La mer 37 : 29–37, 1999
Société franco-japonaise d'océanographie, Tokyo

Optical characteristics of hook line in tuna longline fishing

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Abstract : The in-water apparent contrast of different materials used for hook line in tuna longline fishing was estimated by using their in-water video image. The materials were consisted of three types of wire and nylon monofilament and one fluorocarbon monofilament. Each material was prepared for three operated history in the fishing; a new (no used), 1 day-operated and 7 days-operated hook line samples, respectively.

The apparent contrasts of all kinds of wire hook lines are higher than that of the nylon and fluorocarbon monofilaments. The apparent contrasts of 1 day-operated hook lines are rather lower than that of new hook line materials. The apparent contrasts of 7 days-operated hook lines are rather higher than that of 1 day-operated hook lines.

The nylon and fluorocarbon monofilament hook lines and the 1 day to 3 days-operated hook lines being effective for tuna longline fishing, it is considered that fish are caught by the hook line materials of lower apparent contrast.

Key words *: Visibility, Contrast, Video image, Brightness value, Tuna longline fishing*

1. Introduction

In tuna longline fishing, the book line is generally made of wire or nylon monofilament materials. The catch rate of nylon monofilament hook line is reported to be higher than that of wire hook line (KASUGA, 1990). This higher catch rate is considered to be due to the elasticity characteristic and poor visible range of nylon monofilament; these bring about difficulty for fish both to get free from hook and to detect nylon monofilament hook line, respectively. Moreover some works have been investigated on the optical characteristics of wire and nylon monofilament used as the hook line in tuna longline fishing (NAKAMURA *et al.*, 1990 a, b; WARDLE *et al.*, 1991). However, why nylon monofilament is suitable for the hook line is not clear yet. In the meantime, it is reported that fish use no other sense except the visual sense to detect fishing gear in its vicinity (BLAXTER *et al.*, 1964). From this point of view, the apparent contrast of the hook line with its surr ounding background is considered.

The apparent contrast of an object in the water has been calculated from its luminance with its background which are measured using a luminance meter, but this is difficult to do with a small object in the water. Then luminance measurement of an underwater object can be carried in the laboratory for setting the various optical conditions.

This study proposed a simple investigation method both to estimate the underwater apparent contrast with different materials used for hook line in tuna longline fishing by using an underwater video image, and also to characterize their optical performance.

2. Materials and Methods

1) Materials

Samples of hook line were collected from tuna longline operation during the cruise of the T/S Shinyo Maru of the Tokyo University of Fisheries in 1996. Table 1 shows the samples of

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Table 1. Materails, size, number of sample with different history of using age and the catch

Material	Type	Size		Number of samplee (line)			
		Number*	dia. (mm)	New	1 day	7 days	Catch
Wire	Zinc-alumi-plated	30 (3+9)	1.4	1	2	2	1
Wire	Zinc-plated	30 (3+9)	1.4	1	2	2	0
Wire	Red colour-coated	30 (3+9)	1.4	1	2	2	1
Nylon monofilament	Common White-colored	120	1.95	1	2	2	1
Nylon monofilament	Flexible White-coloured	120	1.95	1	2	2	2
Nylon monofilament	Light grey-coloured	120	1.95	1	2	2	2
Fluorocarbon monofilament	Fluorocarbon	120	1.95	1	2	2	4

*Standardized size of wire and monofilament material in Japan

seven different hook line materials with four different historical hook line materials used in the tuna longline operation and their characteristics. The materials were consisted of three types of wire and nylon monofilament and one fluorocarbon monofilament. Each material was prepared for three operated history in the fishing; "a new" (no use), "1 day-operated" and "7 days-operated" hook line samples, and the hook lines which caught fish hereinafter called "catch line", respectively. A number of the new sample line was only one line for each material compared to two used sample lines because optical characteristics of the new sample lines are about constant. For the catch line, only the good condition lines without twisting or bending were used in the experiments.

2) Methods

The tuna longline fishing operations were carried out by T/S Shinyo-Maru in the Bay of Bengal during the 13–19th of Feb., 1996. Fig. 1 shows seven fishing grounds for the tuna longline operation. In each operation, one hundred baskets were used including seven materials of hook line; six hook lines per basket. The arrangement of the seven materials of hook line is shown in Fig. 2; each material was set for two baskets continuously. After the first tuna longline operation, two hook lines from each materials were collected as "1 day-

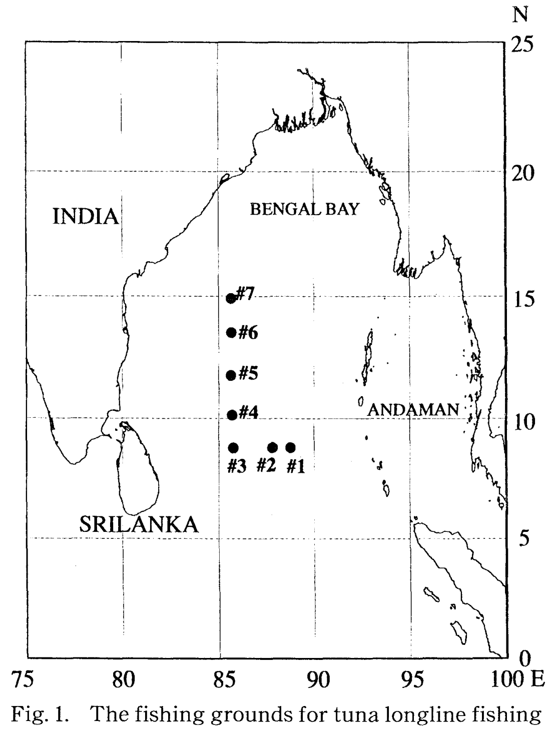

Fig. 1. The fishing grounds for tuna longline fishing operation; figures from #1 to #7 denote seven fishing operations, respectively.

operated" experimental samples. They were rinsed materials were collected as "1 day-operated" experimental samples. They were rinsed with freshwater and dried in shade before being kept in cool conditions. By the same

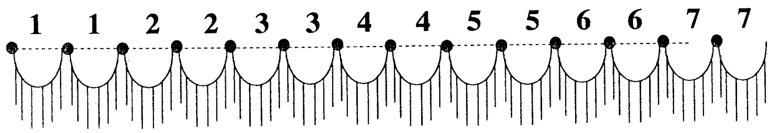

Fig. 2. Diagram of structure in tuna longline fishing gear used. The number 1, 2, 3, 4, 5, 6 and 7 represent seven hook line materials of zinc-alumi-plated wire, zinc-plated wire, red color-coated wire, common white-colored nylon monofilament, flexible white-colored nylon monofilament, light gray-colored nylon monofilament, and fluorocarbon monofilament, respectively.

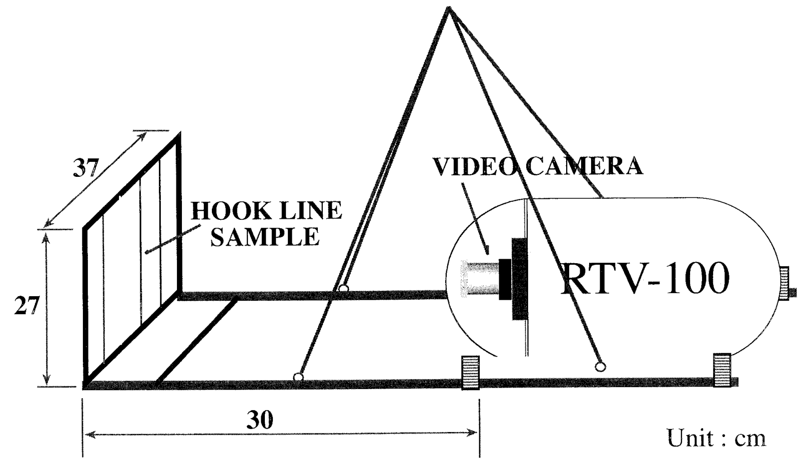

Fig. 3. Instrument for taking an underwater image of hook line samples.

method used in fishing, after seven days the other two lines from each material were collected as "7 days-operated" samples. Furthermore, the hook lines, which caught fish in each fishing operation, were also kept as "catch line" samples; length, weight and species of fish were recorded for every "catch line". These used-line samples were kept for measuring of their apparent contrast.

3) Underwater video image

An underwater video image of the samples was taken during the cruise of T/S Seiyo-Maru of the Tokyo University of Fisheries in the Sagami Bay on the 23rd of May, 1996. The video camera (Nikon Type-5) was set inside the water-proofed case of the Remotely Operated Vehicle (ROV) model "RTV100". Fig. 3 shows arrangement and method to measure the underwater video image of the samples. Due to the visibility of video camera and the small size of the samples diameter being less than 1.95 mm, the distance between the samples and the ROV-video camera was fixed as short as possible at 30 cm. The interval distances between each sample were 7cm apart. The light transmittance (%) in the waters during the experiment was measured by using the STD transmissometer (wavelength 540 nm). As shown in Fig. 4, the profile of light transmittance (%) in the waters of the Sagami Bay clearly shows that the transmittance 85.57% (beam attenuation coefficient; 0.16 m^{-1}) at the depth of 10m reduced to 76.96% (beam attenuation coefficient; 0.26 m^{-1}) at the depth of 17 m. It was overcast sky where the direct light was hardly observed and the irradiance was ranged from 30,000 lx to 50,000 lx on deck. From a forementioned circumstances, the video image was taken up to the depth of 20 m.

The sea conditions such as wave level measured at 3, and wind forces measured at 4 on the

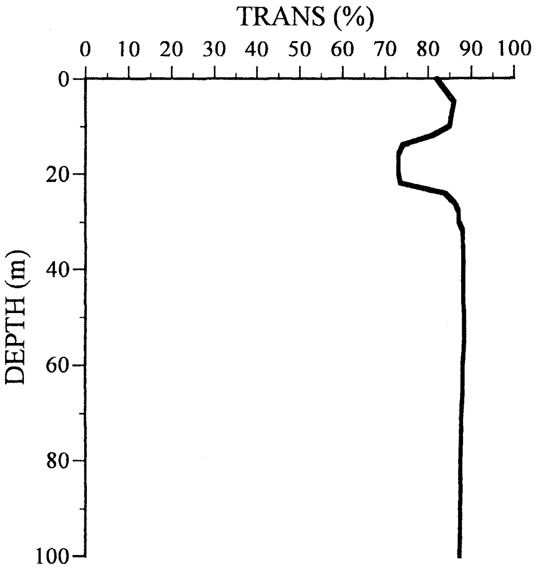

Fig. 4. The profile of light transmittance (%) in the waters of the Sagami Bay.

Beaufort scale were also observed, respectively. In order to prevent bubbles from occurring on the sample line during the experiment, all of the sample lines were soaked in sea water for about 3h.

4) Underwater video image with different distances

An underwater video image of all seven materials with different distances was also taken by two divers in the waters off the Banda Marine Laboratory of the Tokyo University of Fisheries on the 28th of May, 1996. The distances of hook line apart from video camera were changed five steps at 30, 60, 90, 120, and 150 cm, and each step of recording time was 10 s. The vedeo image measurement of these materials was made by an underwater video camera (CCDTR 850, SONY) at the depth of 6m from surface where the water bottom depth was about 10 m. It was cloudy weather where the direct light was hardly observed and the irradiance was 50,000*lx* on deck. The beam attenuation coefficient α (m^{-1}) was calculated to be 0.28m^{-1}, which was defined as shown in the equation (1) (DUNTLEY, 1963)

$$C_{(r_2)} = C_{(r_1)} e^{-\alpha(r_2 - r_1)} \qquad \cdots\cdots(1)$$

where C denote the contrast value at different distances between r_1 and r_2.

5) Underwater apparent contrast

Video image of all materials were captured by video capture soft ware and saved as document file as shown in Fig. 5. The NIF IMAGE 1.55 software was used to measure the brightness value of the sample T_g against its surrounding background B_g. Five positions on each sample were measured to calculate an average value.

In this study, the apparent contrast C_l of sample can be defined as shown in the equation (2) (HIOKI, 1981).

$$C_\ell = \frac{T_l - B_\ell}{T_\ell - B_\ell} \qquad \cdots\cdots(2)$$

where T_l and B_l represent the luminance of sample and surrounding background, respectively.

Then, the video image contrast C_g can also be defined as the function of the brightness value of sample T_g and its background B_g as shown in the equation (3) (NAKAMURA *et al.*, 1995a).

$$C_g = \frac{T_g - B_g}{T_g - B_g} \qquad \cdots\cdots(3)$$

The coefficient of correlation between apparent contrast C_l and video image contrast C_g being high to be 0.95 under the illmination intensities of 40*lx* and over, the relationship between them can be defined as shown in the equation (4) (NAKAMURA *et al.*, 1995 b).

$$C_l = 0.134 \ln C_g + 0.933 \qquad \cdots\cdots(4)$$

According to aforementioned methods, the underwater apparent contrast of each material was estimated.

3. Results

1) Apparent contrasts of hook line material at different conditions

Figure 6 show the apparent contrasts of all hook line materials for the new line in comparison with the 1 day-operated, the 7 days-operated and the catchlines.

Figure 6–a shows the apparent contrasts of the new hook lines. The apparent contrasts of the new wire materials are higher than new

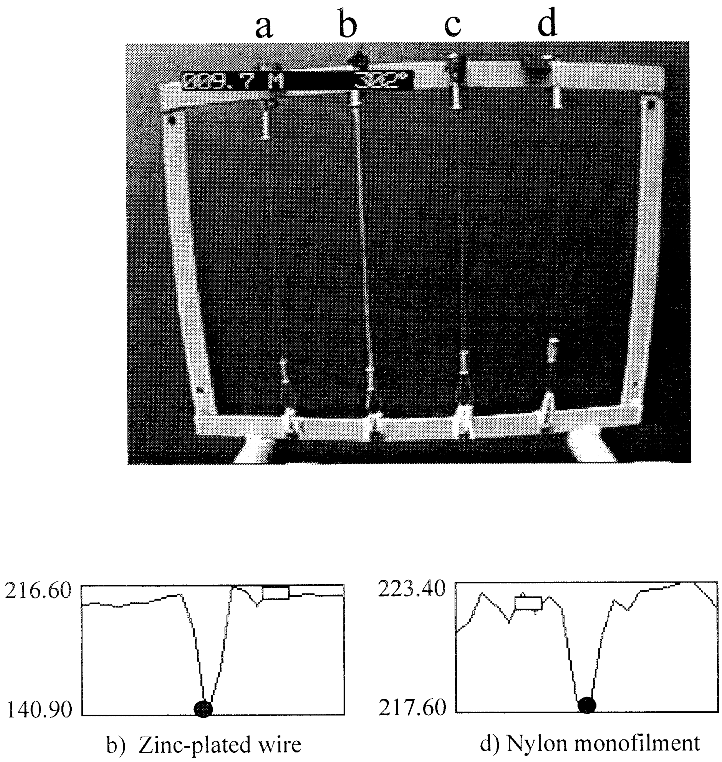

Fig. 5. The image of hook line samples (upper) and measurement of their brightness value with their background (lower).
Symbols a, b, c and d represent hook line samples.
Sumbols ● and □ denote measuring point of hook line sample and background, respectively.

nylon monofilament and fluorocarbon monofilament. Among the wire materials, the apparent contrast of zinc-plated wire is the highest and that of zinc-alumi-plated wire is the lowest. Among the nylon and fluorocarbon monofilament, the apparent contrast of the common nylon monofilament being the highest, that of light gray-colored nylon monofilament is the lowest.

Figure 6–b shows the apparent contrast of 1 day-operated hook line materials. The apparent contrast of 1 day-operated materials is rather lower than that of new materials. The apparent contrasts of 1 day-operated wire materials are distinctly higher than that of the nylon and fluorocarbon monofilament compared with that of new materials. The apparent contrast of the fluorocarbon monofilament is the lowest among all of them. In addition the apparent contrast of the light gray-colored nylon monofilament is two times higher compared to that of the new material.

Figure 6–c shows the apparent contrasts of 7 days-operated hook line materials. The apparent contrast of 7 days-operated material is rather higher than that of 1 day-operated materials. The apparent contrasts of wires are still higher than that of the nylon and fluorocarbon monofilaments.

Figure 6–d shows the apparent contrasts of catch line; the apparent contrasts of all wire materials and the common white nylon monofilament could not be measured due to the bending and twisting which occurred in the fishing operation. The apparent contrasts of the remaining nylon and fluorocarbon

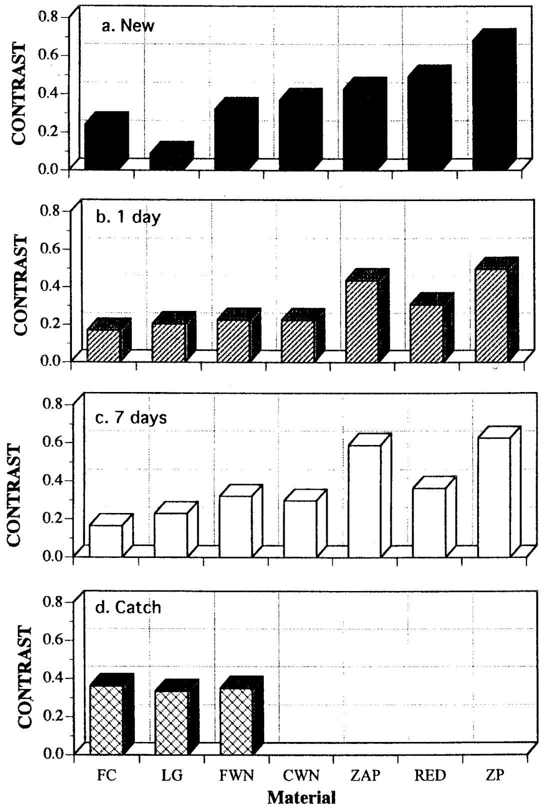

Fig. 6. Apparent contrasts of all materials of sample for the new (a), 1 day-operated (b), 7 days-operated (c) and the catch lines (d).
Symbols FC, LG, FWN, CWN, ZAP, RED and ZP denote hook line materials of fluorocarbon monofilament, light gray-colored nylon monofilament, flexible white-colored nylon monofilament, common white-colored nylon monofilament, zinc-alumi-plated wire, red color-coated wire and zinc-plated wire, respectively.

monofilament catch lines are distinctly higher than that of new, 1 day-and 7 days-operated materials.

These show very clearly that the apparent contrasts of all kinds of wire material are higher than that of the nylon and fluorocarbon monofilaments. Among new hook line materials, the apparent contrast of the light gray-colored is the lowest but it increases when the history is changed to 1 day and 7 days operations. This is the contrary result of the fluorocarbon monofilament whose apparent contrast of new material is higher than that of 1 day-and 7 days-operated materials.

2) Influence of the light transmittance in the water to the apparent contrast

Figure 7 shows the apparent contrasts of all hook line materials for different transmittances of 85.57% and 76.96%, respectively. Regarding this decreasing of the transmittance, it is understood that the apparent contrasts of the hook line materials were also affected. Especially the apparent contrast of wire materials decreases in proportion to decreasing the transmittance. In the case of 1 day-and 7 days-operated nylon and fluorocarbon monofilament, their apparent contrasts seem to be hardly changed with different levels of the transmittance.

3) Apparent contrast with different distances

From the visual observation by two divers it was found that the new fluorocarbon monofilament was poorly visible in the water when compared with the new zinc-alumi-plated wire. Fig.8 shows an example of the apparent contrasts of new zinc-alumi-plated wire

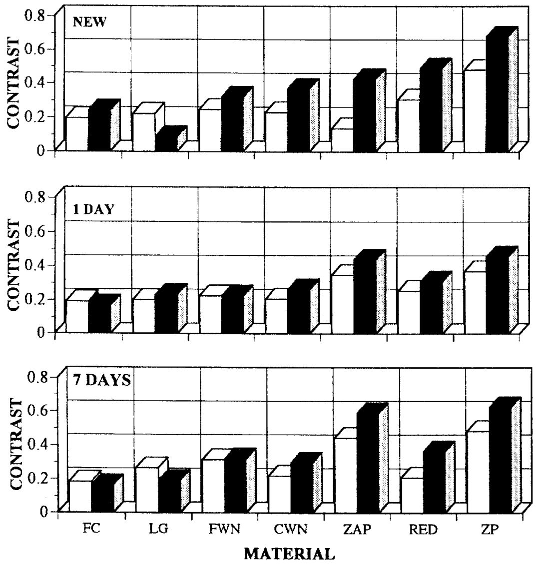

Fig. 7. Apparent contrasts of all materials for the new, 1 day used, 7 days used with different level of transmittance at the depth of 10m and 17m, respectively. Symbols FC, LG, FWN, CWN, ZAP, RED and ZP are same as in Fig. 6.
Symbols ■ and □ denote the transmittance of 85.57% (10m) and 76.96% (17m), respectively.

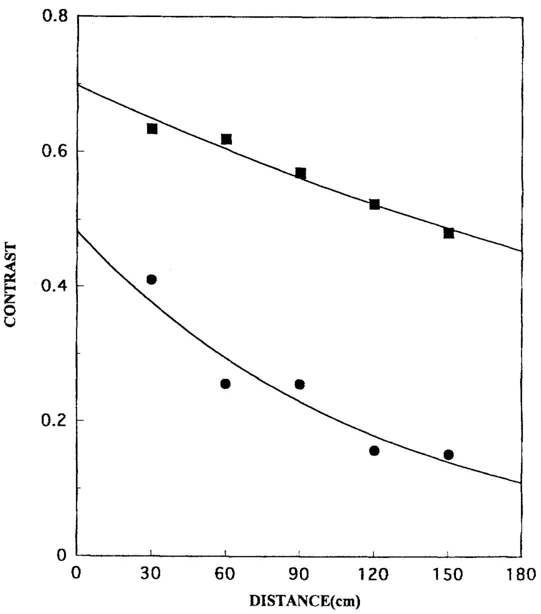

Fig. 8. Relation between the apparent contrast of hook line and the video recording distance. Symbols ■ and ● denote hook line materials of the new zinc-alumi plated wire and fluorocarbon monofilament, respectively.

and fluorocarbon monofilament according to the video recording distance. The beam attenuation coefficient was calculated to be 0.28 m^{-1} by the equation (1). From the figure, the apparent contrasts of zinc-alumi-plated wire are larger than that of fluorocarbon monofilament materials, which seems to support the result from visual observation. The apparent contrast of both materials also decreases as the distance increases. In addition the apparent contrast of the zinc-alumi-plated wire steadily decreases by the distance.

4. Discussion

1) Apparent contrast of 1 day-operated hook line materials

In the squid jigging operation nylon monofilament being used as jigging line, its luminance value (cd/m^2) increased for 3 days-operated; with higher increased for 7 days-operated material (NAKAMURA *et al.*, 1990 b). It is understood that the apparent contrast increases as luminance value increases, in case of the constant background luminance.

From the results in Fig. 6, it is shown that the apparent contrasts of the 1 day-operated hook line materials are lower than that of the new hook line materials in tuna longline. This is a different result from the results on the squid jigging lines. In order to clarify the apparent contrast of the 1 day-operated hook line, its standard deviation is studied. As shown in Table 2, the standard deviations of the apparent contrast are two times larger in the 1 day-operated hook line material than that in the new one; also larger than that in the 7 days-operated one. In this case we understands the mean value of apparent contrast to be small, even though the apparent contrast value varies largely. This large standard deviation of materials means that they stimulate the vision of fishes.

2) Catch analysis related to hook line materials

Figure 9 shows the number and fish species caught related to the materials used as hook lines during seven days operations. Due to the catch result it is clear that the nylon and fluorocarbon monofilament hook lines are better than wire ones. It is also noted that tunas are caught by nylon and fluorocarbon monofilament hook line only. As shown in Fig. 6, with the apparent contrast of the nylon and

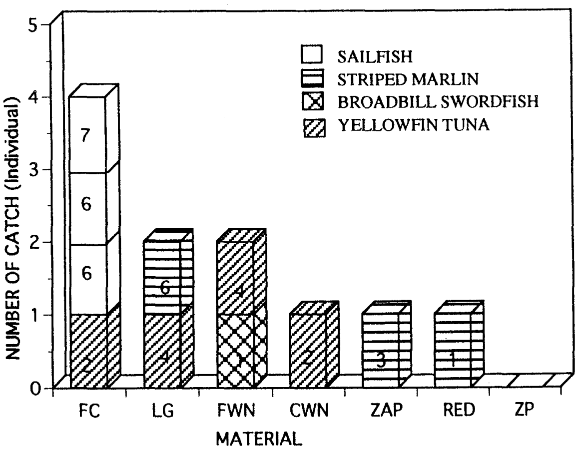

Fig. 9. Number of catch related to hook line materials. A numerical number inside the bar represents the used days of hook line in tuna long line fishing operation. Symbols FC, LG, FWN, CWN, ZP, RED and ZAP are same as in Fig. 6.

Table 2. The mean apparent contrast and standard diviation (SD) of all materials for the new, 1 day used, 7 days used and the catch.

SAMPLES	NEW		1 DAY		7 DAYS		Catch	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Zinc-alumi-plated wire	0.426	0.030	0.437	0.062	0.588	0.034		
Zinc-plated wire	0.682	0.032	0.497	0.060	0.625	0.033		
Red color-coated wire	0.491	0.045	0.308	0.105	0.363	0.043		
Common white-colored nylon	0.367	0.071	0.224	0.112	0.296	0.013		
Flexble white-colored nylon	0.319	0.032	0.225	0.086	0.320	0.060	0.347	0.097
Light grey-colored nylon	0.088	0.021	0.205	0.056	0.229	0.101	0.333	0.027
Fluorocarbon	0.240	0.113	0.169	0.069	0.164	0.050	0.361	0.054

fluorocarbon monofilament hook line being smaller than that of wire one, it is considered that fish are caught by the hook line materials having poor apparent contrast.

Besides, only the 5 and 6 days-operated hook line of fluorocarbon monofilament still could be utilized to catch other species but not for the 4 days-or longer days-operated wire one. With respect to these aforementioned it can be said that the fluorocarbon monofilament is a highly effective material used for the hook line in tuna longline fishing.

3) Sighting range of tunas on the hook line

The value of visual contrast threshold for tuna is not informed, so the value for cod *Gadus morhua* L is applied to tuna; it is reported to be 0.02 (ANTHONY, 1981) which is defined as shown in the equation (5).

$$C=\frac{T_l-B_l}{B_l} \quad \cdots\cdots (5)$$

where C, T_l and B_l represent the apparent contrast, luminance value of sample and surrounding background, respectively.

These are changed by increasing the distance between target and fish eyes. The apparent contrast is decreased by increasing the distance and reaches the visual contrast The relationship between C and C_l from the equation (2) can be defined as shown in the equation (6).

$$C_l=\frac{C}{C+2} \quad \cdots\cdots (6)$$

According to the equation (6), C being 0.02, C_l is calculated to be about 0.01. As shown in Fig. 8, the apparent contrast value is decreased with the increasing of distance; apparent contrast reaches to 0.01 at the distance which is defined as the sighting range of the tuna. For example, the sighting rages of tuna on the new fluorocarbon monofilament and zinc-alumi-plated wire are calculated to be about 5m and 2m in the $0.28\mathrm{m}^{-1}$ of turbid water, respectively.

Acknowledgement

We are most grateful to the Captain Mr. Y. TAKASU and Boatswain Mr. Y. SAITO of Shinyo-maru for their most generous cooperation. We also express our thanks to Misses. N. HANAMURA and K. MORI for their cooperation.

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Received December 4, 1998
Accepted June 10, 1999