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STANDARDIZATIONS OF CPUE OF BLUE MARLIN AND WHITE MARLIN CAUGHT BY JAPANESE LONGLINERS IN THE ATLANTIC OCEAN

Kotaro Yokawa[1,2], Yukio Takeuchi[1], Makoto Okazaki[1] and Yuji Uozumi[1]

SUMMARY

Blue marlin (Makaira nigricans) *and white marlin* (Tetrapturus albidus) *are caught as by-catch species in the Japanese longline fishery that operates in the Atlantic Ocean. Significant changes in gear configuration and main fishing grounds that have occurred since the fishery started in 1956 make it difficult to standardize CPUE by a generalized linear model (GLM) incorporating information about gear configuration. Recently, a new method that uses behavioral constraints of the target species, together with environmental data, to better define effective fishing effort, was developed for CPUE standardization. This new approach is applied to the Japanese catch and effort data of Atlantic blue and white marlins to investigate ways for improving the estimation of abundance indices. Comparisons are made against abundance indices obtained with the GLM standardization approach.*

RESUMEN

La aguja azul (Makaira nigricans) *y la aguja blanca* (Tetrapturus albidus) *son captura fortuita en la pesquería japonesa de palangre que opera en el Atlántico. Los importantes cambios que han tenido lugar en la configuración del arte y en los principales caladeros desde el comienzo de la pesquería en 1956, han dificultado la estandarización de la CPUE por medio del modelo lineal generalizado (GLM) incorporando información sobre la configuración del arte. Recientemente y con el fin de definir mejor el esfuerzo de pesca efectivo, se creó un nuevo modelo que emplea los condicionantes del comportamiento de la especie-objetivo, junto con datos ambientales. Este nuevo enfoque se aplica a los datos japoneses de captura y esfuerzo de la aguja azul y aguja blanca en el Atlántico, para investigar la forma de mejorar la estimación del índice de abundancia. Se establece una comparación con los índices de abundancia obtenidos en la estandarización hecha con el GLM.*

RÉSUMÉ

Le makaire bleu (Makaira nigricans) *et le makaire blanc* (Tetrapturus albidus) *sont capturés comme prise accessoire par les palangriers japonais qui opèrent dans l'océan Atlantique. Les grands changements survenus dans la configuration des engins et dans les principales zones de pêche depuis les débuts de cette pêcherie en 1956 font qu'il est difficile de standardiser la CPUE par un modèle linéaire généralisé (GLM) incorporant l'information sur la configuration des engins. Ces derniers temps, une nouvelle méthode utilisant les contraintes comportementales des espèces-cibles associées à des données environnementales, destinée à mieux définir l'effort de pêche effectif, a été mise au point aux fins de la standardisation de la CPUE. Cette nouvelle démarche s'applique aux données de capture et d'effort japonaises du makaire bleu et du makaire blanc dans l'Atlantique, et vise à rechercher la manière d'améliorer l'estimation des indices d'abondance. Des comparaisons sont effectuées avec les indices d'abondance obtenus au moyen de l'approche de standardisation GLM.*

KEYWORDS

Tuna fisheries, Longlining, By catch, Catch/effort, Fishing effort, Statistical analysis, Habitat

[1] National Research Institute of Far Seas Fisheries, 5-7-1, Orido, Shimizu, Shizuoka 424-8633, Japan.
[2] E-mail:yokawa@enyo.affrc.go.jp

INTRODUCTION

Japanese longliners have exploited Atlantic blue marlin and white marlin as by-catch since 1956, when the fishery commenced. There have been significant changes in operation pattern in terms of gear configuration and main fishing ground for Japanese longliners in the Atlantic Ocean so far (Uozumi and Nakano 1994, Yokawa and Uozumi 2000). Takeuchi (2000) reported that the CPUE standardization of by-catch species with GLM methods under such condition has serious problems in estimating parameters, especially in estimating the yearly trend of CPUE and gear efficiencies simultaneously.

Recently, a new method was developed for CPUE standardization (Hinton and Nakano 1996) that estimates gear efficiencies of longline hooks directly by using behavioral constrains of the target species and environmental data. This method was applied to CPUE standardization of blue marlin and bigeye tuna in the Pacific and produced gainful results (Hinton and Nakano 1996, Bigelow *et al*. 2000).

In this report, this new method by Hinton and Nakano (1996) is applied tentatively to the Japanese catch and effort data of Atlantic blue and white marlins to investigate possible ways to improve the method for estimation of abundance indices for these species. The standardization of CPUEs by GLM, which has been used commonly in ICCAT, was also used to update the CPUE series in order to make comparisons between the two approaches.

MATERIALS AND METHODS

Catch and effort data

Catch and effort data used in this report were the same as in Uosaki (1998) and Uozumi (1998). Two data sets exist in the catch and effort statistics of Japanese longliners. One was Task II data, and the other was Task II with information about gear configuration (number of hooks between floats). Task II data were available since 1956, while Task II with gear configuration data were available only after 1974. CPUE standardizations for the period 1956-75 was conducted using Task II data, and for the period of 1975-98 it was conducted using Task II with gear configuration data using both estimation methods mentioned below.

Method by Hinton and Nakano (1996)

Effective effort data were obtained in the same way as in Hinton and Nakano (1996), considering the vertical distribution of temperature and marlins, and the vertical distribution of hooks. As the statistics of Japanese longliners have no information about gear configuration (number of branch lines between two floats) for the period before 1975, all operations for this period were assumed to use five hooks between two floats.

As for the information on the vertical distribution of Atlantic blue marlin, expressed by the percentage of the population distributed at a given temperature relative to the mixed layer (Dt), the values for Pacific blue marlin estimated by Hinton and Nakano (1996) were applied to data for Atlantic blue marlin assuming that the behaviors of these two species are same (Table 1). The same data were applied for the vertical distribution of white marlin.

Distribution of water temperature at 2 degrees latitude by 5 degrees longitude (2x5) with bimonthly period resolution and with depth resolution of 0, 80, 120, 160, 200, 240, 300 and 400 m were obtained from the database of Global Temperature Profiles in the Joint Environmental Data Analysis Center at Scripps Institution of Oceanography, La Jolla, California, USA. Water temperature at 5 degrees latitude by 5 degrees longitude (5x5) and by quarterly period were developed by taking a simple average of these data, and obtaining an estimate of Dt at each depth stratum, 5x5 degree, and quarter.

Depth of hooks were calculated by assuming a catenary curve model which set the sagging rate as 75%, the length of branch lines as 30 m, and the length of float lines as 20 m for the period before 1985. For the period after 1984, the sagging rate used was 85%, the length of branch line was 45 m and the length of float line was 25 m.

Using the catch and effort data, the vertical distribution of blue marlin and white marlin as shown in Table 1, Dt at 5x5 by quarter with depth resolution of 0, 80, 120, 160, 200, 240, 300 and 400m, and the calculated depth of hooks, the effective fishing efforts on blue marlin and white marlin were developed following the procedure given in Hinton and Nakano (1996) (efective effort was estimated at 5x5, by month, and by gear configuration -- number of branch lines between two floats).

Using these effective efforts, standardized CPUE were obtained by the GLM. The sub-areas used in this method are shown in the lower panel of Figure 1. This area stratification was same as it used in the GLM method shown in the next section for the period of 1975-98. The model included three main effects (year, area, quarter) and two two-way interactions (year*quarter, area*quarter). As the shape of distribution of log-transformed CPUE was not normal, but had long tail to the right as shown in Table 2, a constant value equal to 0.1% of the overall mean CPUE was added in the GLM procedure.

GLM Method

For the sake of convenience, the standardization method of CPUE by GLM done with nominal effort rather than with the effective effort shown in the previous section is referred to as the “GLM method”.

The area stratifications used in the GLM method are shown in Figure 1. There are two area stratifications used for the two periods (1959-75 and 1975-98). The latter area stratification (lower panel of Figure 1) is the same as used for Hinton-Nakano’s method. The same stratifications were used for both blue marlin and white marlin.

With regard to the gear configuration, more than 2 hooks between floats were observed in the statistics and they were categorized into six levels (3-4, 5-6, 7-9, 10-11, 12-15, and >15 hooks between floats). The model included four main effects (year, area, quarter, and gear) and two two-way interactions (area*quarter and year*quarter).

RESULTS AND DISCUSSIONS

Blue marlin CPUE

The values of CPUE standardized by Hinton-Nakano’s method fluctuated before 1971 and then became stable at low level up to 1983 (top panel in Figure 2). In 1984, the values increased drastically and recorded the historically-highest level in 1985. After 1985, CPUE showed a gradual decreasing trend until 1998 with some fluctuations. The value in 1998 was about 80% of the average during 1962-69.

In contrast, the value of CPUE standardized by the GLM method declined steeply for 1961-66. After 1967, it declined with a moderate trend until 1976. During 1976-1985, the CPUE values increased and then decreased very gradually until 1990 when it started to increase slightly (bottom panel in Figure 2).

The distribution of standardized residuals can be more or less assumed to be normal for all models (Figure 4). The standardized CPUE by gear configuration is shown in the top panel of Figure 10. The CPUEs increase with the increase in the number of hooks per basket.

White marlin

The values of CPUE standardized by Hinton-Nakano's method showed steep decline for 1961-76 with two notable peaks in 1961 and 1969 (top panel in Figure 3). The value of CPUE slightly increased in the later half of the 1970s and 1980s and showed gradual declining trend in the 1990s. The value for 1998 was about 2% of that in 1961, and 24% of the average of 1985-89.

The value of CPUE standardized by the GLM method showed a steep decline for 1961-75, and increased slightly for 1977-79. After 1979, the gradual decreasing trend continued until 1998 (bottom panel in Figure 3). The value of CPUE in 1998 was about 2% of that in 1963 and 23% of the average in 1980's.

The distribution of residuals can be more or less assumed to be normal for all models (Figure 4). The standardized CPUE by gear configuration is shown in Figure 10. The CPUEs increase with increasing of number of hooks per basket.

Comparison of blue marlin CPUE between the two methods

Completely different CPUE trends for blue marlin were obtained between Hinton-Nakano's methods and the GLM method. In the results by the GLM method, a sharp decline was observed for 1961-64, while the level of CPUEs did not change so much during the 1960s using Hinton-Nakano's method. On the other hand, in the 1980s, a sharp increase in CPUEs was obtained with Hinton-Nakano's method, while a gradually-increasing trend was obtained with the GLM method. Declining trends in CPUE after 1985 were steeper in the results of Hinton-Nakano's method than in the results of the GLM method.

During the period before 1975, when all operations were assumed to be shallow setting (number of hooks between floats was five), the amount of effective effort estimated with Hinton-Nakano´s approach was less than 1% of the nominal effort in the tropical area of the eastern Atlantic, and more than 25% in the western Atlantic and in the subtropical area (>20 degrees) of the Atlantic (Figure 5). With this method, many effective effort values were calculated as 0 in strata with a positive blue marlin catch after the mid-1980s, when deep longline setting was introduced (bottom two panels in Figure 5).

Figure 6 shows the relationship between the calculated catch per effective effort (CPUSE) and the catch per nominal effort (CPUNE) in the years when relatively large numbers of observations were available. Hinton-Nakano's method has the effect to put higher CPUNEs at lower CPUSEs, and lower CPUNEs at higher CPUSEs, irrespective of the time period examined.

Trend of CPUE in 1960's

In the 1960's a sharp declining trend of CPUE was observed in the results of the GLM method, while the level of CPUEs fluctuated about the same level in the results of Hinton-Nakano's method. The standardized CPUE by area for 1960-65 is shown in Figure 7. With the GLM method, sharp declining trends were observed in the subtropical areas of the western Atlantic (areas 2 and 11— see top panel of Figure 1). As all other areas showed a gradual decreasing trend, the trends of areas 2 and 11 would affect the overall sharp decreasing trend obtained for 1961-65.

In the results of Hinton-Nakano's method, an increasing trend was observed for the period of 1960-64 in the tropical area of the eastern Atlantic (area 7— see bottom panel of Figure 1) and in the tropical area of the central Atlantic (area 4). Because declining trends for 1961-64 were observed in most other areas, the trends in areas 7 and 1 would compensate the declining trends in other areas and produce an overall fluctuating trend for the total areas during 1961-65.

In the results of Hinton-Nakano's method, an increasing trend in CPUE was observed in area 7, while a slight decreasing trend was observed in the same area with the GLM method (area 10, Figure 7). These two conflicting results can be explained by the yearly change in the ratios of nominal to effective effort obtained by Hinton-Nakano's method.

Table 3 shows the calculated values of Dt at 80-120 m by quarter and 5X5 block in area 7 for 1961-65. The values of Dt showed slight increasing tendencies in the period 1961-65 in most of 5X5 block strata during the quarters 3 and 4. In Hinton-Nakano's method, larger values of Dt mean lower percentages of population and, as a result, the ratio of effective to nominal effort becomes smaller. Thus, the reduction of effort increased from 1961 to 1965. As ratios of nominal-to-effective effort reductions were high using Hinton-Nakano's method (e.g. one tenth reduction from 7 degree to 8 degrees, see Table 1), a slight decreasing trend in area 7 by GLM turned into an increasing trend by Hinton's method.

Although such kind of tendencies were not observed in the 1st and 2nd quarters, most of the Dt values were larger than 8 during these quarters (Dt values larger than 8 imply that no population exists in the layer deeper than 80-120 m layer). This hypothesis puts as 0 the effective effort on most of strata in the 1st and 2nd quarters (observations with 0 effective effort were omitted from the CPUE standardization).

Trend in CPUE after the 1980s

In the results of Hinton-Nakano's method, a sharp increase in CPUE was observed in the period 1983-85, while a continuous gradually-decreasing trend was observed since 1980 in the results of the GLM method. The period when a sharp increase in CPUE was observed the former method coincides with the period when the amount of effort of deep longline increased drastically (Yokawa and Uozumi 2000).

Japanese deep longline operations mainly occurred in the tropical area of the southeastern Atlantic where upwelling exists. Because the mixed layer becomes very narrow by the effect of strongup welling in the center of the fishing ground of Japanese longliners (Figure 9), and the shallowest hooks of deep longline are assumed to sink deeper than those of normal and surface longline according to the catenary curve model, almost all hooks in this area since the mid-1980s were calculated to operate deeper than the distribution of blue marlin. Thus, with Hinton-Nakano´s approach, effective effort became quite small and, as a result, CPUE increased suddenly.

If Atlantic blue marlin could be distributed in the colder waters under the mixed layers in strong upwelling areas, then the calculated effective effort would increase, and then the level of CPUE for 1985 would decrease.

The declining trend of CPUE after 1985 was steeper in the results of Hinton-Nakano's method than in those obtained by GLM. The observed differences between the two methods can be explained by the difference of data availabilities. For Hinton-Nakano´s approach, most of the observations since 1985 were obtained from the marginal area of fishing grounds of Japanese longliners, as the effective effort in the center of the fishing ground was 0. The data available for this method after 1985 occurred mainly in the relatively higher latitude areas in the eastern Atlantic (higher than 15 degrees— see Figure 5), where fewer blue marlins occur than in lower latitude areas.

If fish started to disappear in the marginal area of distribution when the fish stock started to decrease, the declining trend of blue marlin CPUE would be more emphasized in the higher latitude area than in the lower latitude area in the eastern Atlantic. Because most of the post-1985 data for Hinton-Nakano´s application come from mainly higher latitudinal areas, the declining trend of CPUE obtained by Hinton-Nakano's method would be steeper than the trend of CPUE obtained by GLM, for which the majority of the data come from the lower latitude area.

CONCLUSIONS

This report tentatively applied Hinton and Nakano's method to standardization of catch and effort statistics of Atlantic blue marlin using behavioral constrains of blue marlin and environmental data. Because some information, such as the vertical distribution of blue marlin (derived from observations made in the Pacific Ocean), the few observations available about hooking depth and time of blue marlin, and lack of information about the underwater movement of hooks, it seems too early to use these results in the stock assessments.

It would be very interesting to investigate the reasons for the large number of 0 effective effort calculated in the tropical area of the central and eastern Atlantic after the middle of 1980s using Hinton-Nakano's method. As the vertical profile of water temperature distribution is quite unique as characterized by a narrow mixed layer and high productivity, the behavior of the Atlantic blue marlin might be different from that of the Pacific blue marlin. Because the majority of data come from the tropical area of the central and eastern Atlantic, especially after the early 1980s, a change in the hypothesis about the vertical distribution pattern of Atlantic blue marlin in this area would affect the final result considerably.

Recent developments of technology are producing the tools which can collect the necessary information for input into Hinton-Nakano's method. Archival tags and pop-up archival tags can collect accurate information about behavior of fish, at short time intervals, and depth and temperature recorders can collect information about the under-water movement of hooks as well as hooking time and depth of fish. Research in these areas should be initiated soon. In addition, the study of feeding behavior of blue marlin would be necessary. This information would provide important data to validate the output of the standardization of CPUE.

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Table 1. The percentage of the population at temperatures (ºC) relative to temperature of the mixed layer (Dt) used in this report.

Blue marlin

? t	0	-1	-2	-3	-4	-5	-6	-7	-8
%	75,9	13,8	5,8	2,1	1,2	0,5	0,5	0,2	0,02

	cpue	Lcpue
Minimum	0,00	3,34
1st Quarter	0,00	3,34
Mean	281,03	4,19
Median	0,86	3,37
3rd Quarter	66,67	4,55
Max	29000	10,28
Total No.	16052	16052
Std. Dev.	970,30	1,39

Table 2. Summary statistics for blue marlin cpue data obtained by the method of Hinton and Nakano (1996). Lcpue means logarithm of cpue.

0N, 15W

	q1	q2	q3	q4
1961	9	10	5	5
1962	8	8	6	6
1963	9	9	7	5
1964	9	8	6	5
1965	8	9	6	5

0N, 5E

	q1	q2	q3	q4
1961	10	10	7	8
1962	10	10	7	9
1963	11	10	8	9
1964	11	10	8	9
1965	10	10	7	9

0N, 10W

	q1	q2	q3	q4
1961	10	11	6	6
1962	9	9	7	7
1963	9	9	7	7
1964	10	9	6	7
1965	9	9	6	7

0S, 5W

	q1	q2	q3	q4
1961	11	11	8	9
1962	11	11	8	8
1963	10	10	8	10
1964	12	11	8	9
1965	10	10	8	9

0N, 5W

	q1	q2	q3	q4
1961	11	11	6	7
1962	10	10	7	8
1963	11	11	8	9
1964	11	10	7	8
1965	10	10	7	8

0S, 0W

	q1	q2	q3	q4
1961	10	9	8	9
1962	10	10	8	8
1963	10	10	9	10
1964	11	9	8	9
1965	9	10	8	9

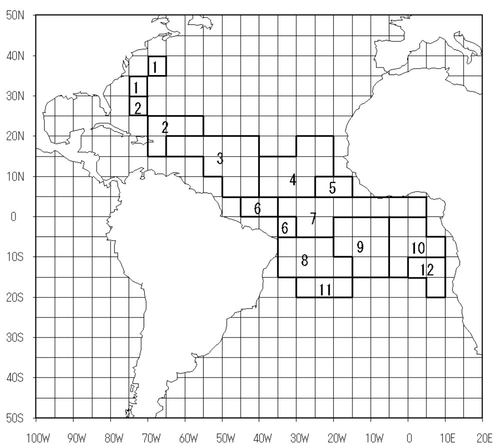
0N, 0W

	q1	q2	q3	q4
1961	11	10	7	7
1962	10	11	8	8
1963	11	11	8	9
1964	11	11	7	8
1965	10	10	7	9

0S, 0E

	q1	q2	q3	q4
1961	10	10	8	9
1962	10	9	9	8
1963	10	9	9	9
1964	11	10	8	9
1965	9	9	8	9

Table 3. The values of Dt of 80m in area 7 by year, quarter, and 5X5 degree block for the period between 1961-1965.



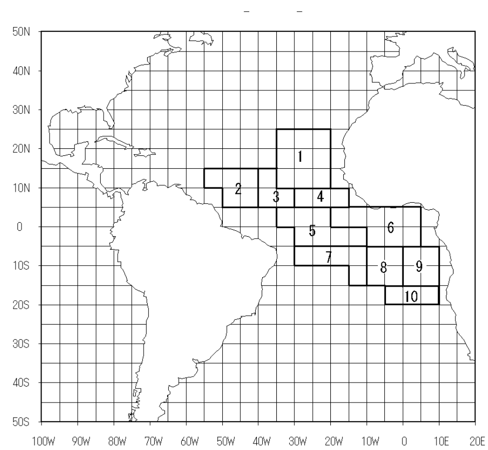


Figure 1. Subarea stratifications for GLM and Hinton-Nakano's method. Left: GLM for 1959-75. Right: GLM for 1975-98 and Hinton's method.

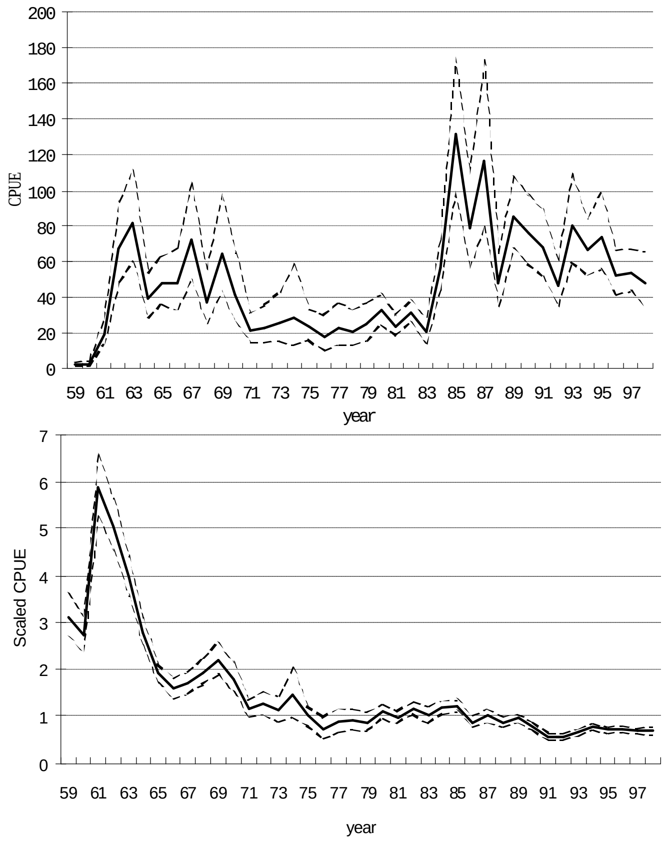


Figure 2. Standardized CPUE of blue marlin caught by Japanese longliners in the Atlantic Ocean with 95% confidential limit. Upper panel: CPUE standardized with Hinton-Nakano's method. Bottom panel: CPUE standardized with the GLM method. All CPUEs were scaled to the value in 1975, which is set at 1.0.

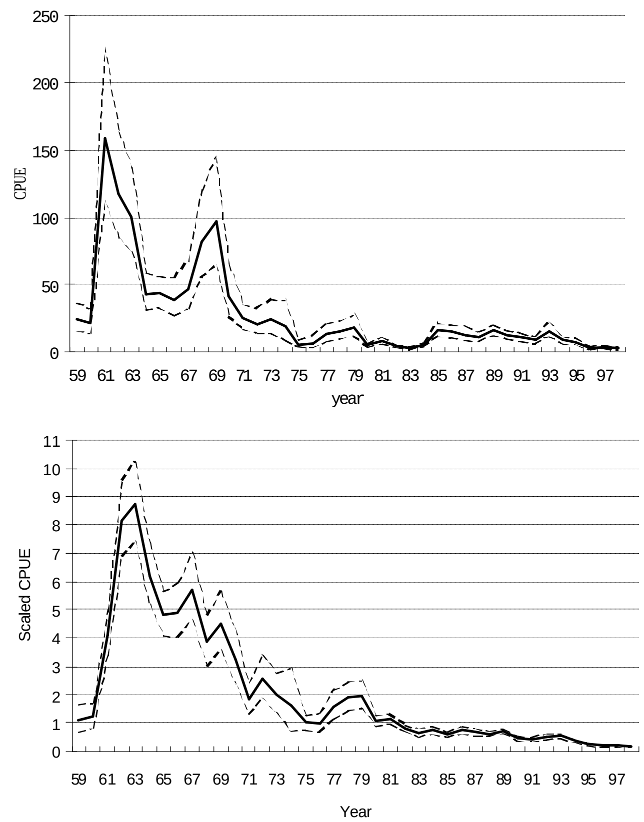


Figure 3. Standardized CPUE of white marlin caught by Japanese longliners in the Atlantic Ocean with 95% confidential limit. Upper panel: CPUE standardized with Hinton-Nakano's method. Bottom panel: CPUE standardized with the GLM method. All CPUE were scaled to the value in 1975, which is set at 1.0.

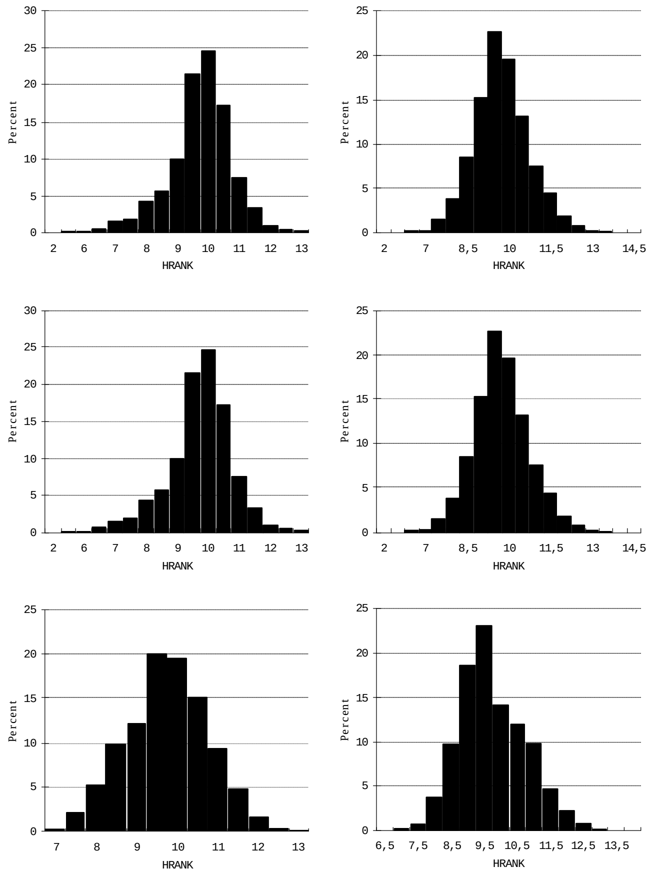


Figure 4. Distribution of standardized residuals of blue marlin cpue analysis (left) and white marlin cpue analysis (right) Top panel: GLM method for 1959-75. Middle panels: GLM method for 1975-98. Bottom panels: Hinton-Nakano's method.

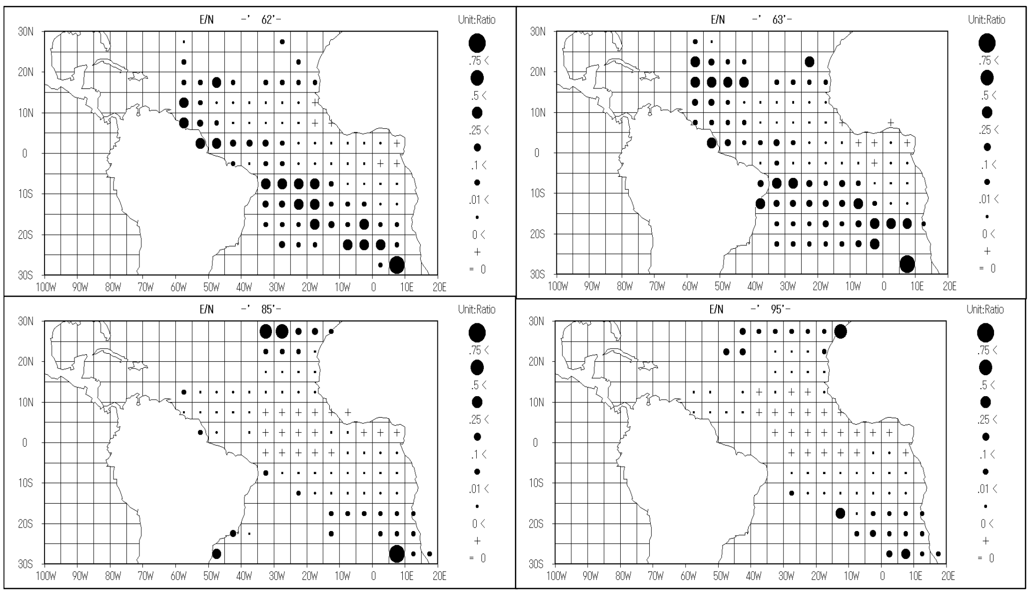


Figure 5.The ratio between the effective effort calculated by Hinton-Nakano's method and nominal effort in 1962 (left top), in 1963 (right top), in 1985 (left bottom), and in 1995 (right bottom).

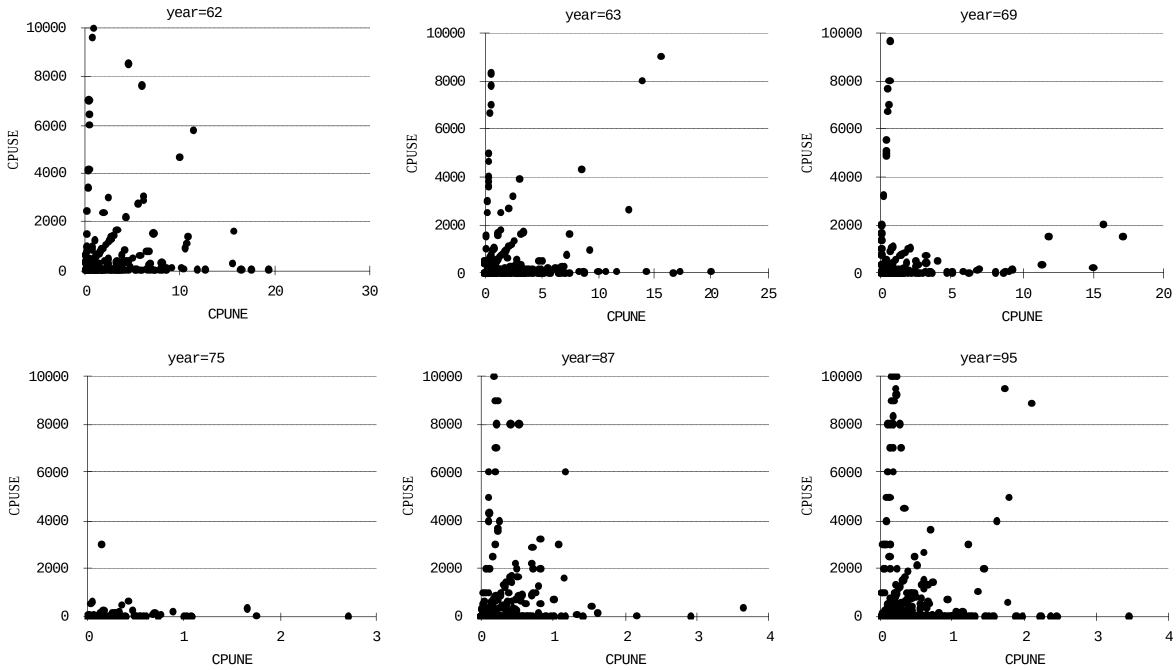


Figure 6. Comparisons between the catch per unit effective effort by Hinton-Nakano's method (CPUSE) and catch per unit nominal effort (CPUNE) in 1962, 1963, 1969, 1975, 1987, and 1995.

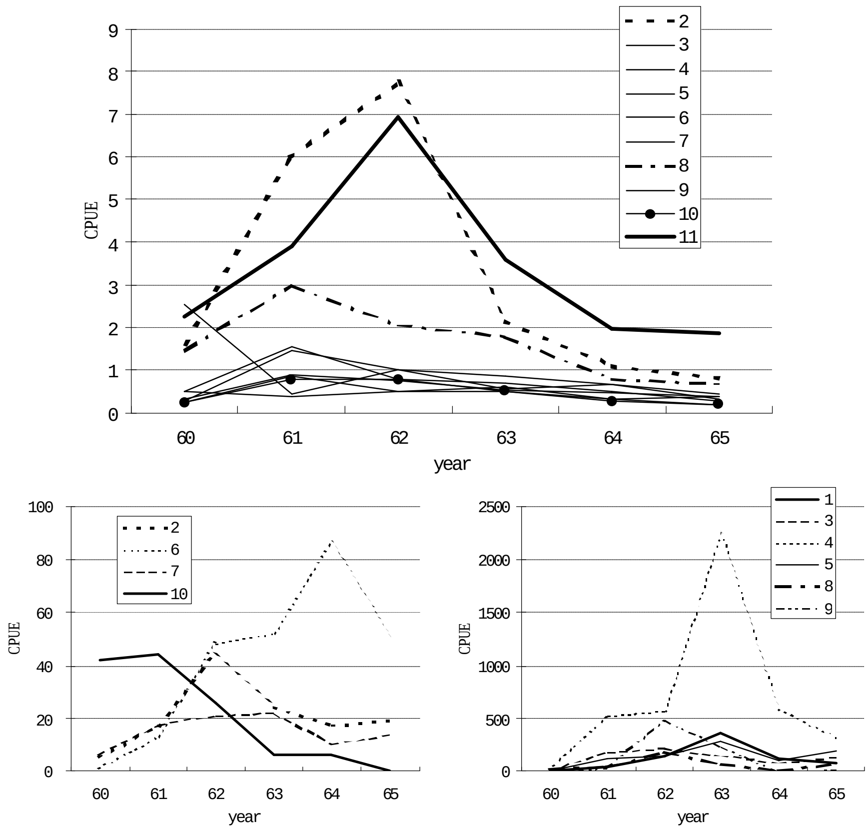


Figure 7. Standardized CPUE of blue marlin by area for 1960-65. Top panel; GLM (Subarea stratificatoins was top panel in Fig.1). Two bottom panels; Hinton's method (Subarea stratification was bottom panel in Fig.1).

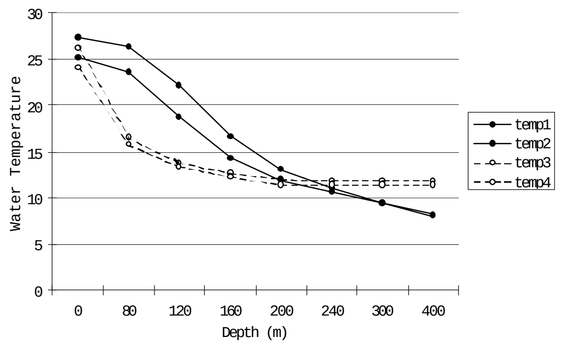


Figure 8. Typical vertical water temperature profiles in the tropical area of the southwest Atlantic in 1962 (temp1 and temp2) and in the tropical area of the east Atlantic in 1962 (temp 3 and temp4).

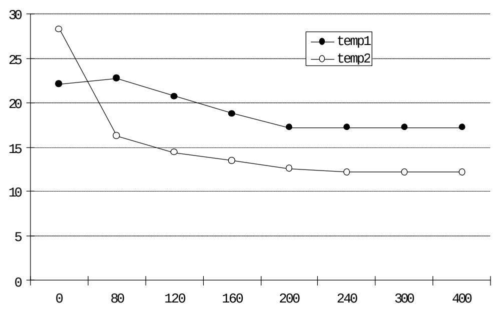


Figure 9. Typical vertical water temperature profiles in the eastern Atlantic in 1995. Temp1 shows the profiles in the marginal area of fishing ground of Japanese longliners. Temp2 shows the profiles in the center of fishing ground of Japanese longliners.

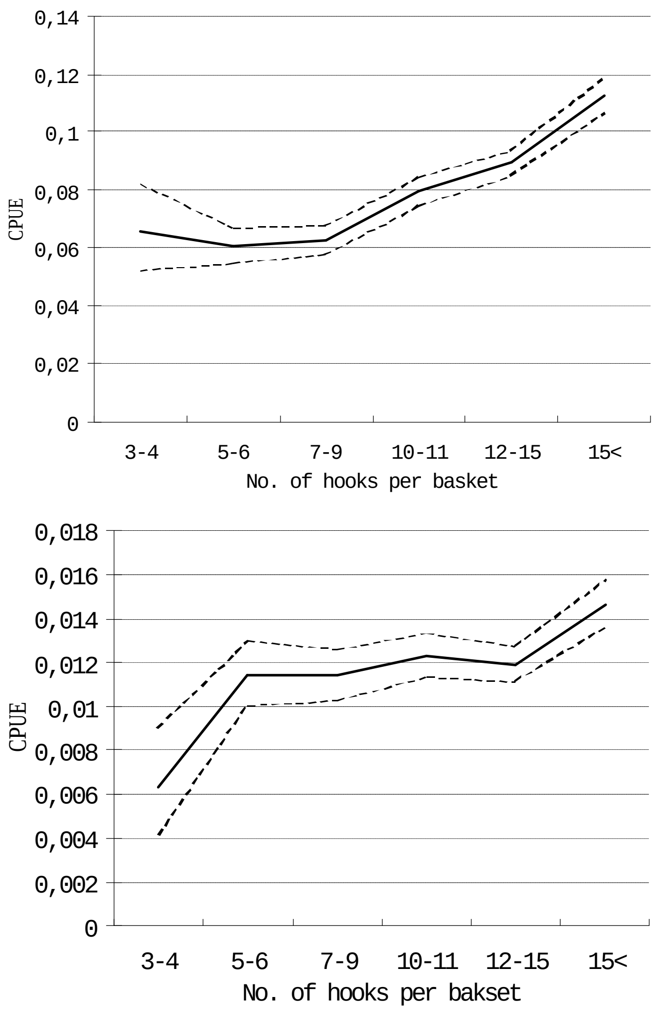


Figure 10. The standardized CPUE by gear configuration obtained from GLM for the period 1975-98. Upper panel: Blue marlin. Lower panel: White marlin