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TRAP FISHING

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PREFACE

It is said that the demersal resources in coastal waters, particularly those in shallow waters and in flat sea-bottom areas, have already been overexploited. However, we can safely assume that there are many areas, even in coastal waters, where these resources are almost untouched because the excessive depth of water or rough sea bottom make the operation of trawl and gill net gear too difficult. In such areas demersal fishing could most profitably be done by trapping. Fishing by traps is also convenient because it allows even very small vessels to operate at fishing grounds where water is deep or the bottom is rough.

At present, trap fishing is not a wide-spread fishing method. Studies of trap gear should be carried out in order to increase its efficiency and the fishing technique, as well as to find the most rational way to utilize the resources.

The present book includes the results of some studies which were carried out to examine the relationship between the catch and the fishing gear or fishing method.

It is my hope that this book will be used as a textbook or a reference book on trap fishing by the trainees of SEAFDEC, as well as other people engaged in fisheries education and training.

I would like to thank Mrs. Marijana Lee who helped me with the preparation of the present book.

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INTRODUCTION

Fishing is broadly classified into net fishing, line fishing and miscellaneous fishing. Trap (or basket or pot) fishing is included in miscellaneous fishing, and is generally operated on a small scale. Traps are used to catch demersal marine animals.

The construction of fishing gear, i.e. the shape, size and the materials of gear vary from one fishing region to the next and according to target marine animals. In most trapping operations, bait is placed into traps to attract marine animals, but non-baited traps are also used widely. Some species with a positive thigmotaxis tend to gather around the traps and use them as a hiding place; in such cases bait is not absolutely necessary.

1. CHARACTERISTICS OF TRAP FISHING

1.1 Trap fishing gear has high selectivity for species of marine animals.

Norman B. PARKS (1973) compared the catch obtained by using trawl net and trap net.

The number of species caught by trawl gear and trap gear were 32 and 5 respectively. This means that traps were selective for certain species, particularly sablefish. Futhermore, it was found that the mean fork length of sablefish caught by traps was longer than that of sablefish caught by trawl gear. This may be attributed to the fact that the larger sablefish are stronger swimmers, which enables them to avoid or escape from a trawl net. Conversely, the large sablefish are more avericious, therefore they are attracted by baited traps and caught.

1.2 A marine animal captured in a trap is protected from predators such as sharks which cannot enter into the trap. Sometimes, however, it is observed that crabs, lobsters or other trapped animals are eaten by octopus, because octopus can enter into the trap from which its prey cannot escape. In the case of line fishing or gill net fishing, it often happens that some of the captured marine animals are damaged by predators.

Fred W. HOPKINS and Alan J. BEADSLEY (1970) made the following observations on trap fishing.

1.3 Captured marine animals can survive several days in a trap, therefore the freshness of catch is very good.

1.4 While the fishing boat is in port because of engine trouble, stormy weather etc, set-trap fishing gear continues fishing at the fishing ground.

1.5 Operation of trap gear is possible in very deep sea as well as in shallow waters.

1.6 If traps are lost on the sea bottom, they continue the unuseful fishing until the trap gear corrodes and breaks up.

2. CLASSIFICATION OF TRAP FISHING GEAR

Shoichi TAKEUCHI (1981) classified trap fishing gear by the shape of trap and by the marine animals aimed at.

2.1 Classification of trap fishing gear by the shape of trap and its characteristics. (Fig. 1)

2.1.1 Truncated corn-shaped trap

A trap of this shape is stabilized on the sea bottom. Most traps for catching crabs or shrimps in Japan are of this type. A crab trap usually has an entrance on its top part, while in the case of a shrimp trap the entrance is on the side.

2.1.2 Rectangular parallelepiped trap

In the United States traps of this type are used for catching *Chionocetes Opilis, Poralithodes comtochatica* and *Anoplopoma fimbria.*

2.1.3 Semicylindrical trap

Such traps are used in many countries, mainly as lobster traps. In Thailand, large-sized semicylindrical traps with wooden frames are used for catching bottom fish.

2.1.4 Collapsible trap

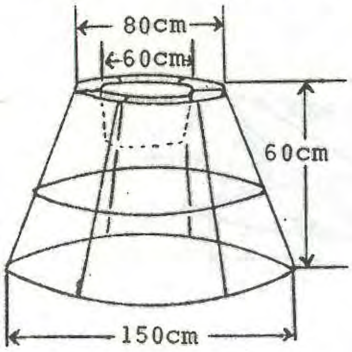
Collapsible traps of any shape have a great advantage in that even a small fishing boat can operate many of them. Blue swimming crabs are caught by this type of trap in Japan.

2.1.5 Others

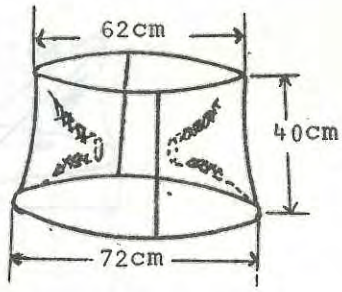
There are many other shapes of traps such as the hemisphere shape, drum shape, scoop shape and various irregular shapes.

Fig. 1 Various trap fishing gear (TAKEUCHI, 1981)

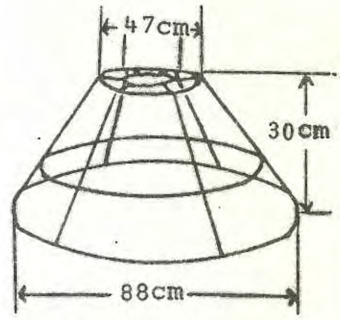
1) Truncated corn-shaped trap



a) Crab trap

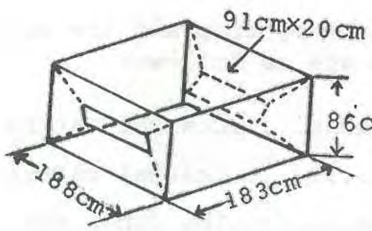


b) Shrimp trap

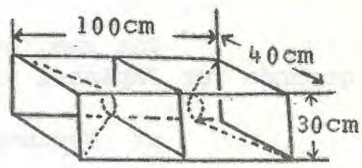


c) Shell trap

2) Rectangular parallelepiped trap

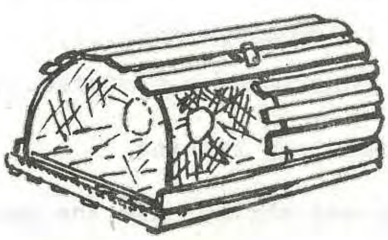


a) Crab trap



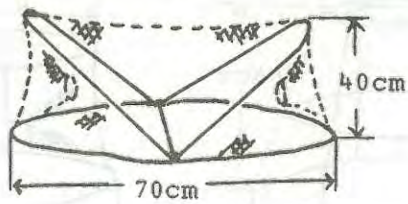
b) Lobster trap

3) Semicylindrical trap



Lobster trap

4) Collapsible trap



Blue swimming crab trap

2.2 Classification of trap fishing by target marine animals

2.2.1 Crab trap fishing

The species of crabs caught by trap and the main fishing grounds for Japanese fishing vessels are as follows:

a) *Neptunus tritubercutatus*.....Coastal waters

b) *Ovalipes punctatus*...........Coastal waters

c) *Chionocetes japonicus*........The Japan Sea

d) *Chionocetes opilio*...........East of Sakhalin Is., and eastern part of the Bering Sea.

e) *Erimacrus isenbeckii*........ "

f) *Lithodes couesi*..............The sea of Okhotsk

g) *Paralithodes platypus*........Oryutoru, Navarin

2.2.2 Shrimp trap fishing

Deep-sea shrimps are the main catch.

a) *Pandalus borealis*............The Japan Sea

b) *Pandalus nipponensis*.........The Japan Sea

c) *Nephrops japonicus*...........Off Japan in the Pacific Ocean

2.2.3 Lobster trap fishing

Lobsters are caught by traps in many countries, but they are caught by gill net in Japan.

2.2.4 Shell trap fishing

a) *Buccinum lenuissimus*

b) *Buccinum tsubai*

c) *Babilonia japoniqa*

These are caught in a coastal waters as well as in deep water in the Bering Sea and the Sea of Okhotsk.

2.2.5 Fish trap fishing

a) *Sphoeroides spadiceus*

b) *Liosaccus pachygaster*

c) *Anplopoma fimbria*

In Japan a) and b) are the main target fish caught by this type of trap, whereas in the United States c) is the main catch.

2.2.6 Octopus and squid trap fishing

3. THE CONSTRUCTION OF TRAP FISHING GEAR AND THE CATCH

3.1 Relationship between the size and/or the shape of trap and the catch

The size and the shape of trap are decided by the following factors:

1) Species of marine animals
2) Easy handling
3) Size of the fishing boat
4) Depth of water

Table 1 shows the shapes and dimensions of various traps used in the world.

Table 1. Shapes and sizes of various traps. (KOIKE, 1981)

Target marine animals	Shape of trap	Diameter or length of bottom	Diameter or length of top	Height
Chionocetes opilio	A	150 cm	80 cm	60 cm
Chionocetes japonicus	A	100-140	75-90	65-120
Neptunus trituberculatus	B	70-82	-	40-42
King crab	C	183-	91	86
Pandalus hypsinolus	A	70	50	32
Pandalus borealis	A	70-95	55-65	21-50
Nephrops japonicus	A	80-100	60-75	47-50
Lobster	C	100	40	30
Spiny lobster	C	81	51	30
American lobster	C	91	64	36
Lobster	B	68	-	51
Puffer	C	50-55	45	30
"	B	40-43	45-55	33-45
Sablefish	C	244-	86	86
Bottom fish	C	183	122	61

A: Truncated corn-shaped trap, B: Semicylindrical trap, C: Rectangular parallelepiped trap.

J.L. (MUNRO (1974) studied the effect of trap size and structure on catch rates by using Antillean fish traps (Fig. 2) in waters off the south coast of Jamaica. According to his findings, when wooden-framed Antillean traps are baited, the shape of the trap is of relatively little importance and the catch is proportional to the size of trap (Table 2).

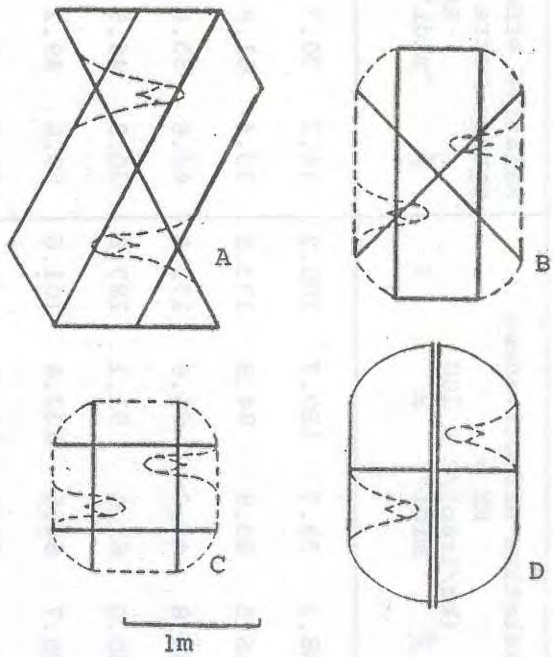


Fig. 2 Plan configuration of four Antillean fish traps; A) Jamaica Z-trap, B) modified Cuban S-trap, C) "midi"-trap, D) stackable S-trap or Ø-trap. Z-, S- and midi-traps have a framework of mangrove or other sticks, while S-traps have a frame constructed of 1.27 cm box section steel. Framework is shown by solid lines and wire mesh-work by broken lines. Maximum aperture of mesh is 4.13 cm. All traps are 61 cm high, but S-traps taper to 51 cm high laterally to permit halves of traps to be stacked. (MUNRO, 1974)

Table 2. Calculation of the comparative catching power or relative effectiveness of baited steel-framed ∅-traps and wooden-framed midi-, S- and Z-traps set for 20-24 h on Pedro Bank, near Jamaica, West Indies. The area in m^2 (X) covered by each trap was ∅, 1.99; Midi, 1.31; S, 2.05; and Z, 2.79 (MUNRO, 1974)

RV "Caranx"	Mean catch rate (kg/trap)				Mean of Midi, S & Z (p)	Relative effectiveness RE = (kg/trap)/P x 100				Relative effectiveness per square metre of trap area RE/X			
Cruise No. & Station	∅	Midi	S	Z		∅	"midi"	S	Z	∅	"midi"	S	Z
1171/4	2.40	1.08	4.10	2.97	2.72	88.2	39.7	150.7	109.2	44.3	30.3	73.5	39.1
1271/4	1.67	2.03	2.13	3.36	2.51	66.5	80.9	84.9	133.9	33.4	61.8	41.4	48.0
1371/2	7.32	3.82	7.30	14.78	8.63	84.8	44.3	84.6	171.3	42.6	33.8	41.3	61.4
1371/4	4.61	6.98	5.85	21.49	11.44	40.3	61.0	51.1	187.8	20.3	46.5	24.9	67.3
1371/6	5.51	3.53	7.32	5.56	5.47	100.7	64.5	133.8	101.6	50.6	49.2	65.3	36.4
1472/5	3.00	2.20	4.31	4.88	3.80	79.0	57.9	113.4	128.4	39.7	44.2	55.3	46.0
1672/1	4.63	4.20	5.76	6.71	5.56	83.3	75.6	103.6	120.7	41.9	57.7	50.5	43.3
1672/3	2.54	3.18	3.51	4.41	3.70	68.6	85.9	94.9	119.2	34.7	65.6	46.3	42.7
Mean	3.96	3.38	5.04	8.02	5.49	76.4	63.7	102.1	134.0	38.4	48.6	49.8	48.0
											48.8 (midi, S, Z)		

Atsushi KOIKE *et al.*[2] (1979) carried out experimental fishing to study the relationship between the size of shrimp traps and the catch (*Pandalus borealis*). Sizes of traps used for this experiment are shown in Fig. 3, and the result of catch is given in Table 3. As shown in Table 3, there was no difference in the amount of catch in large and medium-sized traps, but the catch in small-sized traps was generally less than for the other two sizes of traps.

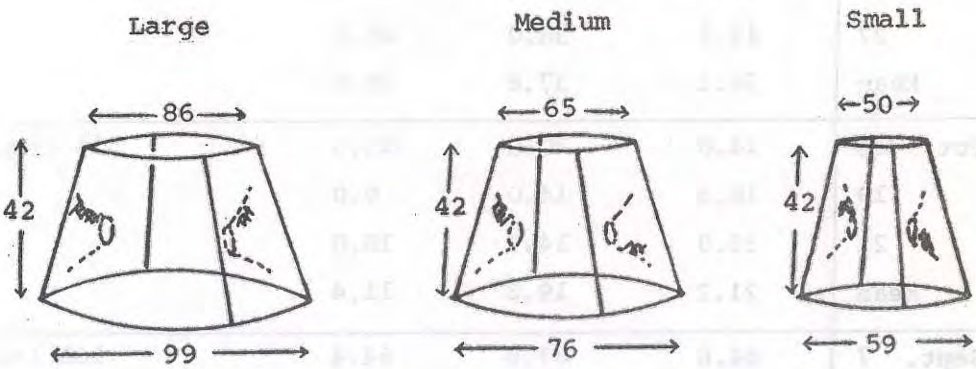


Fig. 3 Sizes and constructions of experimental shrimp traps. (KOIKE *et al.*, 1979)

Table 3. The mean number of pink shrimp catch per trap by different sizes of traps. (KOIKE *et al.*, 1979)

Date		Large trap	Medium trap	Small trap	Total number of traps used
1974	Oct. 20	37.0	37.0	19.0	54 traps
	25	27.7	38.3	39.0	
	27	43.5	38.0	45.2	
	Mean	36.1	37.8	39.9	
1975	Oct. 16	14.0	30.0	15.3	34 traps
	19	16.5	14.0	9.0	
	21	33.0	14.0	10.0	
	Mean	21.2	19.3	11.4	
1976	Sept. 7	84.8	87.6	64.4	162 traps
	9	32.3	46.6	32.8	
	Oct. 19	24.8	39.2	21.9	
	22	27.4	42.1	27.6	
	26	58.9	35.6	19.3	
	28	51.7	51.6	48.1	
	Mean	46.7	50.5	35.7	
1977	Oct. 14	1.7	1.6	1.7	189 traps
	17	22.7	36.7	29.6	
	19	32.2	32.3	30.2	
	21	38.2	26.3	26.2	
	23	7.2	7.3	6.6	
	26	53.3	53.0	41.1	
	28	32.0	34.4	17.6	
	Mean	23.4	24.0	19.1	

It is presumed that, in conditions of high distribution density of shrimps, the saturation point in catch will naturally occur soonest in the case of a small-sized trap. Consequently, in such conditions differences in the amount of catch according to the size of trap are bound to occur.

In order to see whether trap saturation is related to the distribution of density, the catch data shown in Table 3 were devided into two groups. On days when the catch per large-sized trap was more than 32 shrimps, the catch record by each size of trap for that day was marked "large catch", which was considered to be a high distribution density. When the mean catch in large-sized traps was 32 shrimps or less, it was classified as "small catch", which means a low distribution density. These two groups are shown in Table 4. In relatively low distribution density of shrimps, the largest catch was obtained by medium-sized traps whereas there was practically no difference in the amount caught by large and small-sized traps. On the other hand, in conditions of high density of distribution large traps caught more shrimps.

Table 4. The change of the mean number of pink shrimp catch per trap by different sizes of traps according to the amount of catch. (KOIKE *et al.*, 1979)

	Small catch Size of trap			Large catch Size of trap		
	Large	Medium	Small	Large	Medium	Small
	1.7	1.6	1.7	53.3	53.0	41.1
	7.2	7.3	6.6	84.8	87.6	64.4
	14.0	30.0	15.3	58.9	35.6	19.3
	16.5	14.0	9.0	51.7	51.6	48.1
	32.0	34.4	17.6	32.2	32.3	30.2
	22.7	36.7	29.6	38.2	26.3	26.2
	27.7	38.3	39.0	37.0	37.0	19.0
	24.8	39.2	21.9	43.5	38.0	45.2
	27.4	42.1	27.6	33.0	14.0	10.0
				32.3	46.6	32.8
Mean	19.3	27.1	18.7	46.5	42.2	33.6
Ratio	1.00	1.40	0.97	1.00	0.91	0.72

Masatake OKAWARA and Prasert MASTHAWEE (1981) compared the catch of blue swimming crabs in the Gulf of Thailand, using three different sizes of traps. The traps used for this research are illusterated in Fig. 4. The amount of catch in the small-sizes traps was very low compared to that of the medium and large-sized traps (Table 5).

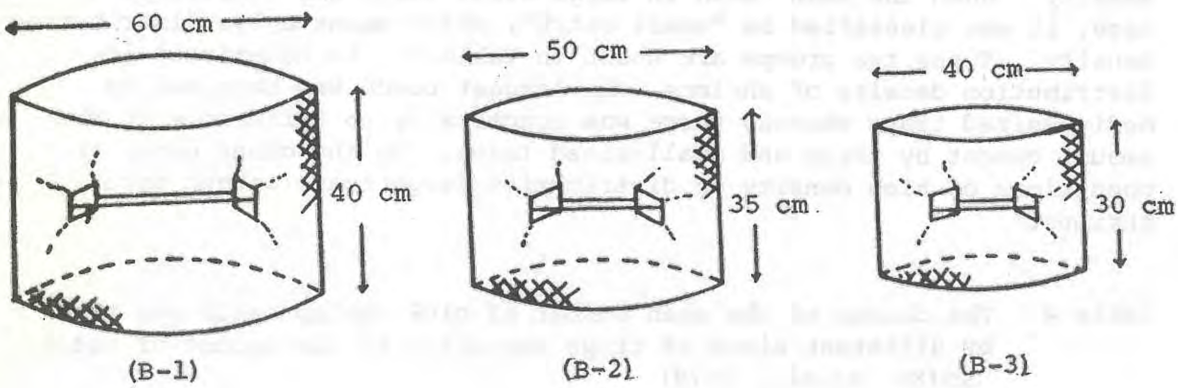


Fig. 4 Three different sizes of traps used for experiment.

Table 5 Number of crabs caught per trap by size of trap

Date	Large(B-1)	Medium(B-2)	Small(B-3)
Feb. 11-12	0.67(12)	1.33(13)	0.33(12)
12-13	0.80(10)	0.50(10)	0.36(8)
15	1.10(10)	1.10(10)	0.22(9)
16	1.13(8)	1.13(8)	1.14(7)
Total	0.90(42)	1.03(40)	0.47(36)

3.2 Relationship between the catch and the size, shape and position of entrance

The entrance hole to a trap should be constructed in such a way that it is easy for a marine animal to get into the trap but difficult to escape. It is therefore important to study factors such as the shape, the size and the position of entrance, which will influence the amount of catch.

A trap fishing experiment to compare the catch efficiency of crab *(Chionocetes japonicus)* trap with three different sizes of entrances, 30, 50, and 70 cm in diameter, was carried out by Yasuo TANINO and Fumihiko KATO (1971).

The number of captured crabs per trap and standard deviation are shown in Fig. 5. It was found that the catch was the smallest in the traps with the entrance of 30 cm in diameter, and the largest in traps with the entrance of 50 cm in diameter. It was supposed that some crabs which entered into the traps with the largest entrance probably escaped by the same way. According to the results of the study it was concluded that a trap entrance of 50 cm in diameter was the most suitable for catching this kind of crab.

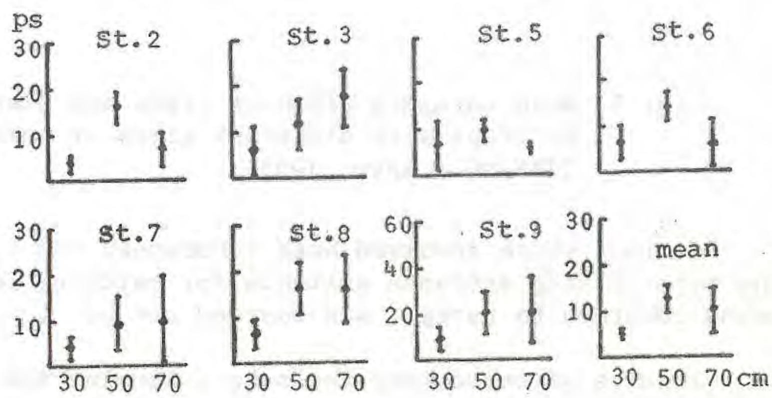


Fig. 5 Number of crabs per trap and standard deviation by traps with three different sizes of entrance. (TANINO & KATO, 1971)

The size of entrance influences not only the amount of catch but the size composition of catch. It was explained by Y.TANINO and F.KATO that there was a significant difference in the size compositions of captured crabs by traps with different size entrances (Fig. 6).

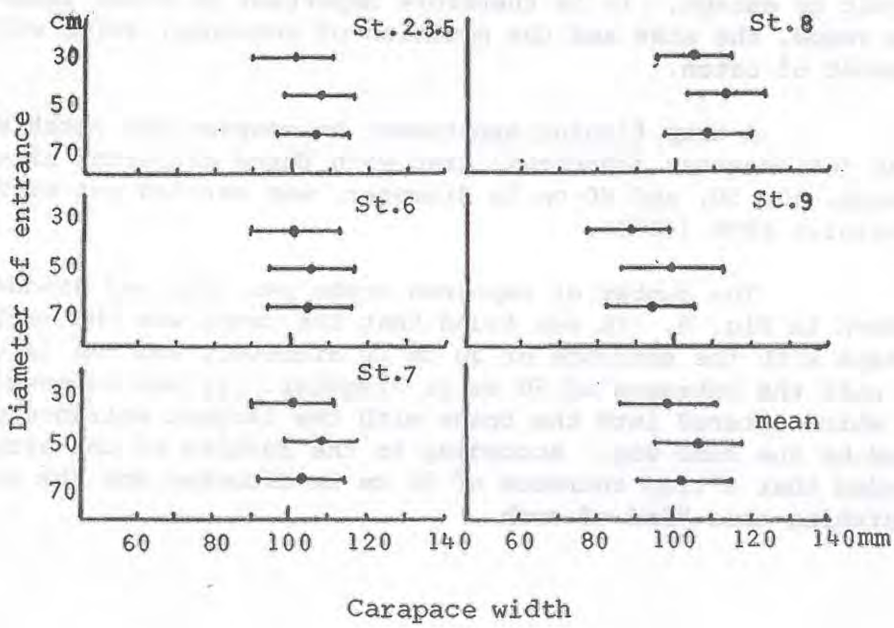


Fig. 6 Mean carapace width of crabs and standard deviation by traps with different sizes of entrance. (TANINO & KATO, 1971)

A study which involved both laboratory and field experiments on the type of trap entrance suitable for catching rock crabs while allowing lobsters to escape, was carried out by A.B.STASKO (1975).

Results of laboratory tests to determine the largest size of crabs and lobsters which could pass through the various sizes of long rectangular entrance opening and various sizes of round and square opening for escapement are shown in Table 6 and Table 7. Most crabs could pass through a long rectangular entrance with width of 44.5 mm, because the crab's body depth (height) which seemed to be a limiting factor to pass the long rectangular entrance was small enough. On the other hand, most legal size lobsters which are more than 81 mm in carapace length were prevented from passing through it, because their carapace height was bigger than the width of this entrance.

As for the escape holes which are designed to allow small marine animals to leave the trap, it was found that round holes were more selective than square holes for retaining commercial size crabs bigger than 89 mm in carapace length, while allowing lobsters to escape. That is to say, the shape of entrance has a selectivity for species.

Table 6 Results of tank experiments to determine what size lobsters and crabs could pass through long rectangular openings. Sizes shown are the largest animals that could pass through. (STASKO, 1975)

Width of opening *(mm)*	Lobsters Carapace length *(mm)*	Crabs Shell width *(mm)*	Berried crabs Shell width *(mm)*
25.5	none	69	none
32	56	79	none
38	62	110	78
44.5	69	121	78
51	83	all	all
57	89	all	all
63.5	92	all	all
70	all	all	all

Table 7 Results of tank experiments to determine what size lobsters and crabs could pass through square and round openings. Sizes shown are the largest animals that could pass through. (STASKO, 1975)

Size of opening (mm)	Lobster Carapace length (mm)		Crabs Shell width (mm)		Berried crabs Shell width (mm)	
	Round	Square	Round	Square	Round	Square
51	66	72	69	89	none	78
57	72	79	75	100	none	86
63.5	83	89	83	121	78	86
70	92	92	96	all	86	all
76	92	all	110	all	86	all

In the field experiments, only crabs were caught in the modified traps with a long rectangular entrance at the top. On the other hand, unmodified traps whose opening was a 12 cm wooden ring at the end of a horizontal funnel made of netting, caught crabs as well as lobsters. However, modified traps caught more crabs than unmodified traps (Table 8).

Table 8 Test fishing with three types of modified lobster traps with entrance at the top, and with unmodified lobster traps, hauled on 8 days from May 22 to June 3. The traps were set in groups of four, each group containing one each of the four types of traps. Totals are number of animals in 51 trap hauls; average is the number of animals per trap haul. Combined numbers are for 204 trap hauls. (STASKO, 1975)

Trap type	No. animals					
	Male crabs		Female crabs		Lobsters	
	Avg	(Total)	Avg	(Total)	Avg	(Total)
38-mm entrance	4.8	(246)	3.1	(156)	0	(0)
44.5-mm entrance	8.1	(412)	2.8	(144)	0	(0)
51-mm entrance	8.1	(415)	2.3	(115)	0	(0)
Unmodified entrance	5.7	(291)	2.8	(143)	1.1	(56)
Combined	6.7	(1364)	2.7	(558)	-	(56)

The position of entrance is also one of the factors which influences the amount catch. Atsushi KOIKE and Hironori ISHIDOYA (1978) surveyed catching efficiency of traps with entrance at the top and traps with entrance on the side, for catching pink shrimp *(Pandalus borealis)*. The result showed that the catch in traps with a side entrance was better than in traps with entrance at the top. (Table 9)

Table 9 Number of pink shrimp caught per trap by the difference of entrance which was the side of the trap or on the upper plane of the trap. (KOIKE & ISHIDOYA, 1978)·

Date			Entrance on the upper plane of the trap	Entrance on the side of the trap
	October	12	1.5(4)	2.7(3)
	"	14	0.3(4)	1.3(3)
	"	17	15.8(4)	21.3(3)
	"	19	23.0(4)	63.7(3)
1977	"	21	5.3(4)	14.0(3)
	"	23	5.0(4)	14.3(3)
	"	26	9.3(4)	23.7(3)
	"	28	14.0(4)	35.9(3)
	Mean		9.3(32)	21.9(24)
Result of analysis of variance			F=7.50(57.7)	F_0=6.51(ρ=0.01)

3.3 Relationship between the mesh size and the catch.

The mesh size of a trap influences the amount and the size composition of catch. It is important to study mesh selectivity to determine the optimum mesh size for various marine animals in order to do the trap fishing more effectively and to protect the resources.

A study on mesh selectivity of West Indian fish traps carried out by David A.OLSEN *et al.* (1978) showed the 1-inch hexagonal mesh traps caught 17.9 times more fish than the 1.5-inch hexagonal netting. The traps with 1 x 2 inch rectangular mesh caught 9.5 times more fish than 1.5-inch mesh traps. Many fish captured by traps with the smallest mesh were below the marketable size, and these fish could not be returned into the water to grow to their full size, because they were already killed by embolism when the trap was hauled to the water surface. Futhermore, if a trap with small mesh size (1-inch) is lost, it may continue catching even juvenile fish and kill them needlessly until the trap corrodes away (see Table 10).

Table 10. Fish species caught in West Indian fish traps made of different mesh sizes. The results are based on 15 hauls of two traps constructed of each mesh poultry cloth (N=30 for each mesh size). The study period was from 26 May to 19 September 1975. Mean standard length is given with standard deviation. (OLSEN *et al.*, (1978)

	Mesh size								
	1-inch hexagonal			1.×2-inch rectangular			1.5-inch hexagonal		
Species	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD
Lutjanidae									
Lutjanus synagris	52	15.7	3.6	117	17.4	2.1	34	20.1	3.7
Rhomboplites aurorubens	720	12.4	1.3	379	14.6	1.3	16	15.6	2.8
Priacanthidae									
Priacanthus arenatus	36	9.9	0.8	9	13.3	7.0			
Sparidae									
Archosargus rhomboidalis									
Catamus pennatula	3	14.0	1.0	1	18.0	-			
Pomadasyidae									
Haemulon aurolineatum	172	13.0	0.8	7	14.4	2.6	2	15.5	-
Carangidae									
Caranx tusus				5	43.1	8.7			
Seriola dumenrili	1	25.0	-						
Balistidae									
Balistes capriscus	1	14.0	-				3	24.2	7.3
Average for all species									

Y.TANINO and F.KATO (1971) reported that traps with a smaller mesh size caught more crabs and there was a significant difference in the size composition of crabs caught by traps with different mesh sizes. On the assumption that the size composition of crabs caught by the traps with smallest mesh size is the same as that of the population in the fishing ground, the relative catch was calculated for each mesh size by class mark of carapace width and selectivity curves were obtained (Table 11 and Fig. 7).

Table 11. Number of Beni-zuwai crabs caught by different sizes of mesh. 55 traps of each mesh size were operated. From the data reported by Tanino and Kato. (KOIKE & OGURA, 1977)

Carapace width(mm) / Mesh size(mm)	~47.5	52.5	62.5	72.5	82.5	92.5	102.5	112.5	122.5	132.5	142.5	142.6~	Total
70	2	23	149	264	222	379	386	488	197	38	3	0	2,151
100	0	0	11	111	117	286	276	380	127	35	2	0	1,345
130	0	0	2	3	17	84	186	223	118	23	1	0	657
160	0	0	1	4	12	37	125	241	101	21	2	1	545
190	0	0	0	0	1	8	27	119	75	23	2	0	255

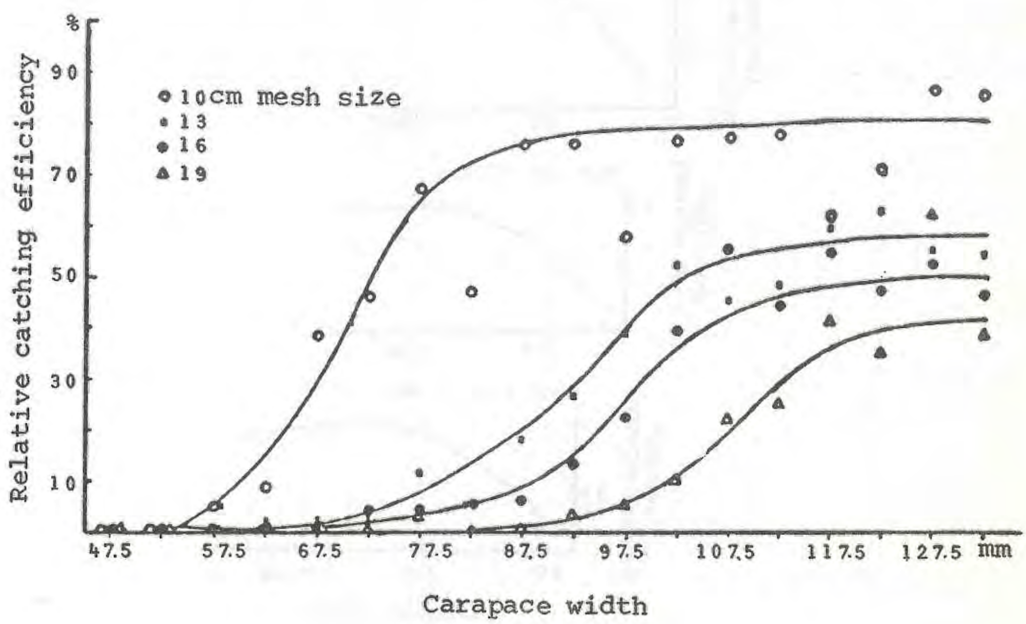


Fig. 7 Relative catching efficiency of each mesh size (10, 13, 16 and 19 cm) againt mesh size of 7 cm. (TANINO & KATO, 1971)

Atsushi KOIKE and Michio OGURA (1977) obtained the mesh selectivity curves of traps for catching Hokkoku-akaebi (pink shrimp) by using ISHIDA's method for estimation of gill net mesh selectivity curve. (Table 12 and Fig. 8)

This method is based on the assumption that the relative efficiency of a mesh size net for b body length fish was equivalent to the relative efficiency of ka mesh size net for kb body length fish.

Table 12 Number of Hokkoku-akaebi caught by different sizes of mesh. 24 traps of each mesh size were operated. (KOIKE & OGURA, 1977)

Mesh size \ Carapace length (mm)	~10	12	14	16	18	20	22	24	26	28	30	32	Total
19.0 mm	4	9	52	52	60	121	245	93	50	25	6	0	717
23.4 mm	0	2	4	18	33	135	272	151	56	19	7	0	697
30.3 mm	0	0	0	0	0	28	139	79	40	13	6	2	307

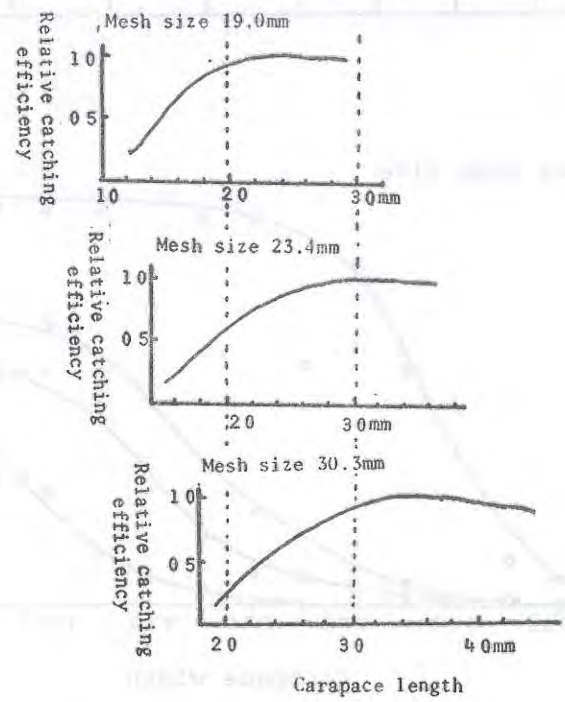


Fig. 8 Selection curves of the trap for Hokkoku-akaebi (diameter of the entrance 90 mm). (KOIKE & OGURA, 1977)

Atsushi KOIKE *et al.* (1981) obtained the mesh selectivity curves of the traps for pink shrimp by another method. Double-frame traps were used for this purpose, with different mesh size netting on the inside and outside trap walls. That is to say, the inside traps were covered with nets of various mesh sizes whereas the outside traps were covered with netting whose size was small enough to prevent the pink shrimp from escaping. Selectivity of mesh was calculated as a ratio of catch in the inner trap against the total catch in both inner and outer trap (Fig. 9).

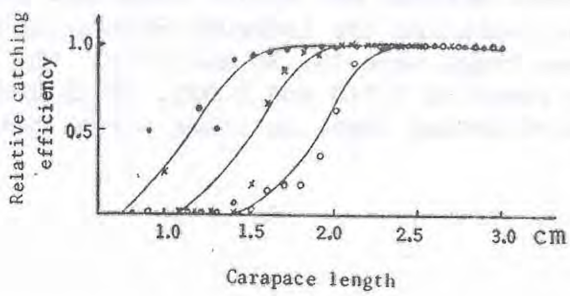


Fig. 9 Mesh selectivity curve of pink shrimp.
•, 1.9cm mesh size; x, 2.3cm mesh size;
o, 3.0cm mesh size
(KOIKE *et al.*, 1981)

The carapace length of pink shrimps of which 50 percent remained in the trap and 50 percent escaped from the trap through meshes are shown in Table 13.

Table 13 Fifty percent selection carapace length of pink shrimp; diameter of entrance was 9cm. (KOIKE *et al.*, 1981)

	Mesh size		
	1.9 cm	2.3 cm	3.0 cm
Double-frame trap (1979)	1.20cm	1.50cm	1.90cm
Ordinary trap (1977)*	1.50cm	1.90cm	2.30cm
Ordinary trap (1979)*2	-	1.65cm	2.05cm

*1 Obtained by ISHIDA's method.

*2 Obtained by comparison of catch of 1.9cm mesh size to each mesh size for each size class.

4. FISHING METHODS AND THE CATCH

4.1 Relationship between the catch and the interval between traps.

The optimum interval between traps is determined by many factors, such as the size of trap, depth of water, hauling facility of the boat and easy handling of gear. The radius of the area in which a baited trap is capable of attracting marine animals is also one of the factors.

Masatoshi SHINODA and Toshio KOBAYASHI (1969) reported on the relation between the catch and the interval between adjoining traps. The distances between traps were 33, 50 and 67 m. The highest catch was observed in the range of 0.018 and 0.025, which indicated the number of traps per length of ground rope, in other words, between 40-56 m intervals (Fig. 10).

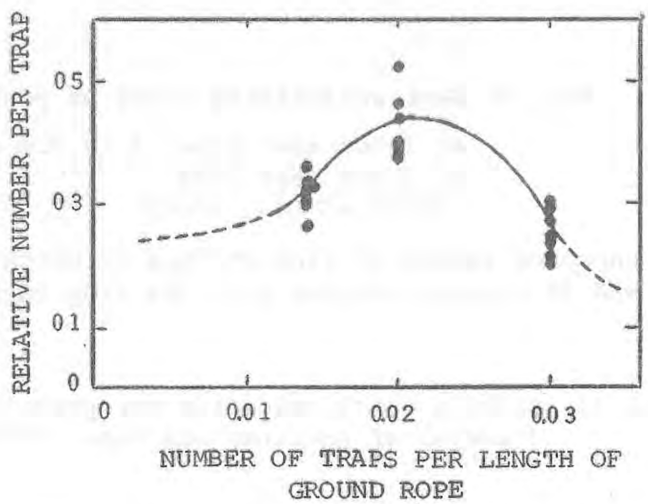


Fig. 10 Relationship between number of traps per meter of ground rope and relative number per trap on average of four mesh sizes. Relative number per trap represents relative number of crabs taken at each of three distances between traps and each plotted point shows value in each test, which amounts to seven operations. (SHINODA & KOBAYASHI, 1969)

The catch was low for the 33 m interval, which may have been caused by overlapping of the attraction area of neighbouring traps. The number of captured crabs per trap per meter of distance between traps is shown in Table 14. The traps which were joined at 33 or 50 m intervals caught more crabs than the traps set at 67 m intervals. This means that, with the 67 m interval, there were crabs which were in the middle between the adjacent traps and which escaped capture because they were out of the attracting range of the bait from either trap. From these results it was concluded that the most effective distance between traps for catching Beni-zuwai crab is about 40-56 m.

Table 14. Numbers of crabs taken per trap per meter of distance between traps, according to mesh size. Trap with 43 mm mesh was not examined at 67 m distance. (SHINODA & KOBAYASHI, 1969)

Distance between traps (m)	Mesh (mm)			
	46	90	120	150
67	-	0.402	0.402	0.298
50	0.593	0.600	0.580	0.480
33	0.603	0.606	0.575	0.515

Atsushi KOIKE *et al*[1]. (1979) also conducted experiments involving the use of gear with different distances between adjacent traps. Table 15 and Table 16 show that greater distances between traps result in better catch. The catch may also be influenced by the speed of current and its direction, because marine animals may be attracted by the smell of bait which drifts from the trap and is carried with the current. Therefore, the speed of current and its direction should be considered as one of the parameters in any study on the influence of distance between traps on the catch.

Table 15. Catch of aquatic animals by traps, with different distances between adjacent traps (Nov. 1976, June 1977 and Nov. 1977). (KOIKE *et al.*, 1979)

Distance between traps	Total number of traps used	Number of aquatic animals caught per trap		
		Ezoisoainame	Akazaebi	Surugabai
10m	184	154(0.84)	62(0.34)	616(3.35)
15m	181	163(0.90)	65(0.36)	834(4.61)
20m	177	187(1.06)	72(0.41)	758(4.28)

Table 16. Catch of Ezoibaragani by trap with different distances between adjacent traps (November 1977). (KOIKE *et al.*, 1979)

Distance between traps	Total number of traps used	Number of Ezoibaragani caught (catch per one trap)
10m	36	388(10.78)
20m	31	336(10.84)
30m	28	536(19.14)

4.2 Relationship between the catch and the immersion time of traps.

It is said that the catch rate of a trap tends to decrease with longer immersion time and the cumulative (total) catch tends towards an asymptote with the increase of immersion time. That is to say, the attracting efficiency of traps is reduced due to the deterioration of freshness of bait, and disappearance of bait as it is consumed by trapped marine animals. Also, there is an increase in escapement of marine animals from the trap.

M. SHINODA and T. KOBAYASHI (1969) did a study on the relationship between the catch and duration of fishing (immersion time) by using the TOYAMA-KAGO, a type of trap used in Toyama Bay for catching Beni-zuwai crab. It was found that the catch by trap immersed for two days was not always twice of that by trap lifted daily (Fig. 11). The equation which represents the relationship between the immersion time and the avarage total catch per trap is as follows;

$$C_t = C_\infty(1-e^{-\beta t})$$

C_t : The avarage total catch per trap

C_∞ : The number of crabs attracted which is dependent upon the type of bait used, the feeding state of crabs, the number of crabs in the area and the distribution of currents.

t : Immersion time (duration of fishing)

β : Parameter which is said to be proportional to the number of crabs in the area. This parameter determines the shape of the curves, i.e., the rate at which catches approach the limit C_∞. The effectiveness of a bait as an attractant can have an overriding influence on this rate in process of time.

The relationship between the immersion time and the catch of TOYAMA-KAGO is shown in Fig. 12.

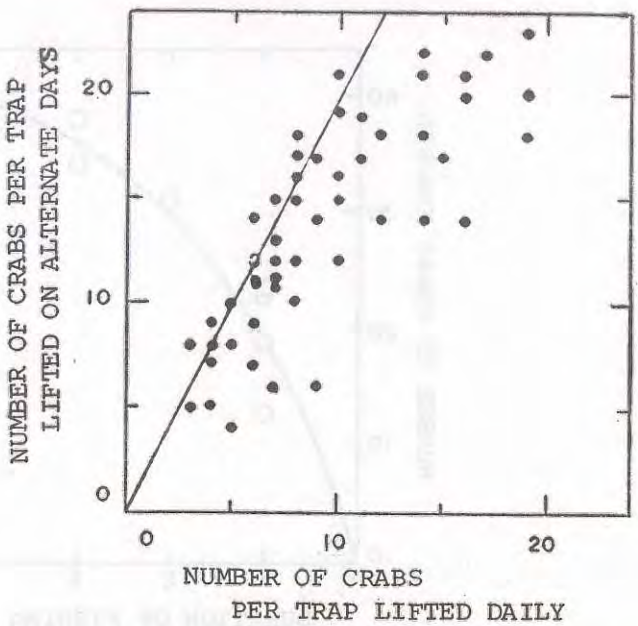


Fig. 11. Relationship between numbers of crabs taken per trap lifted daily and per trap lifted on alternate days, for 52 pairs of commercial catch records selected from data in Toyama Bay. Both parts of each pair were carried out in a same month and in a same area in the Bay. Line shows expected value of double catch made by daily lifting. (SHINODA & KOBAYASHI, 1969)

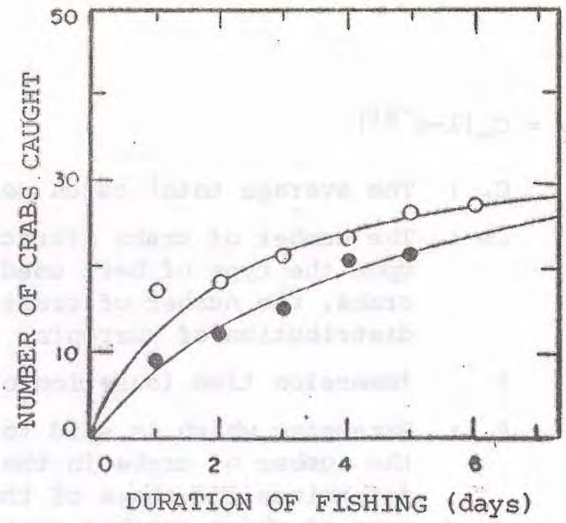


Fig. 12a. Relationship between frequency of lifting traps and average catch of crabs in the commercial fishery. Smooth curves were given by relation (1), in which $C\infty$=30 and β=0.51 (day^{-1}) for catch in the sea off Toyama Prefecture: o, and $C\infty$=30, β=0.29 (day^{-1}) in Toyama Bay: ●, in 1966, respectively.

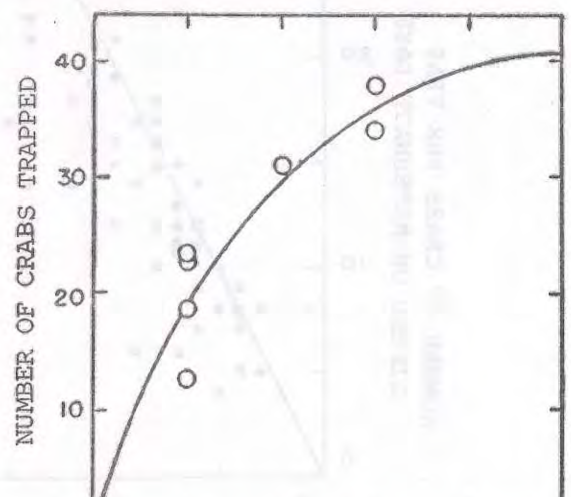


Fig. 12b. Relationship between frequency of lifting traps and average catch of crabs per trap. Smooth curve was given by relation (1), in which $C\infty$=43, β=0.60 (day^{-1}) for catch made by seven experimental fishings in the sea off Hyogo Prefecture. (SHINODA & KOBAYASHI, 1969)

Robert J.MILLER (1978) studied some factors which relate to saturation of crab traps. The catch by trap with exposed bait was higher than that of trap with enclosed bait; however, it did not eliminate saturation (Fig. 13).

The terms, "fished" and "not-fished", which are used in Figs. 13, 14 and 15 have the following meaning;

1) Fished traps were hauled and emptied every 2 hours for 12 hours. Catch data were presented as the accumulated catch.

2) Not-fished traps were also hauled every 2 hours for 12 hours, but crabs were counted and returned into the water still in the traps.

There were differences in catch by each size of trap, and large traps had a higher packing density. The catch by small fished traps was smaller than that of larger fished traps. This means that catches in the small traps were limited or in other words, the traps were saturated (Fig. 14).

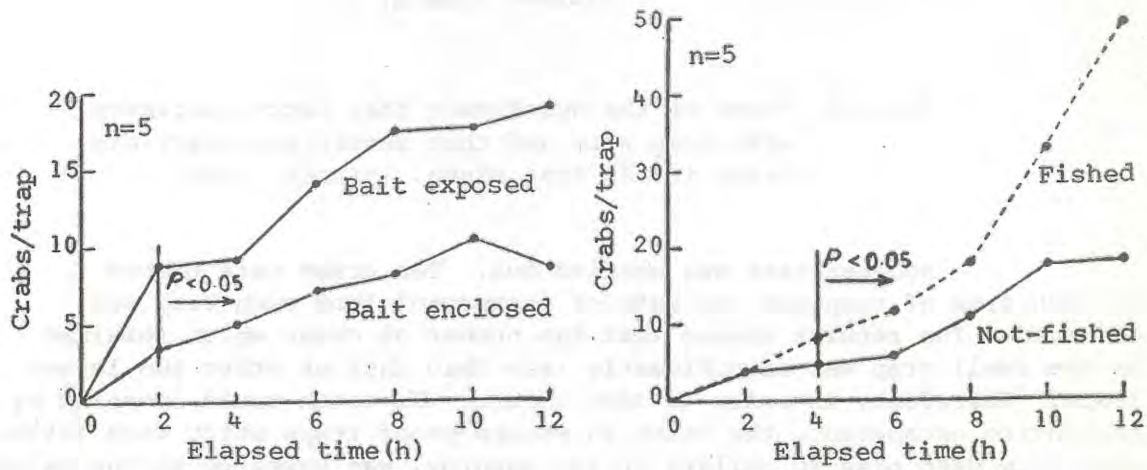


Fig. 13

Test of the hypothesis that catch is greater when bait is exposed than when bait is enclosed in perforated containers. Both treatments are *not-fished.* Vertical line and horizontal arrow indicate that treatments are significantly different from 2 h onward. (MILLER, 1978)

Test of the hypothesis that catch is not limited by trap saturation when bait is exposed. (MILLER, 1978)

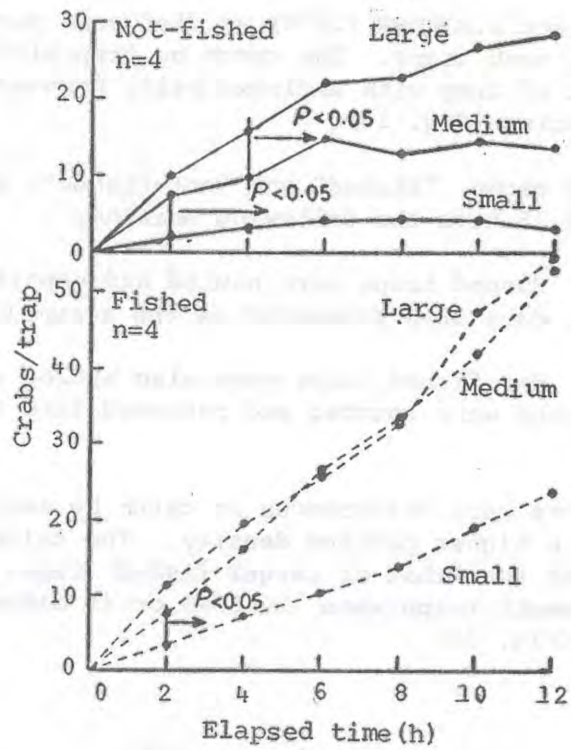


Fig. 14 Tests of the hypotheses that catch increases with trap size and that saturation restricts catch in all trap sizes. (MILLER, 1978)

Another test was carried out. Ten crabs were placed in each size of trap and the rate of escapement from each trap was observed. The results showed that the number of crabs which remained in the small trap was significantly less than that of other two larger traps. Therefore, in order to test whether the catch would increase by preventing escapement, the catch in escape-proof traps which were fitted with 6 cm deep plastic collars in the opening, was compared to the catch in ordinary traps. The escape-proof traps caught more than ordinary traps. However, preventing escapement did not eliminate saturation (Fig. 15).

Consequently, it was found that saturation was caused not only by increasing escapement but also by decreasing ingress, which was caused by the intimidation of crabs that tried to enter by those already inside the trap.

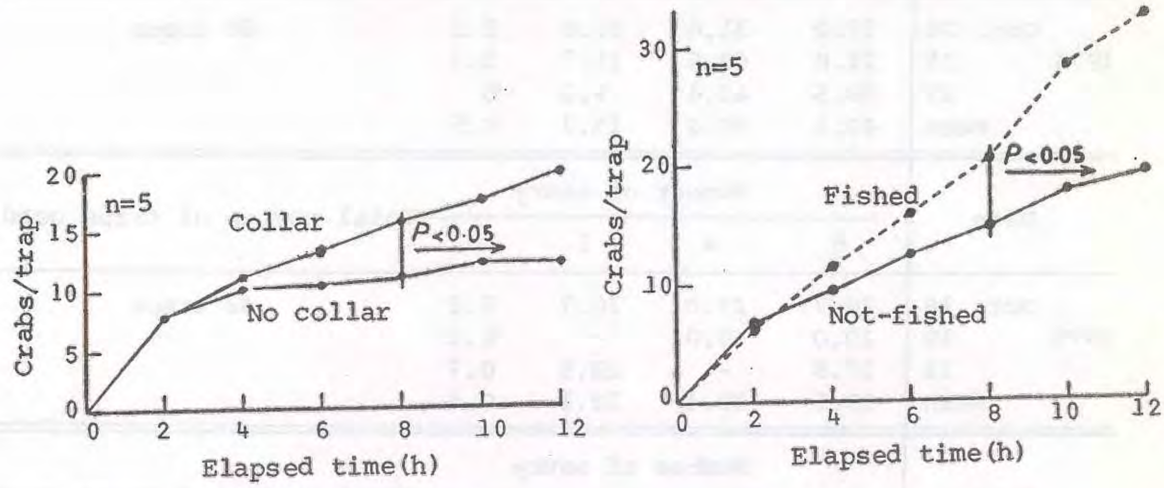


Fig. 15

Text of the hypothesis that catch increases if escape is prevented. (MILLER, 1978)

Test of the hypothesis that saturation does not limit catch if escape is prevented. (MILLER, 1978)

4.3 Relationship between the catch and bait

In order to decide on the kind of bait or the quantity of bait which is to be placed in traps, one has to consider not only its catching efficiency, but also the economic aspect, because some baits may be too expensive for use.

An experimental study on comparison of catch by different amounts of bait fish was carried out by A. KOIKE *et al.*[2] (1979). Table 17 shows that the catch in traps with only one bait fish was the smallest. However, there was no difference in catch between the traps with eight pieces and the traps with four pieces of bait fish.

Table 17. The mean number of pink shrimp catch per trap with different quantity of bait of saury. (KOIKE *et al.*, 1981)

	Date	Number of saury 8	4	1	0	Total number of traps used
1974	Oct. 20	37.0	31.6	22.0	0.2	60 traps
	25	24.8	43.6	15.7	1.2	
	27	58.5	42.4	9.3	0	
	Mean	40.1	49.2	15.7	0.5	

	Date	Number of saury 6	4	1	0	Total number of traps used
1975	Oct. 16	20.7	27.8	10.7	0.2	42 traps
	19	20.0	9.0	-	0.2	
	21	17.8	-	13.5	0.7	
	Mean	19.5	18.4	12.1	0.4	

	Date	Number of saury 8	4	1	Total number of traps used
1976	Sept. 7	92.8	97.1	46.9	108 traps
	9	43.0	39.7	27.0	
	Oct. 19	25.9	38.7	21.3	
	22	41.9	34.7	20.6	
	26	44.7	45.7	23.4	
	28	59.9	59.3	31.6	
	Mean	51.4	52.5	28.5	

	Date	Number of saury 8	4	1	Total number of traps used
1977	Oct. 14	1.7	1.7	1.6	126 traps
	17	34.0	36.4	18.4	
	19	28.8	40.4	25.6	
	21	28.8	40.0	22.0	
	23	8.6	9.0	3.6	
	26	54.0	59.7	33.8	
	28	20.0	40.3	23.7	
	Mean	25.1	32.5	18.4	

It has been known that certain crustacea avoid the dead of the same species; for example, the catch of Australian rock lobsters was reduced when a dead rock lobster remained in the trap.

D.A.HANCOCK (1974), who conducted research on the possibility of developing artificial bait, reported on the attraction and avoidance in marine invertebrates. In one experiment he compared catches of invertebrates in traps baited with only fish, only dead shore crab or a mixture of the two. Table 18 shows that many shore crabs were caught when only fish was used as bait to catch whelks; the crabs, which often feed on whelks, may have caused that only a small number of whelks entered into the traps. On the other hand, the catch of live shore crabs was small when the traps were baited with only dead shore crabs. When fish and dead crab were used together, whelks were attracted, but dead crab also served the purpose of repelling the live shore crabs, which also increased the entry of whelks. It was concluded that artificial bait should have both roles, attraction of the desired species and repulsion of undesirable species.

Table 18. Catches of various invertebrates in traps using different baits. (HANCOCK, 1974)

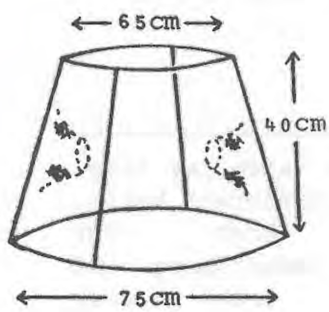
Species caught	Average catch per trap, using different baits: Fish (salted skate)	Crab (dead shore crab)	Fish and crab
Whelks	10.2	22.5	33.8
Live shore crabs	3.6	0.7	1.4
Hermit crabs (*Eupagurus bernhardus* L.)	1.1	1.8	0.8
Starfish (*Asterias rubens* L.)	2.4	2.4	1.7

5. FISHING GEAR AND METHOD: AN EXAMPLE

Trap fishing for Hokkoku-akaebi, *(Pandalus borealis)*

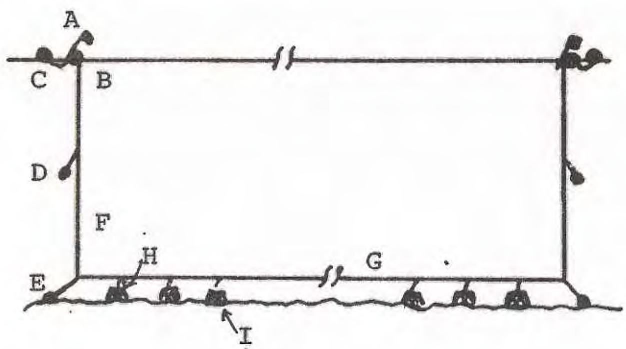
One of the deep sea shrimp resources, Hokkoku-akaebi or pink shrimp *(Pandalus borealis)* in the Japan Sea has been exploited by trap fishing. Trap fishing is operated at the depth of 300-800 m, by small fishing boats of about 10 tons. The shape of the trap and its specifications are given in Fig. 16. A schematic diagram of trap fishing gear and its specifications are shown in Fig. 17.

Shooting of traps is done from the stern part of the boat at full speed. Hauling is done by using a drum. It takes about one and a half hours to haul one unit of line to which 100 traps are attached. Generally five units of line, a total of 500 traps, are hauled on alternate days. While hauling, the traps are rearranged for next shooting on the stern deck and also on the rack which is set outside the boat. The position of crew for shooting and hauling is shown in Fig. 18.



Name	Materials	Size
Frame	Iron bar	Bottom 7 mm ϕ
		Side and Upper 5 mm ϕ
Net	Polyethylene	200 D
		Mesh size 2.3 cm
Entrance		Diameter 9 cm

Fig. 16 Shape and dimensions of a pink shrimp trap.



Mark	Name	Materials	Size	Amount
A	Flag pole	Bamboo		2
B	Buoy	Glass or plastic	Ø 30 cm	2
C	"	" "	"	2
D	Sinker	Stone	10 kg	2
E	"	"	20 kg	2
F	Buoy line	Polyethylene	Ø 20 mm	Depth x 1.5 m
G	Main line	"	Ø 24 mm,	1000 m
H	Branch line	"	Ø 10 mm,	5 m x 100

Fig. 17 A schematic diagram and specifications of trap fishing gear.

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