STOCK ASSESSMENT ON THE INDIAN OCEAN ALBACORE TUNA

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ABSTRACT

This paper deals with the CPUE trend and maximum sustainable yield (MSY) of Indian Ocean albacore tuna. The daily catch records of Taiwanese longliners operated in the Indian Ocean dating back to 1979 were used in this study. Deep longline techniques were introduced in the tuna fishery in the mid-1980s and an effort was made to segregate the statistics of regular longliners from those of deep longliners. A general linear model (GLM) was adopted to standardize the CPUE for data of both time periods, 1979-1985 and 1985-1996. A surplus production model was employed to estimate its MSY and optimum effort (f_{opt}), and the results revealed that, MSY=30.5x10^3 t; = 319 x 10^6 effective hooks.

Introduction

Indian Ocean albacore tunas have been a major resource for the Taiwanese longline fishery since 1960s. Their catch fluctuated mostly between 5,000 and 20,000 t, amounting to about 60 % of the total Indian Ocean albacore catch by all fishing countries. Fishing effort remained stable, at about 50 x 10^6 hooks in the 1960s and 1970s. Thereafter, it increased continuously and reached a peak of 200 x 10^6 hooks during the 1990s. In contrast, the catch per unit effort (CPUE) has decreased significantly since the early 1980s, and this has raised concerns as to the stock status for many scientists (Liu and Lee, 1990), fisheries administrators and industry participants. However, the increased fishing effort was not necessarily concentrated in the areas of convergence of the albacore tuna. Furthermore, since the mid-1980s, some Taiwanese longliners have changed their fishing gear to so called deep longlines by increasing the fishing depth, targeting bigeye tuna instead of albacore. Both situations would lead to an underestimate of the CPUE of Indian Ocean albacore. Unfortunately, it is not possible to distinguish the fishing effort of the deep longliners from that of regular longliners prior to 1995 when the longliners were asked to record the number of hooks per basket they applied in the daily operations. Attempts were made to separate the fishing effort of the deep and regular longliners by Liu, *et al.* (1998, pers. comm.), based on the number of hooks per basket and species composition of the daily catch since 1995. This provides a basis to analyse historical data in terms of the regular fishing effort. By following the results of Liu, *et al.,* this study aims at the analysis of long term CPUE trends based on the Taiwanese longline fishery. Moreover, an attempt is made to elucidate the status of albacore stock by means of a surplus production model.

Materials and methods

The catch statistics, by month and by 5^0 x 5^0 area, dating back to 1967 were kindly made available by the Overseas Fisheries Development Council (OFDC), Taiwan. These data were used to demonstrate the trends of catch, effort and CPUE in a long term. Another data set, on a boat-day basis, covering the period of 1979-1996 was also provided by the OFDC for further analysis in this study.

The definition of albacore (A), bigeye (B) and mixed (M) areas of the Indian Ocean, i.e., South of 15^0S, North of 15^0S and the southwestern part of the Ocean respectively, given by Lin (1998), was adopted for the separation of regular and deep longline effort, in conjunction with the results of Liu, *et al.* (1998, pers. comm.). Their hypothesis is that the fishing depth is a function of the number of hooks per basket, and that this would be reflected by the catch composition.

The operation of Taiwanese deep longline fishery commenced in the mid-1980s, say 1985, and the daily catch statistics dating back to 1979 were split into two groups, 1979-1985 and 1985-1996, with one year overlap for adjustment purposes. The former group was treated as a homogeneous group, while the separation of deep longline and regular longline fisheries was conducted for the latter prior for further analyses.

A generalized linear model (GLM) was employed to standardize the CPUE of the catch statistics of both groups. The model selected is as follows:

$$\text{Ln(CPUE+constant)} = \mu+\text{year}+\text{month}+\text{area}+\text{month*area}+ \varepsilon;$$

Where μ is the overall mean, area is determined according to Lin (1998), and ε is an error term assumed normally distributed with zero mean. The constant adopted was 10 % of the overall nominal CPUE, following the suggestion of Campbell, *et. al.* (1996).

The total yearly albacore catch from Indian Ocean (Anon, 1986-1996), coupled with the average age per albacore individual in the corresponding year, were adopted to calculate the yearly effective effort. Furthermore, a surplus production model (Schaefer, 1957) was employed to estimate the MSY and f_{opt} level of the Indian albacore fishery.

Results and discussion

The catch of albacore by Taiwanese longliners has fluctuated between 0.2 and 1.4 million fish per year during the last three decades, while the nominal effort remained stable until the early 80s, when it began to increase and reached a peak of 200 million hooks in the 1990s (Figure 1). As a result, the nominal CPUE declined apparently during this time period. As suggested by Lin (1998), the Indian Ocean can be roughly divided into three areas, namely areas A, B and M (Figure 2). The catch statistics for each area reveal that, in area A, the fishing effort grew gradually and peaked in recent years at 60-80 million hooks, while in area B it has increased remarkably since the early 80s and reached a maximum of over 120 million hooks in the 90s (Figure 3). In area M, the fluctuation in fishing effort is not perceptible until the 90s, and it is still the lowest among these areas. It is apparent that the increased effort contributed mainly to the area B, followed by area A. Indian Ocean albacore are known to be distributed mainly South of 15^0S*,* implying that the increased effort in area B might not have been targeting albacore tuna, and would underestimate the CPUE level for this area. However, the CPUE in area A shows a similar decline (Figure 4). The decrease in CPUE resulted possibly from the inception of both gillnetters and deep longliners in the mid-80s. In the current study, concerns are emphasized in the latter case, as it was almost impossible to eliminate its effect from the CPUE estimates until recent years. Liu, *et. al.* (1998, pers. comm.) proposes separating the nominal efforts of the regular and deep longline fisheries based on the hypothesis that smaller numbers of hooks per basket applied would possibly target albacore, while greater numbers of hooks might target other species. The

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catch statistics of Taiwanese longliners in 1995 were used to demonstrate the proposed measure, and the results show that operations with less than 11 hooks per bucket would yield a significantly higher ratio of albacore, particularly in area A. Their results are adopted in this study and rearranged, with their permission, as Table 1.

Figure 5 shows the distributions of fishing effort of Taiwanese regular longliners from 1985 to 1996. It is apparent that most of the effort was distributed in area A, and less effort was expended during 1991 and 1992. For the deep longliners, which operated mainly in area B, the effort was generally higher than that of the regular longliners every year (Figure 6), indicating that the majority of the increased effort since 1985 was attributed to the deep longline fishery.

The nominal CPUE for 1979-1985 was standardized by means of a GLM with an adjustment constant of 1.5109. The results of analysis of variance show that the model itself and all the factors are significant, while the Area factor alone explains most of the variance (Table 2). The distribution of standardized residuals shows likely normality as assumed in the model (Figure 7). Similar results were also obtained for the regular longline fishery from 1985 to 1996 (Table 3 and Figure 8). The standardized CPUE during the period 1979-1985 shows a rather stable trend (Figure 9), possibly reflecting a comparably stable exploitation period of the Indian Ocean albacore stock. Over the period 1985-1996, a decrease in the standardized CPUE was observed from 1986 to 1989, suggesting the influence of the gillnet fishery that commenced from the mid-80s (Figure 10). There was a peak CPUE value in 1992, which might be a result of the particular low recovery rate of the logbooks from fishing boats as seen in Figures 5 and 6. However, there is a generally stable trend with a slight increase from 1989 onwards, and this might be a sign of recovery from the impact of the gillnet fishery since the mid-80s. The standardized CPUE values of 1985 from the two time periods above were adjusted to the same level, 10 fish per 1,000 effective hooks, and values of the remaining years were adjusted in proportion to give the CPUE trend from 1979 to 1996 (Figure 11).

A surplus production model (Schaefer, 1957) was employed to estimate the MSY and f_{opt} level of the Indian Ocean albacore fishery using yearly total effective effort and yearly total catch of albacore in weight (Figure 12), and the results are obtained as follows

MSY = 30.5 x 10^3t;

f_{opt} = 319 x 10^6 effective hooks,

$r^2 = 0.515$

The MSY estimate is at a similar level to the average for 1986-1991. Both the MSY and f_{opt} values are about twice those of 1992-1995. These estimates are very optimistic in comparison to the results of previous workers (Liu and Lee, 1990), implying the importance of eliminating the bias caused by the deep longline fishery. However, further study that takes the gillnet fishery into account should be conducted to further elucidate the status of Indian Ocean albacore stock.

References

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Table 1: Criteria (ratio of albacore tuna to the sum of albacore and bigeye catch) for demonstrating the albacore CPUE of regular longliners in the Indian Ocean.

Month	Area A	Area B	Area M
Jan.	>=0.97	>=0.02	>=0.96
Feb.	>=0.97	>=0.02	>=0.96
Mar.	>=0.97	>=0.02	>=0.84
Apr.	>=0.97	>=0.02	>=0.84
May	>=0.97	>=0.02	>=0.84
Jun.	>=0.89	>=0.02	>=0.51
Jul.	>=0.95	>=0.02	>=0.51
Aug.	>=0.91	>=0.02	>=0.66
Sep.	>=0.82	>=0.02	>=0.66
Oct.	>=0.82	>=0.02	>=0.66
Nov.	>=0.97	>=0.02	>=0.96
Dec.	>=0.97	>=0.02	>=0.96

Table 2: Analysis of variance for the GLM standardized CPUE of Indian albacore caught by Taiwanese longline fishery, 1979-1985.

Source	Degree of freedom	Sum of squares	Mean squares	F value	Pr>F
Model	41	209224.7	5103.0415	17302.01	0.0001
Error	131047	38650.905	0.2949393		
Corrected Total	131088	247875.6			
R2=O.8441; C.V. = 28.1163					
Source	Degree of freedom	Sum of squares	Mean squares	F value	Pr>F
Year	6	689.5862	114.93104	389.68	0.0001
Month	11	1030.1894	93.653585	317.54	0.0001
Area	2	180738.52	90369.262	99999.99	0.0001
Month*Area	22	4202.2396	191.01089	647.63	0.0001

Table 3 . Analysis of variance for the GLM standardized CPUE of Indian albacore caught by Taiwanese regular longline fishery, 1985-1996.

Source	Degree of freedom	Sum of squares	Mean squares	F value	Pr>F
Model	46	23976.421	521.2266	1082.71	0.0001
Error	37627	18113.97	0.481409		
Corrected Total	37673	42090.388			
R2 = 0.5696; C.V. = 27.6774					
Source	Degree of freedom	Sum of squares	Mean squares	F value	Pr>F
Year	11	1182.289	107.4808	223.26	0.0001
Month	11	882.70236	80.245669	166.69	0.0001
Area	2	16659.112	8329.5558	17302.46	0.0001
Month*Area	22	1020.5431	46.388324	96.36	0.0001

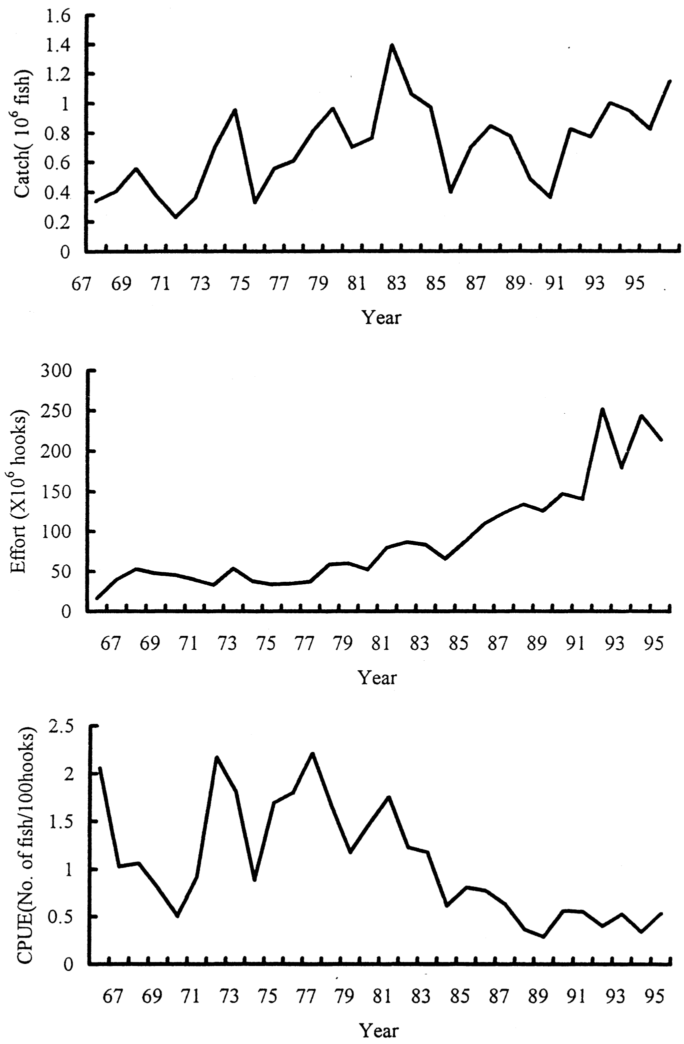


Figure 1: catch, nominal effort and CPUE of the Indian Ocean albacore longline fishery, 1967-96

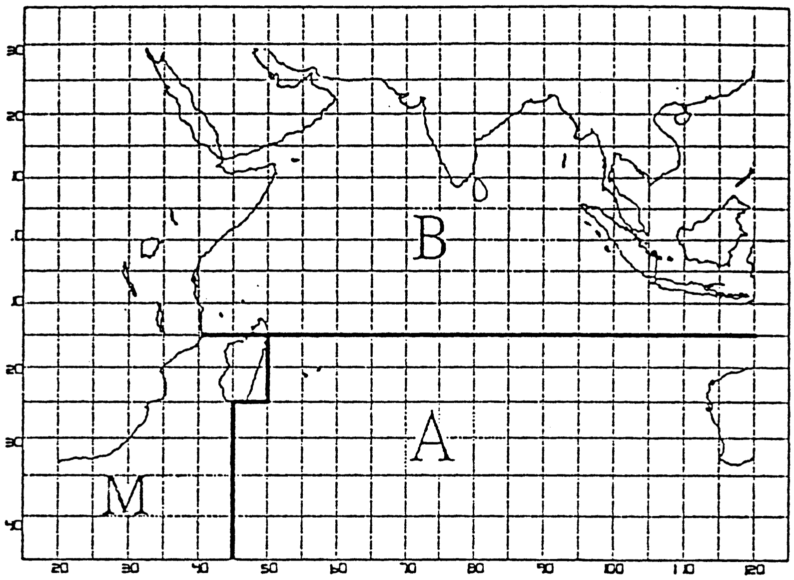
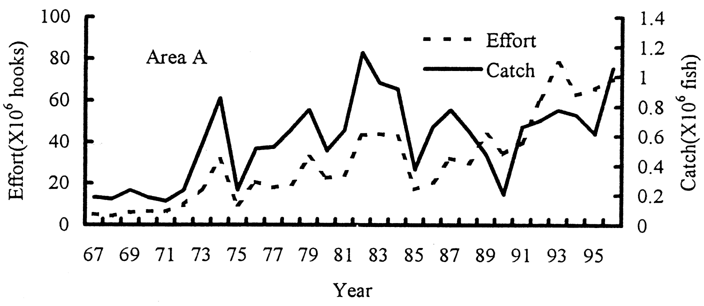
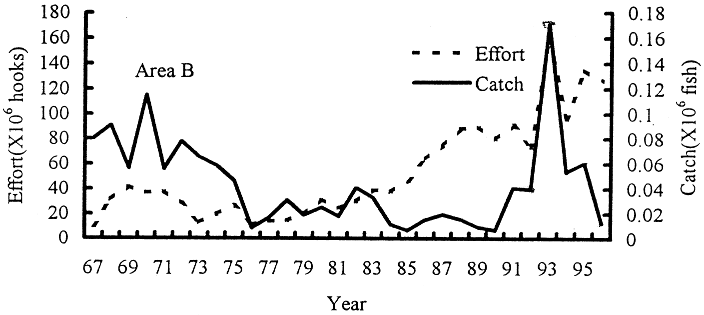


Figure 2 .Map showing the main fishing areas for Indian albacore and bigeye tuna.
Area A: south of Lat. 15° S, mainly for albacore tuna;
Area B: north of Lat. 15° S, mainly for bigeye tuna;
Area M: southwest of Indian Ocean; mixture of both species.





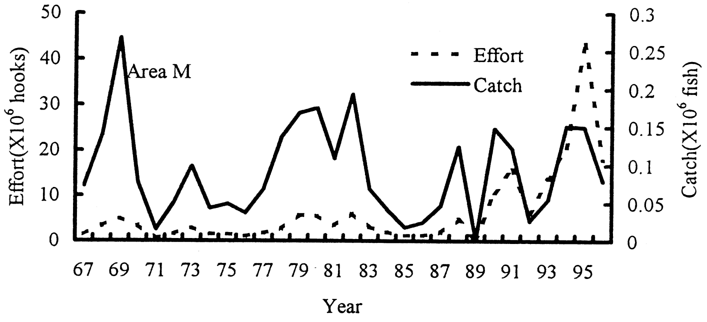


Figure 3: Fluctuation of albacore catch and fishing effort in each area of the Indian Ocean between 1967 and 1996

Figure 4: Annual CPUE of albacore tuna caught by the Taiwanese longline fishery from the three areas of the Indian Ocean, 1967-96

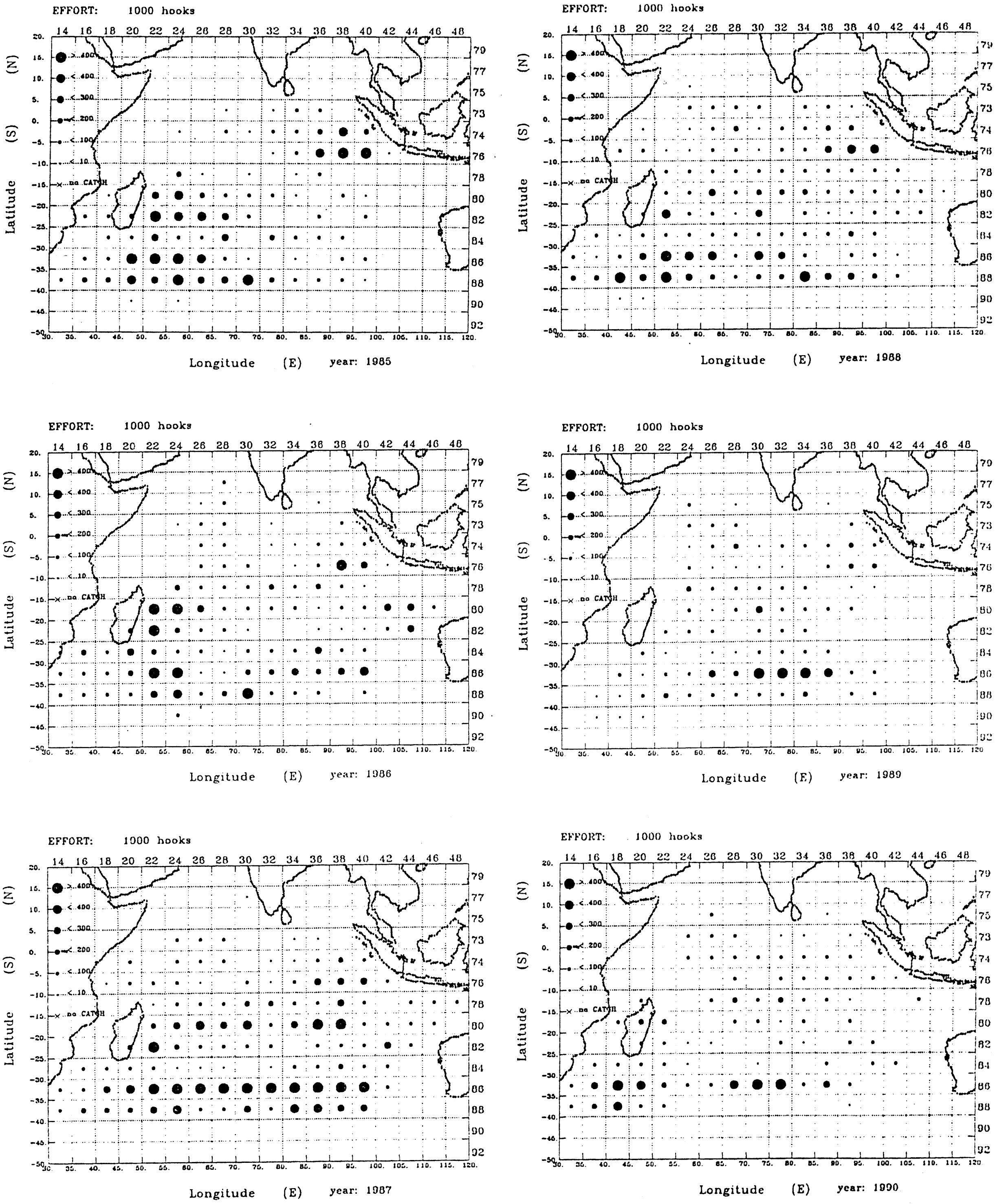
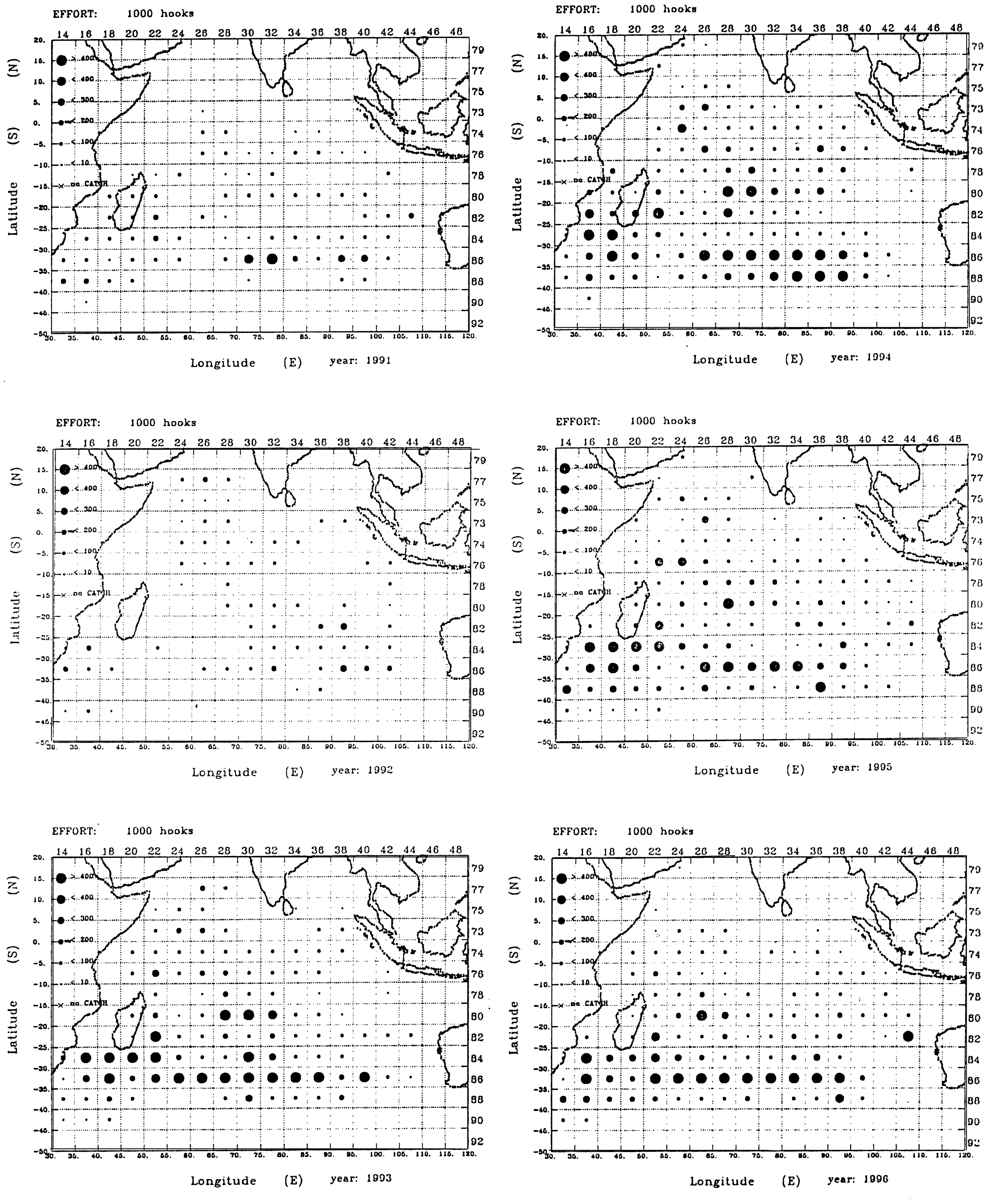


Figure 5: Yearly distribution of fishing effort ascribed to the Taiwanese regular longline fishery operated in the Indian Ocean, 1985-1996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Latitude (S) (N)
Longitude (E)
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year: 1994
year: 1992
year: 1995
year: 1993
year: 1996

Figure 5: (end)

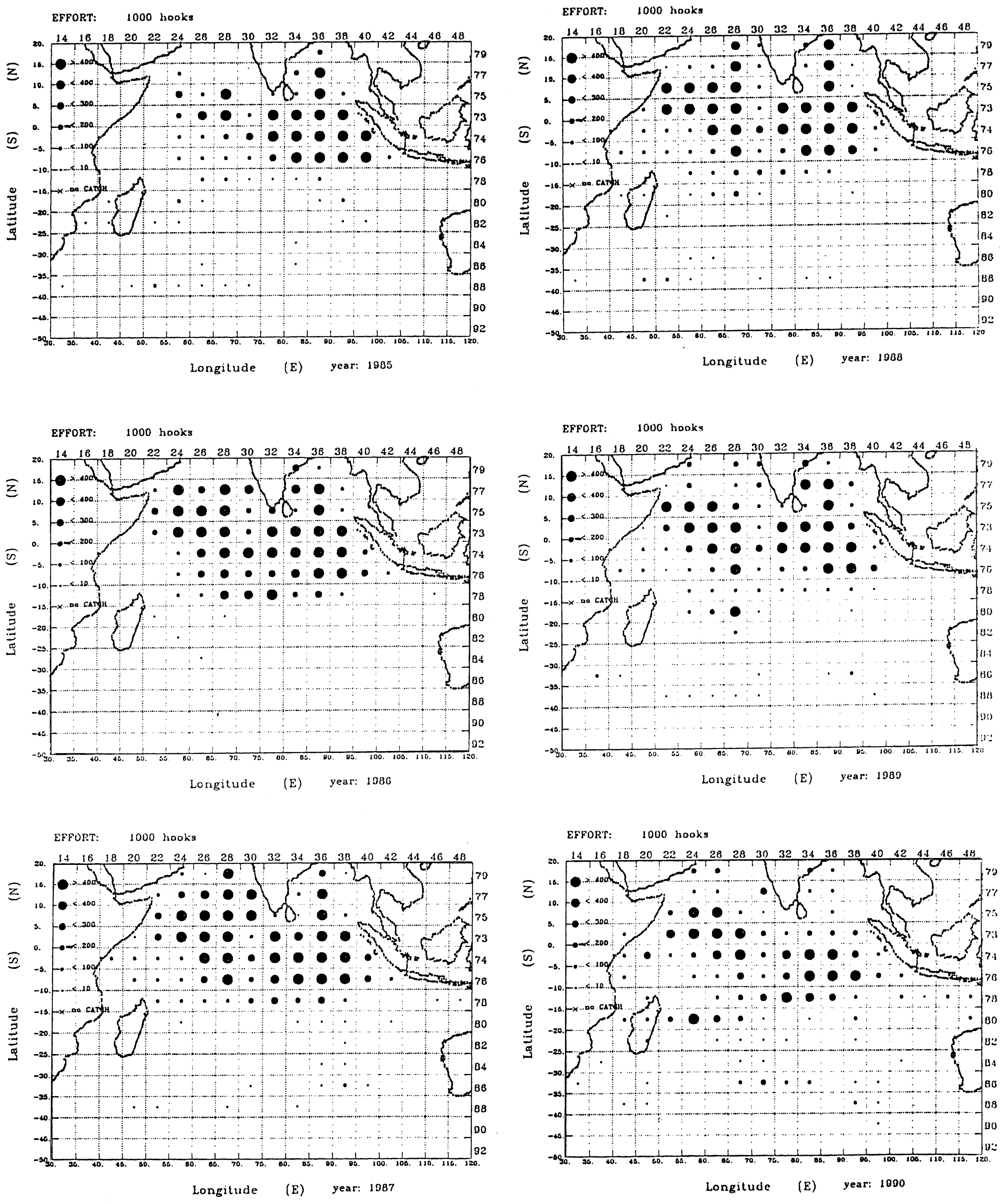
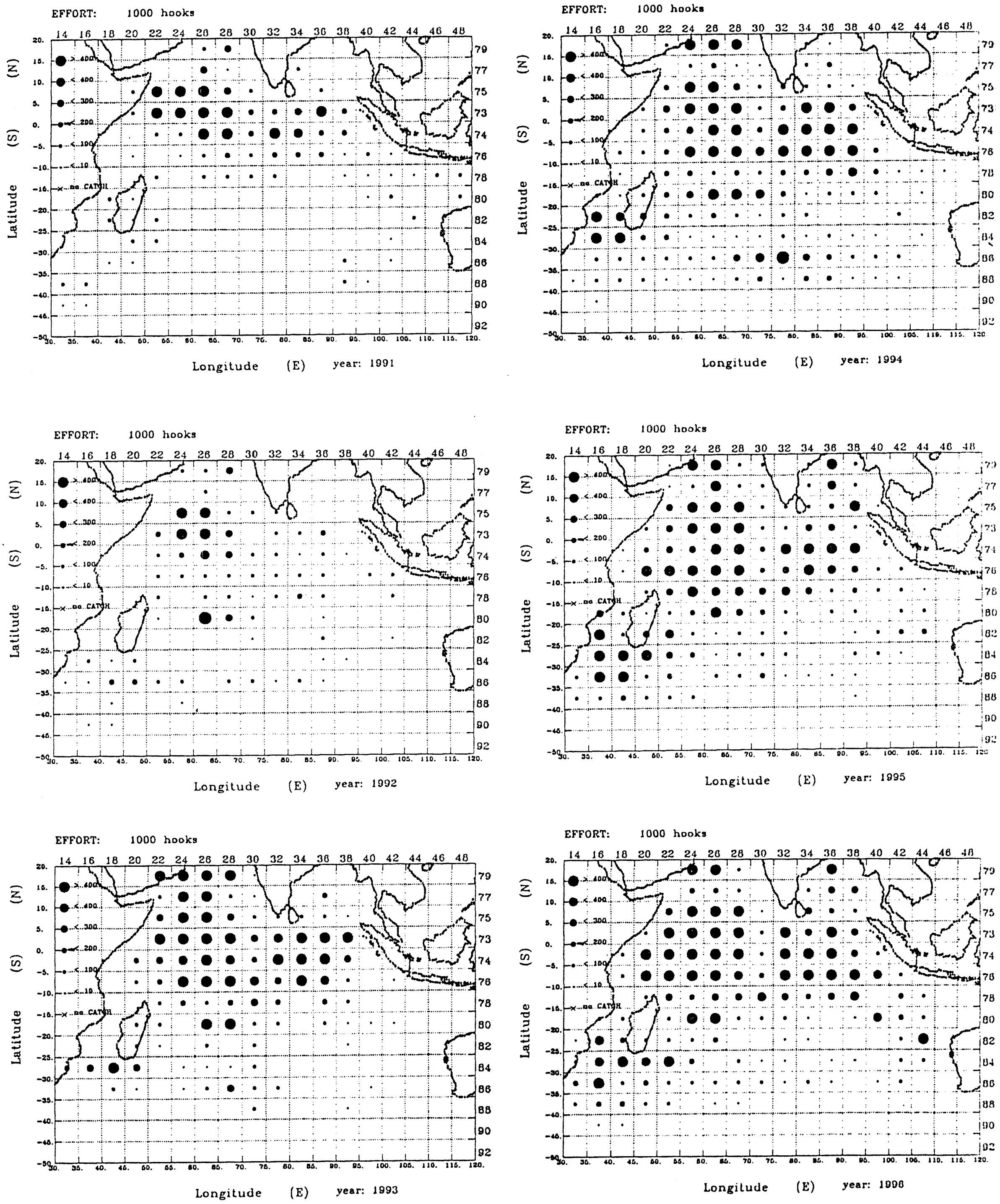


Figure 6: Yearly distribution of fishing effort ascribed to the Taiwanese deep longline fishery operated in the Indian Ocean, 1985-1996


EFFORT: 1000 hooks
Latitude (S) (N)
Longitude (E) year: 1991
EFFORT: 1000 hooks
Longitude (E) year: 1994
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Longitude (E) year: 1996

Figure 6: (end)

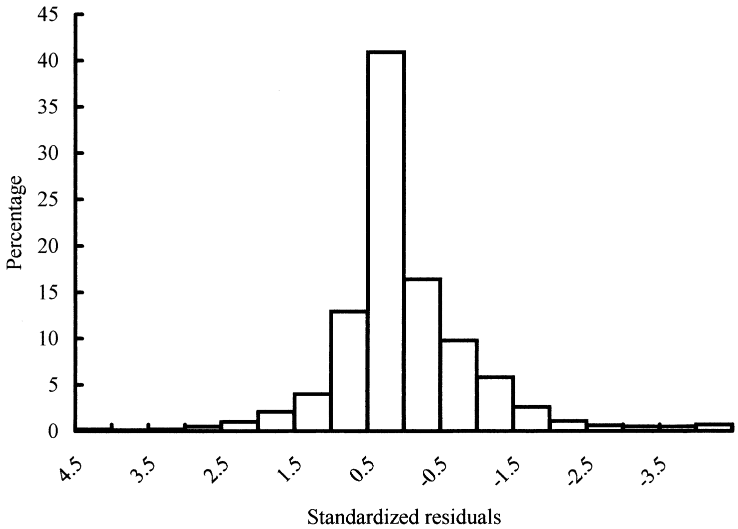

Figure 7: Distribution of residuals in fitting the GLM for the Indian Ocean albacore CPUE, 1979-1985

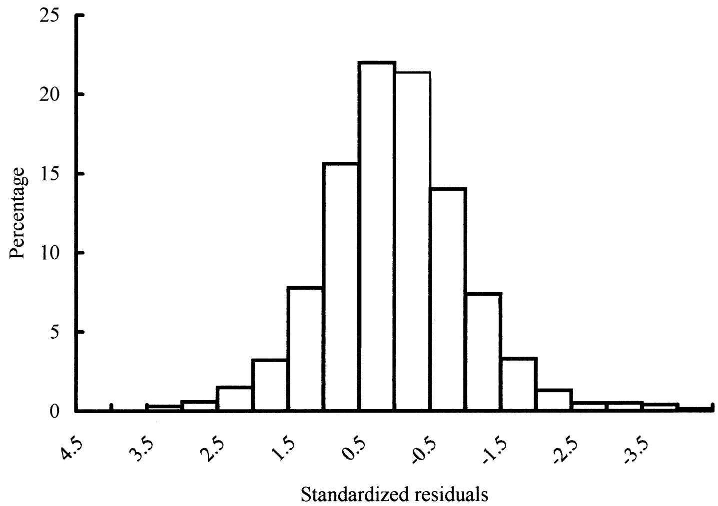

Figure 8: Distribution of residuals in fitting the GLM for the Indian Ocean albacore CPUE, 1985 - 1996

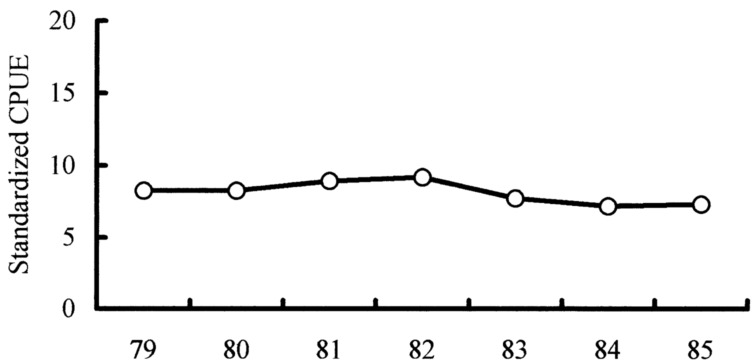

Figure 9: GLM standardised CPUE (No./1,000 hooks) of Indian Ocean albacore tuna for the Taiwanese longline fishery, 1979-1985

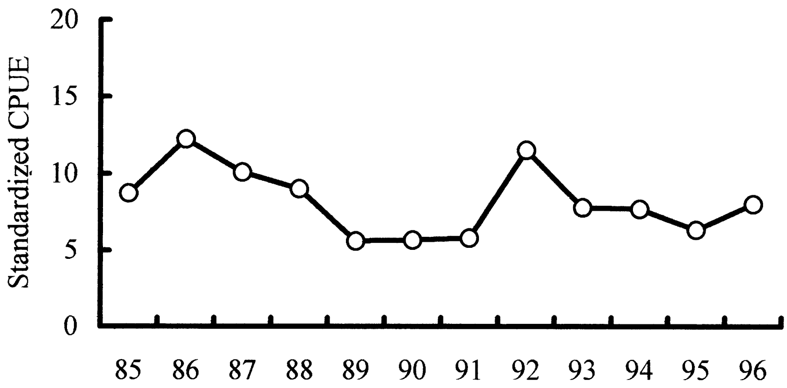

Figure 10: GLM standardised CPUE (No./1,000 hooks) of Indian Ocean albacore tuna for the Taiwanese longline fishery, 1985 - 1996

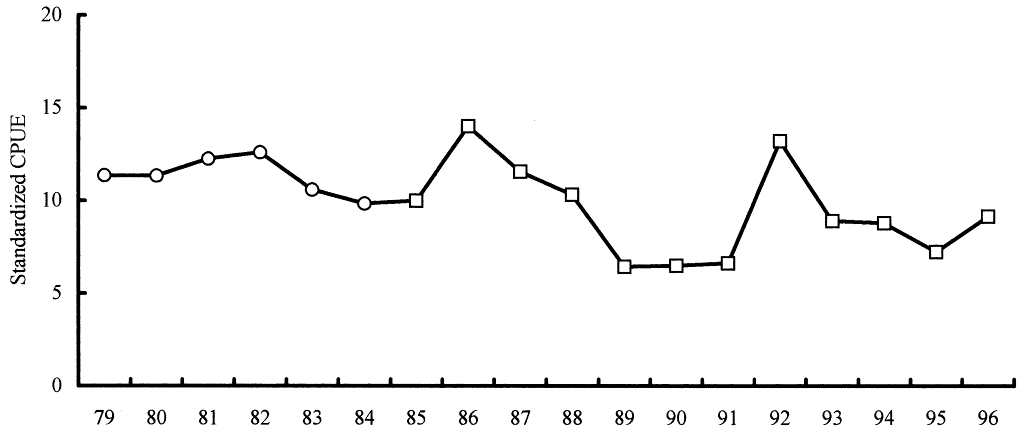

Figure 11: Trend of GLM-standardised CPUE (No./1,000 hooks) for Indian Ocean albacore caught by the Taiwanese longline fishery, 1979-1996

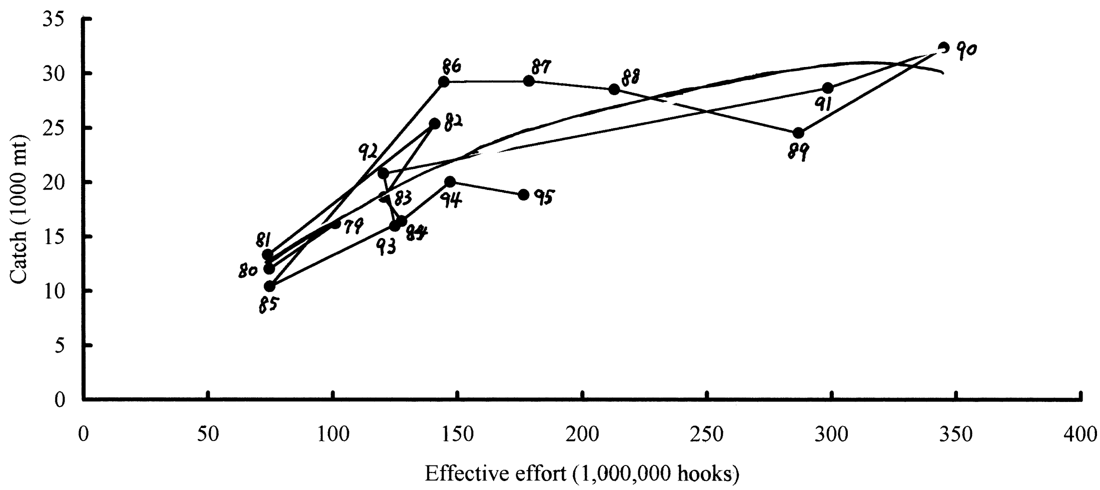

Figure 12: Equilibrium production curve for the Indian Ocean albacore tuna stock based on the results of GLM analysis.
MSY = 30.5 x 10^3 t
f_{opt} = 319 x 10^6 effective hooks
r^2 = 0.515