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印度洋에서의 韓國在來式 및 深層延繩의 漁獲效果와 다랑어類의 鉛直分布

孔 泳・李章旭・金映承・梁元錫
國立水産振興院, 海洋資源部

Fishing efficiency of Korean regular and deep longline gears and vertical distribution of tunas in the Indian Ocean

Yeong GONG, Jang-Uk LEE, Yeong-Seung KIM, and Won-Seok YANG

National Fisheries Research and Development Agency(NFRDA)
2-16, Namhang-Dong, Yeongdo-Ku, Pusan 606, Korea

Yellowfin and bigeye tunas have been targeting and the most important species for the Korean tuna longline fishery in the Indian Ocean. This study is aimed to analyse the fishing efficiency of the regular and the deep longlines and the vertical distribution of tunas, and the weight composition by fishing depth based on the data from Korean tuna longline fishery from 1973 to 1980 and from 1984 to 1986 in the Indian Ocean. It was found that the deep longline gear on bigeye tuna was significantly different from the regular longline gear on yellowfin tuna in the whole Indian Ocean. Yellowfin tuna and billfishes were chiefly distributed at the shallow layer and bigeye at the deep layer. The weight composition of yellowfin and bigeye tunas by depth showed that the deeper the depth, the larger the bigeye distributed.

INTRODUCTION

The experimental fishing operation of the Korean tuna longline was initiated in the Indian Ocean in 1957. The deep longline gear commonly used by the Korean commercial fishing vessels has been introduced in the central equatorial Indian Ocean in 1973 and the fishing activities have been gradually expanded to the whole fishing grounds north of 20 °S of the Indian Ocean (Fig. 1). Total catches of yellowfin and bigeye tunas which were major targeted species for the longline fishing were shown in Figure 2. Until 1974 the yellowfin was dominated in total catch, but it has been replaced by the bigeye since 1975 except 1977. According to the fishing data collected by the skippers, it is assumed that the catch per unit effort (CPUE) by hook will be different by depth of the longline. This may be caused by the diurnal distribution pattern of the tunas in the water column including vertical migration of the fishes. This phenomenon is supposed to be reflected the CPUE as a relative abundance of stock assesment.

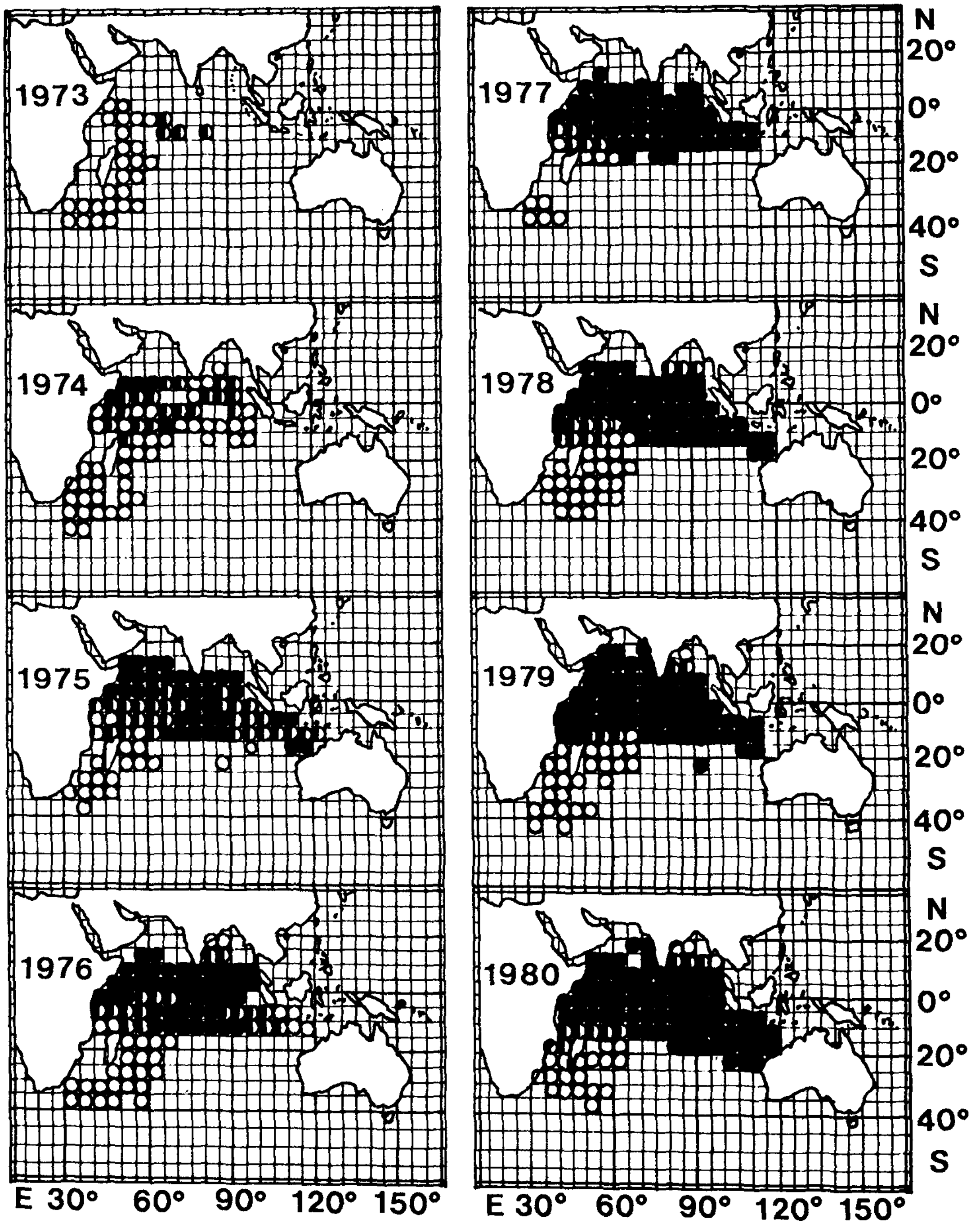

Fig. 1. Geographical distribution of fishing grounds of Korean tuna lingline fishery in the Indian Ocean for 1973~1980. Open circles denote the fishing grounds by regular longline, dark circles for deep longline and semicircles for both longlines.

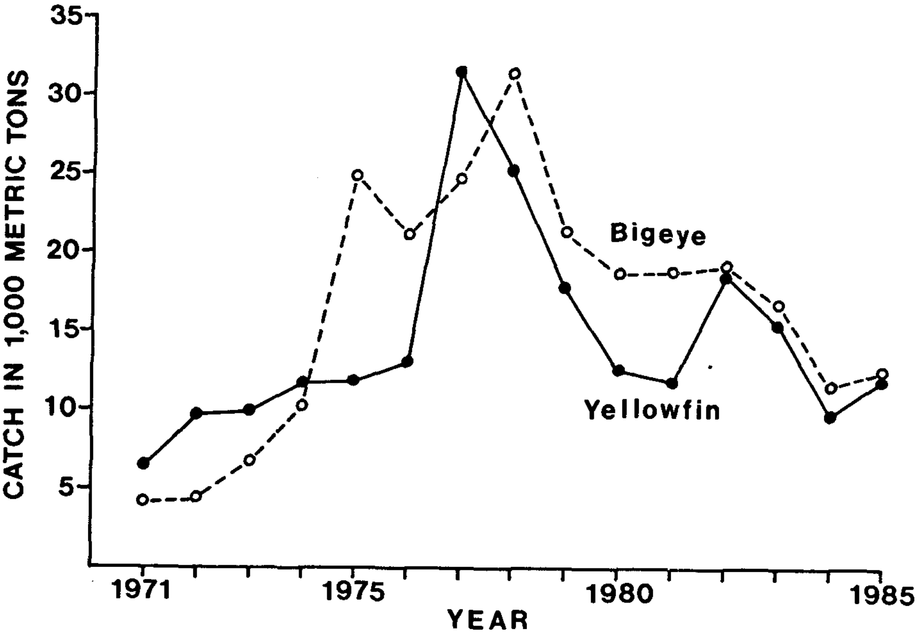

Fig. 2. Catch of yellowfin and bigeye tunas for the Korean longline fishery in the Indian Ocean, 1971~1985.

This paper deals with fishing efficiency of the regular and the deep longlines based on the Korean tuna longline fishing data in the Indian Ocean. Vertical distribution of tunas by size were also examined based on the size data taken by hooks at different fishing depth.

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MATERIALS AND METHODS

All the data used in this report were based on logbooks which have been submitted to the National Fisheries Research and Development Agency (NFRDA), Korea by the skippers during the period of 1973~1980 and 1984~1986. We selected the data for 65,376 baskets from the regular longline gear (RL) and 120,871 baskets from the deep longling gear (DL). Fishing efficiency was compared for yellowfin and bigeye tunas in 1975, in which both gears were simultaneously operated in the same fishing grounds. The study area was devided into 10 subareas (5°lat. × 5°long.) (Fig. 3). The hooking rate of RL (P_1) and DL (P_2) on yellowfin and bigeye tunas had been tested by t-test to verify the significant difference.

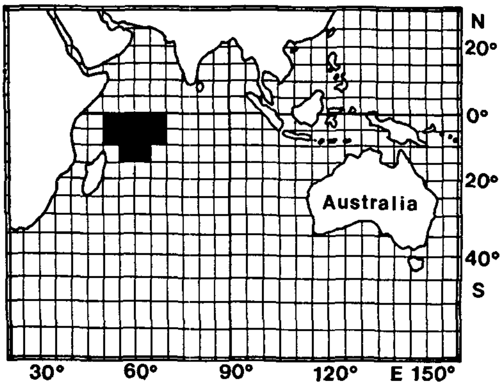

Fig. 3. Index area for comparison of gear efficiency between regular (RL) and deep longlines (DL) for yellowfin and bigeye tunas by Korean longline fishery in the Indian Ocean in 1975.

Fishing efficiency between two gears was calculated as follow:

CPUE = catch in number per 100 hooks

$$\overline{CPUE} = \frac{1}{n} \sum_{i=1}^{n} CPUE$$

FE = CPUE of DL/CPUE of RL

$$\overline{FE} = \frac{1}{n} \sum_{i=1}^{n} FE$$

where, CPUE of DL: catch per unit effort of the deep longling in i-th unit area

CPUE of RL: catch per unit effort of the regular longline in i-th unit area

FE = fishing efficiency in i-th unit area within the index area

$\overline{FE}$ = mean fishing efficiency of the deep longline to the regular longline in the index area

n = number of available unit areas in the index area

With a view to analysing the vertical distribution of tunas and billfishes in terms of fishing depth, the data of 321,408 baskets, 1,955 specimens of yellowfin and 1,734 specimens of bigeye tunas were collected from July 1984 to December 1986 for the deep longline. Theoretical catenary equation described by Yoshihara (1951, 1954) was used to determine the vertical distribution of hanging depth of hooks.

$$Dj = Ha + Hb + L\{(1 + Cot^2\phi)^{1/2} - [(1 - 2\frac{j}{n})^2 + Cot\ \phi]^{1/2}\}$$
$$= Ha + Hb + L[Cosec\ \phi - (Cosec^2\ \phi - \frac{4j(n-1)}{n^2})]$$

Where, Dj: Depth of the hook on the j-th branch line which is hung on the j-th joining point from either end of a unit basket

Ha: Length of the float line, 25*m*

Hb: Length of the branch line, 30*m*

L: Half of the length of the main line in a unit basket, 340*m*

n: Total number of the unit sections of the main line in a unit basket

Tuna longline gear, called a basket, is composed of floats, float line, main line and branch lines. In general, it has 6 branch lines for the regular longline and 13 branch lines for the deep one (Fig. 4).

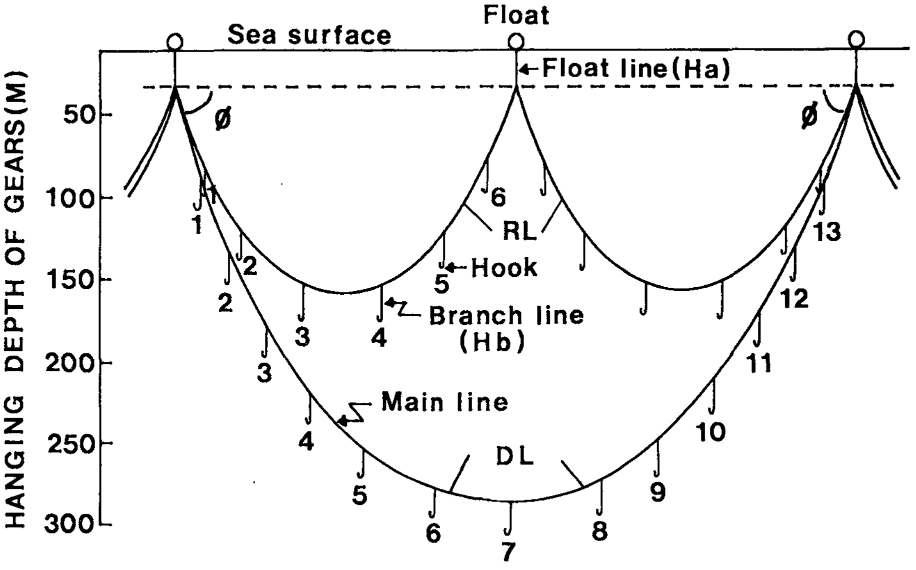

Fig. 4. Regular (RL, 6 branch lines) and deep longline (DL, 13 branch lines) as used by Korean fishermen in the Indian Ocean from 1973 to 1986.

In the equation, the depression angle (between horizontal and tangental lines) of the main line at the connecting point with float line was $\phi=72°$ (X/S=0.6, X: horizontal distance of a set of longline, S: length of main line in a set of longline) as a representative angle for the calculation (Hanamoto, 1974; Suzuki et al., 1977) (Fig. 5).

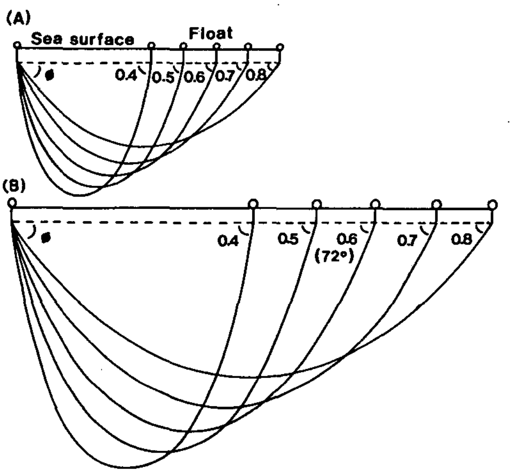

Fig. 5. Changes of sagging rates in a unit basket for the regular longline (A) and the deep longline (B).

RESULTS

1. Comparison of fishing efficiency between the regular and the deep longline gears

The annual changes of distribution of fishing grounds by Korean tuna longline fishery in the Indian Ocean from 1973 to 1980 are shown in Figure 1. The deep longline gear was introduced to the Indian Ocean in 1973. In 1975 half of the fishing ground was covered by the deep longliners. Since 1977 most of the fishing grounds have been gradually replaced by the deep longlines, however, the regular longlines have remained in the southwestern part of the ocean and the Bengal Bay of shallow area.

The hooking rate (CPUE), variance of hooking rate and fishing efficiency by the two types of gears (RL and DL) on yellowfin and bigeye tunas in the index area are summarized in Table 1. The hooking rate of yellowfin tuna by fishing gear of RL and DL was subjected to t-test, rendering $t=4.74$ ($P<0.001$) with a significantly higher hooking rate by RL (0.795%) than by DL (0.662%). While hooking rate of bigeye tuna rendered $t=8.55$ ($P<0.001$) with a significantly higher hooking rate by DL (0.633%) than by RL(0.568%). On the other hand, fishing efficiency for the deep longline gear on yellowfin was about the same, and that of the deep longline on bigeye was 1.56 times lager than that of the regular longline. These indicated that the deep longline should be considered more efficient on bigeye tuna than that on yellowfin tuna.

Table 1. Fishing rates of regular (FL) and deep longliners (DL) on yellowfin and bigeye tunas in the index area in the Indian Ocean in 1975.

	Yellowfin		Bigeye	
	RL	DL	RL	DL
Total catch(no. of fish)	3,120	10,403	2,229	9,944
Total number of hooks used	392,255	1,571,325	392,255	1,571,325
Total number of baskets used	65,376	120,871	65,376	120,871
Hooking rate	0.80	0.66	0.57	0.63
Variance of hooking rate	2.011×10^{-8}	4.185×10^{-9}	1.440×10^{-8}	4.003×10^{-9}
Fishing efficiency of DL compared to RL	1.00		1.56	

2. Vertical distribution of species and size composition of tunas

CPUE of various species and depth of hooks of the deep longline gear were plotted for the western and the eastern Indian Ocean in Fig. 6. In both areas CPUE of yellowfin was high at hanging depth of hooks around 200*m*. Albacore and billfishes showed the similar trends such as yellowfin. CPUE of bigeye, however, showed the highest value at depth of around 300*m*.

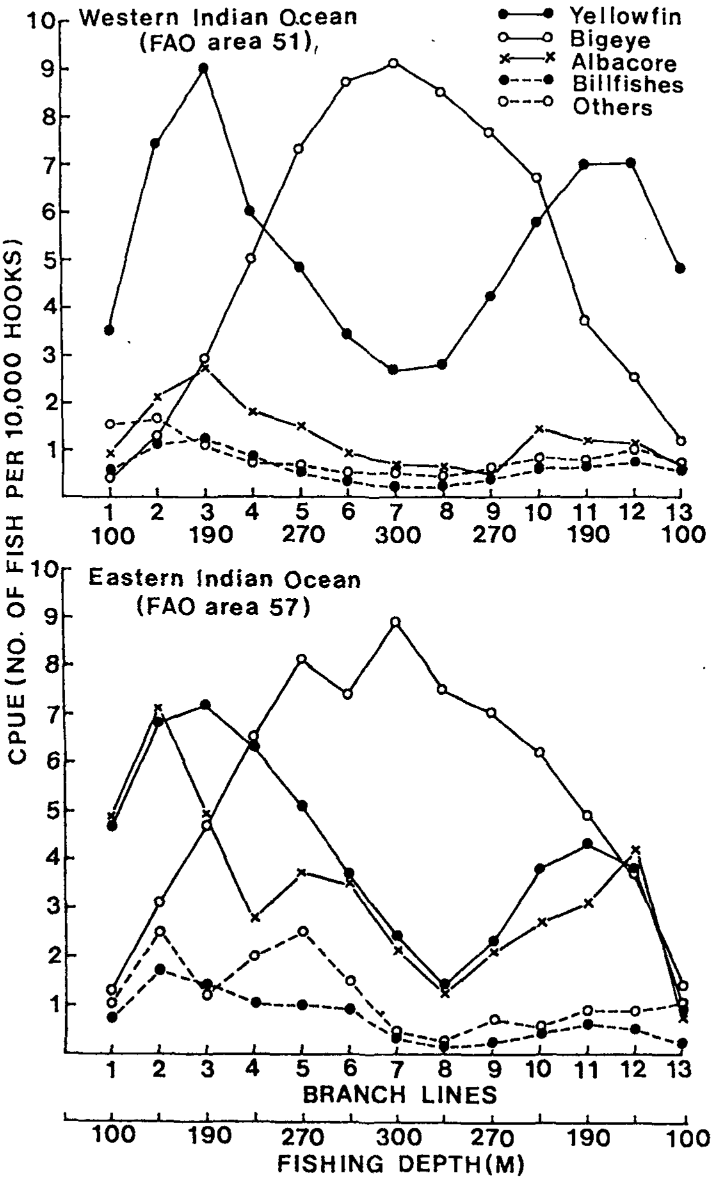

Fig. 6. Catch per unit of effort by species, branch lines and fishing depths caught from the Korean deep longliners in the Indian Ocean from July 1984 to December 1986.

Mean fishing depth of bigeye ($\bar{D}_B$) was shown at 257*m* which was much deeper ($t=17$, $P<0.001$) than that of yellowfin ($\bar{D}_y=215m$). Both species were compared based on the relationship between the depth of hooks and the weight of fishes caught. The following equations were found.

$$\overline{W}_Y = 30.529 + 0.0140D,\ r = 0.84$$

$$\overline{W}_B = 27.626 + 0.0466D,\ r = 0.93$$

where, $\overline{W}_Y$: mean weight of yellowfin

$\overline{W}_B$: mean weight of bigeye

D : depth in meter

Size compositions of yellowfin and bigeye tunas described by gutted and gilled weight in *kg* were compared by fishing depth in Fig. 7. The mean weight of yellowfin was ranged 30.9 to 33.7*kg* in all depths. From depth of 150*m* the mean weight of fish increased with depth to 270*m*. Mean weight of bigeye at each depth appeared that the deeper the depth, the heavier fish caught, and the larger bigeye tunas were caught at depth of 270 to 300*m*.

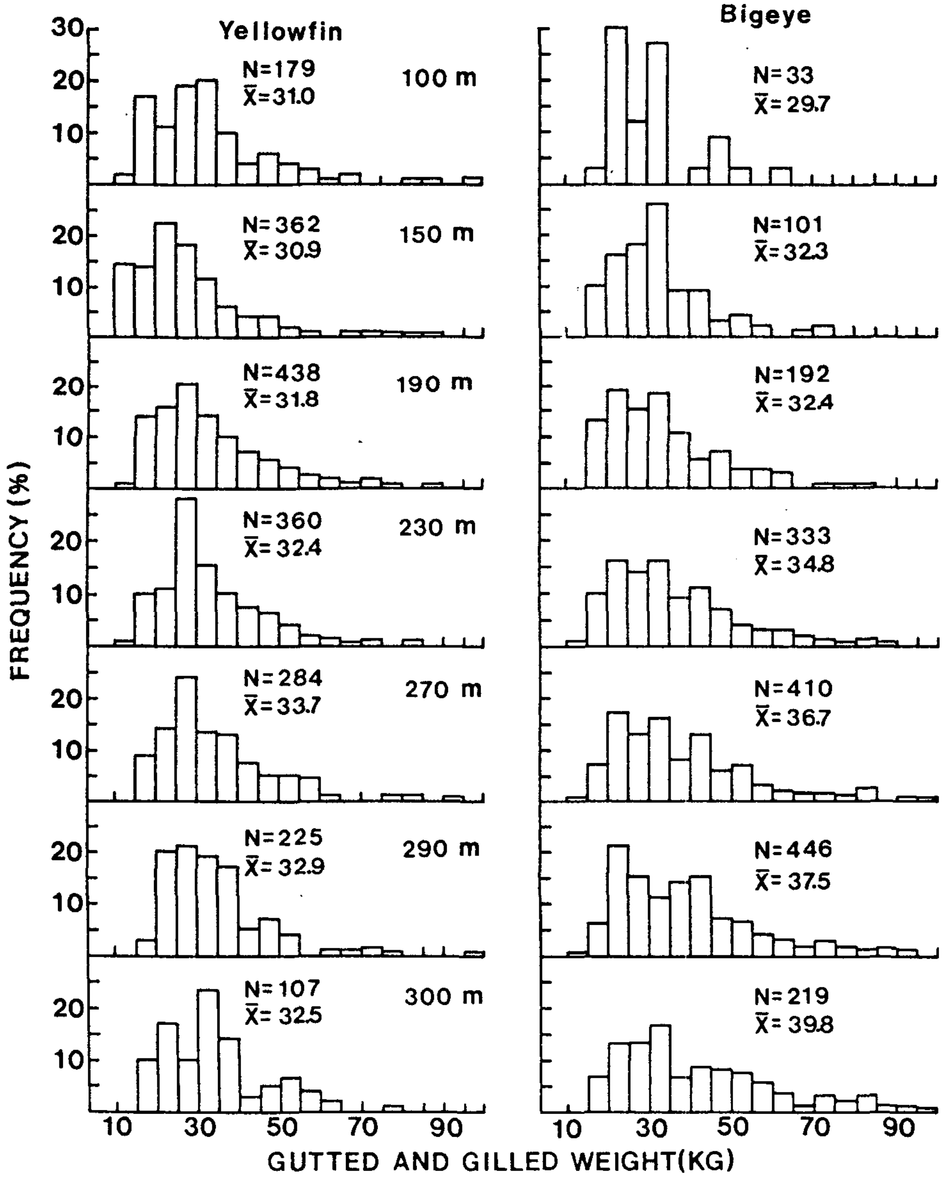

Fig. 7. Weight composition of yellowfin and bigeye tunas by fishing depth caught from the Korean deep longliners in the Indian Ocean from July 1984 to December 1986.

DISCUSSION

There are no established criteria that distinguish between the regular and deep longlines based on the numbers of branch lines associated with the main line of tuna longline gear. Saito (1975) pointed that the regular longline and the deep longline has 6 and 10 branch lines respectively. Koido (1985) separated the regular longline with less than 7 branch lines from the deep longline with more than 9 branch lines. In this report, since most of the fishermen have used 7 to 9 branch lines in a unit basket during the early period of their fishing operations, one set with more than 12 branch lines was classified as the deep longline (Fig. 4).

Based on the hanging depth of hooks calculated theoretically by the catenary curve, maxium depth at which the sagging rate assumed 0.60 estimated to be around 170*m* in the regular longline gear with 6 branch lines and around 300*m* in the deep longline with 13 branch lines.

Korean deep longline had been introduced in the early 1970's, and it is recently being operated in the major part of the fishing grounds. From the geographical distribution of fishing grounds, it was found that the Korean deep longliner operated a couple of years earlier than the Japanese which began in the Banda Sea and its adjacent areas in 1975 (Koido, 1985).

It can be regarded that the deep gear was more effective than regular one for the efficient catch of bigeye tuna in the Indian Ocean. These are similar to the results by Koido (1985), though there were some differences in their absolute values for both species.

CPUE of bigeye by fishing depth after introduction of the Korean deep longline was higher at depth of around 300*m*. CPUE of yellowfin, however, shows the contrary trends with bigeye (Fig. 6). The same results were made in the Central Atlantic by Yang and Gong (1986). These facts apparently suggest that bigeye tuna migrates at the deeper layer than yellowfin tuna (Suda et al., 1969; Hanamoto, 1974; Saito, 1975; Suzuki et al., 1977; Suzuki et al., 1981).

With regard to the size composition by fishing depth, the mean weight of yellowfin was increased in conformity with the depth from 150*m* down to 270*m*, but it was not large at the depth of around 300*m*. As for bigeye, it was larger than yellowfin at each depth. It is distinctly appeared that the deeper the depth, the larger the fish. These informations may be very useful with respect to the interaction of tuna fisheries in the Indian Ocean.

It has been commonly pointed out that highly migratory fishes like tunas are associated with physical factors such as thermoclines, mixed depth and dissolved oxygen (Suda et al., 1969; Saito, 1975). More specific analyses should be carried out in small scale in order to verify the vertical distribution by fishing depth of tunas provided with data including detailed time and area strata in which complicated oceanographic conditions are associated with biological interactions.

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