

Northern Atlantic Albacore Standardized Catch per Unit Effort Trends Derived from the Catch Statistics of the Taiwanese Longline Fishery from 1968 to 2003

Liang-Kang Lee¹, Chi-Lun Wu² and Shean-Ya Yeh^{3*}

¹Department of Fisheries Production and Management, National Kaohsiung Marine University

²Marine Fisheries Division, Fisheries Research Institute

³Institute of Oceanography, National Taiwan University

ABSTRACT

Trends of the catch per unit effort (CPUE) of northern Atlantic albacore (*Thunnus alalunga*) data from the Taiwanese longline fishery were standardized using a generalized linear model (GLM) for the period 1968 to 2003. To construct a GLM, factors of year, quarter, area, and catch level of bigeye tuna (*T. obesus*) were determined and used. Three sub-areas in the North Atlantic defined by Wu et al. (2006) were adopted for the standardization process. The area factor was the most important source of variability, which indicates that a proper aggregation of sub-areas is essential for obtaining a better abundance index. The standardized CPUE trend thus obtained showed (1) a rapid decrease after 1968 to a leveling off in 1993; (2) a sharp decline after 1993 to a nadir in 2000; and (3) a rising trend in the most recent few years.

Key words: northern Atlantic albacore, CPUE trend, standardization, GLM analysis

INTRODUCTION

Atlantic albacore (*Thunnus alalunga*) is a highly migratory pelagic fish species distributed widely in temperate waters. Two stocks have been identified in the Atlantic Ocean, with the northern stock considered to mainly be distributed north of 5°N. Because of its abundance and high commercial value, the scale of utilization of this resource was first industrialized in the early 1960s when the Japanese longline fleet began major fishing efforts targeting the northern Atlantic albacore. Since the mid-1960s,

the Taiwanese longline fleet has been operating in the North Atlantic and became the major fleet catching northern Atlantic albacore by the early 1980s (Fig. 1).

Since the late 1980s, a new type of Taiwanese longliner, or deep longliner (a longline vessel equipped with -60 °C freezing capability), entered the North Atlantic fishing grounds. Although the deep longliner can fish in traditional albacore resident areas, its major target is the Atlantic bigeye tuna (*T. obesus*), which is mainly distributed from 15°N and 15°S. The fishing intentions of the longliners are virtually impossible to identify under the current logbook system. Although efforts have been made to include the number of hooks between two floats in the Taiwanese longline logbook system since 1994 (Hsu, 1999), the flexibility in fishing

*Correspondence: Institute of Oceanography, National Taiwan University, Taipei 106, Taiwan. TEL: 886-2-23637753; FAX: 886-2-23661197; E-mail: sheanya@ntu.edu.tw

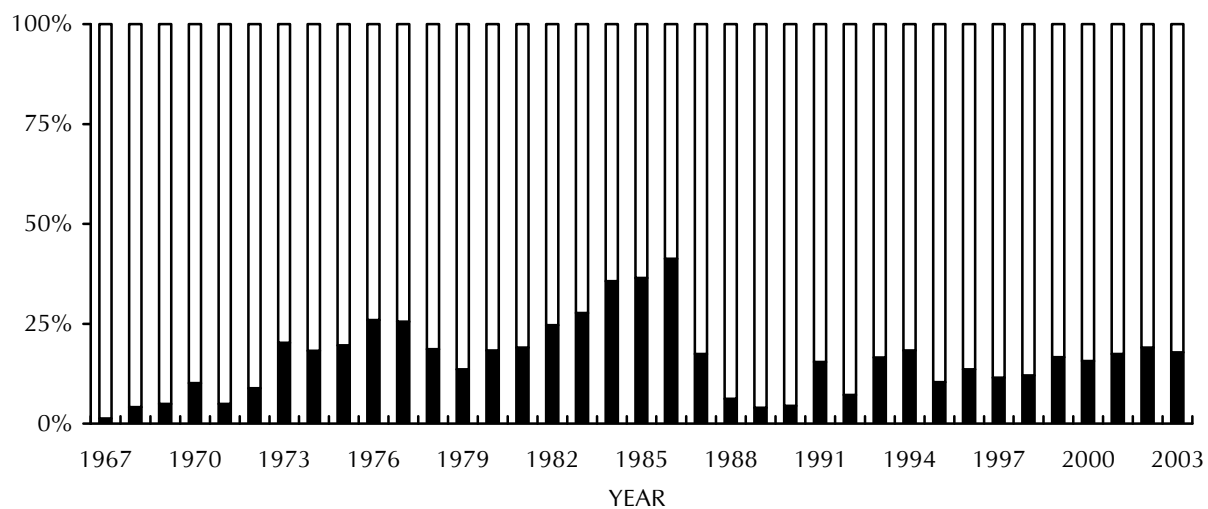


Fig. 1 Percentages of albacore catches by Taiwanese longliners in the North Atlantic Ocean from 1967 to 2003. (data source: ICCAT, 2004, 2006).

operations allowed to captains is still the main source of uncertainty in estimating the catch rates.

The northern Atlantic albacore resource, as one of the management mandates of the International Commission for the Conservation of Atlantic Tunas (ICCAT), is always closely monitored, and its stock condition is frequently assessed. Determining the trends of the standardized catch per unit effort (CPUE), which is equivalent to the stock abundance, of the North Atlantic albacore stock, is one of the major tasks which has to be performed and prudentially analyzed.

Although generalized linear models (GLMs) have commonly been used to standardize CPUE (Chang and Hsu, 1996; Wu *et al.*, 1998; Uosaki, 1999; Wu and Yeh, 1999; Tzeng *et al.*, 2001; Wu, 2001; Yang *et al.*, 2004), caution has to be taken in order to obtain better indications of the true abundance trends. Nakano (1996) specifically indicated that maltreatment on non-species-directed efforts may result in an underestimation on the true abundance trend. Therefore, the main objective of this paper was to identify non-albacore-directed efforts and to apply appropriate adjustments for obtaining better CPUE trends which may reflect true North Atlantic albacore abundance trends.

MATERIALS AND METHODS

Taiwanese longline fishery data from 1968 to 2003 provided by the Oversea Fisheries Development Council of the R.O.C. were used in this study. However, the data for 2003 were still preliminary. Data on the northern stock found north of 5°N in the Atlantic Ocean were used in this study. The resolution of the data, which were compiled from recovered logbooks of Taiwanese longline vessels, was by month, by 5°-square block, and by species. Some of the observations without effort data were deleted. Observations with fewer than 3000 hooks were also not used in this study. The CPUE was defined as the catch in number per 1000 hooks.

The GLM with a normal error structure (Gavaris, 1980; Kimura, 1981) was used to standardize the CPUE of northern Atlantic albacore. The formula of the GLM is as follows:

$$\ln(\text{CPUE} + C) = \mu + \text{yr} + \text{qt} + \text{area} + \text{target} + \text{interactions} + \varepsilon;$$

where $\ln$ is the natural logarithm; CPUE is the nominal CPUE; C is a constant; μ is the overall mean; yr is the effect of year; qt is the effect of quarter; area is the effect of the sub-area; target is the catch rate effects of bet (bigeye tuna), yft (yellowfin tuna; T .

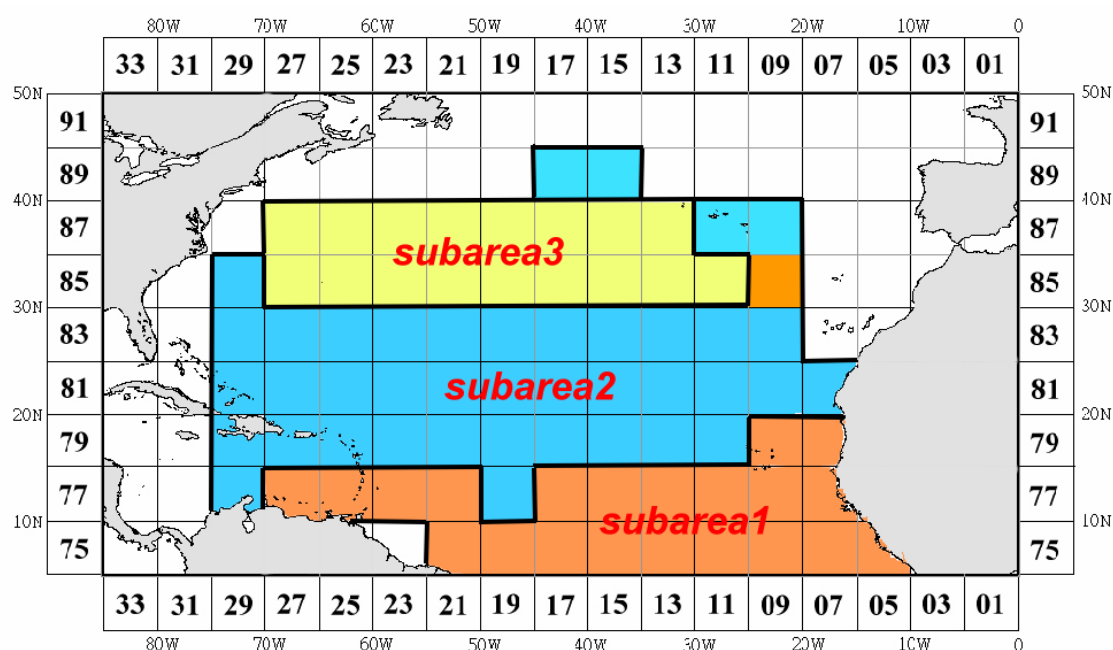


Fig. 2 Map showing the definition of the sub-areas in the North Atlantic Ocean used in the GLM analysis. (courtesy of Wu *et al.*, 2006)

albacares), and *swo* (swordfish); interactions is any combination of two-way interactions, and ε is an error term with $N(0, \sigma)$.

C stands for a constant added to the nominal CPUE in order to avoid logarithmic error calculations due to catches equal to 0. In this study, 10% of the mean albacore nominal CPUE was chosen (Anon, 1997), and the value is 1.56.

To standardize the northern Atlantic albacore CPUE, coverage of the fishing ground and area stratification were adopted from Wu *et al.* (2006). They used the catch rates of albacore, bigeye tuna, yellowfin tuna, and swordfish in 5°-square blocks to process the hierarchical cluster analysis (Ward method; SAS Institute, 1988) in defining the sub-area. The results showed that 79 statistic blocks were grouped into three clusters. Therefore, three sub-areas were also defined in this study (Fig. 2): sub-area 1 covers the waters northward of 5°~15°N which has generally been considered the main fishing ground of deep longline fisheries since the mid-1980s; while sub-areas 2 and 3, respectively located in subtropical and temperate waters, are closely related to higher albacore CPUE values.

The target effect, including bigeye tuna, yellowfin tuna, and swordfish, were incorporated into the model. CPUE values of these species were calculated and coded by quartile (Table 1) as an index of the target effect. When albacore is the target, then the CPUE values of other main species are supposed to be small.

In order to select one set of parsimonious covariates as the final model, three steps were adopted. (1) Using the effects of year, quarter, and area as the basic model, then respectively incorporating their related interactions into it, if the significance of $F > F_{0.01, v1, v2}$ in the new model is promoted, the added interaction item is selected. (2) Incorporating the target effect represented by each of the other three main species into the model resulting from step 1, if the significance of $F > F_{0.01, v1, v2}$ in the new model is promoted, then the added target item is selected. (3) Incorporating the related interactions, respectively, in the model resulting from step 2, and selecting all interactions whose significance of $F > F_{0.01, v1, v2}$ are promoted to form the final model.

All analyses were conducted using the SAS GLM procedures (vers. 9.12, SAS Institute).

Table 1 List of the rank-code derived from the corresponding catch-rate quartile of bigeye tuna (bet), yellowfin tuna (yft), and swordfish (swo), respectively, for the target effect in the generalized linear model analysis

rank-code	bet	yft	swo
1	≤ 0.2	≤ 0.02	0
2	≤ 0.9	≤ 0.1	≤ 0.1
3	≤ 3.5	≤ 0.7	≤ 0.3
4	> 3.5	> 0.7	> 0.3

Table 2 Selection of a parsimonious model in this study

Model	F-value
yr + qt + area	263.87
yr + qt + area + yr*qt	76.36
yr + qt + area + yr*area	112.45
yr + qt + area + qt*area	235.83
yr + qt + area	263.87
yr + qt + area + bet	313.30
yr + qt + area + yft	252.78
yr + qt + area + swo	253.28
yr + qt + area + bet	313.30
yr + qt + area + bet + yr*qt	95.16
yr + qt + area + bet + yr*area	135.70
yr + qt + area + bet + yr*bet	105.44
yr + qt + area + bet + qt*area	280.24
yr + qt + area + bet + qt*bet	265.55
yr + qt + area + bet + area*bet	289.53

RESULTS AND DISCUSSION

Standardized abundance indexes can usually be obtained using GLMs. In these models, several factors may affect the CPUE. But, if there are a large number of irrelevant covariates in it, statistical aberrations will produce a few false positives that appear to influence the response. For this reason,

covariates having no detectable effect on the response should ordinarily be excluded. The selection of a useful set of covariates from a large set of possible covariates to form a parsimonious model is then an essential requirement (McCullagh and Nelder, 1989). In this study, the result of the selection is given in Table 2 and the final model is as follows:

$$\ln(\text{CPUE} + 1.56) = \mu + \text{yr} + \text{qt} + \text{area} + \text{bet} + \varepsilon.$$

The model shows that, only “bet” (effect of the bigeye catch rate) was chosen among the target factors, and all interactions were eliminated by the procedure of covariate selection.

Results of the analysis of variance (ANOVA; Table 3) indicate that the model itself and all factors were statistically significant ($p < 0.0001$), and the area factor was the most important source of variability in the model. Because albacore is a highly migratory species, the geographical density distribution greatly varied. The large effect of the area factor is considered as a matter of course. The area effect that had the largest F -value among the factors also revealed that the sub-area stratification was suitable and was able to effectively distinguish the main operating districts from the regular longline and deep longline fisheries. Among the target factors, only bigeye tuna was selected and had a large F -value (347.69). This may be related to it being the target species of the deep longline fishery, and it has played an important role in the Taiwanese longline fishery. Nevertheless, in spite of the bigeye tuna factor being significant and having a large F -value due to the fishing strategy being closely related to the fishing locality, an appropriate separation of sub-areas making target factors account for the model variation becomes less important (Wu and Yeh, 2004). Both of the factors of year and quarter had weak effects relative to area and bigeye tuna, but they were still significant. The standardized residual pattern is shown in Fig. 3. The pattern is normally distributed, confirming that the log-normal error assumption was satisfactory.

The nominal CPUE series and standardized one estimated from the GLM procedure are shown in

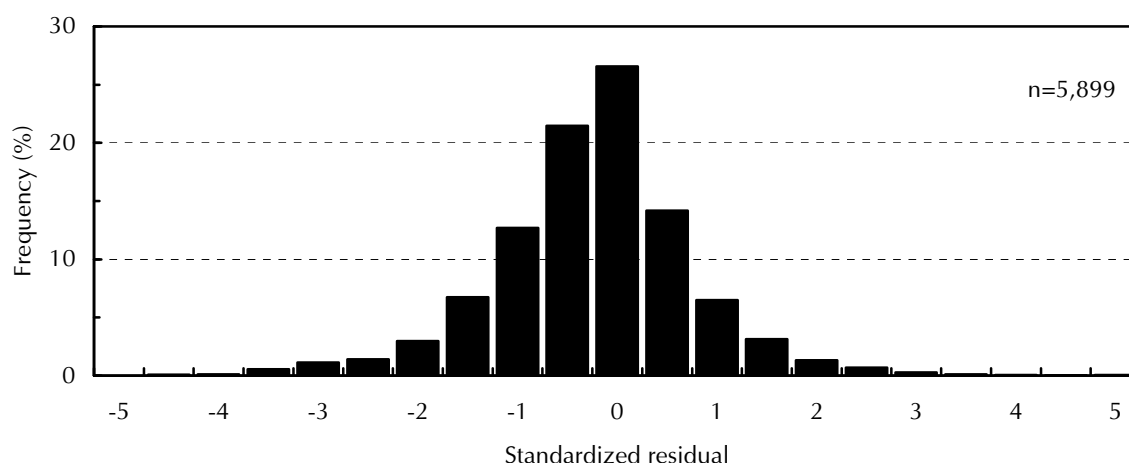


Fig. 3 Plot of standardized residuals derived from the generalized linear model procedure for northern Atlantic albacore.

Table 3 Analysis of the variance of standardized catch per unit effort (CPUE) values using the generalized linear model procedure of northern Atlantic albacore from the Taiwanese longline fishery in the period of 1968~2003

Source	DF	Sum of squares	Mean square	F-value	Pr > F
Model	43	6025.8631	140.1364	313.30	< 0.0001
Error	5855	2618.9309	0.4473		
Corrected Total	5898	8644.7940			
<i>R</i> -squared = 0.6971; C.V. = 29.3554.					
Source	DF	Type III SS	Mean square	F-value	Pr > F
yr	35	599.3442	17.1241	38.28	< 0.0001
qt	3	44.4505	14.8168	33.13	< 0.0001
area	2	1071.2205	535.6103	1197.43	< 0.0001
bet	3	466.5660	155.5220	347.69	< 0.0001

Figs. 4 and 5, respectively. The two CPUE series show different situations, i.e., that the nominal CPUE series was more variable than the standardized one and decreased sharply from 1982 to 1990, excluding 1988. This may have been related to increased efforts of deep longline vessels. However, the standardized series showed less fluctuation during the period. The standardized CPUE series (Fig. 5) showed (1) a rapid decrease after 1968, with leveling off to 1993; (2) a sharp decline after 1993 to its lowest level in 2000; and (3) a rising trend in the most recent few years.

Uosaki (2004) standardized CPUE values for northern Atlantic albacore caught by the Japanese longline fishery from 1975 to 2002. The results showed that standardized CPUE values decreased from 1975 to the late 1990s, and increased thereafter. The patterns of standardized CPUE trends somewhat differ between Japanese and Taiwanese longline fisheries. However, both CPUE trends showed relatively low levels compared to the previous decades around the year 1999 and then increases in the most recent few years. There are some reasons

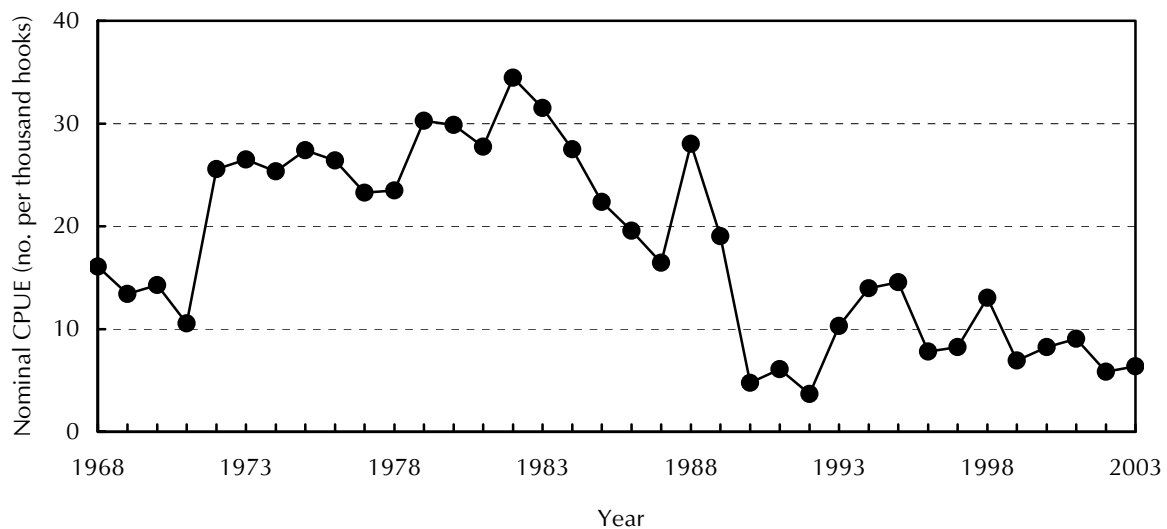


Fig. 4 Nominal catch per unit effort (CPUE) values for northern Atlantic albacore, 1968–2003.

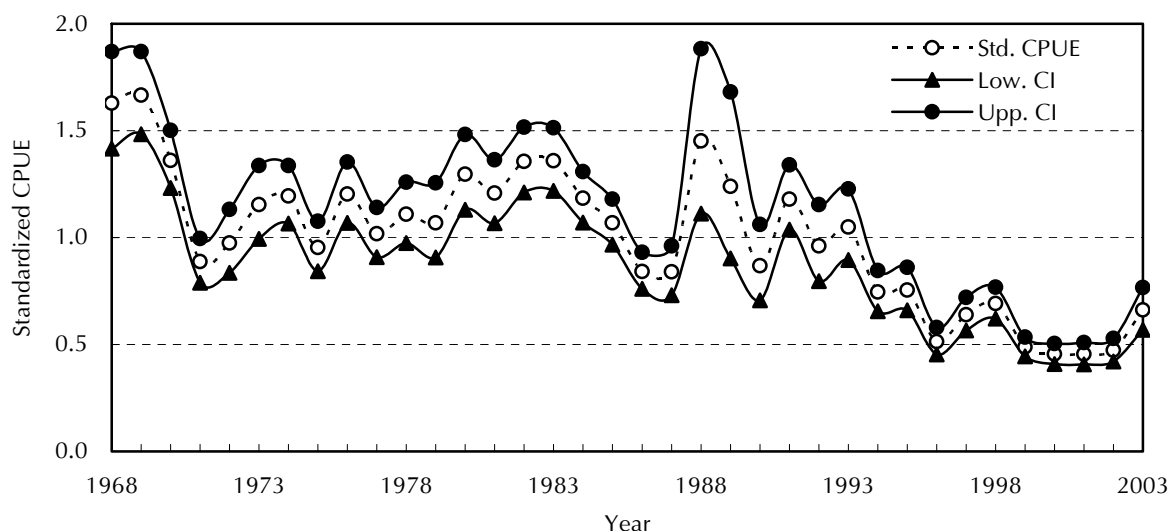


Fig. 5 Standardized catch per unit effort (CPUE) values and the 95% confidence intervals for northern Atlantic albacore, 1968–2003. The mean value was adjusted to 1.0.

which may have caused this difference: Since the albacore is no longer the target species and has become a bycatch species since 1975 for Japanese longliners, their fishing gear may have been modified and therefore the hooking efficiency for this species might have changed. Moreover, Japanese longliners have tended to move southward near the equator to catch bigeye tuna while many Taiwanese longliners have remained in the same northern areas in their search for albacore.

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1968 年至 2003 年間北大西洋長鰭鮪標準化資源豐度指標 之變動趨勢

李梁康¹ · 吳繼倫² · 葉顯楨^{3*}

¹ 國立高雄海洋科技大學 漁業生產與管理系

² 行政院農業委員會水產試驗所 海洋漁業組

³ 國立台灣大學 海洋研究所

摘要

本文依據臺灣鮪延繩釣漁業於 1968 年至 2003 年的漁獲統計資料，使用泛線性模式進行北大西洋長鰭鮪資源豐度指標的標準化。Wu *et al.* (2006) 使用聚落分析法，將北大西洋長鰭鮪漁場分為 3 個亞漁區。此漁區之劃分被引用於本研究中。標準化模式共採用了年、季、漁區和大目鮪四個效應，而以漁區效應的影響最大，顯示適當的亞漁區劃分是得到良好豐度指標所必要。由北大西洋長鰭鮪資源豐度指標標準化結果顯示：(1) 此資源豐度自 1968 年的幾年期間呈現大幅衰退，但之後已呈現回穩直到 1993 年；(2) 1993 年後，本資源再次呈現下降，直跌至 2000 年的歷史性低點；(3) 最近幾年的資源豐度有上升的傾向。

關鍵詞：北大西洋長鰭鮪、資源豐度指標、標準化、泛線性模式

*通訊作者／國立台灣大學海洋研究所, TEL: (02)2363-7753; FAX: (02)2366-1197; E-mail: sheanya@ntu.edu.tw