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AN OVERVIEW OF FISHERY TREND OF TAIWANESE LONGLINERS AND CATCH DISTRIBUTION PATTERN OF THE NORTH ATLANTIC ALBACORE STOCK

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SUMMARY

The catch of north Atlantic albacore by Taiwanese longliners has fluctuated, and the effort measured in number of hooks has increased regularly. In the north Atlantic, the fishing area of Taiwanese longliners was concentrated in the region 35°W westward, albacore was the dominant species among tuna-like fishes; and the albacore catch included mature and immature fishes.

Using the Pella-Tomlinson stock production model to analyze the status of the fishery, preliminary results showed that the maximum sustainable yield ranged from 48.98 (m=1.001) to 51.69 (m=2) thousand tons and the corresponding optimal fishing effort was estimated about 160.62 to 175.46 million hooks, respectively, in transforming all kinds of effort into hooks by the ratio of catch per unit effort for each gear. Consequently, evaluating the 1984 and 1985 catch and effort level, the current resource of the north Atlantic albacore is under-exploited.

RESUME

Les prises de germon de l'Atlantique nord des palangriers taiwanais ont fluctué et l'effort mesuré en nombre d'hameçons a augmenté de façon régulière. Dans l'Atlantique nord, la zone de pêche des palangriers taiwanais s'est concentrée dans la région à l'ouest de 35ºW, le germon étant l'espèce prédominante des espèces voisines de thonidés; les prises de germon comprenaient des poissons matures et immatures.

En utilisant le modèle de production du stock de Pella-Tomlinson pour analyser l'état de la pêcherie, des résultats préliminaires ont montré que la production maximum soutenue allait de 48.98 (m = 1.001) à 51.69 (m = 2) milliers de tonnes et que les efforts de pêche optimaux correspondants étaient estimés à environ 160.62 - 175.46 millions d'hameçons respectivement, en transformant toutes sortes d'effort en hameçons par le pourcentage de prise par unité d'effort pour chaque engin. Par conséquent, en évaluant les prises de 1984 et de 1985 et le niveau d'effort, les ressources actuelles de germon de l'Atlantique nord sont sous exploitées.

RESUMEN

La captura de atún blanco en el Atlántico Norte por palangreros de Taiwan presentaba fluctuaciones, y el esfuerzo medido en número de anzuelos creció de forma regular. En el Atlántico Norte, los caladeros de los palangreros taiwaneses se concentraron en la región occidental de los 35°W, y la especie dominante fue principalmente atún blanco, entre las especies afines; la talla de esta especie incluía ejemplares maduros e inmaduros.

Utilizando el modelo de producción del stock Pella-Tomlinson para analizar el estado de la pesquería, un resultado preliminar mostraba que el rendimiento máximo sostenible oscilaba entre 48.98 (m=1.001) - 51.69 (m=2) mil toneladas, y el esfuerzo de pesca óptimo correspondiente fue estimado en 160.62 - 175.46 millones de anzuelos, respectivamente, transformando todos los tipos de esfuerzo en anzuelos mediante la proporción de captura por unidad de esfuerzo para cada arte. En consecuencia, al evaluar el nivel de captura y esfuerzo de 1984 y 1985, se concluye en que el recurso actual de atún blanco del Atlántico Norte se encuentra subexplotado.

Introduction

As was the albacore fishery, Taiwanese longliners have played their important role in the Atlantic. Almost 90% of the Atlantic tunas-like catches by Taiwanese longliners have been albacore, *Thunnus alalunga*, since 1967, esp. in recent 5 years (Fig. 1 and National Taiwan University 1987). Relatively annual catch of Taiwanese longliners from the southern Atlantic had been still higher than that from the northern Atlantic except the years of 1983 and 1984 (Fig. 2). The catch obviously showed that only a little fluctuation between them, the effort involved in the north Atlantic are in great fluctuation, however (National Taiwan University 1987).

For further studying the interest of some topics in tuna longline fishery and current status of north Atlantic albacore resource, two hypotheses were made *in priori*: (1) an effort change in an area results either from the substitution of lower harvests in that area, or (2) from a declined abundance of albacore stock at a specified region. In accord with these hypotheses, some points could be extended as: (1) the effort willingness to put into a place is proportionally related to catch ratio of two relative places; (2) fishermen tend to fishing their descent species; (3) satisfaction on catch is the main factor deciding the substitution as dissatisfaction is occurred; (4) catch per unit effort (CPUE) is still a good means to express the fishing success and the index of stock abundance, and therefore; (5) satisfaction of fishermen is determined by CPUE of a fishing ground through the viewing of catch ratio between two fishing grounds.

In regard to which of these two hypotheses is the main reason to cause this fluctuation of catch ratio between the southern and the northern albacore stocks, an investigation in this paper dealt with the analysis of fishery trends concerning with Taiwanese longliners, and then, the spatial and temporal pattern of catch distribution. These studies could provide useful information whether the fluctuation is coming from satisfaction of fishermen to the production of a fishing area or not; also the current status of albacore resource and its fishery will be analyzed by Schaeffer production model (Schaeffer 1954; 1957; Ricker 1975) in order to resolve the second hypothesis.

Analysis of fishery trend

Lenarz and Coan (1974) had studied the fishery trends of the surface and longline fisheries, however, there were not a perfect way to measure the fishery trend. Assuming that the correlation of effort putting into an area with the catch may indicate some bright result of this measurement. As is this assumption followed, the hooking rate could represent the density of the stock and the fishing success. Thus, we defined a satisfaction index as:

$$U_{ij} = R_{cij} / R_{eij} \qquad (1)$$

where i = year; j = subregion;
- U_{ij} = satisfaction index (dimensionless);
- $R_{cij} = C_{ij} / C_i^*$ = proportion of catch from subregion j year i (dimensionless);
- $R_{eij} = E_{ij} / E_i^*$ = proportion of effort imposed to subregion j year i (dimensionless);
- C_i^* = total catch of summing over the entire region in year i, and;
- E_i^* = total effort imposed to the entire region in year i.

Obviously, equation (1) could be explicitly shown as:

$$U_{ij} = u_{ij} / u_i^* \qquad (2)$$

where u_{ij} = CPUE of subregion j year i, and;
u_i^* = CPUE of entire region in the year i.

The implication of equation (2) on fishing activity should be:

(1) If $U_{ij} = 1$, fishing activity is even in the whole study region;
(2) If $U_{ij} < 1$, the jth region has been enforced higher effort, and paid lower yield than other regions, and;
(3) If $U_{ij} > 1$, the reverse of (2).

In accord with our assumption, the fishing activity will be substituted if (2) is satisfied because of dissatisfaction; it will remain in the same region if (3) is satisfied, and it is hard to decide the trend under the condition (1).

Consequently, the variability of number of fishing boat operating in three Oceans is shown in Fig. 3. The trend of annual change is apparent that the fishing boats in the Atlantic are more than, but not related to, these in the Pacific and the Indian; these in the Pacific and the Indian, however, show significantly opposite relationship on each other except in 1986. This result may indicate that the effort put in the Atlantic is more stable and independent than in the other two Oceans.

The investigation is extended to the satisfaction measurement, U_{ij}, as equation (1) for the tunas-like species in the three Oceans. The U_{ij} seems to have had different tendency between the Pacific and the Atlantic while it is stable and lower in the Indian (Fig. 4) after 1976. This result is much coincident with the assumption that there are some effort exchange between the Atlantic and the Indian through the South, and between the Indian and the Pacific, but not between the Atlantic and the Pacific (Yang 1970).

The Atlantic albacore population is divided into the South and the North stocks as usual (Ishii 1965; Beardsley 1969; Yang 1970) by means of their biological characteristic. To investigate U_{ij}, Fig. 5 has at first determined that no lag (k=0) could be used to build up the relationship of E_i (the effort ratio) and the C_i (the catch ratio) because the steep drop of autocorrelation coefficient of about 0.93 to 0.38 from lag 0 to lag 1 (Martin and Oeppen 1975). As the result, we fitted this relationship (Fig. 6) as:

$$E_i = 0.1543 + 0.8344\ C_i \qquad (3)$$
$$(R^2 = 0.8186,\ F = 67.701,\ p<0.000)$$

where E_i = effort ratio between the south and the north Atlantic in the year i, and;
C_i = catch ratio between the south and the north Atlantic in the year i.

Catch distribution

Many researchers (e.g., Beardsley 1969; Yang et al 1969; Yang 1970; Le Gall 1974; Bartoo 1979; Yang and Sun 1983, etc.) have claimed that (1) two isolate albacore stocks existed separately in the North and the South Atlantic, respectively, in contrast to Yang's (Yang 1970) discussion that the intermingle between these two stocks occurred during summer season, and; (2) the large and mature spawners are located at low latitude, apparently at southwest area of the north Atlantic; on the other hand, the small and immature albacore are mainly distributed at high latitude. Shiohama and Morita (1974) indicated that the juxtaposition of these two groups is between 30°-35°N; also in accord with this finding, Shiohama and Morita (1974) divided the North Atlantic into two large area, i.e., AL-31 and AL-32.

For the convenience of data processing and without loss generality, we restratify the North Atlantic into four subregion (Fig. 7) to elucidate the patterns of catch distribution of Taiwanese longliners from 1975-1986. The stratification is based on: (1) Shiohama and Morita's concept (Shiohama and Morita 1974); (2) fishery status of Taiwanese longliners; (3) the concentration of hook rate in a 5°x5° quadrat, and; (4) the seasonal variability of hook rate (Yang and Sun 1983).

Both the hook rate distribution (Fig. 8) and mean weight (Fig. 9) of annual catch from 1978 to 1986 reveal that (1) the fishing effort and most of the catch are coming from 35°W westward; (2) in comparison with these four quadrants (Fig. 7), generally, quadrant I has higher hook rate and lower mean weight per individual of catch; (3) quadrant II has lower hook rate and higher mean weight per individual of catch, and; (4) the variability of seasonal movement of mature and immature albacore is very apparent, the high magnitude of mixture of both groups is occurred in April-June; and the declined mixture shows from July to December and departs completely in January- March.

Production analysis

The catch (Table 1) and effort data provided by ICCAT are standardized preliminarily and used in Production analysis (ICCAT 1977 - 1985) here. A Pella-Tomlinson generalized production model (Pella and Tomlinson 1969) and a Graham-Schaefer production model (Graham 1937; Schaefer 1954; 1957) were used to fit the relationship of catch and effort by means of these standardized data, and the optimal effort and maximum sustainable yield (MSY) were estimated in order to assess the status of current north Atlantic albacore stock. In this analysis, how to standardize the catch and effort from different gears is the main and adverse dilemma in accord with current data base.

There are 7 kinds of fishing gears operated in the north Atlantic on albacore stock; and the catchabilities of these gears are unknown so far as either tagging or other estimation of this quantity has never been dealt. preliminarily a catch-weighting approach (Quinn 1983) was used to transform the dimension of effort of each gear into the dimension (in numbers of hook) of longline. This manipulation is mainly based on the assumption that there is the same magnitude of estimated CPUE by any gear used in fishing the albacore in the same space and time, i.e.,

$$E_s/C_s = E_l/C_l \qquad (4)$$

where E_s = effort of "s" gear;
C_s = catch of using "s" gear;
E_l = effort of longliners, and;
C_l = catch of longliners.

Consequently,

$$E_s = (E_i \cdot C_s)/C_i \qquad (5)$$

The result of standardized effort of all kinds of gears on the north Atlantic albacore is tabulated in Table 2 using the method of equation (5).

Furthermore, the relationship of catch per unit effort (in metric ton per 1000 hooks) and effort (in standardized million hooks) is shown in Fig. 10 and Table 3, that m=0; 1.001; and 2 for the undetermined shape parameter of Pella-Tomlinson model; also the production curve on the relationship of yield (in thousand metric tons) and effort (in standardized million hooks) is shown in Fig. 11, which is modified from Fig. 10 that sets m=1.001 and 2. These three kinds of relationship have highly significant hypothesis testing on the regression lines (Table 3). These results show that the best fitting of production curve is between m=1.001 and m=2. For the convenience and not significant different for MSY between m=1.001 and m=2, the MSY and optimal fishing effort to achieve this MSY are calculated from the fitted curve (Ricker 1975):

$$Y = 0.9998\, f - 0.6219 \times 10^{-5} f^2 \text{ for } m=1.001 \qquad (6\text{-}1)$$

$$Y = 0.5892\, f - 0.1679 \times 10^{-2} f^2 \text{ for } m=2 \qquad (6\text{-}2)$$

where Y = total annual of north Atlantic albacore in thousand metric ton, and;
f = total annual standardized fishing effort imposed on the albacore fishery in million hooks.

As estimated from the equation (6), the MSY and the optimal fishing effort for the level of MSY range 48.98 - 51.46 x 10^3 metric tons and 160.62 - 175.47 x 10^6 hooks (Table 3 and Fig. 11). Relatively, both the recent 1984 and 1985 annual catches and fishing efforts used were low (Fig. 11), and in consequence, the CPUE's of these two years (>0.38 metric ton / million hooks) were very significantly higher than the years before (Fig. 10), also compared to the CPUE of optimal condition (CPUE = 0.305 - 0.295 metric ton / million hooks for m=1.001 - 2). This result implies that the availability of this resource is under exploitation currently, and not overfished on this stock is evidenced in a biological sense, although we still hesitate to put too much faith in the estimates of MSY and optimal fishing effort here, because there are in great difference with the estimation (70.4 thousand metric tons for m=1.001 and 59.8 thousand metric tons for m=2) of which the effort was standardized into baitboat fishery (ICCAT Biennial Report, 1984-1985).

Discussion

The results of analyzing fishery trend of Taiwanese longliners and catch distribution pattern in the north Atlantic, obviously depicted 2 facts. First, there is not any phenomenum of significant exchange of Taiwanese longliners operating between the Atlantic and the Pacific Oceans; however, depending on the fishery trend and fishing boat distribution, the exchange existed between the Atlantic and the Indian Oceans in some years. And the increase of fishing boat in the Atlantic recently is due to the construction of new boat and anticipate in the fishery (Personal comm. Taiwan Fisheries Bureau 1987).

Second, Seasonal mean hook rate and mean individual weight of catch are apparently in inverse relation. As is in Figs. 7 and 8, the catch with light mean individual weight and high hook rate appears in the northwest Quadrant (Quadrant I); on the other hand, the heavy mean individual weight and lower hook rate distributes in the southwest Quadrant (Quadrant II), and; only a few catch are recorded in eastern two Quadrants (Quadrants III and IV) by Taiwanese longliners. Moreover, the seasonal variability is very apparent for these phenomena above in January-March for the large sized and small sized albacores are distinctly separated by about 30°N; further in March-June, they are moving close together, and finally; in July- September, they start to segregate each other again.

Regarding to the concentration of albacore fishery and the movement of sized albacore in and out the Biscay Bay, it seems to be like Shiohama and Morita's findings that (1) surface fishery harvesting only the immature fish in high latitudes, and (2) longline fishery for the entire stock (Shiohama and Morita 1974). These results has a little disagreement with Yang and some other researchers (Yang 1970) for that the longline fishery only harvested 5 and above years old fish.

Shiohama and Morita's result could be inferred that longline fishery is to encounter both the mature and immature groups which are distributed either in mixture or in the northwest and the southwest Quadrants, respectively. Lenarz and Coan (1974) cited Aloncle and Delaporte's observation (Aloncle and Delaporte 1973 MS) that for more than one groups of albacore contributes to the eastern Atlantic fishery, but no evidence could be referred which this situation occurs in western Atlantic fishery or not. Recently an example of Liu's report that size composition of albacore caught by Taiwanese longliners is not significantly different among the seasons and subregions (Liu, 1987), unfortunately, not enough size information of surface fishery to be used to compare Liu's result with that of longline fishery. However, both results could be used to elucidate that the resource and utilization of the north Atlantic albacore have never changed a lot since 1974, when Shiohama and Morita (1974) had provided their findings, meanwhile Lenarz and Coan concluded that all available data on the population biology indicates that the northern Atlantic albacore fishing is healthy (Lenarz and Coan 1974). This conclusion is still valid so far.

It is not very faithful estimation of the maximum sustainable yield and optimal fishing effort, although the fitting is excellent. This is due to the method of standardization of effort. First, by the catch distribution, the distinct variability of catch between the Quadrants exists in space and time, then using total catch as the weight to standardize effort seems misleading; second, owing to not enough information, e.g., the unknown catchability, to figure out the relationship between the catch and the biomass, the carrying capacity (or maximum biomass) cannot be estimated. On the other hand, Lenarz and Coan (1974) estimated age specific F=0.40 for ages 3 and 4 by means of Gulland (1965) and Murphy (1965) methods for reverse calculation of cohort analysis. This value is evaluated too low for the longliners (Lenarz and Coan 1974). Therefore, for more reasonable estimate of abundance of north albacore is one of the most important topics for further investigation. However, using present results of maximum sustainable yield and optimal fishing effort as the assessed index of the current fishery status seems without departure too far from the reality.

Acknowledgement

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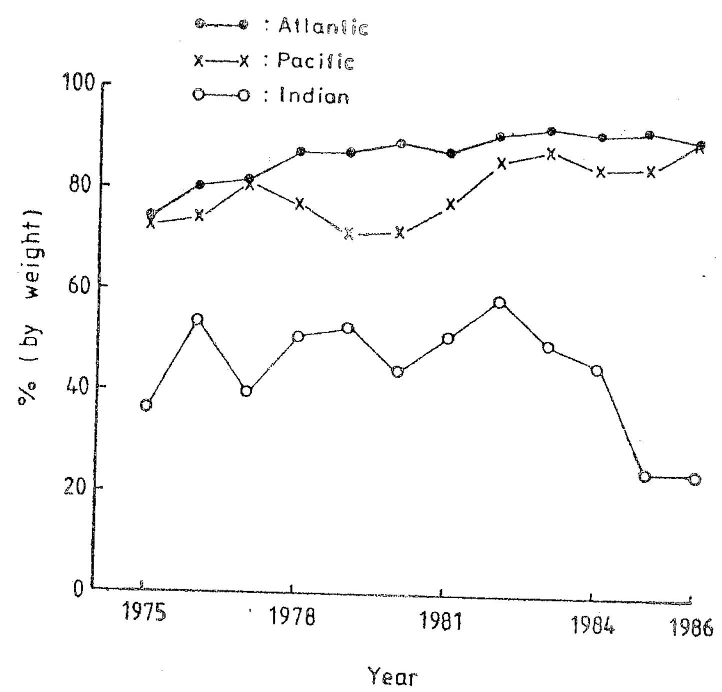

Fig. 1. Catch proportions of albacore, *Thunnus alalunga*, by Taiwanese longliners in the Atlantic, Indian, and Pacific Oceans in the years, 1975-1986.

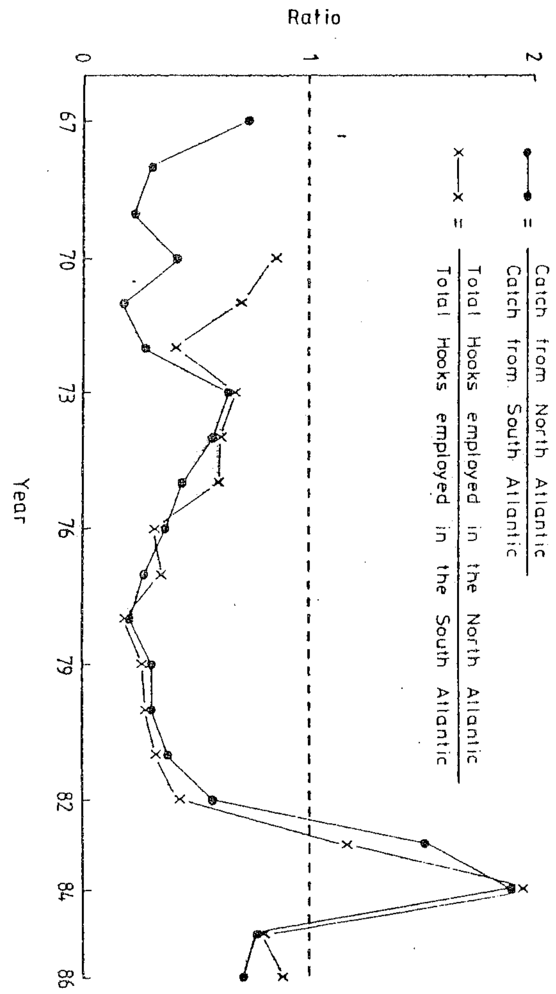

Fig. 2. The catch ratio and effort ratio between the southern and the northern Atlantic albacore stocks.

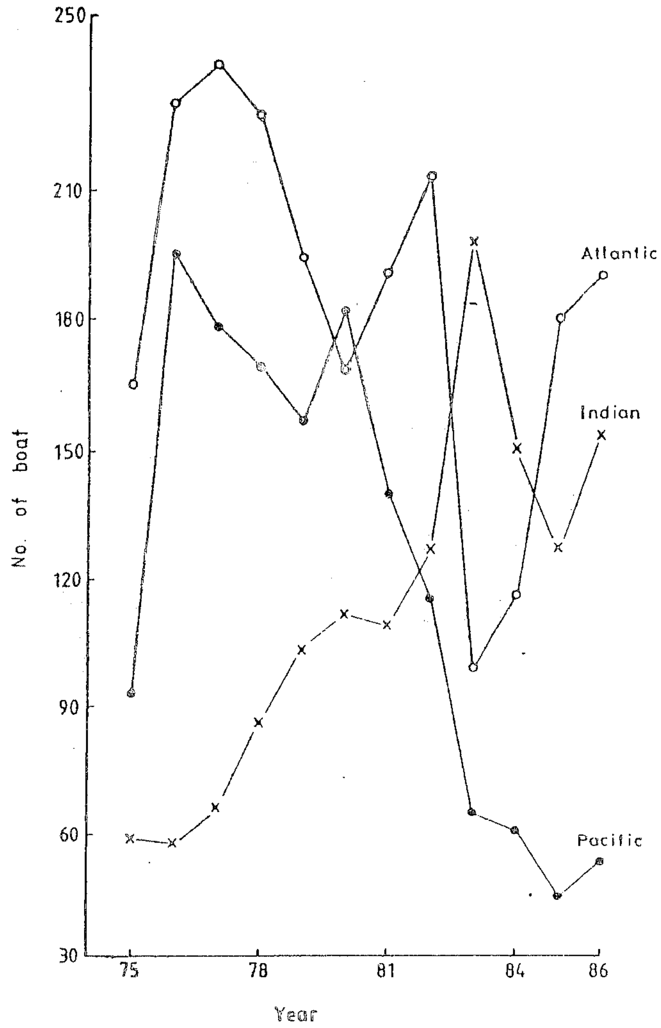

Fig. 3. The variability of number of fishing boat operating in the Atlantic, Indian, and Pacific Oceans.

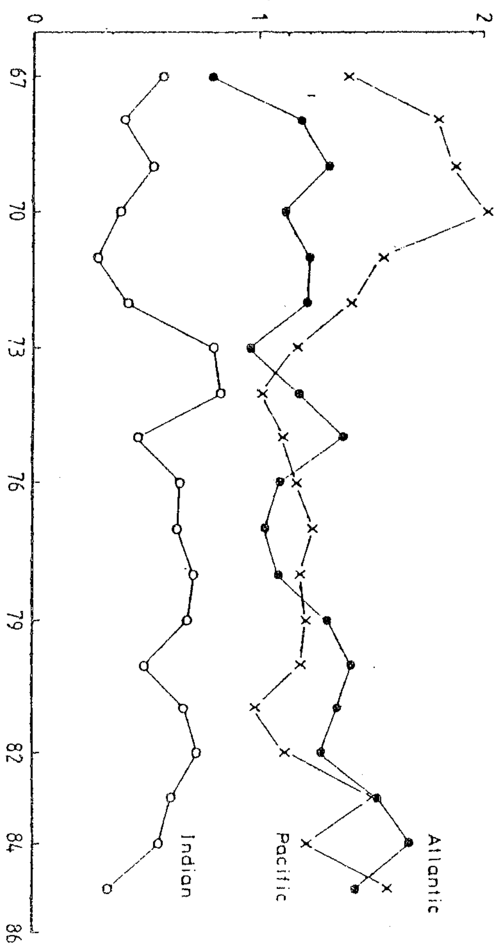

Fig. 4. A satisfaction index (U_{ij}) estimated from the Atlantic, Indian, and Pacific Oceans for the years, 1975-1986.

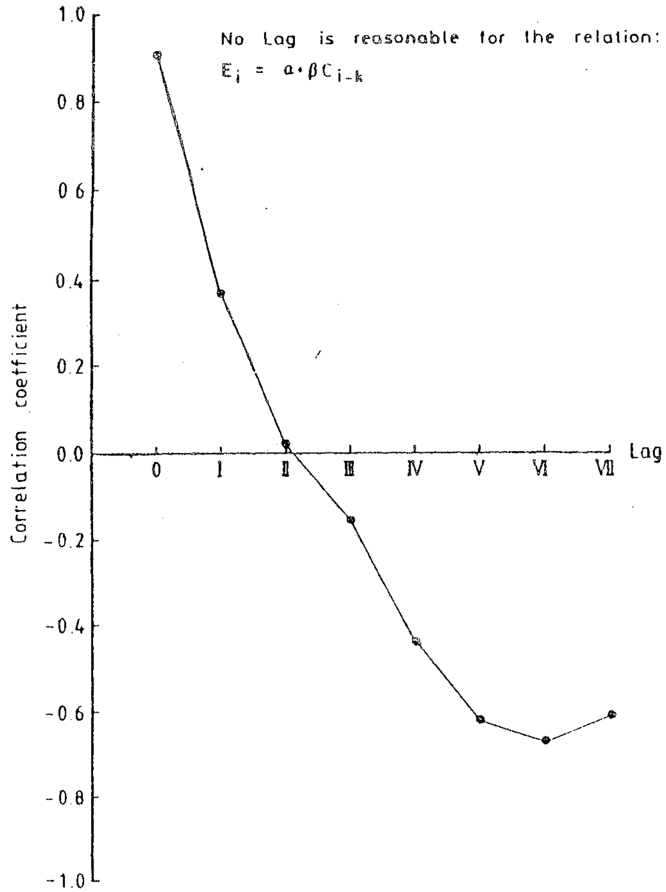

Fig. 5. The comparison of correlations of the relationship between effort ratio and catch ratio with different delays (lag k, k=1,2,...,7), obviously k=0 is the proper result for this relationship.

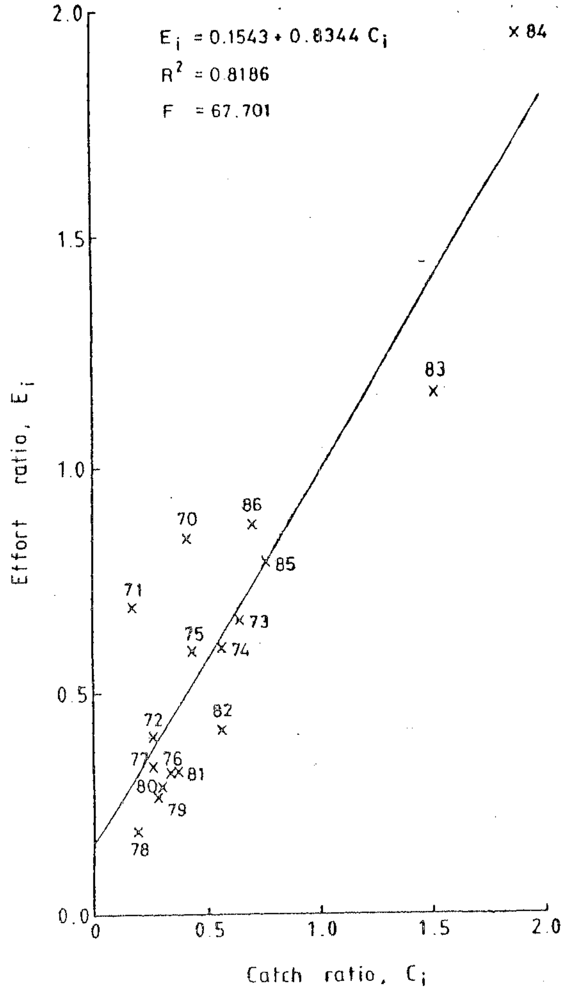

Fig. 6. A regression fitting of the relationship of effort ratio (E_i) and catch ratio (C_i) with null temporal lag (k=0) for the year i, i=1970, 1971,...,1986.

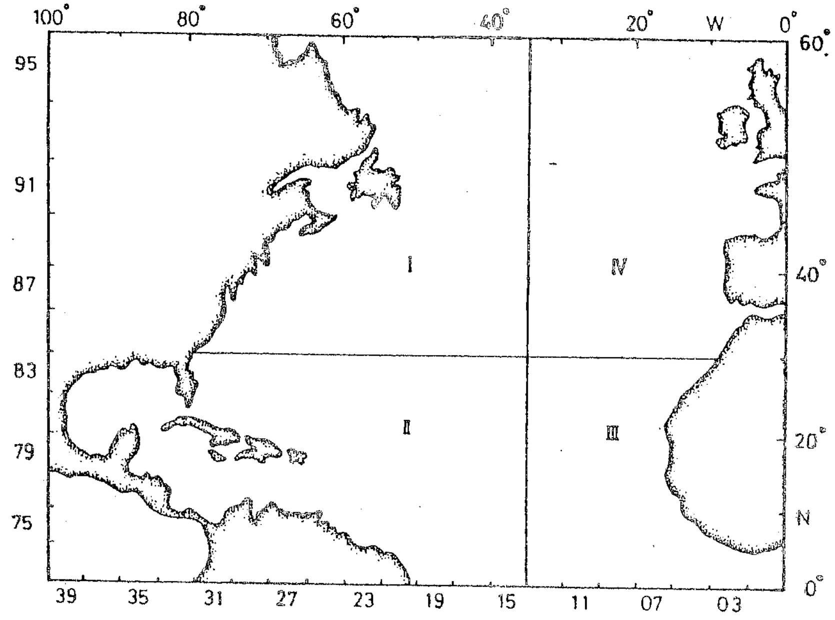

Fig. 7. A stratification of the north Atlantic region for the study of catch properties.

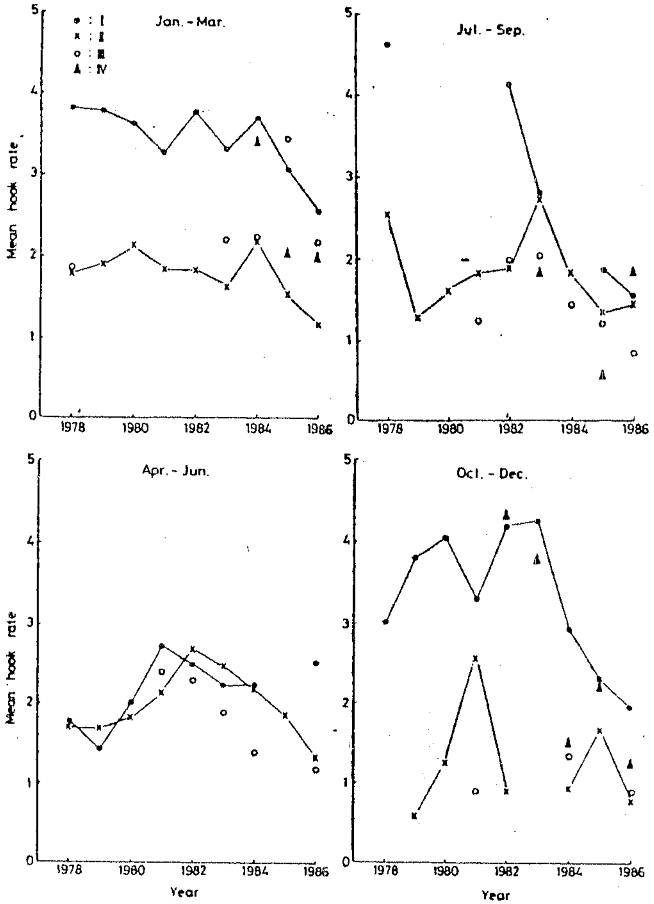

Fig. 8. The distribution of mean hook rate by the different stratified quadrants in the years, 1978-1986.

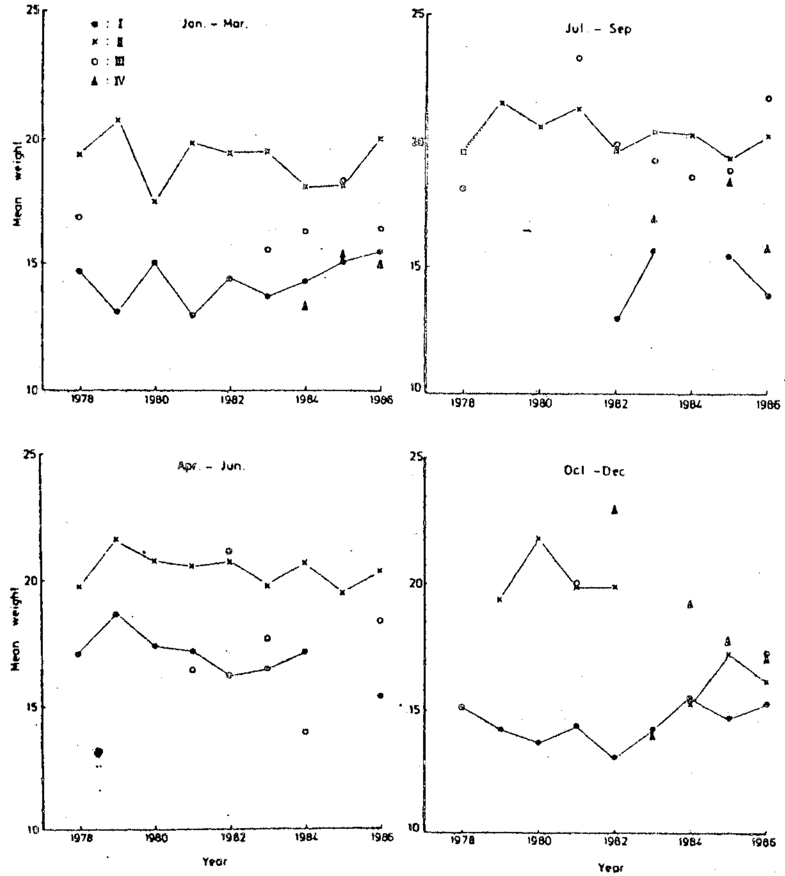

Fig. 9. The distribution of mean weight per individual of annual catch in the years 1978-1986 by the different stratified quadrants.

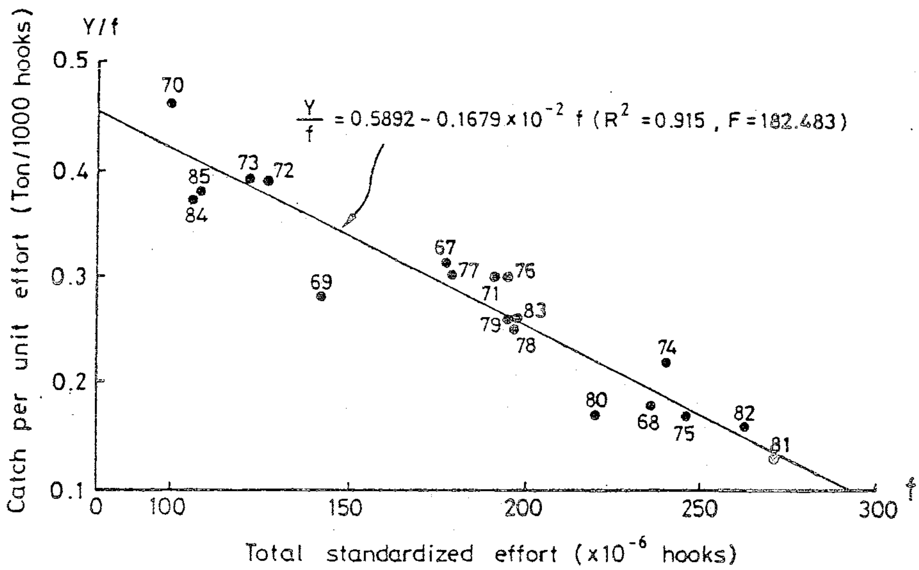

Fig. 10. The relationship of catch per unit effort (Y/f, in metric ton per 1000 hooks) and total standized effort on the longline (f, in million standardized hooks) for the years 1967-1985.

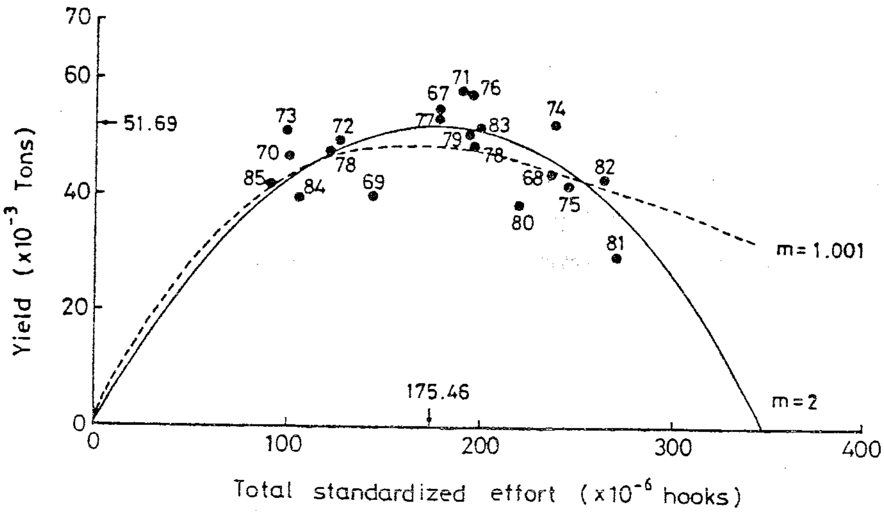

Fig. 11. The fitting of production model for the relationship of yield (Y, in thousand metric tons) and effort (f, in million standardized hooks), where m=2 and k=1 were used since the goodness of fit was shown in Table 3.

Table 1. The catch (thousand tons) by the methods of longline (LL), bait boat (BB), trolling (TR), purse seine (PS), trap (TP), surface (SF), sport (SP), and unknown (UN) in the years of 1967-1985.

Year	LL	BB	TR	PS	TP	SF	SP	UN	Total
1967	5.49	17.60	31.43	.00	.00	.00	.00	.00	54.52
1968	4.51	13.67	24.86	.00	.00	.00	.00	.00	43.04
1969	7.82	14.07	17.92	.00	.00	.00	.00	.00	39.81
1970	6.06	14.39	15.71	.00	.00	.00	.00	.00	46.16
1971	17.85	15.68	24.03	.00	.00	.00	.00	.00	57.56
1972	14.69	8.20	26.53	.00	.00	.00	.00	.01	49.43
1973	18.13	10.13	18.71	.00	.00	.00	.00	.00	46.97
1974	14.64	16.68	20.96	.00	.00	.00	.00	.00	52.28
1975	12.71	19.20	9.47	.00	.00	.00	.00	.00	41.38
1976	23.01	20.40	13.92	.00	.00	.10	.00	.00	57.42
1977	20.87	15.56	16.48	.00	.00	.04	.00	.00	52.95
1978	14.16	11.74	22.57	.00	.00	.12	.00	.00	48.59
1979	12.21	15.94	22.07	.00	.00	.00	.00	.00	50.22
1980	9.45	16.17	12.57	.00	.00	.01	.00	.00	38.19
1981	9.82	13.41	10.80	.00	.05	.05	.00	.00	34.13
1982	13.19	15.86	12.83	.18	.00	.02	.00	.02	42.10
1983	16.59	21.11	12.79	.36	.00	.00	.00	.00	50.86
1984	19.51	8.31	11.03	.56	.00	.05	.00	.00	39.45
1985	17.69	12.61	10.65	.08	.00	.03	.00	.00	41.07

Source: ICCAT. 1977-1985. Statistical bulletin.

Table 2. The standardized effort (million hooks) to the effort of longline for the fishing methods: bait boat (BB), trolling (TR), purse seine(PS), trap (TP), surface (SF), sport (SP), and unknown (UN).

year	LL	BB	TR	PS	TP	SF	SP	UN	Total
1967	17.85	57.21	102.15	.00	.00	.00	.00	.00	177.21
1968	24.63	74.73	135.92	.00	.00	.00	.00	.00	235.28
1969	27.71	49.88	63.53	.00	.00	.00	.00	.00	141.12
1970	34.84	31.22	34.08	.00	.00	.00	.00	.00	100.14
1971	59.28	52.07	79.81	.00	.00	.00	.00	.00	191.16
1972	37.62	21.00	67.95	.00	.00	.00	.00	.03	126.59
1973	46.93	26.22	48.43	.00	.00	.00	.00	.00	121.58
1974	67.25	76.62	96.28	.00	.00	.00	.00	.00	240.14
1975	75.41	113.89	56.21	.00	.00	.00	.00	.00	245.51
1976	77.80	69.00	47.07	.00	.00	.33	.00	.00	194.21
1977	70.19	52.33	55.43	.00	.00	.13	.00	.00	178.08
1978	57.14	47.40	91.09	.00	.00	.49	.00	.00	196.12
1979	47.39	61.90	85.67	.00	.00	.00	.00	.00	194.96
1980	54.26	92.88	72.18	.00	.00	.04	.00	.02	219.38
1981	77.91	106.42	85.68	.00	.40	.42	.00	.01	270.83
1982	82.23	98.85	79.99	1.13	.00	.10	.00	.12	262.43
1983	64.25	81.74	49.52	1.41	.01	.02	.00	.01	196.97
1984	52.53	22.36	29.69	1.49	.00	.15	.00	.00	106.22
1985	39.33	28.03	23.68	.18	.00	.06	.00	.01	91.30

Table 3. The statistics of fitting Pella-Tomlinson production model for the north Atlantic albacore stock in the years, 1967-1985, where the weighting moving average is set to 1 (k=1), M: the undetermined parameter; a: intercept; b: slope; R^2: coefficient of determination; F: F-distribution; MSY: maximum sustainable yield; f_{opt}: optimal fishing effort, and; U_{opt}: catch per unit effor under the MSY.

M	a	b	R^2	F	MSY	f_{opt}	U_{opt}
0	-0.5972	0.2526×10^{-1}	0.809	72.213	39.59	--	--
1	0.9998	-0.6219×10^{-5}	0.893	141.160	48.98	160.62	0.305
2	0.5892	-0.1679×10^{-2}	0.815	152.497	51.69	175.47	0.295