Studies on the Fishery of Zuwai Crab in the Japan Sea—V. On the Estimation of Swept Area of Danish Seine

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In the previous paper,¹⁾ the swept area per unit effort in Danish seine was simply estimated as the circle model. In order to find more exactly the relationship between the efficiency of gear and the swept area of Danish seine, the true swept area which may take a very complicated pattern in field, must be known. The swept area of Danish seine capturing Zuwai crab, *Chionoecetes opilio* (FABRICIUS), was defined as the areas enclosed by the sweep line^{1,2,3)} and that towed by the net. However, we can not easily estimate these areas in field, especially the towed distance of net and the behavior of sweep lines. SUZUKI^{4,5,6)} has theoretically reported the behavior of model sweep lines on the special cases in which the sweep line and warps are laid originally in triangle-shape and quadrilateral-shape, and HAMURO⁷⁾ has discussed on the towed distance of net, in which the net did not move forward remarkably on the basis of field experiment. By means of the radar, the area enclosed by the ropes was evaluated by HIGO,^{2,3)} for the case of the Fish-meal fleet which operated in the Bering Sea. In his experiment in the Bering Sea, "the speed of the shouldering-rope-towing" was about 1.3 knots on the average throughout towing period and the area enclosed by sweep line and warp was approximated as $102 \times 10^4(\text{m}^2)$. However, the towed distance of the Danish seine has not studied yet, as far as the author is aware.

The present paper contains the discussions on the towed distance of net and the enclosed area by ropes on the basis of the field experiment in the sea off Kyoto Prefecture, in May 1968.

Experimental

In the present experiment, the trawl net employed was a standard Danish seine⁸⁾ in the Japan sea and seven hauls were during two days. Sweep line and warps which are illustrated diagrammatically in Fig. 1, were used in the whole course of this experiment. Three boats named A, B, and C engaged the operations. The boat A is a seiner of 41 gross tons with a 120 horse power Diesel engine, B is the radar observation boat, 116 gross tons with a 320

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horse power Diesel engine and C is a pursuit boat of 13 gross ton with a 45 horse power Diesel engine. The pursuit boat C always follows closely after the buoy, which, in order to show the position of the net, was attached to the net with thin polyethylene twine, about 170 m long.

Fig. 1. Construction of warp, sweep line and chain used in this experiment.

The positions of the boats A and C were tracked by the radar on the anchored boat B at the irregular interval ranging from one to ten minutes. By carefully marking the position of boat on the tracing-paper pasted upon the radar-face, the track line was continuously recorded. The radar out-put 8 kw was set on 2 mile range over all experiments.

This experimental area is located in the sea off Kyoto Prefecture around $35^{\circ}45'N$, $135^{\circ}22'E$ and ranging from 96 to 122 m deep, and is not used for the Zuwai crab fishery. The area known to be abundant in this crab is muddy bottom and from 250 to 350 m deep. Various experimental conditions are shown in Table 1.

Table 1. Experimental conditions.

Operation No.	Date	Depth (m)	Current Direction		Current Speed (cm/sec)		Wind Direction	Wind Speed (m/sec)
			10 m depth	100 m depth	10 m depth	100 m depth		
2	May-9	112-115	333°	123°	16	5	NW	4.0
3	"	108-122	345°	no data	21	no data	NW	0.5
4	"	106-117	330°	174°	17	6	E	2.5
5	May-10	96-116	312°	311°	27	14	SSE	3.0
6	"	103-116	345°	294°	26	12	SSE	6.5
7	"	97-114	330°	no data	23	no data	SSE	7.5

Results and Discussion

Seven hauls were made at irregular interval during two days as opportunity allows, of which the first trial resulted in failure from lack of experience, so that the results of six operations are discussed here.

Two positions of boats A and C could be dotted on a tracing-paper. Then, drawing a track line from dot to dot, the loci of towing boat A and pursuit boat C are obtained as shown in Fig. 2. In this figure, the Marks S_n and F_n denote the points where the boat C begins and finishes to pursue after the buoy, the marks S_b and F_b mean the points where

Fig. 2. Radar observations of Danish seine operation.

Table 2. Results obtained in six experimental operations.

	Operation No.						Average of Six Operations
	2	3	4	5	6	7	
Enclosed Area of Sweep Line and Warp (km ²)	1.33	1.31	1.26	1.31	1.33	1.22	1.29
Swept Area of Net (m ²)	9480	—	9180	9840	—	—	9500
Towed Distance (m)	1880	2030	1790	2170	2300	2390	2093
Duration of Towing (sec)	2340	2340	2400	2100	2280	1920	2130
Towing Speed (m/sec)	0.80	0.87	0.74	1.03	1.01	1.24	0.99
Swept Distance of Net (m)	1580	—	1530	1640	—	—	1583
Sweeping Speed (m/sec)	0.68	—	0.64	0.78	—	—	0.70

towing boat A is at the beginning and final stage of towing, respectively. The marks R_0 and R_f represent, respectively, the starting and finishing point of throwing sweep line, chains and warps.

The accuracy of radar observation in the maximum error in distance was ± 37 m and in direction, 30.6 m on the 2 mile range. Then, all positions dotted in Fig. 2 are affected by the measuring error within ± 37 m in distance.

The values resulted from the observation and the estimation are tabulated in Table 2. Here, the mean towing speed of boat A is obtained as towed distance divided by its duration. The towed distance and its duration mean the total length along which the boat A moved from the position S_b to F_b , and the total time elapsed in the process of towing, respectively. The mean sweeping speed of the net is given as the swept distance from S_n to F_n divided by the total time elapsed, which are shown near each small circle in Fig. 2. The evaluated points of the boat C, however, do not always show the true position of the net at the sea bottom. The buoy line attached to the net is about 170 m long and the depth ranges from 96 to 122 m deep. Therefore, the length of buoy line is larger than the depth at the experimental area, and the maximum difference in horizontal distance between the true and observed positions may be about 140 m for the depth of 96 m and about 120 m for 122 m. If these deviations occur at both positions S_n and F_n toward the same direction, the towed distances from S_n to F_n which are estimated from the operations, No. 2, 4 and 5, may be nearly equal to the true distance. Now, consider that the width of this net mouth is kept at about 6 m in the water throughout the towing, the swept area by net would be about 9500 m² on the average of three operations.

Assuming that we can gather crabs from the ground swept by sweep line and that the area of it is nearly equal to that enclosed by sweep line and warp, the total swept area is about $1.293 + 0.009 = 1.302$ (km²) on the average, though there are no conclusive evidences for behavior of sweep line while being towed. Since, however, the crabs in the swept area by net may be more catchable than those in the swept area by sweep line, the both areas are not

considered to have the same catchability. Probably, the net is able to catch various sized crabs presenting in front of the mouth, but the sweep line permits the crabs to escape by leaping over the rope or burrowing into the ground.

In the further studies on efficiency of Danish seine, however, the behavior of sweep line and the animal reactions to line should be visibly cleared by more accurate methods, such as the underwater camera or television. The radar observation used here will be suitable for the determination of position, using higher out-put power.

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