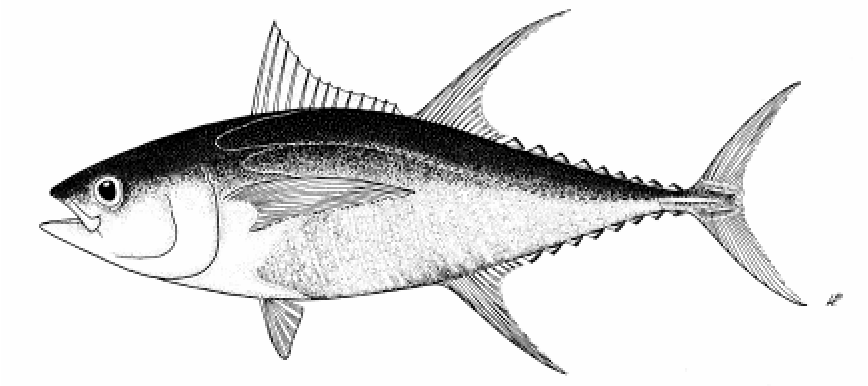
WCPFC–SC1 **EB WP–11**

Western and
Central Pacific
Fisheries
Commission

1st Meeting of the Scientific Committee of the
Western and Central Pacific Fisheries Commission
WCPFC–SC1
Noumea, New Caledonia
8–19 August 2005

Long-term changes in CPUE of sharks and size of blue sharks caught by tuna longlines in the western North Pacific Ocean



H. Matsunaga, H. Shono, M. Kiyota & Z. Suzuki

National Research Institute of Far Seas Fisheries. Shimizu, Japan.

August 2005

Long-term changes in CPUE of sharks and size of blue sharks caught by tuna longlines in the western North Pacific Ocean

Hiroaki MATSUNAGA, Hiroshi SHONO, Masashi KIYOTA & Ziro SUZUKI
National Research Institute of Far Seas Fisheries, Fisheries Research Agency, Japan,
5-7-1 Orido Shimizu-ku Shizuoka-shi, Shizuoka, 424-8633 Japan.
E-mail: matsuh@affrc.go.jp, hshono@affrc.go.jp, kiyo@affrc.go.jp, zsusuki@affrc.go.jp

【Abstract】

Motivated by Ward & Myers (2005) that claimed higher impact of longline fishery on large pelagic community including blue shark, long-term comparison of shark CPUE were made using recent and historical data collected by Japanese research and training vessels in the western North Pacific. Standardized species combined shark CPUE (predominated by blue shark catch and assuming that the shark combined CPUE represents blue shark CPUE in this paper) in the 1930's, 1960's and 1990's did not show any difference but were comparable between these periods. Average body lengths of blue sharks showed a minor decline in some area. The maximum decline of 13% was recorded at higher latitudes, which corresponded to 36 % reduction in body weight, but for the rest of the area there were no declines. Results of the analysis indicated that both CPUE and body size of blue shark varied temporally and spatially, but did not show statistically significant difference in most cases. Therefore, it is concluded that tuna longline fishery did not give a significant impact on blue shark stock which is predominant shark species caught by longline in the western North Pacific Ocean.

【Introduction】

It is considered that the pelagic shark resources in the Pacific Ocean have been stable for a long period since 1970 (Nakano 1996, Matsunaga & Nakano 2005). However, contrary to the general information, Ward & Myers (2005) reported the substantial declines in abundance and body size of apex predators such as large tunas and sharks in the tropical Pacific Ocean by comparing the data from the 1950s scientific survey with those collected by observers in the 1990s. They attributed the phenomena to the selective catch of the large apex predators by fisheries. Especially, the estimated abundance of blue shark in the 1990s was 13% of that in the 1950s and the mean body mass of this species was 52 kg in the 1950s compared to 22 kg in the 1990s. In order to ascertain whether or not these phenomena occurred in the western North Pacific Ocean, we analyzed the CPUE of sharks and the body size of blue shark. We used the data of the tuna longline operations for CPUE and the body size of sharks conducted by research and training vessels of Japan in the 1930s, 1940s, 1960s and 1990s, which cover the wider range of space and time (Okamoto 2004, Suda 1953) than Ward & Myers (2005).

【Material and Method】

The data used for the CPUE analysis was obtained from the tuna longline operations conducted by the research and training vessels of Japan in the period 1935-1945 (referred to the 1930s), 1968-1971 (the 1960s) and 1992-2003 (the 1990s). Unfortunately, there are no relevant Japanese data available for the area Ward & Myers (2005) studied for the period before the 1950s, but areas adjacent to their studied area are available for this study. Considering the distribution of fishing effort in each era (Fig.1), the area from 10S to 50N of the east longitude was divided into six sub-areas by the 10 degree of latitude. We conducted CPUE standardization two times as follows. At first, Analysis-(a) Comparison of CPUE between the 1930s and 1990s in the six sub-areas, next, Analysis-(b) those among three eras in the three sub-areas between 10S and 20N were conducted, because there were no data of the 1960s in the three sub-areas north of 20N. Summary of the operations for research is indicated in Table 1. As large part of the data in the 1930s was not recorded in species name, we calculated CPUE of total sharks, not in the species level. But The CPUE of total sharks is considered to represent that of blue shark because more than 70 % of total shark catch was composed of blue shark (Nakano & Seki 2003) although in the tropical areas catches of silky shark and oceanic whitetip sharks are as dominant as blue shark. Here, we regarded the CPUE trend of total sharks as that of blue shark for the areas roughly north of 10 N (Nakano 1994, Matsunaga & Nakano 1999). In the tropical areas between 10 N and 10 S where Ward and Myers (2005) studied, since all three major shark species show a drastic decline between the two period, the combined shark CPUE still has value to be compared and the combined CPUE is also referred to as blue shark CPUE in this paper.

In order to standardize CPUE of sharks we used generalized linear model in this analysis. We used the CPUE with log-normal error and the calculation was performed through GLM procedure of SAS/STAT package (Version 8.2). The following form was assumed as a full model.

$$\ln(\mathrm{CPUE} + \mathrm{constant}) = \mathrm{INTERCEPT} + \mathrm{ER} + \mathrm{QT} + \mathrm{AREA} + \mathrm{GEAR} + \mathrm{INTERACTION} + \mathrm{ERROR},$$

$$\mathrm{ERROR} \sim N(0, \sigma^2) \qquad (1)$$

where ln: natural logarithm, CPUE: nominal CPUE (catch of sharks in number per 1000 hooks), INTERCEPT: intercept, ER: effect of era, QT: effect of season, AREA: effect of area, GEAR: effect of gear type (number of hooks between floats: NHF), INTERACTION: two way interactions. ERA, QT, AREA and GEAR were incorporated as the main effect.

Precisely, formula (1) is written in formula (2) for (a) and (3) for (b). In order to overcome the problem of zero catch, 1.0 was uniformly added to each value of nominal CPUE as the constant term.

The following two-way interactions were used as a full model. Other interactions could not be included into this full model because of missing data.

- full model -

$\mathrm{Ln}\ (\mathrm{CPUE}_{ijkl} + 1) = \mathrm{INTERCEPT} + \mathrm{ER}_i + \mathrm{QT}_j + \mathrm{AREA}_k + \mathrm{GEAR}_l + (\mathrm{ER*AREA})_{ik} + (\mathrm{ER*QT})_{ij} + (\mathrm{ER*GEAR})_{il} + \mathrm{ERROR}_{ijkl}$ (2)

$\mathrm{Ln}\ (\mathrm{CPUE}_{ijkl} + 1) = \mathrm{INTERCEPT} + \mathrm{ER}_i + \mathrm{QT}_j + \mathrm{AREA}_k + \mathrm{GEAR}_l + (\mathrm{ER*AREA})_{ik} + (\mathrm{ER*QT})_{ij} + \mathrm{ERROR}_{ijkl}$ (3)

where i (ERA): 1-3, j (QT): 1-4 (class 1: Jan-Mar, 2: Apr-Jun, 3: Jul-Sep, 4: Oct-Dec), k (AREA): 1-6, l (GEAR): 1-5 (NHF-class 1: 3-6, 2: 7-10, 3: 11-14, 4: 15-17, 5: 18-24).

We made the model selection using the stepwise F-test (Dobson 1990). As a result of all the test about the path that can be considered, the following model with many explanatory variables was finally selected ((4) for (a) and (5) for (b)). Significant level was set to be one percentage. The results of ANOVA are shown in Table 2.

- final model -

Ln (CPUE + 1) = INTERCEPT + ER + QT + AREA + GEAR + (ER*AREA) + (ER*QT) + (ER*GEAR) + ERROR (4)

Ln (CPUE + 1) = INTERCEPT + ER + AREA + GEAR + (ER*QT) + ERROR (5)

CPUE index in era i and in a whole area is estimated y the following equation ((6) for (a) and (7) for (b)).

$\mathrm{CPUE}_i = \exp \{ \mathrm{INTERCEPT} + \mathrm{ER}_i + (\mathrm{ER*AREA})_{i-} + (\mathrm{ER*QT})_{i-} + (\mathrm{ER*GEAR})_{i-} \} - 1, (i = 1, 3)$ (6)

$\mathrm{CPUE}_i = \exp \{ \mathrm{INTERCEPT} + \mathrm{ER}_i + (\mathrm{ER*QT})_{i-} \} - 1, (i = 1, 2, 3)$ (7)

Where

$(\mathrm{ER*AREA})_{i-} = 1/N_j * \Sigma\, (\mathrm{ER*AREA})_{ij}$, $(\mathrm{ER*QT})_{i-} = 1/N_j * \Sigma\, (\mathrm{ER*QT})_{ik}$, $(\mathrm{ER*GEAR})_{i-} = 1/N_j * \Sigma\, (\mathrm{ER*GEAR})_{il}$

The terms of CPUE_i + constant (i.e. 1) means the Least Squared Means (LSMEANS) of ER effect in GLM procedure of SAS package.

The soak times of longline were not used as the factor because they were not different so much among the three eras.

The data used for the comparison of body length (pre-caudal length in cm: PL) of blue shark among the eras was obtained from the same operations in the 1960s and the 1990s described above. The data of body length in the 1930s was not available but we referred the data in the 1940s which Suda (1953) presented. Though same sub-areas were also set as the CPUE analysis, we could compare the body length between in the 1940s and the 1990s in the two sub-areas of 20-40N and in the 1960s and the 1990s in the three sub-areas of 10S-20N. For the comparison of body length, the averages and their standard deviations of body length were calculated by sex, era and sub-area. And then, the difference was examined by t-test. Significant level was set to be one percentage. For the conversion of the average body length to the average body weight, the formulae which Nakano (1994) introduced in the North Pacific Ocean were adopted. They are as follows.

Male: $BW\ (kg) = 3.293 * PL^{3.225} * 10^{-6}$ Female: $BW\ (kg) = 5.388 * PL^{3.102} * 10^{-6}$

【Result】

Fig. 2 shows the standardized CPUE and 95 % confidence intervals of blue shark by main factors such as era, season, area and NHF from Analysis-(a). The CPUE in the 1990s was significantly larger than that in the 1930s by 41 %. Difference among the seasons was small. There were a decreasing trend of CPUE from higher latitude to lower latitude waters. That of NHF-class 1 (3-6) was much larger than those of other classes (2-5) and negative correlation was also observed between NHF and CPUE.

Fig. 3 shows the standardized CPUE of blue shark by main factors such as era, area and NHF from Analysis-(b). The CPUE in the 1930s and the 1960s were almost the same. That in the 1990s was a little larger than them (27 %). But the difference among the three eras was not detected (1% level of significance). That in the area of 10-20N was larger than those in the areas of 0-10N and 0-10S. That of NHF-class 4 (15-17) was much smaller than other classes (1-3).

Fig. 4 shows the average body length of blue shark and the standard deviation by sex, era and area. There are no size data for the 1960s for the areas north of 20 N and also no size data for the 1940s for the areas south of 20 N. The average body lengths of male and female blue shark in the area of 30-40N in the 1990s were 138.8 cm and 120.7 cm respectively, both of which were smaller than those in the 1940s (male: 156.9 cm, female: 139.5 cm). The average body weights of them were estimated to be 26.7 kg (male), 15.4 kg (female) in the 1990s, and 39.7 kg (male), 24.2 kg (female) in the 1940s respectively. The average body length and weight of female blue shark in the area of 20-30N in the 1990s (167.5 cm, 42.7 kg) was smaller than that in the 1940s (172.3 cm, 46.6 kg), but the difference between them was very small (4.8 cm, 3.9 kg). There were no decreases of body length observed in other cases.

【Discussion】

The result of this study shows that the CPUE of blue shark in the 1990s was in comparable level with those of the 1930s and the 1960s. This result was different with the phenomenon reported by Ward & Myers (2005), which indicated that a substantial decline of CPUE occurred in some areas of the tropical Pacific Ocean. Regarding the body size of blue shark, the average body length and weight in the 1990s decreased by 12 %, 33 % (male) and 13 %, 36 % (female) compared with that in the 1940s in the area of 30-40N. This phenomenon was somewhat similar to what Ward & Myers (2005) reported, but the extent of decrease was very small in comparison with their case (58 %). However, more important is that the decreases in the neighbor area of 20-30N were much smaller (male: 1.3 %, female: 8.4 %) than those mentioned above.

Although the comparison made this paper is different in areas and time period with respect to that by Ward and Myers (2005), our study indicates that no appreciable change in CPUE and size of blue shark was found for the adjacent wider areas studied by Ward and Myers (2005). There is a significant difference between the two studies, especially the extent of areas covered, present study covers by far the larger areas. In addition, the window area selected by Ward and Myers (2005) covers an important area of the tropical waters between 10S to 11N, 175E to 115W. However, it should be noted here that the distribution of fishing effort is concentrated in the very small areas with difference in the concentration area, mostly deep bottom area for the 1950s and sea mount area for the 1990s. In addition, other inherent fundamental difficulty for this type of analyses is that it is not certain whether the comparisons are really possible since the data used Ward and Myers (2005) and present paper both used very old data series which were obtained by quite a different way in operating aspects of longlining as well as many other important factors. In addition, further, both studies compare only average values cut only from two segments in a continuous process of dynamic change in fish populations. In other words, whatever standardizations were attempted so as to make the comparison between the two periods reasonable, there is no guarantee the results obtained are the fact. Those concerns with the data and way of comparison should be born in mind in interpreting the results of two papers.

【Conclusion】

For the wider areas adjacent to the tropical Pacific studied by Ward and Myers (2005), covering areas between 50 N to 10S, 120E to 180, CPUE and body size of blue shark in the western North Pacific Ocean did not show any decrease between the 1950s and 1990s. Therefore, it is concluded that longline fishery did not give a significant impact on blue shark stock which is predominant shark species caught by longline in the western North Pacific Ocean.

【Reference】

Dobson A. J., 1990. An introduction to generalized linear models. Chapman and Hall. 174pp.

Okamoto H., 2004. Search for the Japanese tuna fishing data before and just after World WarⅡ. Bull. Fish. Res. Agen. 13, 15-34.

Matsunaga H. and H. Nakano, 1999. Species composition and CPUE of pelagic sharks caught by Japanese longline research and training vessels in the Pacific Ocean. Fish. Sci. 65(1), 16-22.

Matsunaga H. and H. Nakano. 2004. Blue shark. The Current Status of International Fishery Stocks 283-289 (in Japanese).

Nakano H. 1994. Age, reproduction and migration of blue shark in the North Pacific Ocean. Bull. Nat. Res. Inst. Far Seas Fish., 31, 141-256.

Nakano H.,1996. Historical CPUE of pelagic shark caught by Japanese longline fishery in the world. Information paper submitted to the 13th CITES Animal Committee, Doc. AC. 13.6.1. Annex, 7pp.

Nakano H. and M. P. Seki, 2003. Synopsis of biological data on the blue shark, Prionace glauca Linnaeus. Bull. Fish. Res. Agen. 6, 18-55.

Suda A., 1953. Ecological study of blue shark (Prionace glauca LINNE). Bull. Nankai Fish. Res. Lab., 1(26), 1-11.

Ward P. and R. A. Myers, 2005. Shift in open-ocean fish communities coinciding with the commencement of commercial fishing. Ecology, 86(4), 835-847.

Table1 Summary of the operations

Era	1930s (1935-1945)	1960s (1967-1971)	1990s (1992-2003)
No of operations	2279	628	3490
No of hooks (*1000)	1916	1111	5021
No of sharks	23915	6135	60607

Table 2 ANOVA table for the finally selected model in the GLM analysis.

①Analysis-(a) Comparison of CPUE between 1930s and 1990s in the six sub-areas

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	25	1739.3	69.6	83.4	<.0001
Error	5733	4782.2	0.8		
Corrected Total	5758	6521.6			

R-Square	Coeff Var	Root MSE	logCPUE Mean
0.267	41.460	0.913	2.203

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ER	1	6.1	6.1	7.4	0.0067
QT	3	10.8	3.6	4.3	0.0048
AR	5	47.2	9.4	11.3	<.0001
GEAR	4	753.4	188.4	225.8	<.0001
ER*AR	5	75.6	15.1	18.1	<.0001
ER*QT	3	15.1	5.0	6.1	0.0004
ER*GEAR	4	89.7	22.4	26.9	<.0001

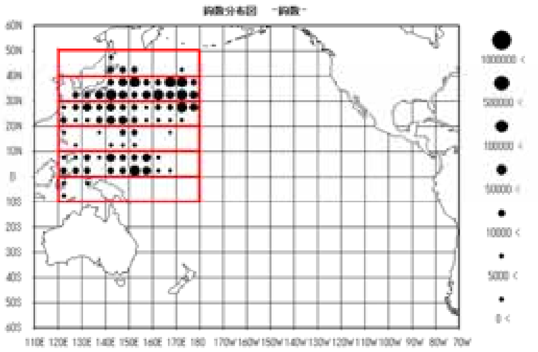
②Analysis-(b) Comparison among three eras in the three sub-areas between 10S and 20N

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	16	255.1	15.9	41.4	<.0001
Error	2951	1135.6	0.4		
Corrected Total	2967	1390.6			

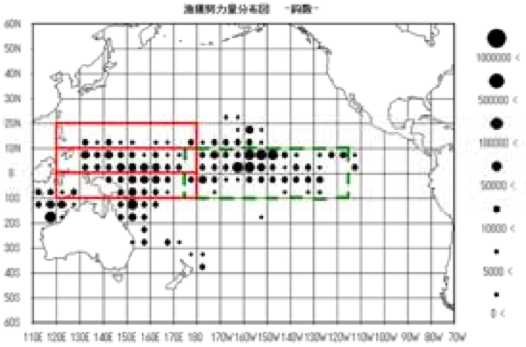
R-Square	Coeff Var	Root MSE	logCPUE Mean
0.183	30.245	0.620	2.051

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ER	2	3.2	1.6	4.1	0.016
AR	2	44.1	22.1	57.3	<.0001
GEAR	3	34.6	11.5	30.0	<.0001
ER*QT	9	20.9	2.3	6.0	<.0001

1930s (1935-45)



1960s (1967-71)



1990s (1992-2003)

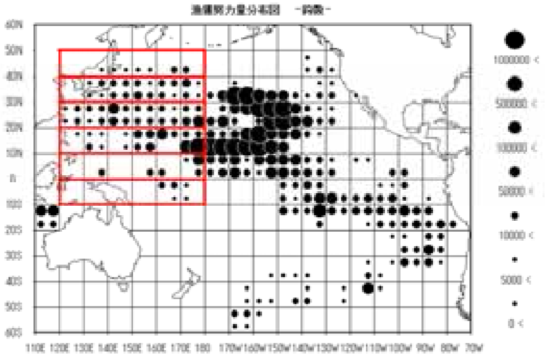


Fig.1 Distribution pattern of fishing effort by Japanese reseach & training vessels indicated in number of hooks and the sub-area for research in the three eras. The area Ward & Myers (2005) studied is indicated by dotted line in the panel of the 1960s.

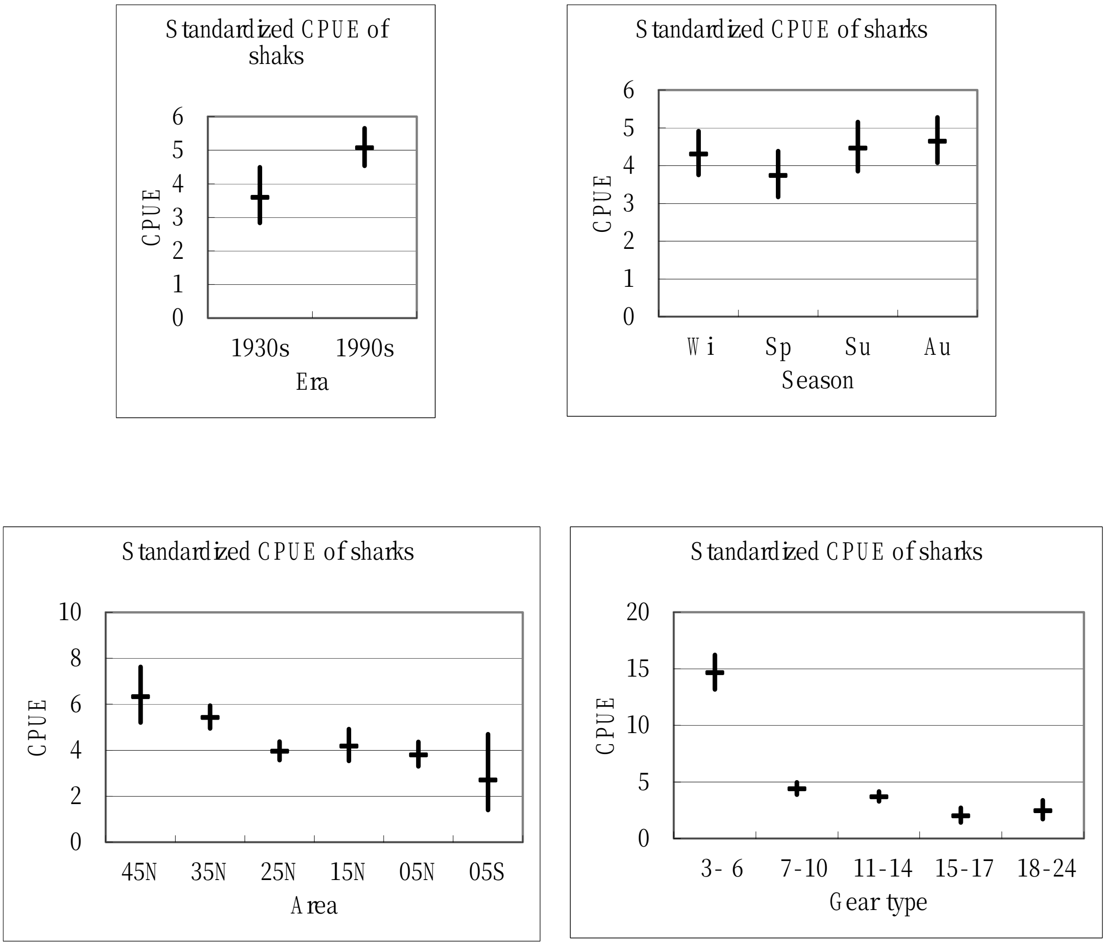


Fig.2 Standardized CPUE of sharks and 95 % confidence intervals by era (upper-left), season (upper-right), area (lower-left) and gear type (lower-right) in the two eras

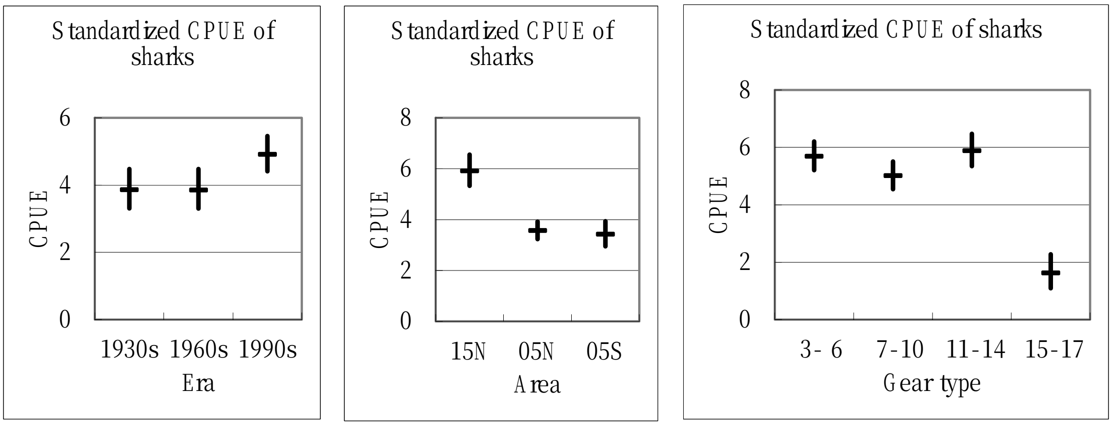


Fig.3 Standardized CPUE of sharks 95 % confidence intervals by era (left), area (center) and gear type (left) in the three eras (1930s, 1960s and 1990s).

120E - 180

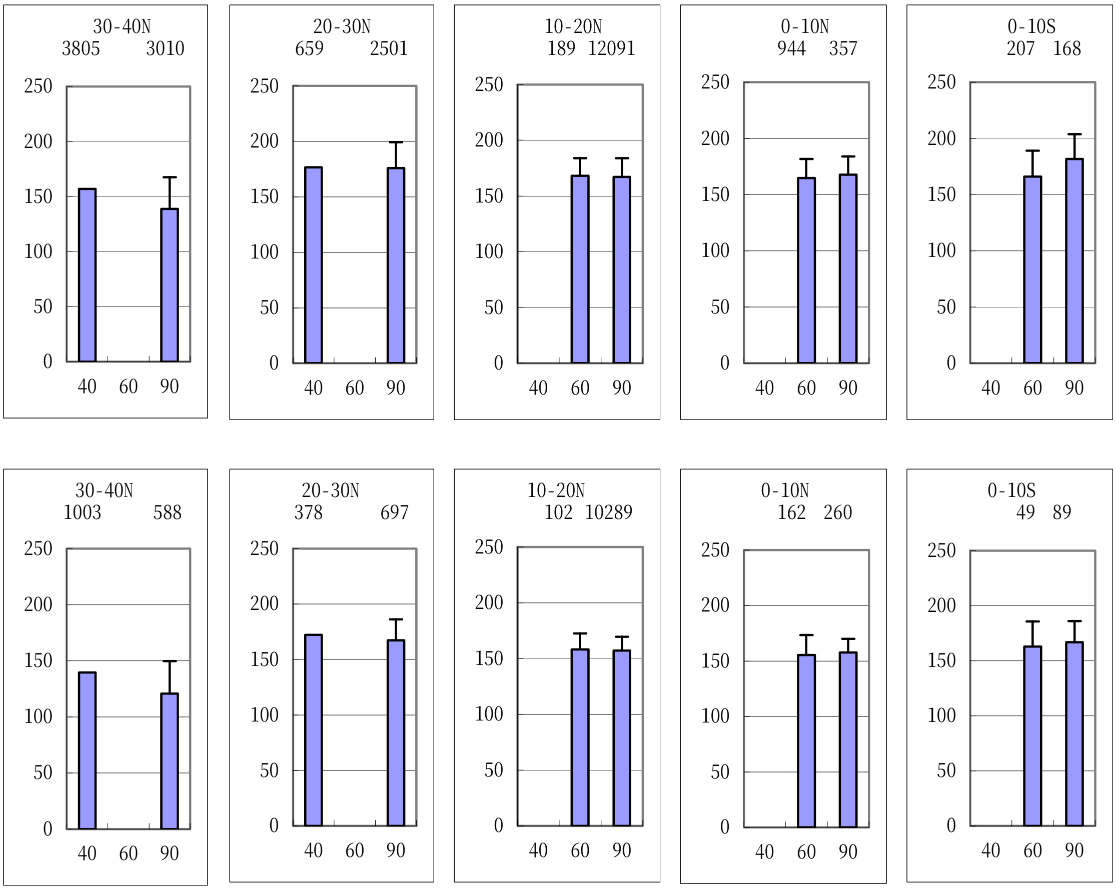


Fig.4 Average body length and Standard Deviation of blue shark by area and era (upper:♂、lower:♀).
Sample sizes are indicated just above frame of the figure.
No estimates of standard deviations were available for the 1940s data.