イルカ類の漁具素材の認知に関する基礎的考察

A basic study on recognition for fishing gear's material by porpoise

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はじめに

北太平洋漁業国際委員会（ＩＮＰＦＣ）は、我が国の主要漁業の一つであるサケ・マス流網漁業で混獲される海産ほ乳動物（主としてイシイルカ Phocaena dallii True）に対する混獲防止を強く要求している。

これに対応して、中空糸、音波発生器といった混獲防止に有効と思われる機器などが考案され、その有効性が実証されつつある。

これら混獲防止措置の効果を更に高める、あるいは新たな混獲防止機器の研究・開発を図るには混獲される海産ほ乳動物の視覚、聴覚の能力、とくに流網を構成している網糸、網地に対する認知、識別能力を確めることが必要である。

主たる混獲ほ乳動物であるイルカ類が視覚、聴覚によって餌、障害物を認知し、形象物、色などを識別する能力を有することは多くの実験、研究によって明らかにされている。しかし、網糸、網地といった漁具素材の糸の太さ、色、あるいは目合などが変化した場合の認知、識別能力について取り扱ったものは見当らない。

本報告は、イシイルカの漁具素材に対する認知、識別能力を確める基礎的資料を得る目的で行っているイシイルカと同じ北方系のシロイルカ（Delphinapterus leucus）を供試イルカとした実験の一部である。

本実験では、1　単一の素材の網地と一部に中空糸を編網した網地の２種の網地の目合を変えた場合

2　供試イルカのエコーロケーションの能力を遮断して網糸、網地の糸の太さ、色を変えた場合

以上について認知実験を行い、各種網糸、網地を正しく認知した回数と認知に要した時間を計測した。

各計測を統計処理して認知能力を検定した。

供試イルカは千葉県鴨川シーワールドで1976年9月に飼育を開始したシロイルカで予め実験装置に備えた網糸、網地を認めた場合に認知動作（実験装置に吻タッチ）を行うよう"条件付け"訓練を施してある。

実験水槽　実験を行った鴨川シーワールド飼育水槽を示す（図1）。

水槽内には実験装置を供試イルカのスタートラインから7.0 mの位置に備えた。

水槽内の水中照度は、340～650ルックスであった。

実験装置　実験1では塩化ビニール管で60.5×40.0 cmの3個の枠を設けた。任意の枠の1つに各種の網地を張った。

実験2では供試イルカのエコーロケーションの能力を遮断するため、前面に透明アクリル板（厚さ5.0 mm）2枚に挟まれた透明ガラス板（厚さ5.0 mm）、後面に透明アクリル板（厚さ5.0 mm）1枚を取り付けた115.0×53.0×18.0 cmの木製の箱を設置した。箱の内部は中央で2つに区分してある。任意の一方の区分に各種網糸、網地を着装した。

なお、本実験で用いた各種網糸、網地の繊維はモノフィラメントである。

実験装置の模式図を示す。（図2）

結果と考察

実験1　単一素材の網地（以下、網地1という）、一部（枠の面積の1／3）に中空糸を編網した網地（以下、網地2という、網地1、2とも糸の太さ0.6 mm）の目合3.0、6.0、9.0、11.0 cm、計8種の網地について、それぞれ40回認知実験を行った。

正しく認知した回数とその割合を示す（表1）。

各網地の正誤認知動作回数をX^2検定した結果は、網地2、目合6.0 cmの場合を除いて有意（有意水準95 %、以下、同じ）となり、供試イルカはほとんどの網地の存在を確実に認知するといえる。

畠山らは、バンドウイルカのクリックである周波数75 KHzの超音波による単一素材の網地と一部に中空糸を編網した網地の反射損失を測定して、中空糸を編網した網地の反射損失が小さいことを確めた。本実験では供試イルカのクリックに対する各網地の反射損失を測定していないが、反射損失が畠山らの実験結果と同様であるとすると、網地2は網地1に比べて認知が容易であると考えられる。したがって、網地2、目合6.0 cmの場合の本実験の結果は肯けない。供試イルカの精神状態、あるいは疲労といった何らかの理由に起因することも考えられる。同網地については以下の検討から除いた。

供試イルカがスタートして認知動作を行うまでの所要時間（以下、認知時間という）が認知の難易を示しているものとして、正しく認知した場合の認知時間を計測した。

認知時間の平均値、標準偏差を示す（表２）。

網地１、２とも目合が大となるにしたがって認知時間は短い（ただし、網地1、目合3.0 cm は当らない）。同じ素材の網地の場合には目合が大きい程容易に認知する傾向が認められる。同じ目合の網地１、２の認知時間は、すべての目合で網地２が短い。中空糸の編網が認知を容易にしていることがうかがえる。しかし、この場合の認知時間の平均値の差の検定結果は有意水準が低く、中空糸の編網が認知を容易にすると断定はできない。

実験2. 実験２は供試イルカの視覚のみによる網糸、網地の認知能力を確めることを目的としている。

実験装置に用いたアクリル板、ガラス板の超音波透過率を示す（図３）。

供試イルカの飼育水槽内でのクリックの周波数は主として 80 − 100 K Hz である。したがって、アクリル板は約 85 − 90 %、ガラス板は約 35 − 40 %の透過率となる。

また反射波の小さい物体（網糸、網地……反射損失 55 dB 以上）が反射波の大きい２個の物体（アクリル・ガラス板……反射損失 10 dB 以下）の狭い間にはさまれた状態にある。クリックスが透明板を透過する時減衰することとイルカの強い２個のエコーの間にある微少エコーを分離して認知することは困難であることから、エコーロケーションを遮断しているものと判断した。

白色網糸、網地（目合 6.0 cm）の各種糸の太さ（0.25、0.6、1.2 mm）別、網糸（糸の太さ 0.6 mm）、網地（糸の太さ 0.6 mm、目合 6.0 cm）の各種色（赤、緑、青、黒、白、無色、緑《中空糸》）別にそれぞれ 20 回以上認知実験を行った。

正しく認知した回数とその割合を示す（表３）。

各種網糸、網地の正誤認知動作回数を X^2 検定した。網糸は糸の太さ 0.6、1.2 mm、色赤、青、黒、白、網地は糸の太さ 0.6、1.2 mm、色赤、青、黒、白、無色、緑（中空糸）の場合に有意となり、供試イルカはこれらの網糸、網地の存在を確実に認知するといえる。

糸の太さ 0.25 mm では網糸、網地とも有意水準が低く、糸の太さが細くなると認知が困難になると推察される。しかし、網糸、網地を認知していると認められる糸の太さのいき値は確認していない。網糸では有意水準が低い無色、緑（中空糸）が網地の場合には有意となる。網糸と網地では認知能力に違いがあることを示唆している。

供試イルカはスタートして実験装置の手前で一旦停止した後認知動作を行う。そこで、停止してから認知動作を行うまでに要した時間（以下、この時間を認知時間という）が認知の難易を示しているものとして、正しく認知した場合の認知時間を計測した。

認知時間の平均値、標準偏差を示す（表４）。

認知時間の平均値の差を検定した。

網糸、網地とも糸の太さ 0.6、1.2 mm の場合には糸の太さが太いとき認知時間は短いが有意な差はない。同じ太さの網糸と網地では有意となり、網地が網糸に比べ認知が容易であることが認められた。

網糸、網地の色別の検定結果を示す（表５）。

網糸は、黒、赤、青、白の順に認知時間が長くなるが、その差は黒と白との間のみ有意である。網地は、赤、黒、白、青、緑（中空糸）、無色の順に認知時間が長い。赤と青、無色、緑(中空糸)、黒と青、緑（中空糸）の間で有意である。色によって認知能力に違いがあるといえよう。

また、同色の網糸と網地では網糸を認知したすべての色で有意となり、この場合も網地が網糸に比べ認知が容易であることが解った。

本実験を行うにあたり、供試イルカの提供、”条件付け”訓練に多大の御協力を頂いた鴨川シーワールド鳥羽山館長、海獣展示課の諸氏に深謝致します。

Table 1. Number of recoginition of two type netting

Mesh	Netting 1			Netting 2		
	Number of experiment	Number of recoginition	Rate of recoginition	Number of experiment	Number of recoginition	Rate of recoginition
3.0 cm	40	24	60.0%	40	25	62.5
6.0	40	28	70.0	40	16	40.0
9.0	40	23	57.5	40	33	82.5
11.0	40	24	60.0	40	24	60.0

Netting 1 : Unity material

Netting 2 : Partly hollow tube strands

Table 2. Necessary time of recoginition of average and standard deviation (Two type)

Mesh		Netting 1	Netting 2
3.0cm	Average	5.66 sec	5.51 sec
	Standard deviation	0.58	0.54
6.0	Average	6.07	
	Standard deviation	1.06	
9.0	Average	5.72	5.29
	Standard deviation	1.05	0.55
11.0	Average	4.80	4.75
	Standard deviation	0.42	0.57

Netting 1 : Unity material

Netting 2 : Partly hollow tube strands

Table 3. Number of recoginition of each thickness and color of netting cord and netting

Thickness of cord	Netting 1			Netting 2		
	Number of experiment	Number of recoginition	Rate of recoginition	Number of experiment	Number of recoginition	Rate of recoginition
1.2 mm	27	26	96.3%	20	20	100.0%
0.5	20	17	85.0	20	14	70.0
0.25	20	13	65.0	20	11	55.0

Color	Netting 1			Netting 2		
	Number of experiment	Number of recoginition	Rate of recoginition	Number of experiment	Number of recoginition	Rate of recoginition
Red	21	21	100.0%	20	20	100.0%
Blue	21	21	100.0	20	19	95.0
Black	21	21	100.0	20	19	100.0
White	21	18	85.7	20	20	100.0.
Green	20	11	55.0	20	12	60.0
Colorness	20	11	55.0	20	19	95.0
Green *	20	11	55.0	20	18	90.0

* Hollow tube strands

Table 4. Average necessary time of each thickness and color of netting cord

Thickness of cord		Netting cord Stop--Recoginition	Netting Stop--recoginition
1.2 mm	Average	1.84 sec	1.41 sec
	Standard deviation	0.53	0.50
0.6	A	2.04	1.52
	S.D	0.52	0.47

Color		Netting cord	Netting
Red	A	1.61sec	0.95sec
	S.D	0.50	0.18
Blue	A	1.63	1.21
	S.D	0.41	0.29
Black	A	1.53	1.02
	S.D	0.42	0.25
White	A	1.87	1.13
	S.D	0.61	0.50
Green	A		
	S.D		
Colorless	A		1.24
	S.D		0.48
Green *	A		1.22
	S.D		0.29

* Hollow tube strands

Table 5. Examination of difference of average necessaeytime of each thickness and color of netting cord and netting

Nettin cordg

	Red	Blue	Black	White
Red		0.142	0.567	1.502
Blue			0.794	1.491
Black				2.112
White			•	

Z (upper right) / RESULT (lower left)

• : Significance (Z ≧ 1.96)

Netting

	Red	Blue	Black	White	Colorless	Green *
Red		2.92	0.99	1.48	2.46	3.21
Blue	•		2.38	0.62	0.24	0.12
Black		•		0.87	1.8	2.25
White					0.7	0.67
C	•					0.15
Green *	•		•			

Z (upper right) / RESULT (lower left)

• : Significance (Z ≧ 1.96)

* Hollow tube strands

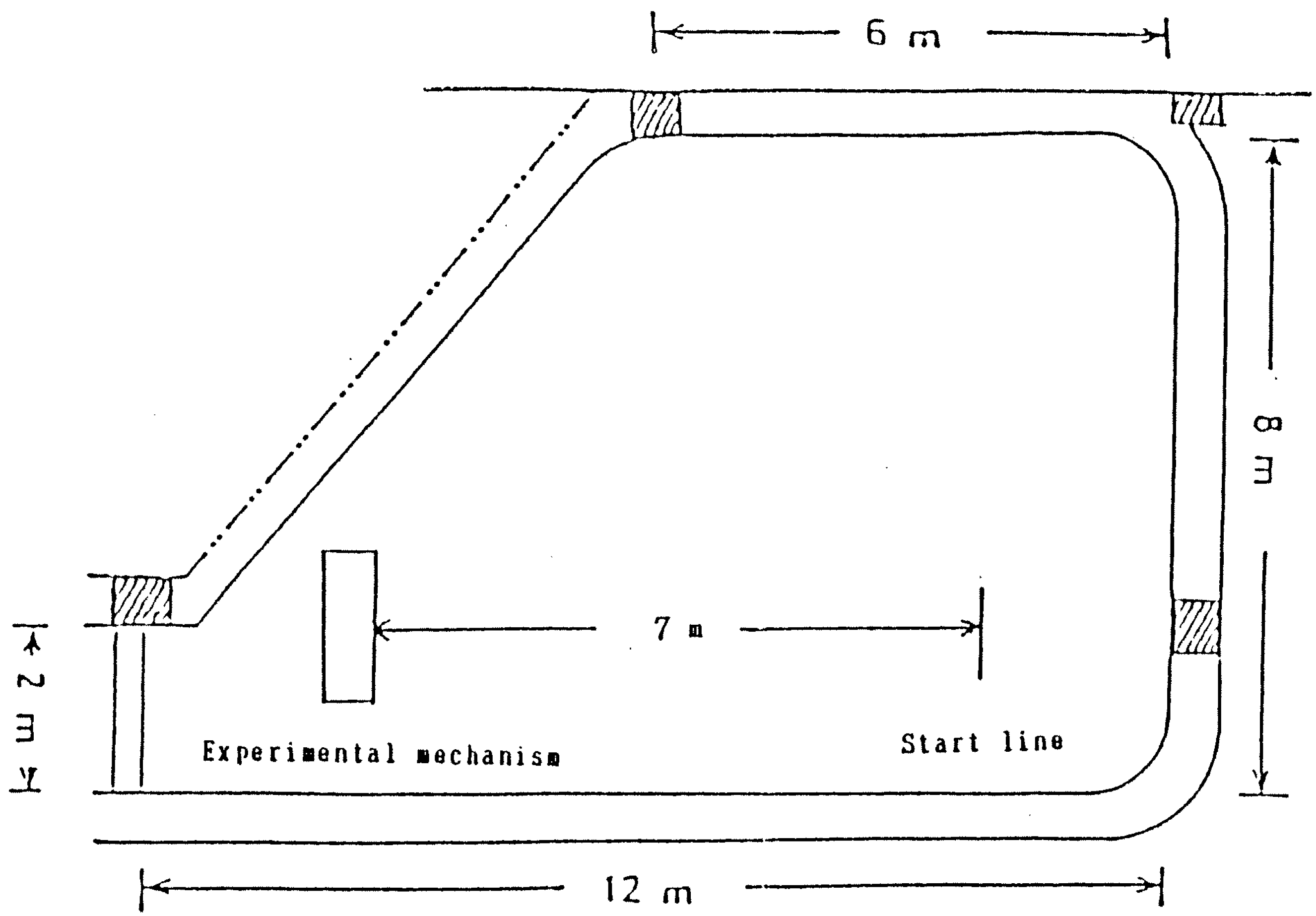
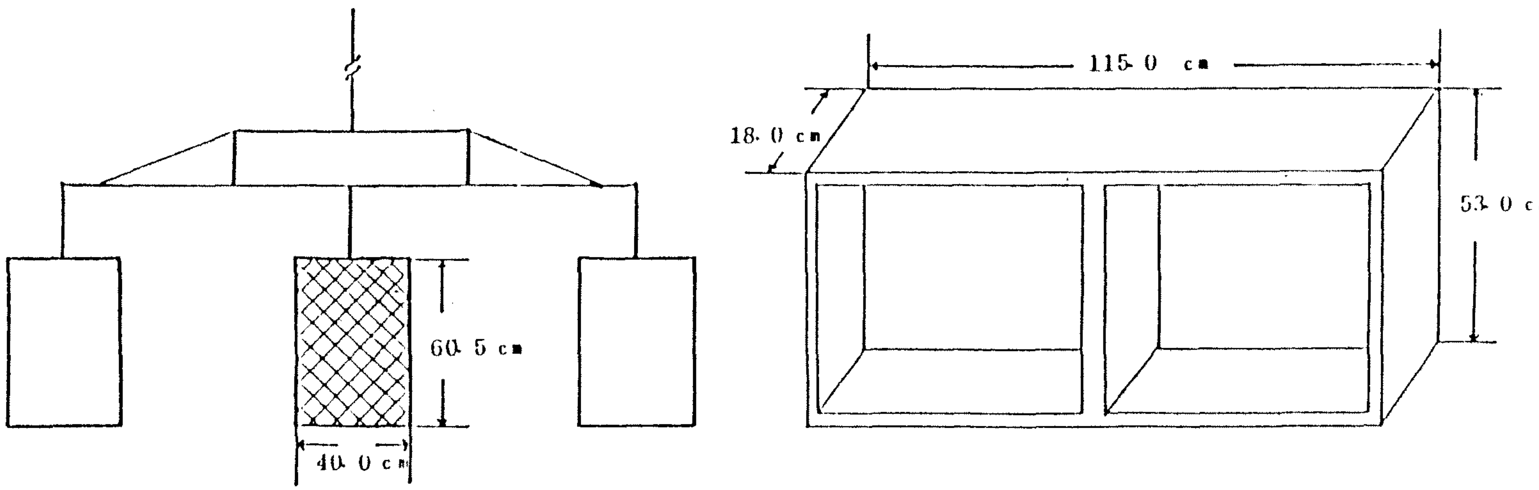


Fig. 1. REARING POOL (KAMOGAWA SEA WORLD MAEINE THEATER)



EXPERIMENT 1 EXPERIMENT 2

Fig. 2. EXPERIMENTAL MECHANISM

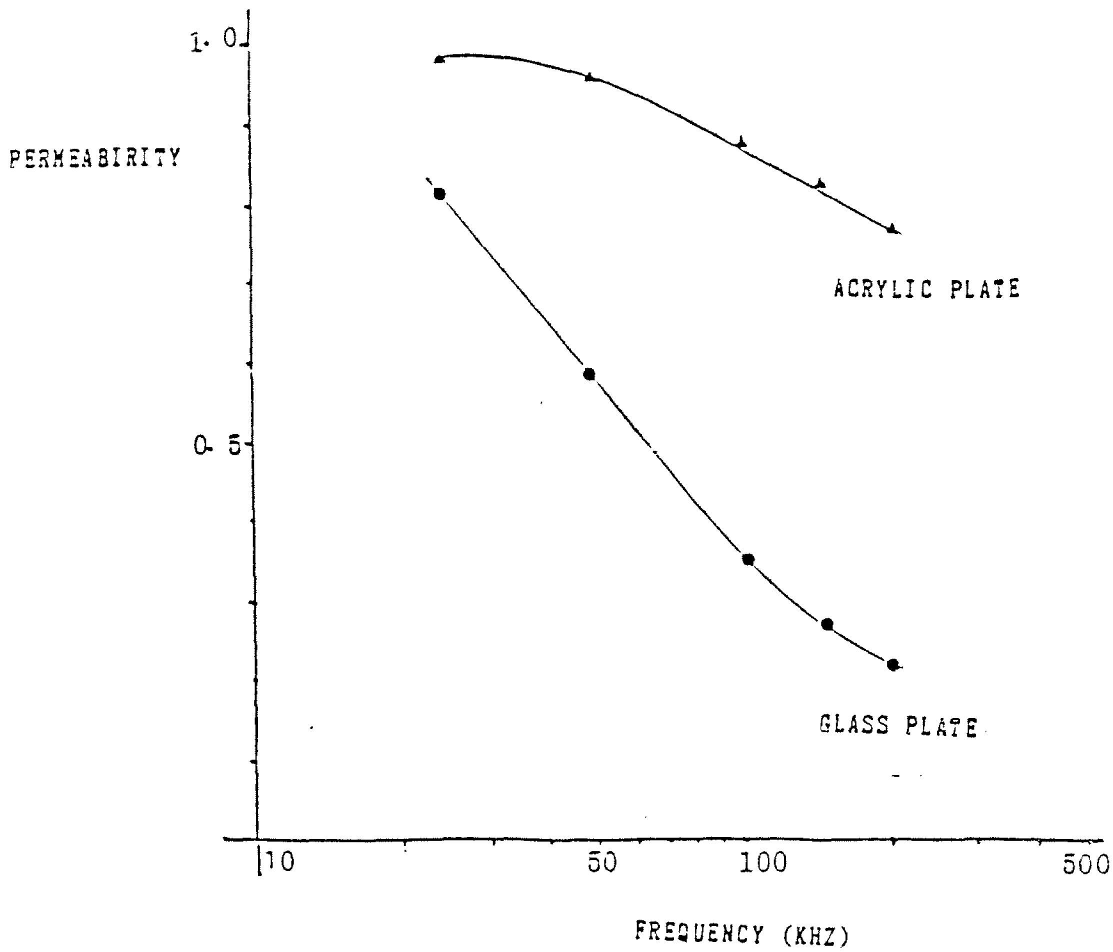


Fig.3. Permeability of supersonic waves of aqrylic plate and glass plate

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TRANSLATION

BASIC STUDIES ON RECOGNITION OF GEAR MATERIALS BY PORPOISES

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Introduction

The International North Pacific Fisheries Commission requires prevention of incidental catch of marine mammals (principally Dall's porpoise (*Phocoenoides dalli*)) in the salmon gillnet fishery which is one of Japan's major fisheries.

To meet this requirement, the gear or equipment such as air tube thread net, sound generators, etc., which are deemed effective in preventing incidental catch, have been designed and their effectiveness is being verified.

In order to improve these measures and to attempt to develop new gear or equipment to prevent the incidental catch, it is necessary to examine the visual and auditory sensitivity of porpoise, particularly its ability in recognizing and discriminating between thread of net and net itself.

It has been clarified through a great number of experiments and studies that porpoises, which are the major species of marine mammals caught incidentally, have ability to recognize food and obstacles and to discriminate between shapes and colors by visual and auditory sensations. However, studies have not been done which deal with ability of porpoise to recognize and discriminate net material such as thread of net and net by thickness of thread, color, or mesh size.

This report describes a part of the study which is being conducted to obtain basic data on ability of Dall's porpoise in recognizing and discriminating the net materials by using Beluga (*Delphinapterus leucas*) which are found in the North Pacific as is Dall's porpoise.

In this study, the following experiments on recognition were conducted to determine frequencies of correct recognition of threads or nets and time required for recognition were measured by each type.

Experiment 1

Variables	Mesh sizes
Materials	Net of single material threads and net with certain portions woven with air-tube thread

Experiment 2

Variables	Thickness and color of thread
Materials	Thread itself and net

In shutting off echolocation ability of the Beluga

Recognition ability was tested by processing values of measurement statistically.

The porpoise used was a Beluga which has been fed at the Kamogawa Sea World Aquarium since 1976 September and "conditioned" to make the recognition action; trained to touch experiment equipment with the snout when it recognizes the thread or net which is set in the experiment equipment.

Water tank used

An illustration of the water tank of the Kamogawa Sea World Aquarium in which the experiments were made is shown in Fig. 1. The luminous intensity in the water of the tank ranged from 340 to 650 lux. Equipment was set at a distance of 7.0 m from the start line of the porpoise.

Equipment used

In Experiment 1, three frames (60.5 x 40.0 cm) of vinyl-chloride pipe were set and one type of net was stretched on one of the frames chosen randomly. In Experiment 2, in order to shut off the function of echolocation, a wooden box (115.0 x 53.0 x 18.0 cm) was set, the front of which consisted of three panels (a 5.0 mm thick glass panel between 5.0 mm thick acrylic panels) and the back of which was a 5.0 mm thick acrylic panel. The box had a vertical partition in the middle and one combination of color or thread, and thread itself, or net was set in one portion of the inside chosen randomly. All types of threads and nets were monofilament fibers.

Schematic illustrations of experimental equipment are shown in Fig. 2.

Results and discussion

Experiment 1

Recognition experiments were conducted 40 times for each combination of net type and mesh size. There were two net types: (Net 1) composed of single material threads, (Net 2) net type with a portion (one-third of the area enclosed in the frame) woven with air threads (diameter of threads of both types of net was 0.6 mm), four mesh sizes: 3.0, 6.0, 9.0, or 11.0 cm: namely, a total of eight combinations were examined.

Frequencies and rates of correct recognition are shown in Table 1. All results of χ^2-test for frequencies of correct and incorrect recognition actions were significant (at 95% significant levels, hereafter the same) except for the combination of Net 2 and 6.0 cm mesh size, in which it was certain that the porpoise used recognized the existence of most nets.

By measuring the reflection losses of nets composed of single material thread and those woven with air tube threads in certain parts by using 75 kHz supersonic waves, the same frequency as the clicks emitted by Bottlenose dolphin, Hatakeyama et al. verified that the reflection loss of the latter type of net is smaller. Although reflection losses of each type of net for clicks of the porpoise used were not measured in this study, assuming that reflection losses show the same tendency as shown in the results of the study conducted by Hatakeyama et al., recognition is considered to be easier for Net 2 than Net 1. Therefore, it is a question that the results for the combination of Net 2 and 6.0 cm was not significant in this study. This may be attributable to some factors such as state of mind or fatigue of the porpoise. The result for this combination was excluded in the following discussion.

Assuming the time taken by the porpoise from start to recognition action shows difficulty in recognition, recognition time was measured in case the porpoise recognized correctly.

Mean values and standard deviations are shown in Table 2.

For both Net 1 and Net 2, recognition time was shorter as the mesh size became larger except for the combination of Net 1 and 3.0 cm mesh size. There is a tendency that recognition was easier as the mesh size became larger for each type of net. Recognition times for the same mesh size between Net 1 and Net 2 showed a shorter time for Net 2 over all mesh sizes. We may presume that air tube threads woven into the net make recognition easier but we may not make this conclusion because the results of the test for differences in mean values of recognition time were of low significance.

Experiment 2

The purpose of Experiment 2 was to examine the recognition ability for thread or net by vision only.

Supersonic transmission factors of acrylic and glass panels are shown in Fig. 3. Major component of frequency of clicks emitted by the porpoise used in the water tank ranged from 80 to 100 kHz. Therefore, supersonic transmission factors of acrylic and glass panels at this frequency range are about 85 to 90% and about 35 to 40%, respectively.

The objects such as thread or net from which the reflected waves are weak (reflection losses are 55 dB or more) are set between the materials such as acrylic or glass panels from which the reflected waves are strong (reflection losses are 10 dB or less). Since supersonic pulses used in echolocation are attenuated when they pass through the transparent panels and it is difficult for the porpoise to detect distinctively the minute echo which comes between two of the strong echoes, it was concluded that the echolocation was shut off.

By thickness (0.25, 0.6, and 1.2 mm) of white thread of the material [thread itself or net (6 cm mesh size)] or by color [red, green, blue, black, white, colorless, green (air tube thread)] of material [thread (0.6 mm diameter) or net (0.6 mm diameter thread and 6.0 cm mesh size)], recognition experiments were conducted 20 times or more. Frequencies and rates of correct recognition made are shown in Table 3.

For frequencies of correct and incorrect recognition actions, χ^2-test was conducted by each combination of thread diameter or color and thread itself or net. Significant results were observed for thread itself of 0.6 or 1.2 mm diameter or red, blue, black, or white and for net of 0.6 or 1.2 mm diameter threads, or red, black, white, colorless, or green (air tube thread). This suggested that it is certain that the porpoise recognized the existence of these threads or nets.

When 0.25 mm diameter thread was used, the significant levels were low for both thread itself and net. Accordingly, it is presumed that the recognition becomes more difficult as the diameter becomes smaller but we did not examine diameter of thread which is considered as the threshold of recognition of thread itself or net. In the case of colorless or green (air tube), while a low significant level was observed in the results of experiments for thread itself, there is significance in the results for net. This suggests that there is a difference in recognition ability between thread itself and net.

The porpoise made a recognition action after stopping briefly in front of the equipment. Therefore, by assuming the time taken from the stop to recognition action ("recognition time") shows difficulty in recognition, we measured the recognition time when correct recognition was made.

Mean values and standard deviations of recognition times are shown in Table 4. Differences in the mean values were tested. Both the results for thread itself and net indicated that shorter recognition times were observed for the greater diameter with respect to the experiments for 0.6 and 1.2 mm but difference was not significant.

For the same thread diameter, a significant difference was observed between thread itself and net and it was found that net is more easily recognizable compared to thread itself.

Results of the test for thread itself or net by color of thread are shown in Table 5.

For thread itself, recognition time becomes larger in sequence of black, red, blue, and white but a significant difference is observed only between black and white. For net, recognition time becomes larger in sequence of red, black, white, blue, green (air tube), and colorless and significant differences are observed between red and blue, colorless or green (air tube), and black and blue or green (air tube). One may say that recognition ability varies with colors.

Between thread itself and net in the same color, significant differences are observed for all colors where thread itself was recognized. It is found that net is recognized with more ease compared to thread itself.

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TABLES 1 TO 5 AND FIGS. 1 TO 3 ARE IN ENGLISH IN THE JAPANESE DOCUMENT