

Fundamental Studies on the Fishing Efficiency of Purse Seine

Elof Machten KATIANDAGHO* and Takehiko IMAI**

Abstract

Studies on the efficiency of purse seines were carried out in a water circulating experimental tank in a static water condition using five simplified seine models of different hang-in ratios. The results indicate that the seine with hang-in ratio of 34 % sank the fastest and seines with 25 % and 30 % of hang-in ratios had sinking speeds nearly equal to each other. The final depth of the former seine wall was 91 % of the designed seine depth, while that for the later was 97 % and 100 %. From this data it is thought that a net with about a 30 % hang-in ratio is the most efficient for both fishing and also in terms of construction.

Model experiments on the two net designs of mackerel purse seines operating in Indonesian waters revealed high sinking speed those are 53 % and 40 % of setting time, after that time both model nets decreased the sinking speed. So it is recommended to commence pursing because at this moment, the stretched seine wall of model net A showed 72 % and model net B showed 86 % of seine depth. The effects of various pursing speeds and pursing times on the purseline tension of two model nets A and B showed a quadratic function. The purseline tension of model net A was greater value than that of model net B, the reason might be caused by the different design and size of the seine used in the experiment. The relationship between pursing speed and the value of square root of the opening area of seine bottom by initial opening area of seine bottom was a linear function. The opening area of the seine bottom of model net B was faster closing than for model net A, even though the purseline length of model net B was longer than of model net A.

Introduction

Indonesian waters have considerable resources of various species. There are over one hundred species of fish and other marine organisms contributing to sea fisheries production in Indonesian waters. These are grouped into four categories ;

* エロフ M. カチアングゴ, サム・ラトランギ大学水産学部漁業学科, インドネシア
Faculty of Fisheries, Sam Ratulangi University : Manado, North Sulawesi, INDONESIA

** 今井健彦, 鹿児島大学水産学部漁具学講座

Fishing Gear Science, Faculty of Fisheries, Kagoshima University : Shimoarata-4 Kagoshima 890, JAPAN

crustaceans (e. g., primarily shrimps); demersals (e. g., ponyfishes, groupers, and snappers); small pelagics (e. g., mackerels, scads, pomfrets, sardines, and anchovies); and large pelagics (e. g., tunas); FAO (1980).

The commercial exploitation of pelagic species in Indonesia is mainly by purse seines, beach seines, gill nets, lampara nets, raft-lift nets, trolling, and pole-and-lines, all of which are operated by non-mechanized traditional crafts. Before purse seine introduced extensively, the fishermen most familiar with lampara net in the Bali Strait and in the Java Sea. However, the still have problems with lampara gear that is, when the net has been hauled, fish can escape under of the leadline. The purse seine came to be used extensively after 1973 to replace lampara net. The government of Indonesia suspended trawl net to prevent demersal resources and supported purse seine by low interest loan.

The catch from Indonesian waters has a good demand both domestically and overseas. The perspective demand of fish for the Southeast Asian countries in 1980 was about 6.0–7.0 million metric tons, while in 1985 estimated to be 7.0–8.5 million metric tons, UNAR (1978). Therefore, it is thought that the prospects for the Indonesian pelagic fisheries are good. The application of the purse seine will also have a good prospect. Despite the growing importance of purse seining, researchers have made little attempt to improve the basic means of capture namely, the purse seine. In this respect, purse seining lags far behind trawling, for which the techniques and the designs of the gear have been thoroughly studied in many countries during the last decade. Many studies have been made on the physical characteristics of the purse seine to improve fishing efficiency which have been carried out by BEN YAMI and GREEN (1968), GREEN (1964), HAMRE (1963), IITAKA (1965), INOUE (1961), KONAGAYA (1966), (1971), MCNELLY (1961), and NOMURA *et al.* (1967a), (1967b). To obtain some fundamental information on the physical characteristics and gear efficiencies of Indonesian mackerel purse seines, the authors carried out a series of experiments in the water circulating experimental tank on the static water condition.

Materials and Method

Five simplified seine models are used in the first phase of this experiment carried out in a static water condition, in the circulating experimental tank. Each seine had 3.00 m of corkline length and 0.81 m of net depth. The hang-in ratio of them was determined to be 30 % E_2 , 34 % E_3 , 40 % E_4 , and 50 % E_5 from the mackerel purse seine, which are commonly used in the Indonesian coastal waters. While the 25 % hang-in ratio for E_1 was determined from the average value of the Japanese mackerel purse seine. Each seine was constructed from a same netting materials, that is made polyamide 210 denier 3×3 multi-filament yarn of netting twine with a diameter of 0.41 mm and a stretched mesh size of 20 mm using Weaver's knot netting. The main lines (corkline, first leadline, and gavels) are constructed from a netting

twine of polyamide 210 denier 6×3 multi-filament with a diameter of 0.60 mm except for the second leadline, which was of polyvinyl-alcohol 20's 3×3 netting twine and had a diameter of 1.01 mm.

Each seine models was rigged with 73 pieces of plastic floats with 28.5 g of total buoyancy on the corkline and 100 pieces of thin lead plate with 13.0 g of total under-water weight (including purse ring weight) on the leadline. The seine models are showed in Figure 1 and Table 1.

In the second phase of the experiment, two net designs of mackerel purse seine operating in Indonesian waters are used, namely; model net A was reduced from net A on a scale of $1/76.7$, while model net B was reduced from net B on the scale of $1/141.1$ based upon Dr. TAUTI's (1934) method of fishing net reduction. Various values ascribed to the model and full-scale net are distinguished hereafter by one prime (') and two primes (''), respectively.

The reduction factors between the model and the full-scale, were ascertained to be as follows (TAUTI, 1934):

- (1) Ratio of reducing scale $\lambda'/\lambda'' = A$
- (2) Ratio of twine diameter and that of mesh size

$$D'/D'' = L'/L''$$

- (3) Ratio of rope diameter

$$D_1'/D_1'' = \sqrt{(\lambda'/\lambda'')(V'/V'')^2(\rho_1'' - 1)/(\rho_1' - 1)}$$

- (4) Ratio of buoyancy and sinker and that of the force acting on the net

$$F_f'/F_f'' = F_s'/F_s'' = (\lambda'/\lambda'')^2 (V'/V'')^2$$

- (5) Time required to attain a corresponding stage of fishing operation of the purse seines

$$t'/t'' = (\lambda'/\lambda'')/\sqrt{(D'/D'')(\rho_1' - 1)/(\rho_1'' - 1)}$$

Model net A was a type of tapered seine constructed of two wings, two shoulders, and a bunt was located at middle of the seine; model net B was a type of rectangular seine with a bunt located at the end of its. Those two models are showed in Figures 2 and 3. Both of the model nets had a corkline length of 3.00 m and the depth of model net A was 0.81 m and that of model net B was 0.44 m. The principal dimensions of both model nets are tabulated in Tables 2 and 3. The ratio of reduced-scale model and the full-scale net of the mackerel purse seine is provided in Table 4.

In order to observe the sinking speed and sinking depth of the five seine

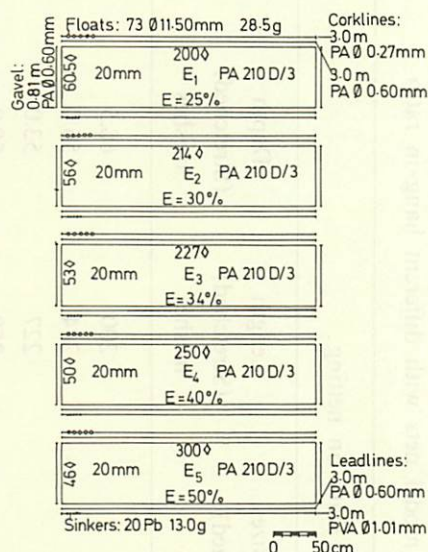


Figure 1. Construction diagram on the simplified five model nets with different hang-in ratio. \diamond : meshes, E_1 to E_5 : model nets, E' : hang-in ratio.

Table 1. Specification on the five simplified model nets with different hang-in ratio

Model nets	Data on netting					
	Material	Twine size	Mesh size (Stretched) mm	Length (Stretched) meshes	Depth (Stretched) meshes	Hang-in ratio (E') %
E ₁	Nylon(PA)	210 D/3	20	200	66.5	25
E ₂	Nylon(PA)	210 D/3	20	214	56.0	30
E ₃	Nylon(PA)	210 D/3	20	227	53.0	34
E ₄	Nylon(PA)	210 D/3	20	250	50.0	40
E ₅	Nylon(PA)	210 D/3	20	300	46.0	50

Items	Data on lines, floats, and sinkers						
	Material	Diameter mm	Shape	Length meters	Weight in water grams	Buoyancy grams	Numbers pieces
Corklines	Nylon(PA)	0.27 ; 0.60	twisted	3.00			2
Leadlines	PA ; PVA	0.60 ; 1.01	twisted	3.00			2
Gavels	Nylon(PA)	0.60 ; 0.60	twisted	0.81			2
Floats	Plastic	11.50	spherical			0.39	73
Sinkers	Lead (Pb)	18.4×2.4×0.23	plate		0.13		100

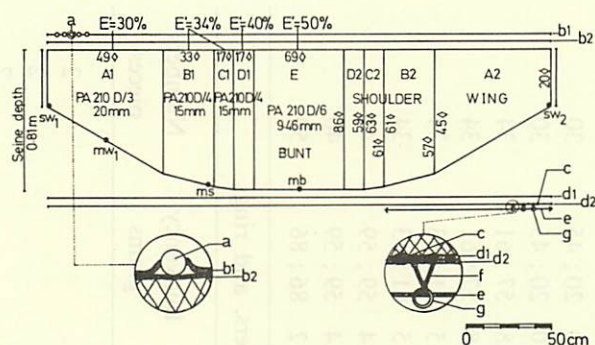


Figure 2. Constrction diagram model net A

a : Floats 59 pieces plastic

 ϕ 12 mm 9.57 g/mb₁: Corkline 4.50 m PE ϕ 1.04 mmb₂: Corkline 3.00 m PE ϕ 0.44 mm

c : Lead 100 pieces 2.50 g/m

d₁: Leadline 3.17 m PVA ϕ 1.01 mmd₂: Leadline 3.17 m PVA ϕ 1.01 mme : Purse line 3.91 m PVA ϕ 1.01 mmf : Pursing ring bridle PVA ϕ 1.01 mm

g : Pursing ring Cu 6.00/0.90 mm

● : Shows the measured point of leadline

sw₁ : Side wing

ms : Middle shoulder

sw₂ : Side wingmw₁ : Middle wing

mb : Middle bunt

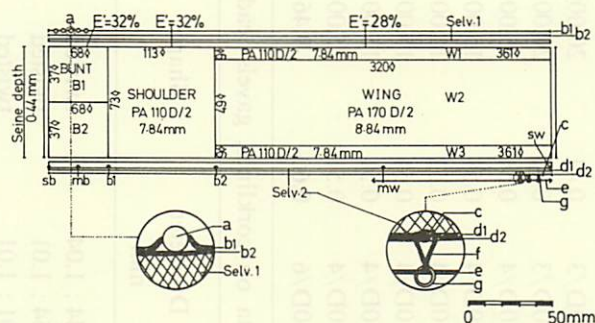


Figure 3. Construction diagram model net B

a : Floats 118 pieces plastic

 ϕ 12 mm 19.27 g/mb₁: Corkline 4.50 m PA ϕ 0.65 mmb₂: Corkline 3.00 m PA ϕ 0.65 mm

c : Lead 123 pieces 3.02 g/m

d₁: Leadline 3.25 m PVA ϕ 0.54 mmd₂: Leadline 3.25 m PVA ϕ 0.65 mme : Purse line 5.66 m Cu wire ϕ 0.74 mmf : Pursing ring bridle PVA ϕ 0.67 mm

g : Pursing ring Cu 5.60/0.75 mm

● : Shows the measured point of leadline

sb : Side bunt

mb : Middle bunt

b₁ : Between bunt and shoulderb₂ : Between shoulder and wing

mw : Middle wing

sw : Side wing

Table 2. Specification for model net A

Netting sections	Data on netting						
	Material	Twine size	Diameter mm	Mesh size (Stretched) mm	Length (Stretched) meters	Depth (Stretched) mm	Hang-in ratio (E') %
Wing : A ₁	Nylon (PA)	210D/3	0.41	20.00	0.98	408.9 ; 898.0	20 ; 45
A ₂	Nylon (PA)	210D/3	0.41	20.00	0.98	408.9 ; 898.0	20 ; 45
Shoulder : B ₁	Nylon (PA)	210D/4	0.51	15.00	0.49	853.5 ; 907.8	57 ; 61
B ₂	Nylon (PA)	210D/4	0.51	15.00	0.49	853.5 ; 907.8	57 ; 61
C ₁	Nylon (PA)	210D/4	0.51	15.00	0.20	907.8 ; 937.5	61 ; 63
C ₂	Nylon (PA)	210D/4	0.51	15.00	0.20	907.8 ; 937.5	61 ; 63
D ₁	Nylon (PA)	210D/4	0.51	15.00	0.20	880.4 ; 880.4	59 ; 59
D ₂	Nylon (PA)	210D/4	0.51	15.00	0.20	880.4 ; 880.4	59 ; 59
Bunt : E	Nylon (PA)	210D/6	0.60	9.46	0.54	817.2 ; 817.2	86 ; 86

Items	Data on corklines, gavels leadlines, bridles, pursing line, floats, sinkers, and rings						
	Material	Diameter mm	Shape	Length meters	Weight in water grams	Buoyancy grams	Numbers pieces
Corklines	PE	0.44 ; 1.04	twisted	3.00 ; 4.50			2
Leadlines	PVA	0.54 ; 1.01	twisted	3.17 ; 3.17			2
Gavels	PVA	1.01 ; 1.01	twisted	0.22			2
Bridles	PVA	1.01	twisted	0.01			35
Pursing line	PVA	1.01	twisted	3.91			1
Floats	Plastic	12.00	spherical			0.49	59
Sinkers	Lead (Pb)	16.0×2.0×0.27	plate		0.08		100
Pursing rings	Copper (Cu)	6.00/0.90	ring		0.12		35

Table 3. Specification for model net B

Netting sections	Data on netting					
	Material	Twine size	Diameter mm	Mesh size (Stretched) mm	Length (Stretched) meters meshes	Depth (Stretched) mm meshes
Wing : W ₁	Nylon (PA)	110D/2	0.27	7.84	2.83	70.56
W ₂	Nylon (PA)	170D/2	0.22	8.84	2.83	433.16
W ₃	Nylon (PA)	110D/2	0.27	7.84	2.83	70.56
Shoulder: Sh	Nylon (PA)	110D/2	0.27	7.84	0.89	572.32
Bunt : B ₁	Nylon (PA)	110D/2	0.27	7.84	0.53	290.08
B ₂	Nylon (PA)	110D/2	0.27	7.84	0.53	290.08
Selvedge : Selv. 1	Nylon (PA)	210D/3	0.41	7.35	4.25	3.68
Selv. 2	Nylon (PA)	210D/4	0.51	22.86	4.25	34.29
						1.5
Items	Data on corklines, leadline, gavels, bridles, purse line, floats, sinkers, and rings					
	Material	Diameter mm	Shape	Length meters	Weight in water grams	Buoyancy grams
Corklines	PA	0.65 ; 0.65	twisted	3.00 ; 4.50		
Leadlines	PVA	0.54 ; 0.65	twisted	3.25 ; 3.25		
Gavels	PVA	0.54 ; 0.54	twisted	0.44		
Bridles	PVA	0.67	twisted	0.01		
Purse line	Cu wire	0.74	twisted	5.66		
Floats	Plastic	12.00	spherical			0.49
Sinkers	Lead (Pb)	16.0 × 2.0 × 0.27	plate		0.08	
Pursing rings	Copper (Cu)	5.60/0.75	ring		0.08	

Key : E' = Hang-in ratio ; (cl) = corkline ; (ll) = leadline ; (-) = denotes that the edge concerned is laced to another.

Table 4. Dimension of the reducing ratio of the experimental condition of two model nets A and B

Items Net types	$\frac{\lambda'}{\lambda''}$	$\frac{D'}{D''}$ or $\frac{L'}{L''}$	$\frac{D_1'}{D_1''}$	$\frac{F_t'}{F_t''}$ or $\frac{F_s'}{F_s''}$
A	$\frac{1}{76.7}$	0.41	0.07	0.89×10^{-5}
B	$\frac{1}{141.3}$	0.30	0.05	1.50×10^{-5}

A : Mackerel purse seine belong to Marine Fisheries Training Center Aertembaga Bitung, Indonesia.

B : Mackerel purse seine belong to P. T. Tirta Raya Mina Pekalongan, Indonesia.

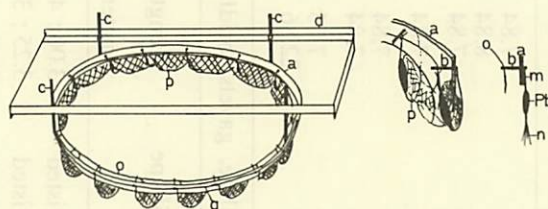


Figure 4. Schematic drawing shows a rough sketch of circular frame fit with model net by model net holders set up in the water circulating experimental tank.

- a : Circular frame
- b : Electric terminals (16)
- c : Adjusting screws (4)
- d : Head bridge
- m : Model net holder with a lead as sinker (16)
- n : Thin copper wire
- o : Electric cable at inside circular frame
- p : Model net
- q : Electric cable at outside circular frame
- pb : Lead

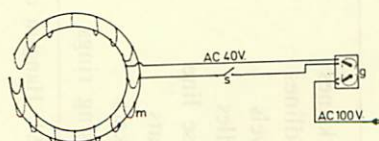


Figure 5. Schematic drawing shows the electrical circuit of the setting apparatus for model net.

- g : Transformer
- m : Model net holder with a lead as sinker
- s : Switch

models in the first phase of the experiment, the model net was hung from a circular frame by thin copper net holders. The circular frame was 3.00 m in circumference and is adjusted by screws under the head bridge so that the seine was one cm above the water surface (see Figure 4). The electrical circuit is illustrated in Figure 5. When the switch is closed, electric current cuts the thin copper wires of the all net holders and the net falls simultaneously into the water. The sinking speed of leadline was observed through an observation window and recorded with a camera every second until the net was stretched out. Measurements were carried out on the depth of the leadline, using a scaled stick installed in the tank by reading photographs.

The second phase experiments were carried out on the models of Indonesian mackerel purse seines. The experiments were carried out in two steps, the first to determine the setting condition of the seines and the later to determine the pursing conditions. The experimental equipment for setting the net consisted of a circular frame with a 3.00 m circumference with 16 net holders, setting winch, winch controller, scaled sticks, and camera. The pursing equipment consisted of a pursing winch, winch controller, and tension meter. The setting and pursing equipment is showed in Figures 6 to 8.

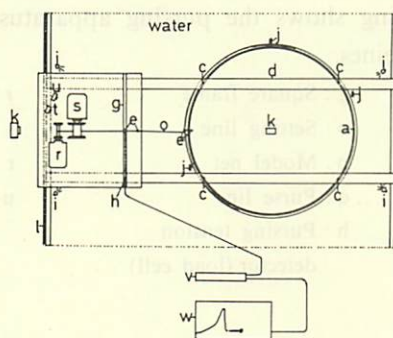


Figure 6. Schematic drawing shows the experimental equipment set up in the water circulating experimental tank for two model nets of Indonesian purse seines.

- | | |
|---|------------------------------|
| a : Circular frame | k : Camera (2) |
| c : Adjusting screws (4) | l : Observing window |
| d : Head bridge | o : Setting line |
| e : Pulleys (4) | r : Setting winch |
| f : Base board | s : Pursing winch |
| g : Square frame | t : Setting winch controller |
| h : Pursing tension detector
(load cell) | u : Pursing winch controller |
| i : Electric lamps (4) | v : Strain amplifier |
| j : Scale sticks (3) | w : Pen recorder |

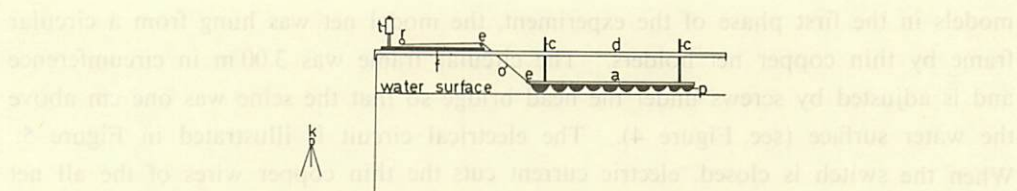


Figure 7. Schematic drawing shows the setting apparatus for two model nets of Indonesian purse seines.

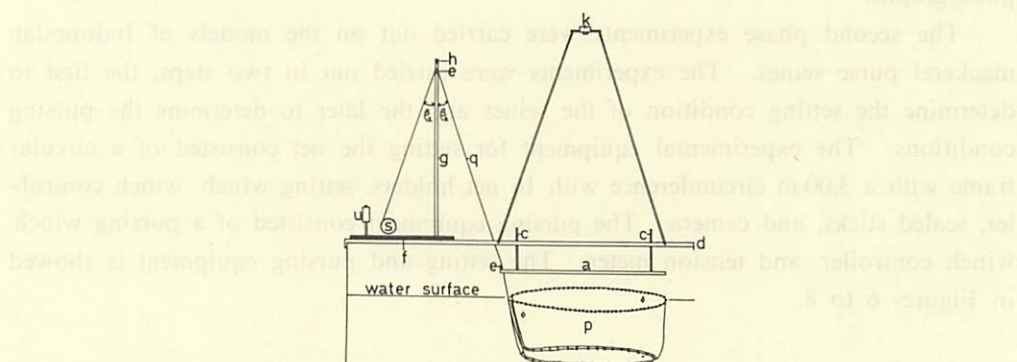


Figure 8. Schematic drawing shows the pursing apparatus for two model nets of Indonesian purse seines.

- | | | |
|--------------------------|--|------------------------------|
| a : Circular frame | g : Square frame | r : Setting winch |
| c : Adjusting screws (4) | o : Setting line | s : Pursing winch |
| d : Head bridge | p : Model net | t : Setting winch controller |
| e : Pulleys (4) | q : Purse line | u : Pursing winch controller |
| f : Base board | h : Pursing tension detector (load cell) | |

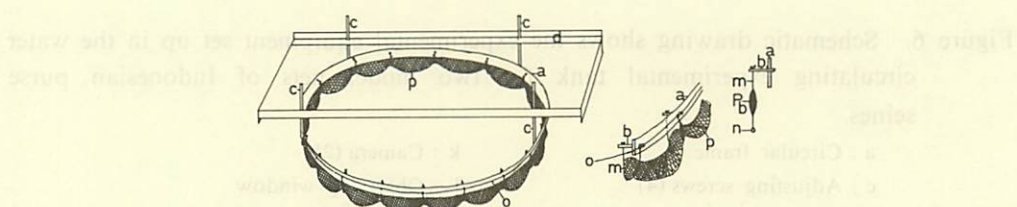


Figure 9. Schematic drawing shows a rough sketch of circular frame fit with model net holders set up in the water circulating experimental tank.

- | | |
|----------------------------|-----------------------------------|
| a : Circular frame | n : Small ring of copper material |
| b : Hanging screws (16) | o : Setting line |
| c : Adjusting screws (4) | p : Model net |
| m : Model net holders (16) | Pb : Lead |
| d : Head bridge | |

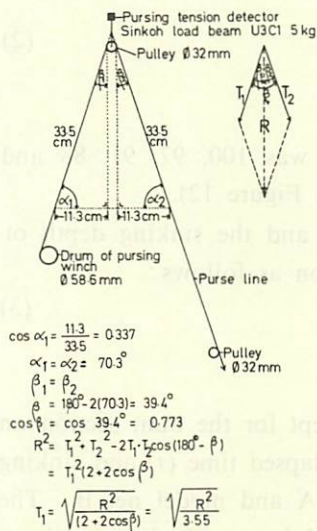


Figure 10. Determination of purse line tension, $T(g)$.

R : Resistance recorded by tension meter system

$T_1 = T_2$: Tension of purse line

β : Angle between T_1 and T_2

The model net was hung under the circular frame by the net holders and when wound the setting line by setting winch the line pass through end ring of the all net holders (see Figure 9), so it is possible to set the net from one end to the another. The setting speed can be adjusted by using the setting winch controller. The pursing begins as soon as the net is set and the pursed at a constant speed with both purseline ends. Those ends passing through pulleys which connected to a load beam (Shinkoh U3C1 5kgf), and then connected to a strain amplifier (Y. E. W. 3458-10) and pen recorder (Y. E. W. 3052). It was therefore possible to record the resistance of the whole pursing operation. These resistance values were converted to purseline tension, and the analytical method is expressed in Figure 10.

Results

The observations of the five simplified models are presented in Figure 11. The sinking depth (d) was a quadratic related to the sinking time (t), so the equation is as follows :

$$d = a t^2 + b t + c \quad (1)$$

where d : Sinking depth of lead line (cm)

t : Sinking time (s)

From the five seines experimental values of stretched depth, the relationship between hang-in ratio ($E\%$) and depth of leadline sinking ratio ($P\%$) might be

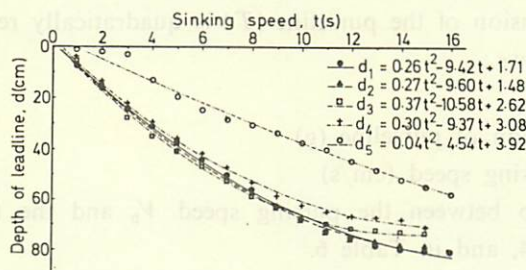


Figure 11. Relationship between the sinking time, $t(s)$, and the sinking depth of leadline, $d(cm)$, during experiment on the five simplified model nets. d_1 , d_2 , d_3 , d_4 , and d_5 denoted equations for model nets E_1 , E_2 , E_3 , E_4 , and E_5 , respectively.

denoted by a linear function as follows:

$$P = dE' + e \quad (2)$$

where P : Ratio of leadline sinking depth (%)

E' : Hang-in ratio (%)

The ratio of designed depth versus stretched depth was 100, 97, 91, 88 and 72 %, for models E_1 , E_2 , E_3 , E_4 and E_5 , respectively (see Figure 12).

The relationship between the time to set the net (t) and the sinking depth of the leadline (d) can be represented by a quadratic function as follows:

$$d = f t^2 + g t + h \quad (3)$$

where d : Depth of leadline (cm)

t : Elapsed time (s)

All of the seine sections sank at the same speed except for the bunt section on both models. Figure 13 shows the relationship between elapsed time (t) and sinking depth of leadline (d) for the bunt section of model net A and model net B. The fastest sinking speed of the leadlines was for the first eighth seconds for model net A; and the highest speed obtained for the first fourth seconds was for model net B. After that the rate of sinking speed decreased until the end of the net reached. Also, the sinking speed appears to be independent of the setting speed. The relationship between the elapsed time and the sinking depth of leadline can be represented by the linear functions as follows:

$$d_1 = it \quad (4)$$

$$d_2 = jt + k \quad (5)$$

$$d_3 = m \quad (6)$$

where d_1 , d_2 , d_3 : Depth of leadline (cm)

t : Elapsed time (s)

The value of "i", "j", "k" and "m" for the two models are tabulated in Table 5. From Figure 13 it can be seen that the sinking speed decreased rapidly, about 53 % and 40 % of elapsed time on model net A and model net B, when the seine wall was stretched out to 72 % and 86 % respectively.

The tension of the purseline gradually increased when the pursing speed was accelerated. The tension of the purseline (T) is quadratically related to the pursing speed (V_p) as follows:

$$T = n V_p^2 \quad (7)$$

where T : Tension of purseline (g)

V_p : Pursing speed (cm/s)

The relationship between the pursing speed V_p and the tension of purseline showed in Figure 14, and in Table 6.

The pursing time (t_p) depends on both the pursing speed (V_p) and the construction of the seine, therefore it might be influenced by the tension on the purseline.

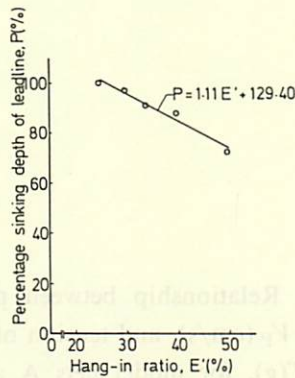


Figure 12. Relationship between hang-in ratio, E' (%), and percentage sinking depth of leadline, P (%), during experiment on the five simplified model nets with the different hang-in ratio.

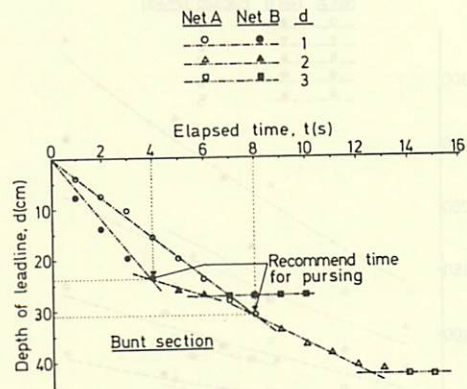


Figure 13. Relationship between elapsed time, t (s), and sinking depth of leadline, d (cm), if plotted partly in linear regression of bunt section for model nets A and B. d_1 , d_2 , and d_3 are the linear regression of extend stage, transition stage and final stage after fall down the seine in experiments.

Table 5. The " i ", " j ", " k ", and " m " values in the equations showing relationship between elapsed time and sinking depth of two model nets A and B as calculated from the obtained results of second phase experiments.

Model nets	A				B			
	i	j	k	m	i	j	k	m
d_1 (○)	-3.92				d_1 (●)	-6.31		
d_2 (△)		-2.63	-10.29		d_2 (▲)		-1.70	-17.20
d_3 (□)				-32.74	d_3 (■)			-27.40

Table 6. The " n " values in the equations showing the relationship between the pursuing speed and tension of purse line of two model nets A and B as calculated from the obtained results of the second phase experiments

Items	A	B
	n	n
T_1	0.02	0.01
T_2	0.05	0.02
T_3	0.08	0.05
T_4	0.13	0.08
T_5	0.20	0.14

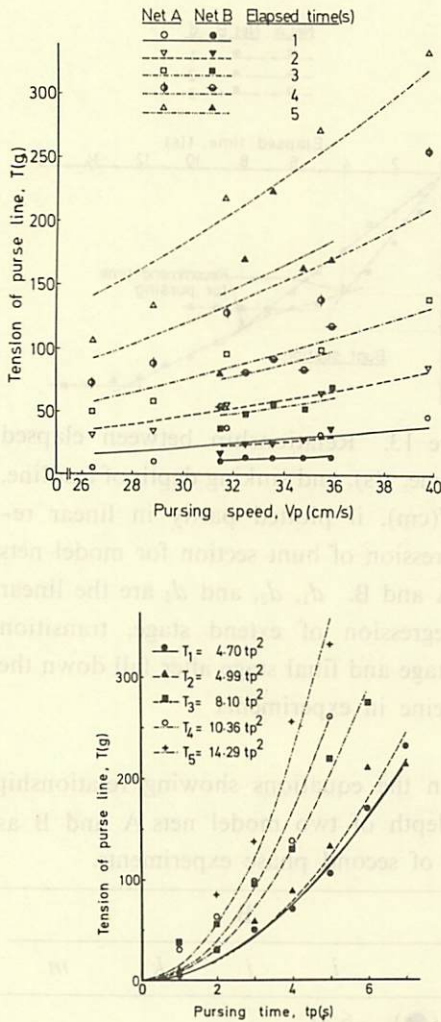


Figure 15. Relationship between pursing time, t_p (s), and tension of purse line, T (g), during experiments on model net A. T_1 , T_2 , T_3 , T_4 , and T_5 denoted the equations for pursing speeds of 26.5, 28.9, 31.8, 35.5, and 39.8 cm/s, respectively.

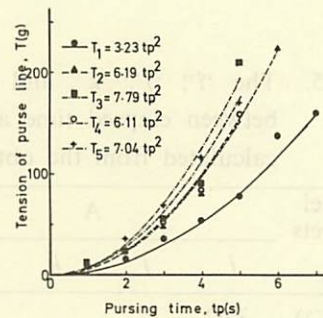


Figure 16. Relationship between pursing time, t_p (s), and tension of purse line, T (g), during experiments on model net B. T_1 , T_2 , T_3 , T_4 , and T_5 denoted the equations for pursing speeds of 31.5, 32.5, 33.6, 34.8 and 39.8 cm/s, respectively.

It was observed that the tension of the purseline (T) and the pursing time (t_p) of the two nets can be expressed by a quadratic relation as in Figures 15 and 16. So it is possible to denote the relation as follows:

$$T = p t_p^2 \quad (8)$$

where T : Tension of purseline (g)
 t_p : Pursing time (s)

Figure 14. Relationship between pursing speed, V_p (cm/s), and tension of purse line, T (g), for model nets A and B. T_1 , T_2 , T_3 , T_4 , and T_5 denote the equations at one second intervals.

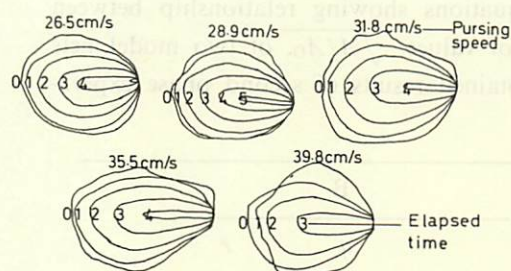


Figure 17. Variation of the opening area of the seine bottom during the pursing of model net A.

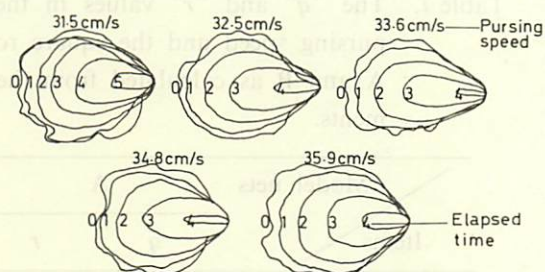


Figure 18. Variation of the opening area of the seine bottom during the pursing of model net B.

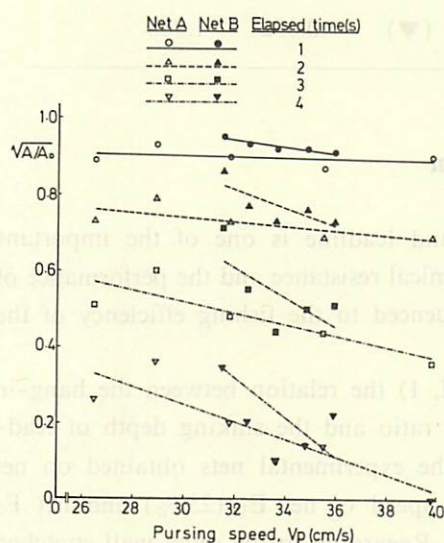


Figure 19. Relationship between the pursing speed, V_p (cm/s), and the square root of non-dimensional values, $\sqrt{A/A_0}$, during experiments on model nets A and B. A/A_0 denoted ratio of the opening area of seine bottom A (cm^2), to the opening area of seine bottom at the beginning pursing A_0 (cm^2). $\sqrt{A_1/A_0}$, $\sqrt{A_2/A_0}$, $\sqrt{A_3/A_0}$, and $\sqrt{A_4/A_0}$ denote the equations at one second intervals.

The decrease in the opening of the seine bottom at one second intervals during pursing is illustrated in Figures 17 and 18. The opening area decreased as the pursing speed and pursing time increased. At the beginning, the area showed various values, therefore the relation denoted as the function between the pursing speed (V_p) and square root of A/A_0 . In this case A was an opening area of seine bottom at one second intervals and A_0 was the opening area at the beginning of pursing. The relationship can be expressed as follows:

$$\sqrt{A/A_0} = q V_p + r \quad (9)$$

where V_p : Pursing speed (cm/s)

From Figure 19 it can be seen that the value of $\sqrt{A/A_0}$ decreased as the pursing speed increased and the values of coefficient " q " and constant " r " on the equation (9) are tabulated in Table 7.

Table 7. The "q" and "r" values in the equations showing relationship between pursing speed and the square root of values, $\sqrt{A/A_0}$, of two model nets A and B as calculated from the obtained results of second phase experiments.

Items \ Model nets	A		B	
	q	r	q	r
$\sqrt{A_1/A_0}$ (○)	-0.001	0.938	(●)	-0.008 1.196
$\sqrt{A_2/A_0}$ (△)	-0.006	0.909	(▲)	-0.024 1.570
$\sqrt{A_3/A_0}$ (□)	-0.014	0.950	(■)	-0.038 1.834
$\sqrt{A_4/A_0}$ (▽)	-0.023	0.941	(▼)	-0.052 1.988

Discussion

The hanging of netting on the corkline and leadline is one of the important elements which directly influence the hydrodynamical resistance and the performance of the seine wall, and therefore, this element influenced to the fishing efficiency of the seine.

The first phase of the experiment obtained, 1) the relation between the hang-in ratio and the sinking speed, 2) of the hang-in ratio and the sinking depth of leadline, and, 3) the highest sinking speed from the experimental nets obtained on net E₃ with a 34 % hang-in ratio. The sinking speed of net E₁ (25 %) and net E₂ (30 %) were similar to net E₃ (see Figure 11). Regarding to the seine wall stretched length, net E₁ obtained 100 % of its stretching ratio, net E₂ 97 %, and net E₃ 91 % (see Figure 12). The seines with a greater than 30 % of hang-in ratio become entangled during setting seine because of the excess netting. So the best choice of hang-in ratio is 30 % for fishing efficiency.

The fishing efficiency of a purse seine is mainly determined by the operational speed (setting and pursing), and the sinking speed of the seine. The operational speed determine the ability of enclosing a school of fish, and the sinking speed is also important to prevent the fish escape. Several elements of the operation depend upon the design of the seine, such as, the sinking speed of the leadline, the shape of seine before and during pursing, and the opening seine bottom during each stage of pursing.

In the second phase experiments, the sinking speed of every section of netting were very similar, except for the bunt sections of models A and B.

It was also detremined that the sinking speed is independent of the setting speed because the setting of the models only fall down from circular frame, In real

operations leadline sinking depth depends on the setting speed of the seiner, setting condition for the particular school of fish, and current and wave conditions.

The recommended time to commence pursing determined by Figure 13, is when 53% of the setting time elapsed on model net A (2 min and 7 sec. for the full-scale net) stretched seine depth ratio obtained 72% (25.7 m for full-scale) and 40% of the setting time elapsed on model net B (1 min and 22 sec for full-scale) stretched seine depth ratio obtained 86% (45.6 m for full-scale), after that the sinking speed decreased rapidly and then enough stretched seine wall to prevent the fish escape.

To compare two Indonesian mackerel purse seines designs and one Japanese mackerel purse seine design (net C), field research was carried out on net C. The sinking speed of net A was 3.9 cm/s (5.5 m/min for full-scale), and net B was 5.9 cm/s (12.5 m/min for full-scale) in the experimental tank and net C was 21.2–35.0 cm/s (12.7–21.1 m/min determined by net-sonde) in the field. The results of nets B and C were similar but net A had a slow sinking speed. It is thought that the reason for this is that nets B and C have nearly the same hang-in ratio of about 30%, but net A has a bigger hang-in ratio. Although other important factors also influencing these are the weight of the ballast, mesh size, twine size, and the materials used. The influence of hang-in ratio and net depth on the characteristics of the purse seine according to KONAGAYA (1971), is that the sinking speed of shallow nets with a large hang-in ratio was faster than that of deep nets with a small hang-in ratio.

The pursing to close the seine bottom is very important to prevent the fish from escaping. During pursing the opening decreases but the tension of purseline increases. It seems both models gradually acquired a cup shape, and become more cup-like towards the final stages of pursing.

In this experiment the pursing speed chosen was 26.5 cm/s (0.42 m/s for full-scale) to 39.8 cm/s (0.62 m/s) for model net A and 31.5 cm/s (0.57 m/s) to 35.9 m/s (0.66 m/s) for model net B. The purseline tension of the two models when gradually increased at various pursing speed (see Figure 14). Within the range of 31.5 cm/s to 35.9 cm/s the tension on the purseline of model net A was rather greater than of model net B. The maximum tension at the final stage of pursing, converted from the results of models to full-scale, was 90.5 to 117.6 kg for net A and 218.2 to 283.3 kg for net B. According KONAGAYA (1966), the relationship between pursing speed and purseline tension during pursing operation might given as a linear function, and the seine shape during pursing depends chiefly upon the d/l ratio of the netting, in this case d is a twine diameter and l is a leg length of netting mesh. The most favourable shape such as cupping or scooping was observed in the case of model net A which had a larger d/l ratio than model net B.

The pursing time plays an important role in fishing efficiency, and it depend on the winding ability of seine winch. The relationship between purseline tension

and pursing time might be expressed as a quadratic function (8), the relation for model net A is shown in Figure 15 and that for model net B is shown in Figure 16. IITAKA (1965), described that at the beginning stage of pursing, the leadline is still sinking, the tension on the purseline increases slowly only after it increases rapidly. Figure 19 shows the relationship between the pursing speed and the opening of the bottom of two models at one second intervals.

The opening of model net B closed more rapidly than model net A. It might be caused by the different material of purseline or design of the seine. A poly vinyl alcohol fibre twisted was used in model net A and a thin copper wire rope was used in model net B. The shape of seine bottom opening was an ellipse, this elongation was due to the increased drag on the central part of the seine, model net A was more elongated than model net B, possibly because of the position of the bunt section, difference of the mesh size, or twine size.

Acknowledgement

The authors are greatly indebted to Professor Nobio HIGO Dr. and Research Associate Shigeru FUWA of the Laboratory of Fishing Gear, Faculty of Fisheries, Kagoshima University for their guidance, assistance, cooperation, helpful suggestions and all the facilities provided in these experiments. We are further indebted to Shizuo TABATA for his help of the making model nets.

Thanks are also extended to Junichi TAKAMURA, the owner of Fukuho Suisan Kabushiki Kaisha in Nagasaki, fishing-master NORIMURA, the Shofuku Maru No. 1, and crew members of the vessel too numerous to mention individually, who contributed greatly to the success of our field research.

References

- BEN YAMI, M., and R. E. GREEN. (1968). Designing an improved California tuna purse seine. U. S. Fish. Wild. Serv., Fish. Ind. Res., 4 (5): 183-207.
- Food and Agriculture Organization of the United Nations. (1980). Implication of the extension of national jurisdiction for fisheries management and development. (Reported by an FAO Mission to the Government of Indonesia). Jakarta, Indonesia.
- GREEN, R. E. (1964). Norwegian bluefin tuna seines. Faster sinking, faster hauling than U. S. nets. Pacif. Fisherman, 62(1): 10-11.
- HAMRE, J. (1963). Some technological aspects of the Norwegian tuna purse seining fishery. Fisk Dir. Skr. Ser. HavUnders., 13: 106-119.
- IITAKA, Y. (1965). Studies on the mechanical characters of purse seine in relation to its fishing efficiency. Mem. Fac. Agric. Kinki Univ., 2: 1-74.

- INOUE, M. (1961). A study of the fishing power of the purse seine fishery. J. Tokyo Univ. Fish., Japan, 47(2): 123-248.
- KONAGAYA, T. (1966). Studies on the purse seine-I. Effect of the pursing velocity. (In Japanese) Bull. Japan. Soc. Sci. Fish., 32(6): 506-510.
- KONAGAYA, T. (1971). Studies on the design of the purse seine. J. Fac. Fish. Pref. Mie, 8(3): 209-296. (In Japanese).
- MC NELLY, R. L. (1961). The purse seine revolution in tuna fishing. Pacif. Fisherman, 59(7): 27-58.
- NOMURA, M., Y. TAWARA, K. MORI, Y. OSAWA, and K. KUMURA. (1967a). Study on behaviour of purse seine-I. Experiments of small model purse seine for horse-mackerel and mackerel. (In Japanese). Bull. Tokyo Reg. Fish. Res. Lab. 49: 11-39.
- NOMURA, M., Y. TAWARA, K. MORI, Y. OSAWA, and K. KUMURA. (1967b). Study on behaviour of purse seine-II. Experiments of small model purse seine for horse-mackerel and mackerel. (In Japanese). Bull. Tokyo Reg. Fish. Res. Lab. 49: 41-51.
- TAUTI, M. (1934). A relation between experiments on model and fullscale of fishing net. Bull. Japan. Soc. Sci. Fish., 3(4): 171-177.
- UNAR, M. (1978). Potensi Sumber Perikanan Sebagai Landasan pengembangan usaha perikanan. Simposium modernisasi perikanan rakyat, SMPR/78 No. p 49. LPPL, Jakarta. (In Indonesian).

(Received September 9, 1985)