On the Estimation of Sweep Area of Sweeping Trammel Net (Kogisiasiami)*

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The sweep area of sweeping trammel net¹⁾ must be known in order to investigate its catch efficiency, which is defined as the ratio of the capture per unit operation to the living fish stock within the region swept by the operation. In the sweeping trammel net fishery, there have appeared no researches in this field, as far as the authors are aware.

The present paper contains the discussions on sweep area of the sweeping trammel net on the basis of the field experiment performed off Hamada, Shimane Prefecture, during the summer of 1966. This experiment was undertaken to deduce an experimental relation to express the sweep area by the size of net, the duration of towing and the power of engine.

Experimental

Fishing gear: In the present experiment, two types, A and B, of trammel net were employed. The details of the type A are as follows.

Inner webbing: twine; nylon 210 denier 3 strands, 0.04 mm in diameter, mesh size; 60 mm in stretched measure, 50 meshes in depth.

Outer webbing: twine; nylon, 210 denier 6 strands, 0.06 mm in diameter, mesh size, 360 mm in stretched measure, 5 meshes in depth.

Float line: polyethylene, 6 mm in diameter, 43.6 m in length.

Lead line: polyethylene, 6 mm in diameter, 45.5 m in length.

Float: plastics, 25 mm in diameter, 82.5 g in buoyancy, at regular intervals of 120 cm along the float line.

Sinker: terra-cotta, 25 mm in diameter, 37.5 g in air, at regular intervals of 37 cm along the lead line.

The other type B is similar to the type A, except that the mesh size of inner webbing is 75 mm in stretched measure. Of ten shackles used in the experiment, seven shackles are of type A, and the rest are of type B. Two boats engaged in the experiment are of same type of 3 gross tons with a 14 horse power Diesel engine. The other accessories of this gear are illustrated diagrammatically in Fig. 1.

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Method: From the operation No. 1 to No. 5, the type of net, A and B, were arranged as shown in Fig. 1. In No. 6 and No. 7, the experiments were carried out

Fig. 1. Diagrammatic sketch of sweeping trammel net in operation. The arrangement of net shows the case of the operation No. 1 to No. 5.

in condition that both ends of the shackles were taken off from the above arrangement, and in No. 8 and No. 9, more one shackle was taken off from each end.

Fig. 2. Chart showing operation location, operation numbers, and contours.

This experimental area is shown in Fig. 2. This area known to be a good branquillos fishing ground, is muddy bottom and from 80 to 120 m deep. The numbers in Fig. 2 show the order of operations. The method of operation employed here was the same fashion to that in Wakasa Bay¹⁾. This is the original method in operation of the sweeping trammel net: The one end of net is anchored at a point of the bottom, and the other is towed by a boat so as to set a circular course with respect to the anchored end. But only the operation No. 5 was made according to the method at Shimane or Ehime Prefecture; the towing end is towed in a semi-circular course, then this towing end is anchored and fixed, then the previous anchored end is picked up and towed counterwise to the same manner, and this process is repeated several times, though in the present operation it was made twice.

The position of the boat was determined by the following method: Choose three clearly visible objects, such as lighthouse, mountaintop, small island, in the range of about 10 km from the boat, two angles between them were measured aboard with sextant at an interval of 15 minutes. The position of anchored buoy was determined by the same method on a boat which always followed closely after the buoy. In order to show the position of both ends of the net, thin vinilon twines, 150 m long, were attached to the respective net ends. Then buoys with red flags were tied to the upper ends of these twines. Their positions were also determined with sextant from both of the boats.

The tension acting on the warp was measured with 500 kg spring balance. The declination of warp, the wind speed and direction were also measured in the usual manner. Various experimental conditions are shown in Table 1.

Table 1. Experimental conditions.

Operation No.	Date	Length of net (m)	Number of shackle	Length of warp (m)	Area of net (m ²)	Direction of rotation	Wind Direction	Wind speed (m/sec)
2	7-23	436	10	706	872	A*	S	4.3
3	"	"	"	"	"	"	W	5.1
4	7-24	"	"	"	"	C**	SW	4.1
5	"	"	"	"	"	...	WSW	4.2
5-1	"	"	"	"	"	A	"	4.2
5-2	"	"	"	"	"	C	"	4.1
6	7-25	354	8	"	708	A	SW	4.0
7	"	"	"	"	"	C	W	4.4
8	7-29	268	6	584	536	A	S SW	2.7
9	"	"	"	"	"	"	NW	2.8

* Anticlockwise.

** Clockwise.

Results and Discussion

The accuracy of sextant reading was within the range of 10 seconds, and the difference in time to read two angles was kept in the range of 30 seconds. Taking these circumstances into account, the error in measuring the positions was found to be within 50 m. All positions thus determined, of both boats and both ends of the net, can be plotted on a chart. Then, drawing a smooth curve to fit by eye to these points, the locus of movement of the gear is obtained. Fig. 3 shows examples of various types of operations, in which the marks ⊙, ●, and ○ represent observed points of the two boat, outer, and inner ends of the net, respectively. The marks S, and F, denote the points in which the net is begun and finished to tow, respectively. As the towing operation No. 5 was made according to the method of Shima-

ne or Ehime, the first half course of operation is shown with a set of marks S_1 and F_1 , and the later with S_2 and F_2 as shown in Fig. 3-B. In these figures, the broken and the dotted straight lines indicate

the approximate position of the net and the warp, respectively, at the beginning and final stage of towing.

The mean towing speed of boat is obtained as the towed distance divided by its duration. Here, the towed distance means the total length along which the tow boat moved from the point S to F, and the duration is total time elapsed during the process. The sweep area is defined as the total area enclosed with the lines of net, at the beginning and final stage of towing, and the loci drawn by its both ends, as shown by the hatched parts in Fig. 3. The observed points of the net end, however, do not always show the true position. Because the buoy line attached to the net end is not equal to the depth

Fig. 3. Examples of operation types. The operation No. 4: A, No. 5: B, No. 7: C, No. 9: D. Hatched parts indicate sweep area.

at the fishing ground. For instance, the depth being 100 m, since the buoy line employed is 150 m long, the maximum difference in the horizontal distance between

Table 2. Results obtained in this experiment.

Operation No.	Sweep area* (q' km ^{2})	Tension in warp** (T kg)	Declination of warp** (α°)	Resistance of net* (R kg)	Duration of towing** (t sec)	Towed distance* (l_s m)	Towing speed* (v m/sec)
2	0.349	121.1	9.38	119.5	4500	3230	0.718
3	0.525	147.6	8.57	145.9	7620	5770	0.758
4	0.534	112.4	5.50	111.9	8100	5780	0.714
5	0.593	120.9	...	119.8	7800	5670	0.727
5-1	0.413	122.4	9.00	120.9	4200	3100	0.738
5-2	0.180	119.4	6.40	118.7	3600	2580	0.715
6	0.300	115.1	9.10	113.6	8100	5890	0.728
7	0.654	109.0	4.63	108.6	8100	6290	0.777
8	0.301	88.1	9.43	86.9	6300	4800	0.761
9	0.348	96.1	9.60	94.8	7200	5070	0.704

* Estimated values.

** Observed values.

the true and observed positions would become about 110 m, even if the location of the buoy was measured exactly. Since, however, these deviations would occur in the same manner to both ends, it is supposed that the area defined above is nearly equal to the true value. The results obtained are tabulated in Table 2.

Consider that a tow boat moves an arc distance l_s along a circular course of radius of rotation r with respect to a center point, then the sector area enclosed by the locus of the boat is $rl_s/2$. Assuming that the length of net l is proportional to the radius r , the sweep area q' is proportional to $l_s l$. In Fig. 4, the observed values of the sweep area q' are plotted against the values of $l_s l$. From this, both values seem to be kept a proportional relationship. Since the towed distance l_s of the boat equals the product of the towing speed v and the duration of towing t , we have

Fig. 4. Proportional relationship between $l_s l$ and sweep area q' . Figures indicate operation number, and A, B and C, respectively, the mean value of sweep area in 6, 8 and 10 shackles.

$$q' = k_0 l v t, \quad (1)$$

where k_0 is the coefficient of proportionality. From Table 3, the mean value of k_0 is

Table 3. Numerical values of proportional coefficient

Operation No.	k_0 (—)	k_1 (kg sec ² /m ⁴)	k_2 (h.p. sec/kg m)	k_4 (m ^{5/3} h.p. ^{1/3} sec)
2	0.248	0.266	0.163	0.663
3	0.208	0.291	0.127	0.590
4	0.212	0.252	0.175	0.564
5	0.240	0.260	0.161	0.651
6	0.144	0.303	0.169	0.387
7	0.293	0.254	0.166	0.844
8	0.233	0.279	0.212	0.601
9	0.256	0.358	0.210	0.607
	0.230	0.283	0.173	0.613

obtained to be nearly equal to 0.23 under the present circumstances.

This value of k_0 will be applicable to the analysis of fishery resource of sweeping trammel net, so far as the mode of operation is not so different from the present experiment. Therefore, if the value of l , and the product tv or l_s are known, we can estimate q' by Eq. (1). The length of net and the duration of towing may be obtained from fishery records, but the towing speed or the towed distance would be difficult to be known. Since towing speed depends on the power of engine installed in the boat and on the size of the net used, we shall try to express the towing speed

by these two factors.

Now, consider the case in which a boat with a engine of P h.p. tows a net of area S at a speed v . The resistance R of net is proportional to the area of net and proportional to square of towing speed, provided that the hydrodynamic resistance of warp is negligibly small as compared with total resistance of the net. The observed values of R are plotted against the values of Sv^2 as shown in Fig. 5, which shows that this is in linear relation. Here, R is calculated by the relation $R = T \cos \alpha$, T and α being the tension and the declination of warp, respectively. Thus we have

$$R = k_1 Sv^2 \quad (2)$$

where k_1 is a coefficient and is shown numerically in Table 3.

On the other hand, the effective engine power P_B may be proportional to the value of Rv , if the engine revolution is kept always constant during full course of towing. We have no researches on the relation between the nominal engine capacity P and the effective engine power P_B for such a small engine, from 3 to 35 h.p., as employed in this fishery. In the case of large trawler, KOYAMA²⁻⁴⁾ reported that P_B is proportional to 1.7 powers of P in the range $300 < P < 2000$ h.p., and that P_B is directly proportional to P in $2000 < P < 3500$ h.p. For the sake of simplicity, assume that P_B is proportional to P , and neglect the resistance acting on the boat as compared with that of net, we have

$$P = k_2 Rv, \quad (3)$$

where k_2 is a constant coefficient. In the present experiment, since the engine re-

Fig. 5. Proportional relationship between Sv^2 and resistance R .

volution was kept always constant during the experiment, the relation (3) holds. From Table 3, the values of k_2 seem to be nearly constant except the operation No. 3, No. 8, and No. 9. These discrepancies are supposed to be dependent largely upon the wind.

Eliminating R from Eqs. (2) and (3),

$$v = k_3 \sqrt[3]{P/S} , \quad (4)$$

where $k_3 = (k_1 k_2)^{-1/3}$. Then, substituting Eq. (4) into Eq. (1), we obtain

$$q' = k_4 l t \sqrt[3]{P/S} , \quad (5)$$

where $k_4 = k_0 k_3$. Letting h be the depth of net, since $S = lh$, Eq. (5) is reduced to

$$q' = k_4 t \sqrt[3]{l^2 P/h} . \quad (6)$$

The values of k_4 are calculated on the basis of data listed in Tables 1 and 2, and are shown in Table 3 using the units; meter, second and horse power. While it seems to be nearly constant irrespective of the variety of operational conditions, we may notice some unusual values in operation No. 6 and 7. If we take the mean values for operations in which the same number of net shackles, i.e., 6, 8 and 10 shackles, were employed, the value k_4 can be regarded as constant, and are 0.606, 0.616 and 0.617, respectively. Taking the field conditions in the experiment into account, these results seem to be considerably accorded with the theory.

This equation and the mean value of k_4 throughout this study have been applied to the investigation concerning the catch efficiency of sweeping trammel net in the branbuillos fishery in Wakasa Bay, and the results will be presented in a succeeding paper.

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