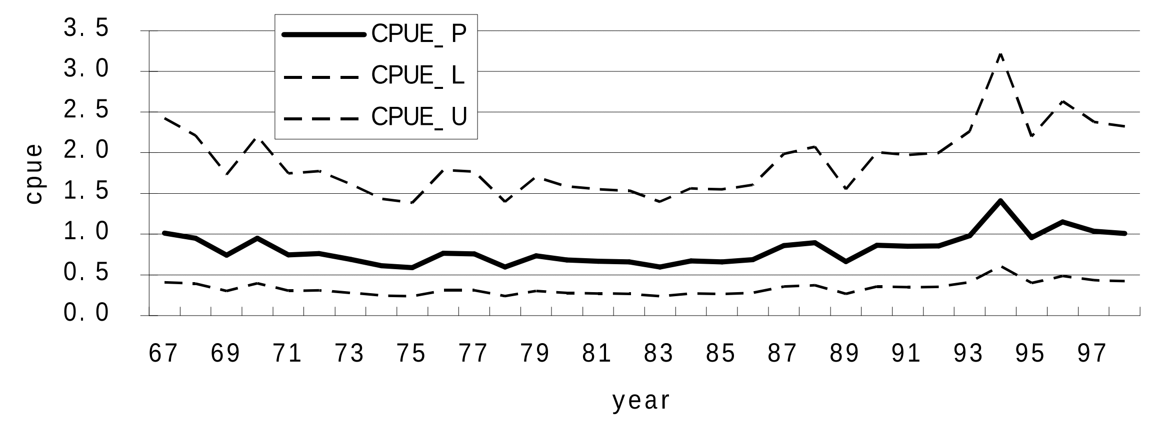

Fig. 7. Standardized and nominal CPUE of swordfish caught by Taiwanese longliners for 1967-98 in the Indian Ocean.

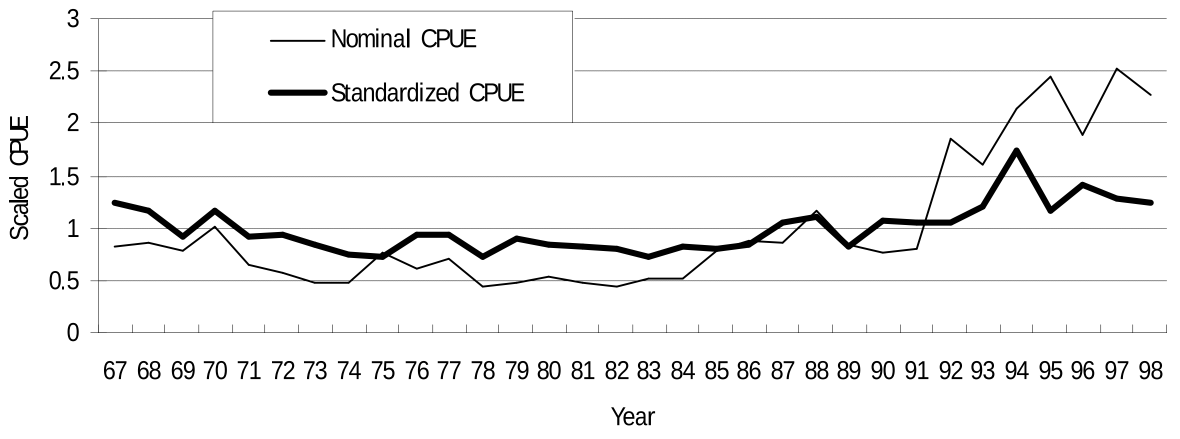

Fig. 8. Standardized and nominal CPUE of swordfish caught by Taiwanese longliners in the Indian Ocean. All the value of CPUE were scale to the average value of time series whichset at 1.0.

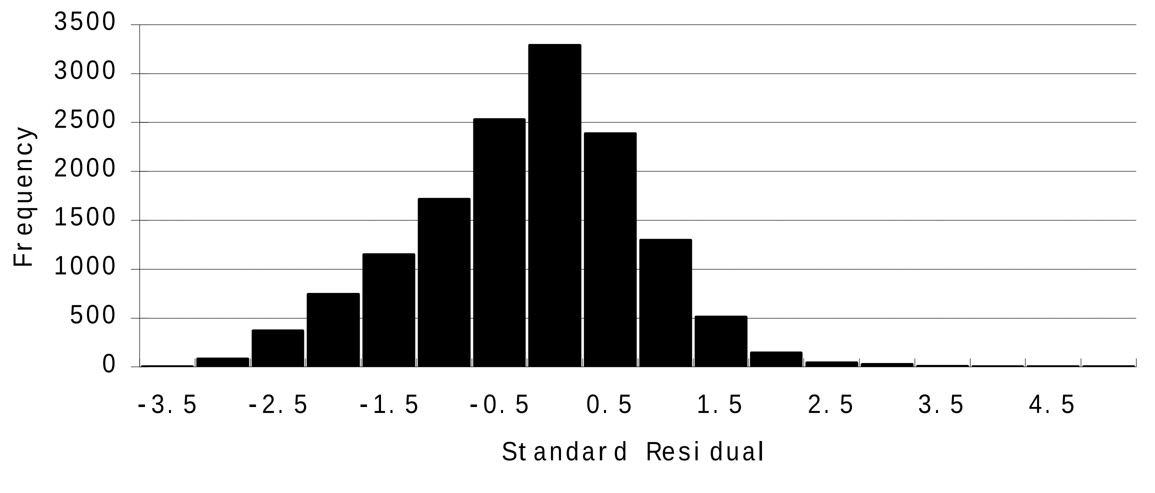

Fig. 9. Distribution of residuals for the Taiwanese longliners.

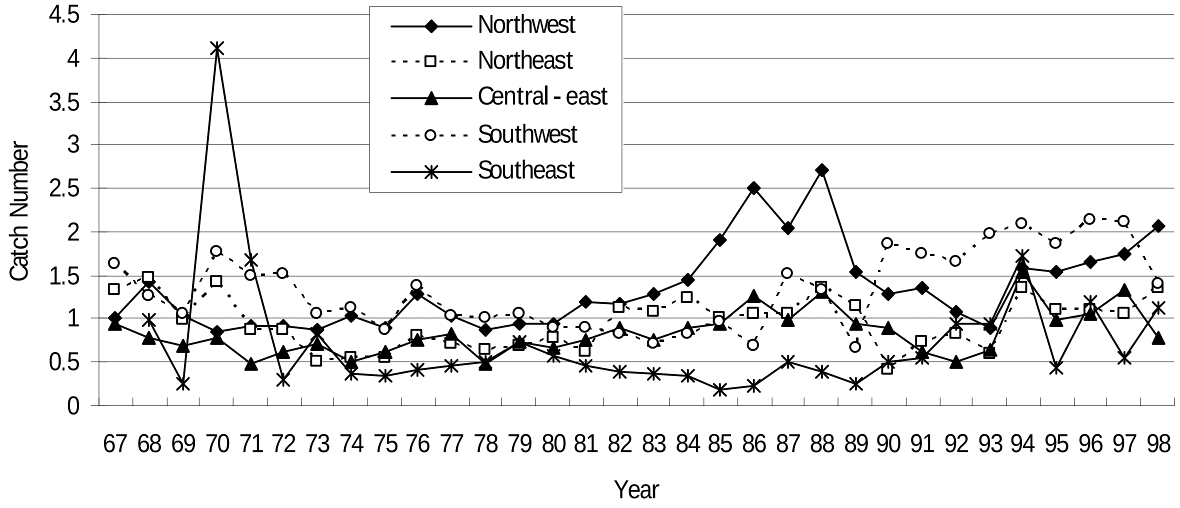

Fig. 10. Standardized CPUEs (after 1975) of swordfish caught by Japanese longliners by five regions in the Indian Ocean. Standardized CPUE of each region was obtained by using the data of main sub-areas in that region. Sub-areas selected to calculate the regional CPUE were as follows; 12, 13, 16), and southeast (areas 14, 15, 19, 20).

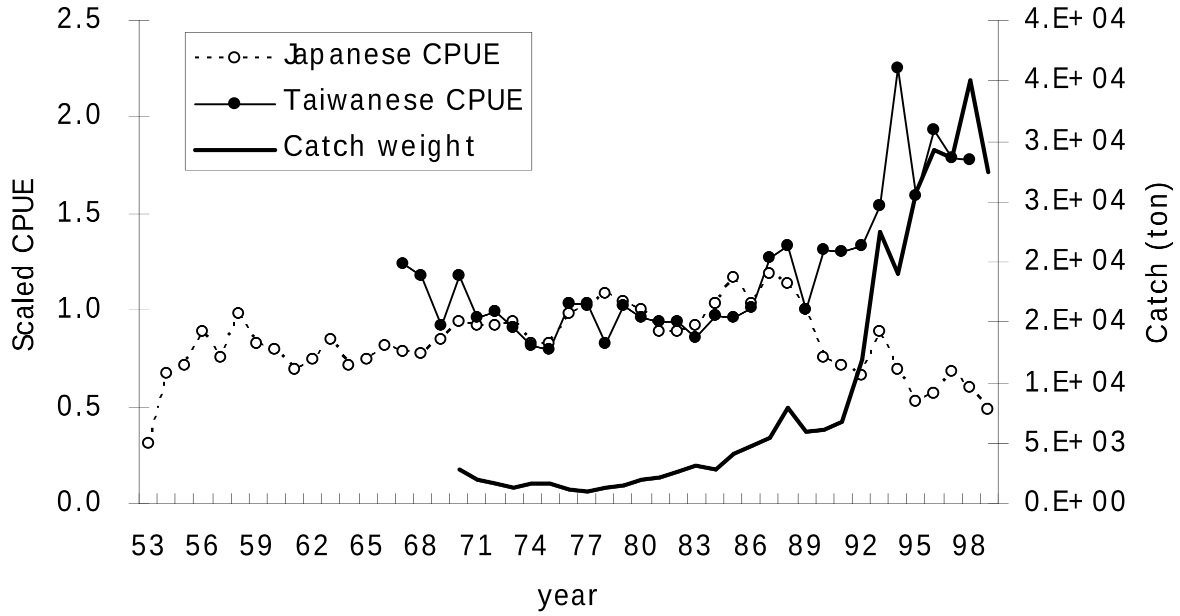

Fig. 11. Standardized CPUEs of swordfish caught by Japanese and Taiwanese longliners, and the total catch amount (ton) of swordfish in the Indian Ocean. Values of CPUEs scaled to the average valueof each time series which set at 1.0.

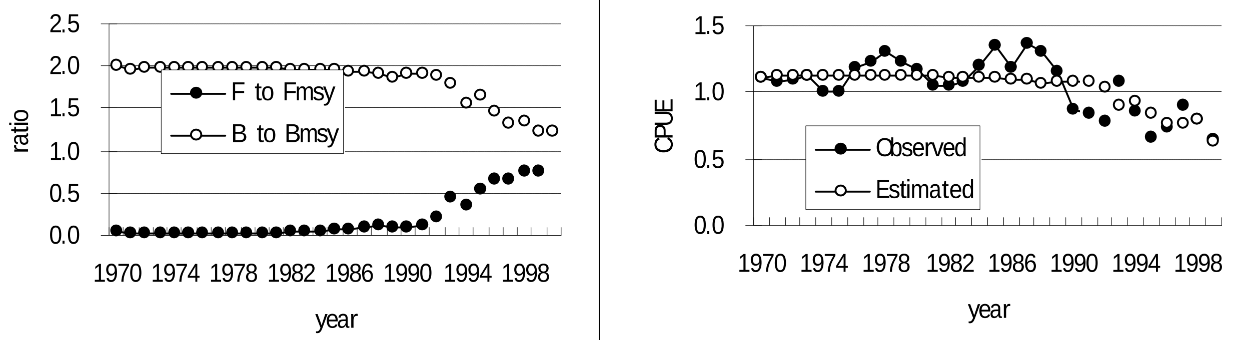

Fig. 12. Output of first run of ASPIC by using data of Total catch amount and the standardize dCPUEs of Japanese longliners for the period between 1970-1999. No input parameters was fixed initially.

Parameter	Estimate	Formula	Related quantity	
MSY	Maximum sustainable yield	3.259E+04	Kr/4	
K	Maximum stock biomass	6.235E+03		
Bmsy	Stock biomass at MSY	3.118E+03	K/2	
Fmsy	Fishing mortality at MSY	1.045E+01	r/2	
F(0.1)	Management benchmark	9.407E+00	0.9*Fmsy	
Y(0.1)	Equilibrium yield at F(0.1)	3.226E+04	0.99*MSY	
B-ratio	Ratio of B(2000) to Bmsy	1.235E+00		
F-ratio	Ratio of F(1999) to Fmsy	7.654E-01		
F01-mult	Ratio of F(0.1) to F(1999)	1.176E+00		
Y-ratio	Proportion of MSY avail in 2000	9.449E-01	2*Br-Br^2	Ye(2000) = 3.079E+04

.... Fishing effort at MSY in units of each fishery:

fmsy(1)	Simulated Fishery #1	5.716E+04	r/2q(1)	f(0.1) = 5.144E+04

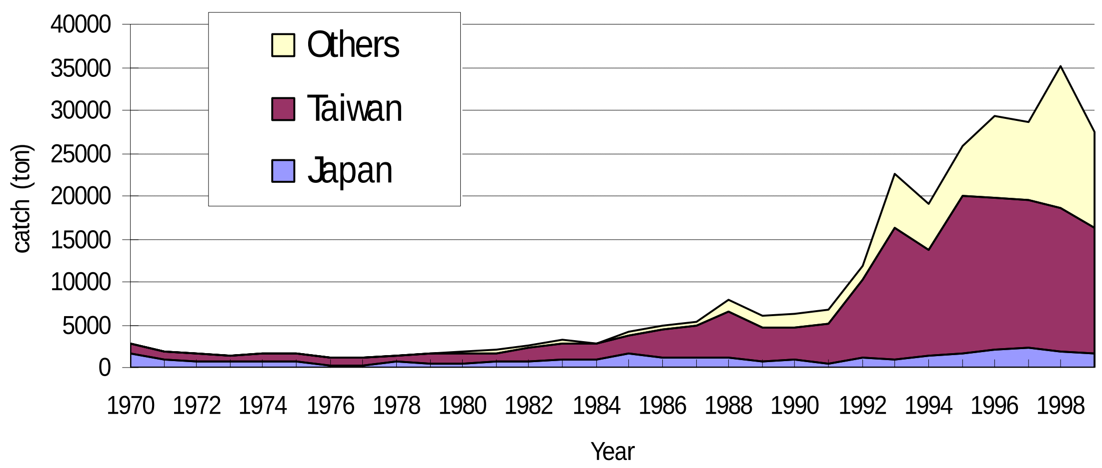

Fig. 13. Catch amount (ton) of swordfish in the Indian Ocean by country.

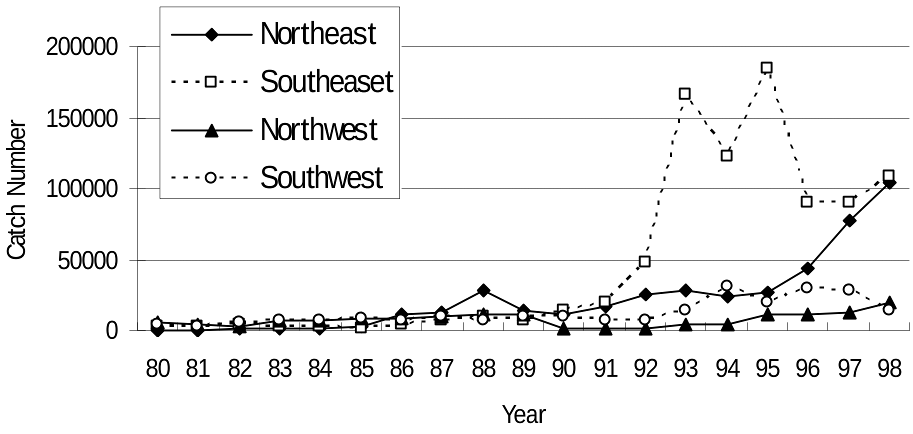

Fig. 14. Catch number of swordfish caught by Taiwanese longliners for the period between 1980-98 by four regions. The boundary between north and south Indian Ocean was set at equator and the boundary between east and west was set at 75°E.

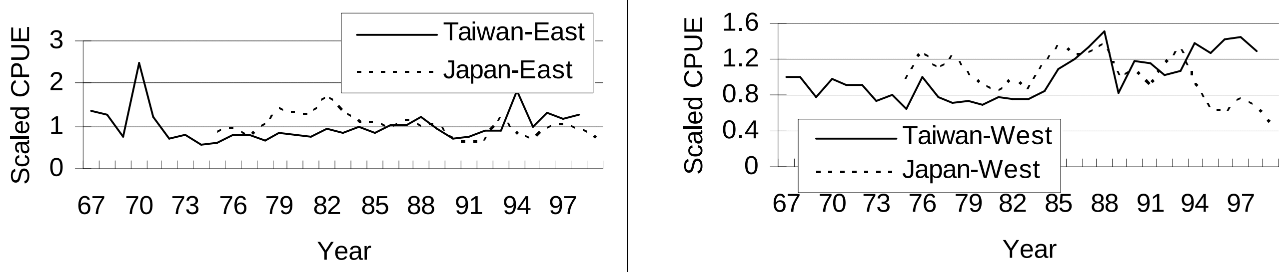

Fig. 15. The mean value of standardized CPUEs of Japanese and Taiwanese longliners of the eastern regions (left panel) and the western regions (right panel). All the mean values were scaled to the average of their time series which were set at 1.0.