SHRIMP TRAWL FISHING EXPERIMENT

On the fishing comparison between Mexican net type and commercial net type

Department of Fisheries
Ministry of Agriculture
Bangkok, Thailand

and

Training Department
Southeast Asian Fisheries Development Center
Bangkok, Thailand

June, 1971

SHRIMP TRAWL FISHING EXPERIMENT

On the fishing comparison betwcen Mexican
net type and commercial net type

Department of Fisheries
Ministry of Agriculture
Bangkok, Thailand

and

Training Department
Southeast Asian Fisheries Development Center
Bangkok, Thailand

June, 1971

CONTENTS

List of figures

List of tables

I. Introduction

The next five years plan (1972–1976) of the fisheries development project, one of the aim to increasing the shrimp production for the local consumption and export, the project should be carried out the two items as follows:

1. To harvest the shrimp from natural water by improving the fishing gear
2. Shrimp farming

According to the fisheries census of the Fisheries Department in the year of 1967 the number of shrimp beam trawl fisheries consists of about 424 units, 75 percent of which are small size of boat (less than 10 tons) and also small size of net. The Fisheries Department contemplate to improve the shrimp trawl fisheries on it's gear to be advance and expect the catch of more shrimps (follow item 1).

The Fisheries Department, therefore, request fishing gear expert from Southeast Asian Fisheries Development Center (SEAFDEC) for joining shrimp trawl fishing experiment. Thus, the main purpose of this experiment are to find rational and effective shrimp trawl net design operating both in the Gulf of Thailand and Indian Ocean for commercial fishing vessel, to make simplify the construction of net for the fishermen use and to define the optimum size of net relatively with the size of horse power of vessel engine.

II. Procedure of the experiment

At the fishing ground of shrimp, three vessels were employed in the same time, the same place and the same operating condition, using three different design of shrimp nets respectively and change the combination of vessels and nets during six days operation as stated in the following programme.

1. The members participated in this experiment were as follows:

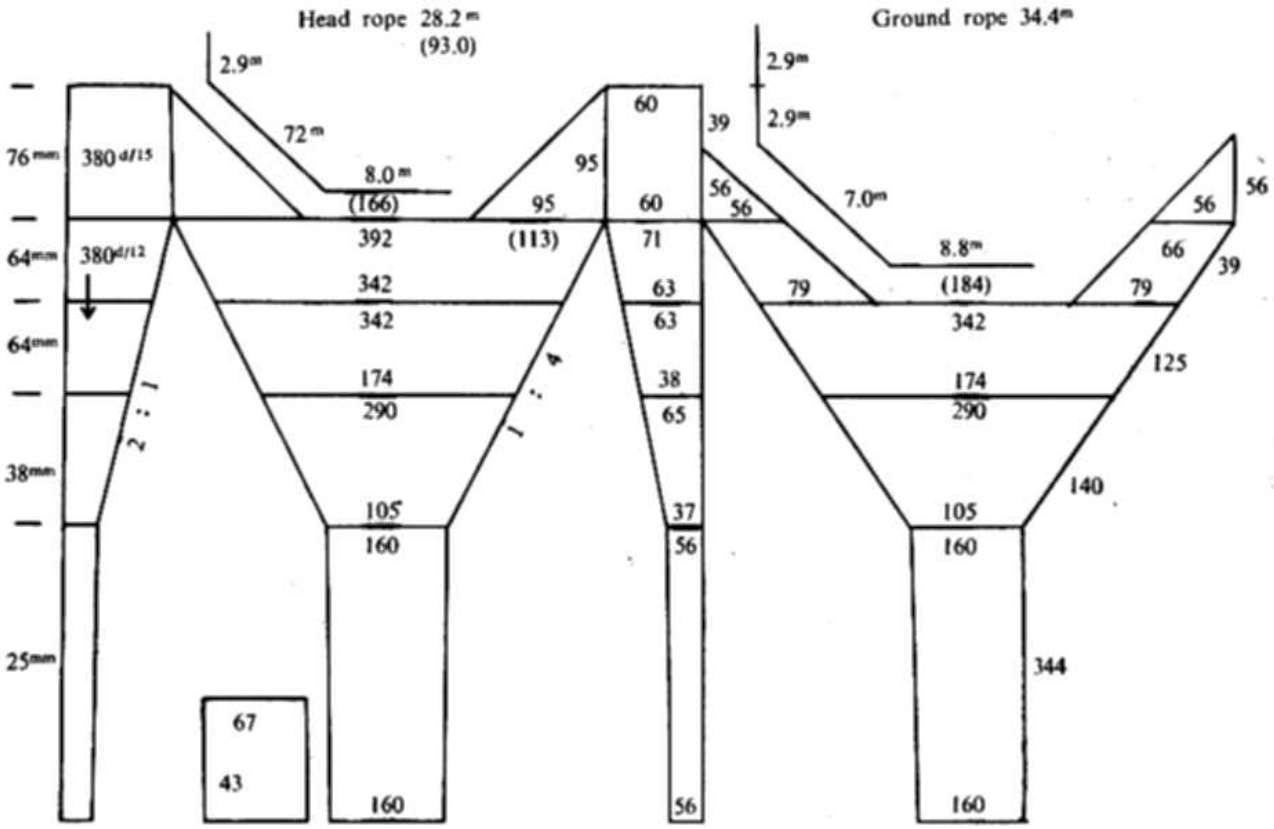
	Name of vessel–aboarding
Department of Fisheries, Thailand	
German Expert	
Dr. G. Kuhlmorgen–Hille (Biologist)	Rv. Pramong 2
Mr. F. Eggers (Gear)	Pramong 6
Officer	
Mr. S. Ruamragsa	Pramong 2
Mr. K. Chareonphanich	Pramong 7
Biologist	
Mr. S. Sithichaikasem	Pramong 2
Mr. V. Tasananukulkit	Pramong 2
Mr. S. Chulasorn	Pramong 6
Mr. V. Chomchurai	Pramong 7
Training Department, Southeast Asian Fisheries Development Center	
Instructor	
Dr. M. Nomura	Pramong 2
Mr. Y. Nishioka	Pramong 6
Mr. K. Kitagawa	Pramong 6
Mr. S. Kobayashi	Pramong 7
Mr. T. Yamazaki	Pramong 6
Mr. A. Wada	–
Trainees of SEAFDEC (10) for fishing training	Pramong 2, 6 and 7

All total in number of members including staffs and crews were fifty two.

2. Net design used for the experiment

The design of three shrimp trawl nets used for the experiment were adopted as shown in Fig. 1.

Net deign : d_1



Specification :

Head rope	28.2m	
Ground rope	34.4m	
Safety rope (Polyethylen)	30m	Dia 20mm
Bridle rope	5m	
Float (Plastic)	6"	16 pcs
Chain	1/4"	34kg, each 5kg to the top end of lower wing

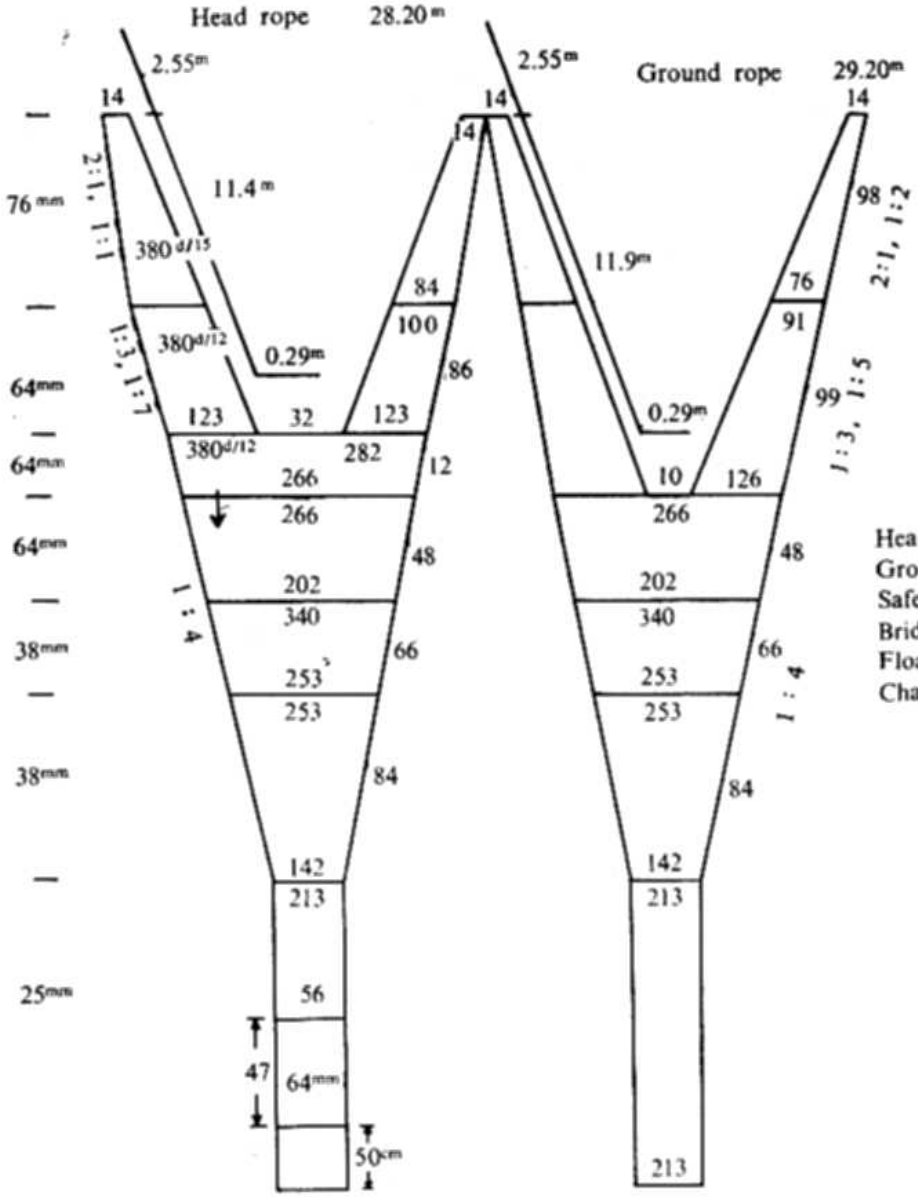
Fig. 1 The design of net

d_1 : Mexican type shrimp trawl net

d_2 : Half size of Mexican type shrimp trawl net

d_3 : Commercial trawl net localey used

Net deign : d_3

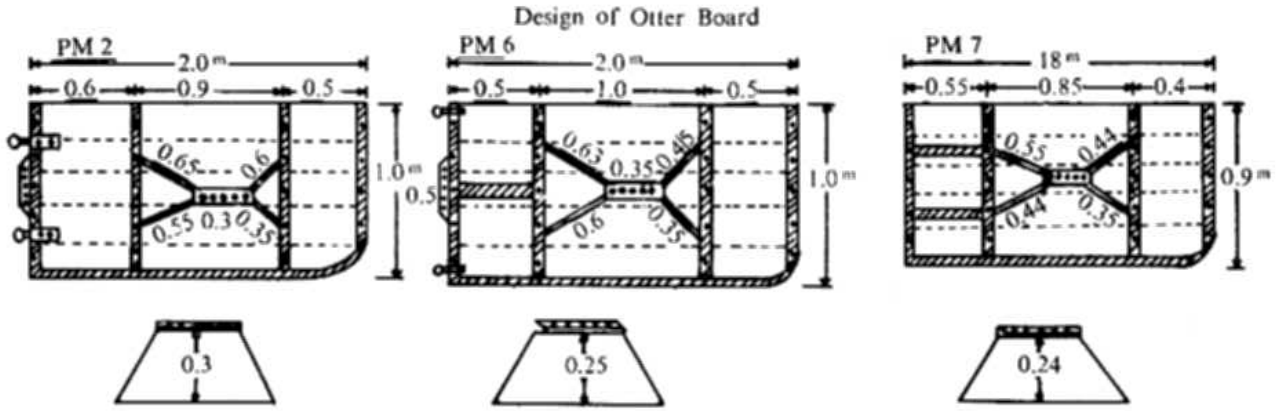


Specification :

Head rope		28.20m
Ground rope		29.20m
Safety rope		30m
Bridle rope		5m
Float	6″	15 pcs
Chain	1/4″	33.5kg, each 5kg to the top end of lower wing

Table 1. Specification of three boats used in comparative experiment

Name	Mark	Length	HP	Otter Board	Officer	Adviser	Biologist	Crew	Intructor	Trainee	Total
PM 2	b_1	23m	320	2m x 1m	1	1	3	10	1	3	19
PM 6	b_2	23	335	2 x 1	—	1	2	10	3	4	20
PM 7	b_3	16	175	1.8 x 0.9	1	—	2	6	1	3	13
Total					2	2	7	26	5	10	52



As for Mexican net type, the semi-ballon type was applied as it was the most popular type. And the size of net was so decided as adapting to 180 horsepower of engine. The commercial net type was adopted just as the same design which is used in commercially and it was almost the same size as Mexican type net. The third net design was the same proportion as the first one, but was just half of size in all parts. These three nets were adopted for the comparison of fishing efficiency.

3. Kinds of boat used for the experiment

The specification of three boats and their otter board are tabulated in Table 1.

For the analysis of catch ability the following symbols concerning with important factors are used as shown in Table 2.

Table 2 The symbols of the factors

Factor	Symbol	Remarks
Boat	b_1	Pramong 2
	b_2	Pramong 6
	b_3	Pramong 7
Net	d_1	Mexican type net (Semi-ballon)
	d_2	Half size of the above Mexican net (Same proportion)
	d_3	Commercial net type, almost same in size as d_1
Fishing time	n_1	17 : 00 – 18 : 00
	n_2	18 : 30 – 19 : 30
	n_3	20 : 00 – 21 : 00
	n_4	2 : 30 – 3 : 30
	n_5	4 : 00 – 5 : 00
	n_6	5 : 30 – 6 : 30
Fishing place	p_1	Fishing places from p_1 to p_6 are shown in Fig. 2.
	p_2	
	p_3	
	p_4	p_3 and p_6 are the same place
	p_5	
	p_6	

III. Combination of factors, fishing experiment and the results of catch

The program of combination on net, boat and time during six days operation were carried out from 13th to 19th of January 1971, at the fishing ground around island Chang (Coh Chang). In six days' operational program the former half three days experiment can complete all combination of a round, so that this could be said as the first round (hereinafter I round) experiment. The latter half three days experiment, therefore, is said as the second round (hereinafter II round) experiment on this report. After I round experiment was completed some improvement and changing condition on the gear were carried out in successive experiment of II round. The improvement and new condition of II round were as follows:

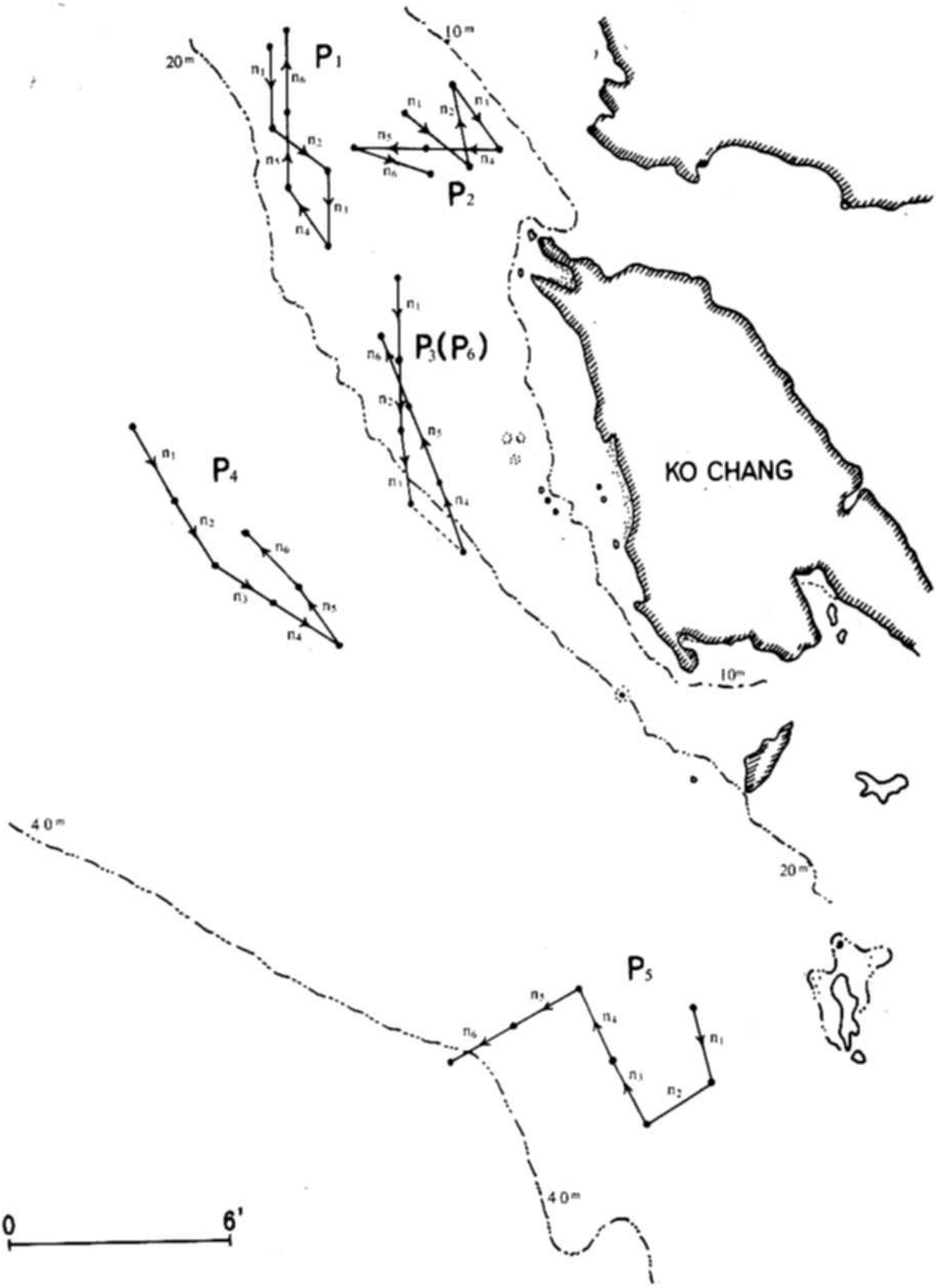


Fig. 2 A cruise traces of six operational places off the east coast of Gulf of Thailand undertaken by Prameng 2,6 and 7 from 13th to 19th, January, 1971.

d_1 : Giving 5 meters bridle rope between leg and otter board

d_2 : Giving 7 meters extension wing (ditachable net were given in between upper and lower of bridle rope and leg respectively as extension wing)

d_3 : Making 1 meter longer in lower leg of both sides, so that the total length of ground rope become 31.20 meters, and with 5 meters bridle rope same as d_1

The way of attachment in which the ground chain fixed to ground rope were changed in all nets.

The comparative fishing experimnt were conducted in the following operational system in which two boats b_1 and b_3 should keep the same direction with the leader boat b_2 having 100 meters distance of interval with each other, trawling the net just one hour and always keeping 2.0 miles per hour of towing speed.

The schedule and experimental combination on net, boat and time are tabulated in Table 3.

The operational conditions of six days' fishing are shown in Table 4.

The catch result by experimental combination of I round and II round are tabulated in Table 5.

IV. Results of analysis on the catch

1. Appreciation by figures

On the basis of the catch statistics shown in Table 5, the catch between nets (d) and boats (b) of I round experiment and II round experiment are illustrated in Fig. 3.

According to these figures the catches of Shrimp total, Fish (duck fish plus commercial fish) total and Grand total show somewhat characteristic trend. It seems there are some different catch by kinds of net.

Next, the catch classified by nets (d) and places (p) of I and II round are also illustrated in Fig. 4. The differences of catch by nets (d) and places (p) are more clearly understood in the figure than Fig. 3.

The catch classified by operational time (n) in each day on Shrimp and Fish (duck fish plus commercial fish) are shown in Fig. 5.

From the figures it is realized that there might be no systematic in the catch by operational time through lst day to 6th day both in Shrimp and Fish.

2. Evaluation by the Analysis of Variance

2–1. Two-factor; boat and net

In the cases of the factors of more than two populaion we shall consider of the very general technique known as the analysis of variance (A.V.). The object of A.V. is to provide statistics which are useful in comparing population means; the method can be used only with normal variables. The general procedure of A.V. is to determine how much of the variation in our observation is due to population differences and how much to random variability; by comparing the contribution of these two kinds of variation we can determine the importnce of the population differences.

The most convenient measure of variation with a normal variable is a sum of squares. All A.V. begin, therefore, by the computation of a sum of squares to measure the overall variation of all the samples taken together; this is total sum of squares. Next, the calculation is done on how much of the variation can be ascribed to the population differences that interest us and then,

Table 3 Schedule and experimental combination of net, boat and time during 6 days operation (2 rounds).

12th Jan.	Leave Bangkok (Morning) ; Banpae, Preliminary operation (Afternoon)							
13th	Preliminary operation (Day time) , Leave Banpae to fishing ground (Coh chang)							
I. st. Round	13th	Evening to night				14th	Night to morning			
		Boat	b_1	b_2	b_3		Boat	b_1	b_2	b_3
		Net	d_1	d_2	d_3		Net	d_1	d_2	d_3
		n_1	$n_1b_1d_1$	$n_1b_2d_2$	$n_1b_3d_3$		n_4	$n_4b_1d_1$	$n_4b_2d_2$	$n_4b_3d_3$
		n_2	$n_2b_1d_1$	$n_2b_2d_2$	$n_2b_3d_3$		n_5	$n_5b_1d_1$	$n_5b_2d_2$	$n_5b_3d_3$
		n_3	$n_3b_1d_1$	$n_3b_2d_2$	$n_3b_3d_3$		n_6	$n_6b_1d_1$	$n_6b_2d_2$	$n_6b_3d_3$
		Person	19	10	13		Person	19	20	13
		Place	P_1				Place	P_1		
	14th	Evening to night				15th	Night to morning			
		Boat	b_1	b_2	b_3		Boat	b_1	b_2	b_3
		Net	d_2	d_3	d_1		Net	d_2	d_3	d_1
		n_1	$n_1b_1d_2$	$n_1b_2d_3$	$n_1b_3d_1$		n_4	$n_4b_1d_2$	$n_4b_2d_3$	$n_4b_3d_1$
		n_2	$n_2b_1d_2$	$n_2b_2d_3$	$n_2b_3d_1$		n_5	$n_5b_1d_2$	$n_5b_2d_3$	$n_5b_3d_1$
		n_3	$n_3b_1d_2$	$n_3b_2d_3$	$n_3b_3d_1$		n_6	$n_6b_1d_2$	$n_6b_2d_3$	$n_6b_3d_1$
		Person	19	20	13		Person	19	20	13
		Place	P_2				Place	P_2		
	15th	Evening to night				16th	Night to morning			
		Boat	b_1	b_2	b_3		Boat	b_1	b_2	b_3
		Net	d_3	d_1	d_2		Net	d_3	d_1	d_2
		n_1	$n_1b_1d_3$	$n_1b_2d_1$	$n_1b_3d_2$		n_4	$n_4b_1d_3$	$n_4b_2d_1$	$n_4b_3d_2$
		n_2	$n_2b_1d_3$	$n_2b_2d_1$	$n_2b_3d_2$		n_5	$n_5b_1d_3$	$n_5b_2d_1$	$n_5b_3d_2$
		n_3	$n_3b_1d_3$	$n_3b_2d_1$	$n_3b_3d_2$		n_6	$n_6b_1d_3$	$n_6b_2d_1$	$n_6b_3d_2$
		Person	19	20	13		Person	19	20	13
		Place	P_3				Place	P_3		
II. Round	16-17th	Same as 13-14th , Place P_4								
	17-18th	Same as 14-15th , " P_5								
	18-19th	Same as 15-16th , " P_6 (Same as P_3)								
	20th	Physical measurement on net (Day time) at Banpae								
	21th	ditto								
	22nd	Arrangement, Going back to Bangkok								

Table 4 Operational condition.

Day and Place	Date	Operational time	Cloud	Wind	Bottom of nature	Wave	Depth of water	Warp length	Towing direction	Remarks
1st Day P_1	13th	n_1	2	SW 2	S.	1	18m	100m	180°	Small size Shrimp, fishes.
		n_2	2	SW 2	S.	1	18–17	100	110°	Crab. flat fish, jelly fish many kind of fish.
		n_3	2	SW 2	S.M.	1	15–16	100	180°	Shell
	14th	n_4	2	S 2	S	2	17–18	100	330°	Fishes Shell & sea cucumber
		n_5	5	NE 3	S	2	18	100	0°	Fishes, Shell, Sea urchen
		n_6	3	NE 2	S	2	18	100	0°	Big Shrimp. fish & shell
2nd Day P_2	14th	n_1	2	W 2	M.S.	1	16	100	137°	Fishes.
		n_2	2	W 2	M.S.	1	12	100	340°	Fish gilling at wing.
		n_3	2	W 2	M.S.	1	10.5	100	145°	Wing is fouled with mud.
	15th	n_4	7	E 1	M.S.	1	11–15	100	270°	Small fish, shell.
		n_5	8	E 2	S	2	15–17	100	270°	Small shell & octobus.
		n_6	3	SE 2	S	2	17	100	115°	Jelly fish, sponge.
3rd Day P_3	15th	n_1	2	S 3	M.S.	2	15	100	190°	Star fish.
		n_2	3	SSW 2	S.M.	2	15–16.5	100	190°	Ray, shark, fishes.
		n_3	6	SSW 1	M.S.	2	18–21	100	190°	Shrimp.
	16th	n_4	4	S 1	S.M.	2	21–18	100	355°	Big shrimp.
		n_5	3	S 1	S.M.	2	18–17	100	0°	Shrimp. Crab. fish.
		n_6	4	S 1	S.M.	2	17	100	0°	Shrimp. octobus.
4th Day P_4	16th	n_1	3	S 3	M	3	27	150	150°	Sea urchen, fishes.
		n_2	3	SW 4	M	3	28–29	200	155°	Sea urchen, small quantity of Shrimp
		n_3	3	SW 4	CY	3	28	200	120°	ditto
	17th	n_4	3	S 3	CY	3	27	200	120°	Fishes
		n_5	3	S 3	M.S.	3	27	150	315°	Sea urchen, fishes.
		n_6	3	S 3	M.S.	3	26	150	315°	Fishes.
5th Day P_5	17th	n_1	1	SW 2	S.M.	3	33	200	170°	Fishes.
		n_2	3	SW 2	S.M.	3	33	200	220°	Fishes, small quantity shrimp
		n_3	3	SW 2	S.M.	3	33	200	220°	ditto
	18th	n_4	1	SW 2	S.M.	2	33	200	315°	Net d_1 is broken (spare net)
		n_5	1	NW 2	M	2	34	200	240°	Small catch
		n_6	1	E 2	M	2	36	200	240°	Oyster Shell
6th Day P_6 (P_3)	18th	n_1	5	W 3	M.S.	2	15	100	215°	Small shrimp
		n_2	5	W 3	M.S.	2	15	100	180°	ditto
		n_3	5	E 2	M.S.	2	17	100	180°	Small shrimp, small fish.
	19th	n_4	6	W 1	M.S.	2	18–19	100	180°	Good catch
		n_5	3	N 2	M.S.	2	22–19	100	0°	Flat fish etc.
		n_6	3	N 2	M.S.	2	19	100	334°	Sea urchen

Table 5. An overall table showing the catch for each boat in relation to net design and operational time (I)

I. Round

(kg)

1st Day (13–14)		Pramong 2 (b_1)							Pramong 6 (b_2)							Pramong 7 (b_3)						
		d_1							d_2							d_3						
		n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T
Sh.	B.S.	–	–	0.19	–	0.32	0.59_5		–	0.06	–	0.08_5	0.06	0.18		0.40	0.30	0.25	0.08	0.45	0.40	
	M.S.	0.34	0.06	0.27_5	0.31	0.25	0.26		0.06	–	0.07_5	0.05	–	0.09		0.15	0.15	0.75	0.04	0.08	0.05	
	S.S.	21.73	8.03	11.51_5	11.55	14.87	12.83_5		6.44	4.10	3.32	0.115	8.20	3.73		10.00	3.25	2.05	0.93	2.21_5	1.20	
	T.	22.07	8.09	11.98	11.92	15.44	13.69	83.19	6.50	4.16	3.39_5	0.25	8.26	4.00	26.56	10.55	3.70	3.05	1.05	2.74_5	1.65	22.74_5
Duck Fish		13.45	41.20	42.50	28.00	52.00	9.70	186.85	29.00	20.00	22.00	20.00	18.00	15.50	124.50	21.00	9.20	9.60	7.20	5.50	6.00	58.50
Com. Fish		19.30	16.17	20.14	20.59	17.04	24.70	117.94	8.98	7.87	11.46	10.01	9.10	13.85	61.27	6.60	2.60	4.90	2.09	2.49	6.00	24.68
Gr. Total		54.82	65.46	74.62	60.51	84.48	48.09	387.38	44.48	32.03	36.86	30.26	35.36	33.35	212.34	38.15	15.50	17.55	10.34	10.73	13.65	105.92

2nd Day (14–15)		Pramong 2 (b_1)							Pramong 6 (b_2)							Pramong 7 (b_3)						
		d_2							d_3							d_1						
		n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T
Sh.	B.S.	0.14	–	0.13_5	–	–	–		–	–	0.14_5	–	0.21	–		0.10	0.62	1.80	0.42	0.45	0.10	
	M.S.	0.09	0.23	0.54	0.19	0.05_5	0.03		–	0.34_5	1.08_5	0.39	0.13	0.05		0.18	0.44	0.52	0.22	0.23	0.12	
	S.S.	1.03_5	1.06_5	1.66	2.35	3.56	3.90		0.01	3.85_5	3.07	5.71	7.86	0.15		1.50	5.00	7.80	7.80	9.40	12.00	
	T.	1.26_5	1.29_5	2.33_5	2.54	3.61_5	3.93	14.98	0.01	4.20	4.31	6.10	8.20	0.20	23.02	1.78	6.06	10.12	8.44	10.08	12.22	48.70
Duck Fish		2.20	15.40	13.65	13.84	11.50	16.20	72.79	2.68	5.05	4.20	7.83	15.24	3.50	38.50	19.65	45.00	11.70	28.00	25.30	11.60	141.25
Com. Fish		7.72_5	9.23_5	9.01_5	9.15	12.69_5	6.69	54.51	7.60	4.56	10.18	4.20	14.62	6.50	47.66	4.15	9.80	11.02	12.05	21.42	11.14	69.58
Gr. Total		11.19	25.93	25.00	25.53	27.81	26.82	142.28	10.29	13.81	18.63	18.13	38.06	10.20	109.18	25.58	60.86	32.84	48.49	56.80	34.96	259.53

3rd Day (15–16)		Pramong 2 (b_1)							Pramong 6 (b_2)							Pramong 7 (b_3)						
		d_3							d_1							d_2						
		n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T
Sh.	B.S.	–	0.27	0.56	0.80	0.13	–		–	0.37	1.38	1.14	0.18	–		–	0.26	1.14	0.85	0.38	0.20	
	M.S.	–	0.62	0.95	0.66	0.25	0.17_5		0.28	0.87	1.94	0.58	1.04	0.77		0.02	0.14	0.29	0.08	0.14	0.09	
	S.S.	0.03_5	4.59	7.21	1.26_5	3.33	3.91		3.82	14.64	16.88	14.28	29.58	27.73		0.40	2.90	4.10	2.01	4.02	5.50	
	T.	0.03_5	5.48	8.72	2.72_5	3.71	4.08_5	24.75	4.10	15.90	20.20	16.00	30.80	28.50	115.50	0.42	3.30	5.53	2.94	4.54	5.79	22.52
Duck Fish		1.78	10.50	15.50	1.55	6.30	7.50	43.13	12.80	14.50	12.70	4.60	6.40	17.80	68.80	5.85	9.74	12.20	10.06	8.12	14.00	59.97
Com. Fish		8.41	42.67	7.28	10.84	11.01	9.57	89.78	9.80	67.20	21.04	24.39	22.29	17.65	162.37	20.60	32.60	7.60	3.30	8.66	13.22	85.98
Gr. Total		10.22_5	58.65	31.50	15.11_5	21.02	21.15_5	157.66	26.70	97.60	53.94	44.99	59.49	63.95	346.67	26.87	45.64	25.33	16.30	21.32	33.01	168.47

Note : Sh : Shrimp, B.S : Big shrimp, M.S : Medium size shrimp, S.S : Small size shrimp, T. : Total

Table 5. An overall table showing the catch for each boat in relation to net design and operational time (2)

II. Round

(kg)

4th Day (16–17)		Pramong 2 (b_1)							Pramong 6 (b_2)							Pramong 7 (b_3)						
		d_3							d_1							d_2						
		n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T
Sh.	B.S.	–	0.38	0.70_5	0.07	0.07_5	0.60		0.40	0.60	0.80	0.40	0.52	0.65		–	0.66	0.86	0.54	0.16	0.46	
	M.S.	–	0.87	0.98	0.67_5	0.46	0.37		0.04	1.70	1.48	1.33	1.04	0.50		–	0.08	0.10	0.01	0.02	–	
	S.S.	0.06	0.16	0.20_5	0.52	0.30_5	0.13		0.10	–	0.42	1.07	0.94	–		0.02	0.02	0.04	0.02	0.06	0.72	
	T.	0.06	1.41	1.89	1.26_5	0.84	1.10	6.56_5	0.54	2.30	2.70	2.80	2.50	1.15	11.99	0.02	0.76	1.00	0.57	0.24	1.18	3.77
Duck Fish		25.20	0.50	1.70	10.00	11.09	1.50	49.99	37.45	16.75	5.00	8.00	8.00	3.00	78.20	32.32	12.60	0.70	8.81	7.00	4.50	65.93
Com. Fish		30.21	14.93	14.56	11.87	10.96	22.21	104.74	50.34	51.01	20.13	19.74	19.63	22.71	183.56	17.12	19.05	5.90	9.53	9.56	7.52	68.68
Gr. Total		55.47	16.84	18.15	23.13_5	22.89	24.81	161.29_5	88.33	70.06	27.83	30.54	30.13	26.86	273.7_1	49.46	32.41	7.60	18.91	16.80	13.20	138.38

5th Day (17–18)		Pramong 2 (b_1)							Pramong 6 (b_2)							Pramong 7 (b_3)						
		d_2							d_3							d_1						
		n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T
Sh.	B.S.	0.08_5	0.51	0.38	0.16_5	1.02	0.07_5		0.20	1.24	0.49	0.60	0.40	0.58		0.25	0.58	0.44	1.50	1.88	0.96	
	M.S.	0.14	0.32	0.17	0.35_5	0.30	0.14_5		–	0.76	0.58	0.13_5	0.42	–		0.01	0.16	0.30	0.82	0.28	0.08	
	S.S.	0.01_5	0.21	0.07	0.38	0.24	0.31		0.01	0.40	0.13	0.66_5	0.18	0.55		0.01	0.42	0.02	–	0.64	1.20	
	T.	0.24	1.04	0.62	0.90	1.56	0.53	4.89	0.21	2.40	1.20	1.40	1.00	1.13	7.34	0.27	1.16	0.76	2.32	2.80	2.24	9.55
Duck Fish		3.57	0.90	6.85	4.00	4.50	2.00	21.82	3.44	8.40	11.20	20.00	11.25	5.76	60.05	27.54	19.32	27.62	21.00	14.16	20.90	130.54
Com. Fish		18.64	6.19	9.18	11.34	4.32	17.39	67.06	22.23	10.23	13.99	14.20	6.97	42.50	110.12	9.64	12.57	11.62	9.10	6.12	18.22	67.27
Gr. Total		22.45	8.13	16.65	16.24	10.38	19.92	93.77	25.88	21.03	26.39	35.60	19.22	49.39	177.51	37.45	33.05	40.00	32.42	23.08	41.36	207.36

6th Day (18–19)		Pramong 2 (b_1)							Pramong 6 (b_2)							Pramong 7 (b_3)						
		d_1							d_2							d_3						
		n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T
Sh.	B.S.	0.07_5	0.06	1.25	0.66	0.29	0.45_4		–	–	1.17	0.48	0.28	–		0.12	0.44	0.34	0.10	0.76	0.22	
	M.S.	0.19	0.88	1.57	1.06	1.07	0.42		–	0.51	0.56	0.15	0.23	0.15		0.20	0.52	0.28	–	0.22	0.12	
	S.S.	7.94_5	19.20	7.13	5.60	5.32	0.72_5		3.30	3.89	1.27	0.32	1.69	0.45		3.20	10.00	1.51	0.50	2.02	0.28	
	T.	8.21	20.14	9.95	7.32	6.68	1.60	53.90	3.30	4.40	3.00	0.95	2.20	0.60	14.45	3.52	10.96	2.13	0.60	3.00	0.62	20.83
Duck Fish		24.30	21.14	25.00	55.00	43.00	10.00	178.44	7.50	5.00	3.50	11.80	9.00	18.00	54.80	17.80	21.40	9.26	3.90	22.44	35.20	110.00
Com. Fish		13.67	24.38	31.75	45.10	43.10	38.73	196.73	8.88	7.51	8.96	12.97	20.80	28.33	87.45	5.40	9.94	4.14	2.70	12.76	20.95	55.89
Gr. Total		46.18	65.66	66.70	107.42	92.78	50.33	429.07	19.68	16.91	15.46	25.72	32.00	46.93	156.70	26.72	42.30	15.53	7.20	38.20	56.77	186.72

Note : Com. Fish : Commercial fish, Gr. Total : Grand total

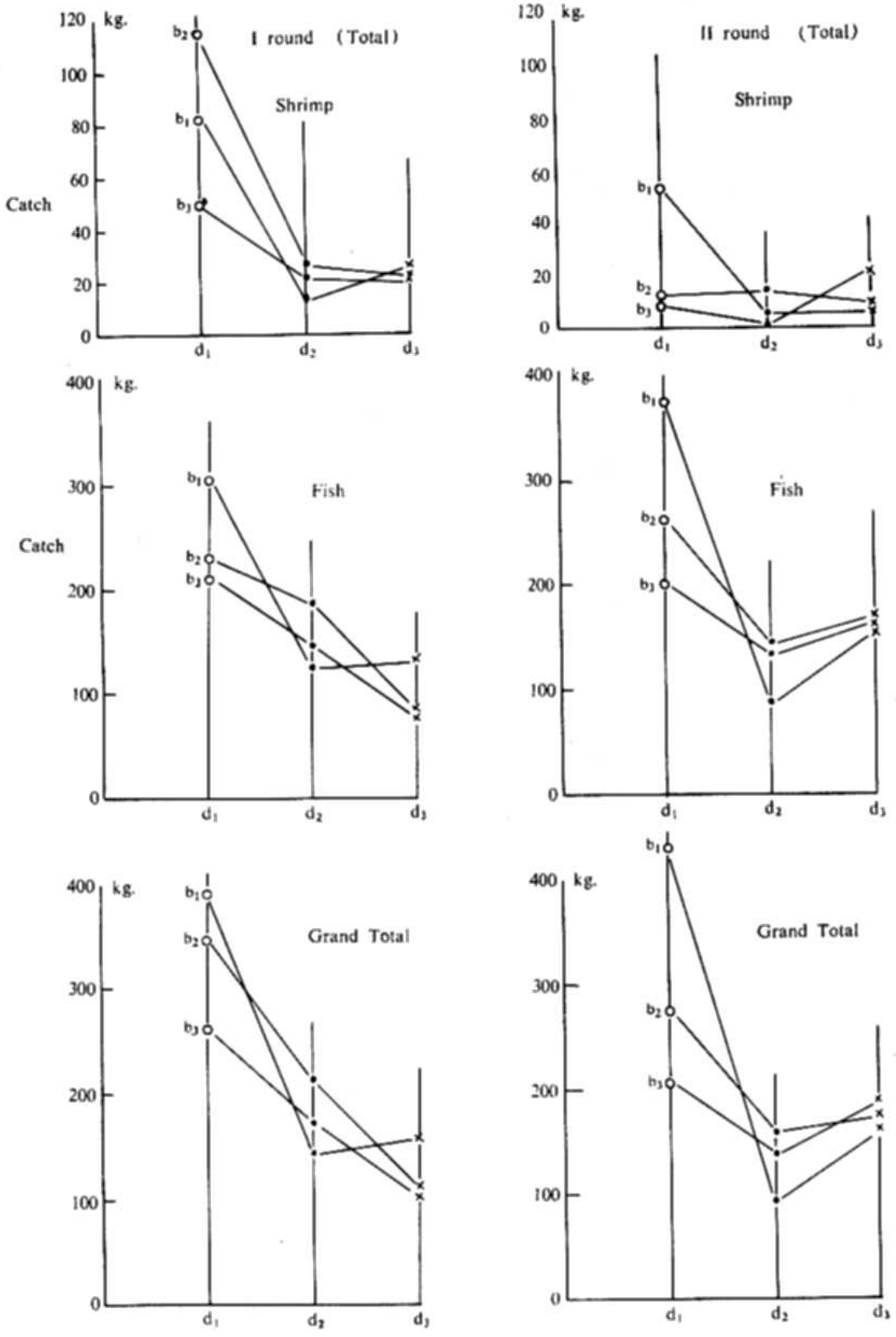


Fig. 3 Catch difference between net (d)

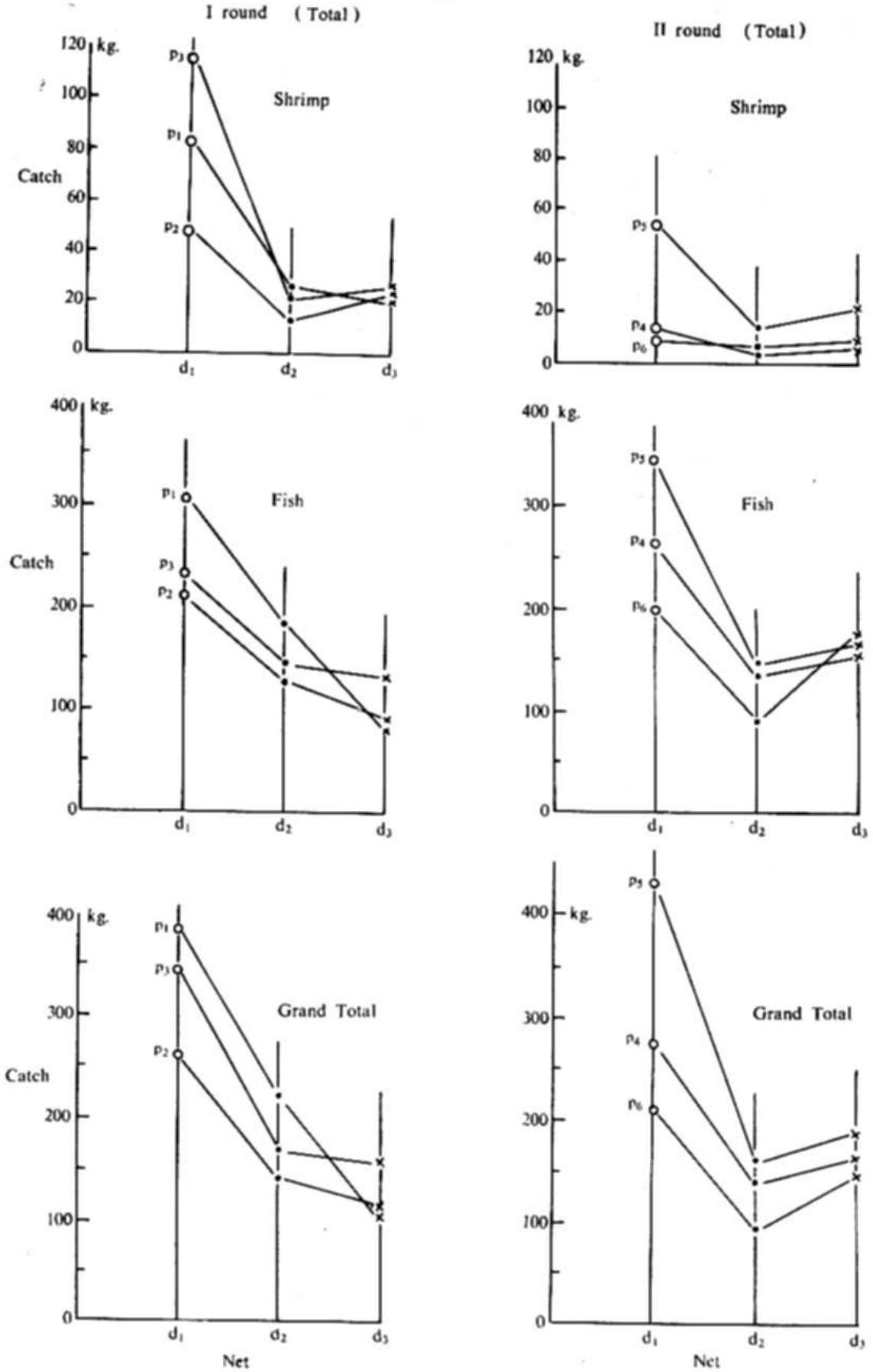


Fig. 4 Catch difference classified by net (d) and Fishing place (p)

by substracting this variation from the total sum of squares, we obtain the residual sum of squares which measures the contribution of random effects to the overall variation.

In the two-factor classification, we have the factors, boat and net, at K and N levels, giving KN observations in all as shown in Table 6.

Table 6. General formulae for the two-factor, boat and net at K and N levels for analysis of variance.

Factor d \ Factor b		Boat	Total	Mean
		$b_1\ b_2\ b_3 \ldots\ldots\ldots b_k$		
Net	d_1	$x_{11}\ x_{21}\ x_{31} \ldots\ldots\ldots x_{k1}$	$x_{.1}$	$\bar{x}_{.1}$
	d_2	$x_{12}\ x_{22}\ x_{32} \ldots\ldots\ldots x_{k2}$	$x_{.2}$	$\bar{x}_{.2}$
	.	. . . x_{ij} .	.	.
	.	. . . .	.	.
	d_N	$x_{1N}\ x_{2N}\ x_{3N} \ldots\ldots\ldots x_{kN}$	$x_{.N}$	$\bar{x}_{.N}$
Total		$x_{1.}\ x_{2.}\ x_{3.} \ldots\ldots\ldots x_{k.}$	x	
Mean		$\bar{x}_{1.}\ \bar{x}_{2.}\ \bar{x}_{3.} \ldots\ldots\ldots \bar{x}_{k.}$		$\bar{x}$

From this table we can calculate the following variation

1). Total sum of squares

$$S_{bd} = \sum_{i=1}^{K}\sum_{j=1}^{N}(x_{ij}-\bar{x})^2 = \sum_{i=1}^{K}\sum_{j=1}^{N} x_{ij}^2 - \frac{x^2}{KN}$$

2). Sum of squares between boats (Columns)

$$S_b = N\sum_{i=1}^{K}(\bar{x}_{i.}-\bar{x})^2 = \frac{1}{N}\sum_{i=1}^{K} x_{i.}^2 - \frac{x^2}{KN}$$

3. Sum of squares between nets (Rows)

$$S_d = K\sum_{j=1}^{N}(\bar{x}_{j}-\bar{x})^2 = \frac{1}{K}\sum_{j=1}^{N} x_{.j}^2 - \frac{x^2}{KN}$$

The analysis of variance will be done in the table of next operation

Factors	Sum of squares (s.s)	Degree of freedom (d.f.)	Mean square (M.s)	Variance ratio (F)
Between boats	S_b	K−1	$\frac{S_b}{K-1}$	$\frac{\text{Boat M.s}}{\text{Res. M.s}}$
Between nets	S_d	N−1	$\frac{S_d}{N-1}$	$\frac{\text{Net M.s}}{\text{Res. M.s}}$
Residual	$S_{bxd} = \sum_{i=1}^{K}\sum_{j=1}^{N}(x_{ij}-\bar{x}_i-\bar{x}_j+\bar{x})^2$	(K−1)×(N−1)	$\frac{S_{bxd}}{(N-1)(K-1)}$	
Total	$S_{bd} = \sum_{i=1}^{K}\sum_{j=1}^{N}(x_{ij}-\bar{x})^2$	KN−1		

Then, we can draw the calculation whether between boats and between nets are significant or not respectively at 1 percent or 5 percent level by judging the value of variance ratio comparing with the value of F–table.

Following to this process the catch data of I round, shrimp on b and d factor are tabulated from the data of Table 5 as shown in Table 7

Table 7 Catch data of I round, shrimp on b and d

d \ b	b_1	b_2	b_3	T
d_1	83.19	115.50	48.70	247.39
d_2	14.98	26.57	22.52	64.07
d_3	24.75	23.02	22.75	70.52
T.	122.92	165.09	93.97	381.98

In the same arrangement for I round Fish and I round Grand total, the variance ratio of two factor, b and d, by taking logarithmic value of catch are calculated as shown in Table 8.

Table 8 Analysis of variance, I round

Factor	Symbol	d.f	Variance ratio F		
			Shrimp	Fish	Grand total
Boat	b	K–1 = 2	1.12	0.79	0.85
Net	d	N–1 = 2	18.02**	12.51*	16.03*
Residual	b x d	(K–1) (N–1)=4			
Total	b d	KN–1 = 8	$F_4^2(0.05) = 6.94$, $F_4^2(0.01) = 18.00$		

From this table, in every three case the factor d is significant at 5 and 1 percent level.

2-2. Two-factor; net and operational time

Next, the data are arranged by two factors as d (net) and n (operational time). The catch data of lst day, Shrimp from the data of Table 5 is shown in Table 9.

Table 9 Catch data of lst day, Shrimp on d and n

n \ d	d_1	d_2	d_3	T
n_1	22.070	6.500	10.550	39.120
n_2	8.090	4.160	3.700	15.950
n_3	11.980	3.395	3.050	18.425
n_4	11.920	0.250	1.050	13.220
n_5	15.440	8.260	2.745	26.445
n_6	13.690	4.000	1.650	19.340
T	83.190	26.565	22.745	132.500

After arranging the same kind of treatment making tables independently on Shrimp and Grand total of 1st, 2nd, 3rd, 4th, 5th, and 6th day respectively, the variance ratio on these 12 cases are tabulated in Table 10.

Table 10 (1) Analysis of variance, 1st day, 2nd day and 3rd day

Factor	Symbol	d.f	Variance ratio F					
			1st day		2nd day		3rd day	
			Shrimp	G. Total	Shrimp	G. Total	Shrimp	G. Total
Net	d	2	32.72**	32.19**	9.00**	16.97**	52.36**	29.50**
Operational time	n	5	5.10*	0.95	2.43	3.08	4.20*	12.40**
Residual	d x n	10						
Total	d n	17						

$F^2_{10}(0.05) = 4.10$, $F^2_{10}(0.01) = 7.55$,

$F^5_{10}(0.05) = 3.33$, $F^5_{10}(0.01) = 5.64$

Table 10 (2) Analysis of variance, 4th day, 5th day, and 6th day

Factor	Symbol	d.f	Variance ratio F					
			4th day		5th day		6th day	
			Shrimp	G. Total	Shrimp	G. Total	Shrimp	G. Total
Net	d	2	6.00*	8.57*	2.4	17.62**	10.97**	9.65**
Operational time	n	5	1.70	8.80**	2.32	4.20*	6.01**	0.73
Residual	d x n	10						
Total	d n	17						

From this table it is understood that the factor d is quite significant at 1 percent lebel almostly, but the factor n is sometimes significant and sometimes is not. The result of the factor n was already discussde through the interpretation on Fig. 5.

2-3. Three-factor; net, place and operational time

The catches, x_{ijf}, by the factors of d, p and n of I round, Shrimp are arranged in Table 11.

Table 11 Catch data of I round, Shrimp on d, p and n

d / n \ p	d_1			d_2			d_3		
	p_1	p_2	p_3	p_1	p_2	p_3	p_1	p_2	p_3
n_1	22.07	1.78	4.10	6.50	1.26_5	0.42	10.55	0.01	0.03_5
n_2	8.09	6.06	15.90	4.16	1.29_5	3.30	3.70	4.20	5.48
n_3	11.98	10.12	20.20	3.39_5	2.33_5	5.53	3.05	4.31	8.72
n_4	11.92	8.44	16.00	0.25	2.54	2.94	1.05	6.10	2.72_5
n_5	15.44	10.08	30.80	8.26	3.61_5	4.54	2.74_5	8.20	3.71
n_6	13.69	12.22	28.50	4.00	3.93	5.79	1.65	0.20	4.08_5
T	83.19	48.70	115.50	26.56_5	14.98	22.52	22.74_5	23.02	24.75

$$\sum_{i=1}^{K}\sum_{j=1}^{L}\sum_{f=1}^{N} x_{ijf} = 381.970$$

Assuming that the difference of catch between net will not be equal in accordance with places and operational time, the interaction d x p and d x n should be discussed taking as a factor. Thus, after making the same process of calculation we get the analysis of variance on three-factor as shown in Table 12.

Table 12 Analysis of variance, I round, Shrimp

Factor	s.s	d.f	M.s	Variance ratio
d	1202.49	2	601.25	33.60**
p	162.97	2	81.48	4.54*
n	135.74	5	27.15	1.51
d x p	220.72	4	55.18	3.08*
d x n	155.61	10	15.56	0.87
Error	537.47	30	17.91	
Total	2415.00	53		

$F^{2}_{30}(0.05) = 3.32$

$F^{2}_{30}(0.01) = 5.39$

$F^{4}_{30}(0.05) = 2.69$

$F^{10}_{30}(0.05) = 2.16$

From the table of analysis of variance we can get the following result.

1). The difference between net (d) is significant at 1 percent level indicating d_1, d_3, d_2 as the orders of catching efficiency.

2). The difference between operation place (p) is also significant at 5 percent level indicating p_3, p_1, p_2 as the orders of superiority.

3). The difference between operational time (n) is far from significant.

4). The interaction d x p could exist.

5). There is no significant interaction d x n.

In the same manner, analysis of variance, II round, Shrimp could be tabulated also in Table 13.

Table 13 Analysis of variance, II round Shrimp

Factor	s.s	d.f	M.s	Variance ratio
d	83.948	2	41.974	6.99**
p	176.333	2	88.166	14.69**
n	77.575	5	15.515	2.59*
d x p	63.720	4	15.930	2.65
d x n	23.779	10	2.378	0.39
Error	179.969	30	5.999	
Total	605.324	53		

From the table of analysis of variance the difference between net (d), the difference between operating places (p) and the difference between operational time (n) are all significant, giving the orders of superiority as d_1, d_3, d_2; p_6, p_4, p_5 and n_2, n_1, n_5 n_3, n_6, n_4.

2-4. The orders of superiority in net design

Through the discussion on the analysis of variance in 2–1 to 2–3, the orders of catch efficiency between net are clearly indicated in the following Table 14.

Table 14 Orders of catch efficiency between net

object \ order	Superiority orders in catch		
	1	2	3
I round Shrimp	d_1	d_3	d_2
„ Fish	d_1	d_2	d_3
„ G. Total	d_1	d_2	d_3
II round Shrimp	d_1	d_3	d_2
„ Fish	d_1	d_3	d_2
„ G. Total	d_1	d_3	d_2

V. Discussion

1. The fishing efficiency of Mexican type net

As clearly understood in Table 14, Mexican type trawl net d_1 got the most high fishing capability in shrimp fishing when it was compared with commercial trawl net d_3, almost the same size as d_1. Perhaps one of main reason is that d_3 constructing with two-seam net will have less opening height in the net mouth than d_1, four-seam net. The adequate design of Mexican trawl net, the type of flat, ballon and semi-ballon for instance, should be adopted by the kind of shrimp and the character of fishing ground through further experiment. The size of net also should be decided according to the size of engine power of boat.

2. Improvement of the gear in the experiment

2-1. Chain attachment and ground rope

The method of joining the chain to ground rope were different between I round experiment and II round one as shown in Fig. 6.

We could not understand yet the effectiveness of changing the method of joining the chain because we could not compare the catch itself on this point, between I round and II round experiment, but this problem is rather important for designing the net. It will be much related with the condition of fishing ground.

As for the tickler chain it is rigged between the otter boards or from the groundrope extensions. It has such function to scare the shrimp up off the bottom and drive into the net because it is a little ahead of the ground rope. Sometimes groundrope can take some interspace from the bottom because of this tickler chain, if the bottom is not so smooth or rubbishy. Ordinary the distance between ground chain and tickler chain is 25 to 30 centimeters at the center of net and this distance will have some connection with the speed of pulling and bottom nature.

For catching not only shrimp but also fishes 3 to 3.5 miles per hour of rather high speed will be necessary for this particular purpose. And the weight of ground rope and chain might be increased.

2-2. Bridle rope and extension wing (detachable wing)

On the discussion of shrimp trawl experiment at Cochin, India, Dr. Miyamoto pointed out the catch is much related to the horizontal spreading of the mouth of net rather than the opening height of the net. The experiment of the report were done on the comparison of catch between with sweep line (bridle rope) or without one, and also the comparison of catch between with detachable wing or without one.

The design of Mexican type shrimp has usually short wing. On the other hand, both Japanese type and Norwegian type net has long wing in the construction. Therefore it is very much worth while to study on the effectiveness of the length of wing for the catch of shrimp.

The shrimp catch ratio of d_1 to d_2 in I round and II round are shown in Table 15.

Table 15 Shrimp catch ratio of d_1 to d_2

	I round		II round
1st day	$\frac{83.19}{26.56} = 3.2$	4th day	$\frac{11.99}{3.77} = 3.2$
2nd day	$\frac{48.70}{14.98} = 3.3$	5th day	$\frac{9.55}{4.89} = 2$
3rd day	$\frac{115.50}{22.52} = 5.1$	6th day	$\frac{53.90}{14.45} = 3.7$

Comparing I round and II round from this table, the catch ratio of I round is a little bigger than that of II round. This difference may be caused by the effect of improvement of the gear at II round, but it is not so clearly understood on the effect of detachable wing. Therefore the problem of increasing the horizontal spread of the mouth of net is also important subject to study for shrimp trawl net operating in these area, and it must be in close connection with the behaviour of shrimp particulary when they come out off the bottom scared by chain.

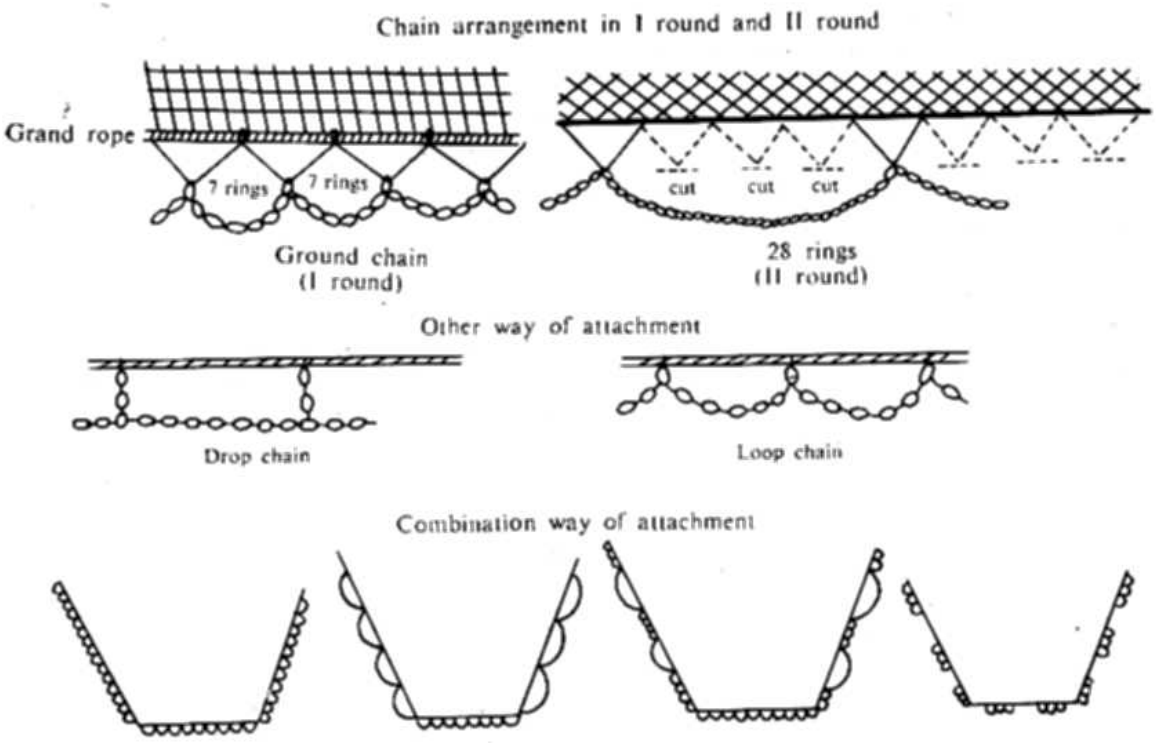


Fig. 6 Ground rope and chain

2-3. Arrangement the length of ground rope

On commercial net d_3 at II round experiment, the length of the ground rope was made 2 meters longer than I round expriement. This operation must bring on the otter board into heel down. Thus, this improvement on the gear may result some effect in the catch of II round as seen in Table 14.

2-4. Comparison of catch between full size d_1 and half size net d_2

Actually through this experiment the catch of shrimp itself were not enough in the quantity. So, the experiment may be arduous to make absolute conclusion on the catch ratio of d_1 to d_2. Bearing this in mind, however, when we contemplate Table 15 some consideration might be discussed on the comparison between 2-net system trawling and 1-net system trawling as follows. From the table the catch of half size net d_2 is nearly one-third of the catch of full size net d_1. Therefore, the ratio of the catch of 1-net system trawl net of a certain length in size to the catch of 2-net system trawl net of half length of the former one in size will be obtained nearly as 3 to 2. Accordingly, the size of 2-net system trawl net should be decided as nearly three-fourth of length of 1-net system net for taking the same catching ability.

Then the ratio of hydraulic resistance of net between these two systems will be found as :

$$1^2 : 2 \times (3/4)^2 = 1 : 1.1$$

So, the hydraulic resistance which impose to the boat will be the same in value if we obey this calculation.

3. The resistance of net measured by tension meter and spreading distance of O.B.

On 20th and 21st of January, the tension of a warp of net d_1 operating by various towing speed were measured by tension meter. At the same time

the net was measured on the spreading distance of otter board by fish finder and on the net height opening by depth meter. The tension of a warp and the distance between otter boards are illustrated in Fig. 7.

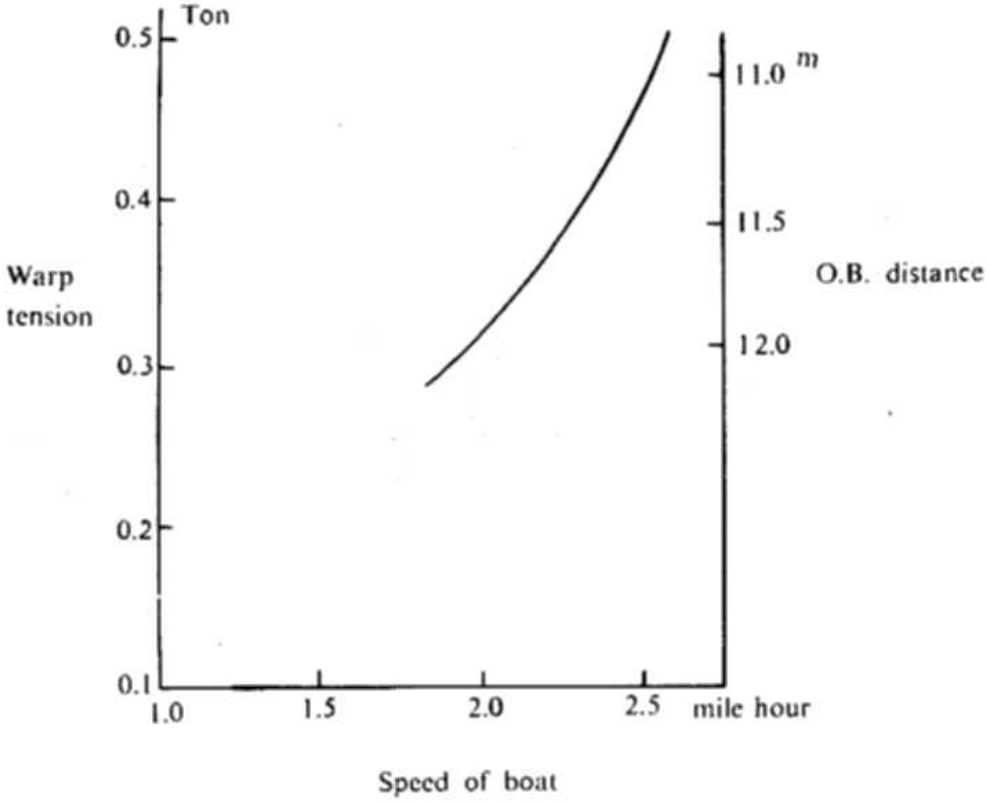


Fig. 7 Warp tension and otter board distance of net d_1

4. The relation between the size of net and horse power of engine

Denoting the size of net as the length of head rope in meter, then the relation between horse power of engine and the length of head rope of 1-net system shrimp trawl are discussed and calculated in Table 16.

The hydraulic resistance of our experimental net d_1, for instance, which was designed so as to fit with 180 HP of engine and with the speed of 2.5 miles per hour is understood to coincide with the results of Fig. 7 and Table 16. The result of calculation of Table 16 are expressed in Fig. 8 on the relation between net size and engine power.

On the basis of these results of discussion the major part of net relating to the horse power could be averagely calculated in Table 17 which will be some benefit for the fishermen to decide the size of net of shrimp trawl of 1-net system.

Table 16 Discussion table on the resistance of net and it's size

Abbreviation	Description	Remarks
I. H. P.	Indicated horse power	p.s.
B.H.P.	Brake horse power	I.H.P. x (0.85 – 0.05) (loss by pumping, loss by mechanical friction)
S.H.P.	Shaft horse power	B.H.P. x 0.9
N.H.P.	Effective horse power for towing net	S.H.P. x 0.2

$$R = \frac{75 \times N.H.P.}{v}, \qquad \lambda^2 = \frac{R_{(net)}}{12.5 \times D/L \times v^2} \text{ ... (Dr. Tauti's Formula)}$$

$$R_{(net)} = R - R_{(otter)} \fallingdotseq R \times \frac{1.5}{2.5}, \qquad (\lambda')^2 = 4.05 \times I.H.P. + 55.8 \text{ (Dr. Miyamoto's Formula)}$$

v	I.H.P.	S.H.P.	N.H.P.	R	$R_{(net)}$	λ (D/L = 0.06*)	λ'
2.5 mile/h	180 ps	130 ps	26 ps	1,560 kg	936 kg	28 m	27.6 m
2.0	,,			1,950	1170	38.8	,,
2.5	150	108	21.6	1,296	778	25.8	25.7
2.0	,,			1,620	972	36	,,
2.5	120	86.4	17.3	1,037	622	23	23.3
2.0	,,			1,297	877	34	,,
2.5	100	72	14.4	864	518	21	21.4
2.0	,,			1,080	647	29	,,
2.5	80	57.6	11.5	691	414	18.8	19.2
2.0	,,			864	517	26	,,
2.5	50	36	7.2	432	259	15	16
2.0	,,			640	324	21	,,
2.5	30	21.6	4.3	259	155	11	13
2.0	,,			324	194	16	,,

part	twine size	mesn size		D/L
wing	380d/15	76 mm	$\frac{0.15 \times 2}{7.6}$	0.04
square	/12	64	$\frac{0.13 \times 2}{6.4}$	0.04
belly Baiting	/12	38	$\frac{0.13 \times 2}{3.8}$	0.07
cod–end	/12	25	$\frac{0.13 \times 2}{2.5}$	0.10

Mean = 0.06*

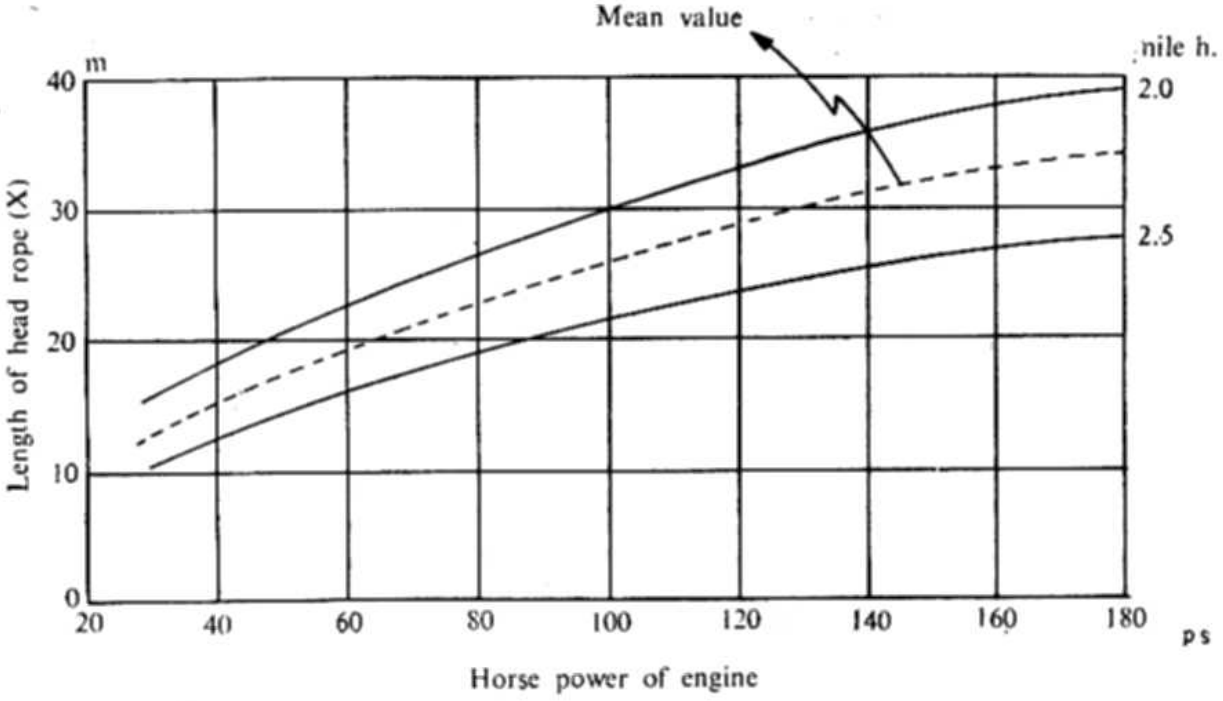


Fig. 8 The relation between horse power of engine and the length of head rope

Table 17 Size of major part of net relating to horse power of engine

Items \ Horse power	180 ps	150	120	100	80	50	30
Head rope	35m	32	28	26	22	17	12
Ground rope	41	38	33	31	26	20	15
Net—Wing	380/15, 76mm	,,	,,	,,	,,	,,	,,
Net—Square	/12, 64	,,	,,	,,	,,	,,	,,
Net—Belly, Baiting	/12, 38	,,	,,	,,	,,	,,	,,
Net—Cod-end	/12, 25	,,	,,	,,	,,	,,	,,
Chain	34kg	29	21	19	14	11	5
Otter board	1 x 2m	.9x1.8	.8x1.6	.75x1.5	.65x1.3	.50x1.0	.35x0.7

VI. Further study in future

The fishing comparison experiment on Mexican type net contributes good informations particulary on the effectiveness of this type. The next proceeding steps of the study and it's extension will be proposed as follows:

1). To make experiment on the design of Mexican net in various kinds of type which will be relating to the condition of fishing ground locally and also to the kinds of shrimp.

2). To get confirmation on the merit and demerit of four-seam net and two-seam net especially to the shrimp.

3). To make experiment on how to maintain the horizontal spreading of the mouth of net such as using detachable wing.

4). To make experiment for catching good fish as well as shrimp into separate cod end.

5). To improve the facilities of fishing boat to be adopted for shrimp trawling.

6). To test the possibility and effectiveness of 2-net system of shrimp trawl locally.

Acknowledgement

Through conducting this experiment, many thanks should be given to the instructors of SEAFDEC and German experts for their nice cooperation in work with the officers, the scientists, crew members of Department of Fisheries. For the training some of statistical calculation were imposed to the trainees of SEAFDEC under the guidance of the instructor. Their works as a fishing training practice and mathematical calculation are also appreciated.

Thanks also should be given to Dr. M. Nomura, SEAFDEC, for his preparation of this report.

References

1. Miyamoto H. : Report to the Government of India on establishment of a fishing gear research laboratory, 1968 ; FAO No. TA 2599
2. Kondo Y. : Study of tension distribution in nets and fishing gear; Journal of the Tokyo University of Fisheries, Special edition, Vol 5. No. 2, March, 1962
3. Miyamoto H. : On the relation between otter trawl gear and towing power; Modern Fishing Gear of the World, April, 1959
4. Robas J. : Shrimp trawling gear as used in the Gulf of Mexico ; Modern Fishing Gear of the World, April, 1959
5. Lorimer P.D. & Junes W.J. : Australian prawn trawling gear, Australian Fisheries, No. 6, 1969

2. From the result of 1, $n_1=n_2=n_3=n_4=n_5=n_6=1$ will be permissible. Then c is expressed as c $\propto$ b.d.p. The following expressions, therefore, can be made up from the catch data of Shrimp total in Table 5.

$$\frac{p_1b_1d_1}{83.19}=\frac{p_1b_2d_2}{26.565}=\frac{p_1b_3d_3}{22.745} \quad \text{-----(1)} \qquad \frac{p_4b_1d_2}{6.565}=\frac{p_4b_2d_1}{11.99}=\frac{p_4b_3d_2}{3.77} \quad \text{-----(4)}$$

$$\frac{p_2b_1d_2}{14.98}=\frac{p_2b_2d_3}{23.02}=\frac{p_2b_3d_1}{48.70} \quad \text{-----(2)} \qquad \frac{p_5b_1d_2}{4.98}=\frac{p_5b_2d_3}{7.34}=\frac{p_5b_3d_1}{9.55} \quad \text{-----(5)}$$

$$\frac{p_3b_1d_3}{24.75}=\frac{p_3b_2d_1}{115.50}=\frac{p_3b_3d_2}{22.52} \quad \text{-----(3)} \qquad \frac{p_6b_1d_1}{53.90}=\frac{p_6b_2d_2}{14.45}=\frac{p_6b_3d_3}{20.83} \quad \text{-----(6)}$$

From the equations (1) and (6), the relation of

$$\frac{(b_1d_1)^2}{83.19\times 53.90}=\frac{(b_2d_2)^2}{26.565\times 14.45}=\frac{(b_3d_3)^2}{22.745\times 20.83}$$ is found out, thus

the equation (7) may be realized.

$$\frac{b_1d_1}{66.5}=\frac{b_2d_2}{19.65}=\frac{b_3d_3}{21.75} \quad \text{-----(7)}$$

In the same way, the following equations may be obtained.

From (2) and (5); $\frac{b_1d_2}{8.64}=\frac{b_2d_3}{13.0}=\frac{b_3d_1}{21.56}$ -----(8) and,

from (3) and (4); $\frac{b_1d_3}{12.75}=\frac{b_2d_1}{37.2}=\frac{b_3d_2}{9.21}$ -----(9).

Multiplying equations as (7) × (8) × (9), the relation of

$$\frac{b_1^3}{66.5\times 8.64\times 12.75}=\frac{b_2^3}{19.65\times 13.0\times 37.2}=\frac{b_3^3}{21.75\times 21.56\times 9.21}$$

is obtained, thus the equation (10) will be realized.

$$\frac{b_1}{19.5}=\frac{b_2}{21.2}=\frac{b_3}{16.3} \quad \text{-----(10)}$$

So, the proportion among the Index of fishing efficiency of the boat may be expressed as follows;

$$b_1 : b_2 : b_3 = 0.92 : 1.00 : 0.77$$

3. The following equations may be calculated as,

from (7) ÷ (10); $\frac{d_1}{3.35}=\frac{d_2}{0.925}=\frac{d_3}{1.33}$ -----(11),

from (8) ÷ (10); $\frac{d_2}{0.443}=\frac{d_3}{0.615}=\frac{d_1}{1.32}$ -----(12) and,

from (9) ÷ (10); $\frac{d_3}{0.652}=\frac{d_1}{1.75}=\frac{d_2}{0.565}$ -----(13).

Thus, the following expressions may be realized by multiplying equations as (11) × (12) × (13) :

$$\frac{d_1^{\,3}}{3.35 \times 1.32 \times 1.75} = \frac{d_2^{\,3}}{0.925 \times 0.443 \times 0.565} = \frac{d_3^{\,3}}{1.33 \times 0.615 \times 0.652}$$

So, the proportion among the Index of fishing efficiency of the net may be expressed as follows :

$$d_1 : d_2 : d_3 = 1.00 : 0.31 : 0.41$$

4. From the assumption $c \propto b.d.p$, c can be expressed as $\frac{b.d.p}{c} = \frac{1}{K}$. Here, K is a proportional coefficient.

So, from equation (1), $\frac{p_1^{\,3} b_1 b_2 b_3 d_1 d_2 d_3}{83.19 \times 26.565 \times 22.745} = \frac{1}{K^3}$ is obtained. In the samy way from the equations of (2), (3), (4), (5) and (6) the following expression will be formulated as :

$$\frac{1}{K^3} = \frac{p_2^{\,3} b_1 b_2 b_3 d_1 d_2 d_3}{14.98 \times 23.02 \times 48.70} = \frac{p_3^{\,3} b_1 b_2 b_3 d_1 d_2 d_3}{24.75 \times 115.50 \times 22.52} = \cdots\cdots\cdots\cdots$$

Taking the cube root of the above equation, the proportional expression of the Index **p** is found to be as follows :

$$\frac{p_1}{36.9} = \frac{p_2}{25.6} = \frac{p_3}{40.0} = \frac{p_4}{6.67} = \frac{p_5}{7.05} = \frac{p_6}{25.3}$$

From this result of proportional value it is found that in this fishing area the value of the Index **p** is big in the fishing ground of less than 20 meters depth and is small in the fishing ground of more than 20 meters depth.