Moving Direction of Japanese Sardine School on the Basis of Aerial Surveys*¹

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The flight surveys were conducted five times during the day in the waters off the southeast coast of Hokkaido where a big catch of sardine *Sardinops melanosticta* has been taken. In the area sardine schools were easily sighted, but were only distinguished by dark color against lighter background of the sea. To examine a moving direction of school, an experiment was conducted near the fishing ground. In the experiment, it was carried out that floaters fixed to a seamarker were airdropped near a school, and after relative changes between the school and the seamarker were compared each other. The visual observations were conducted 4 times around the fishing ground. The shape of the schools was observed by sight and the number of schools was counted.

From the result of the experiment, it is concluded that the front of the school, which indicates the direction of movement, is dark blue color and the rear is watery blue color. That is, by observing the shape and tone or shade of color of a school, we can easily estimate the moving direction of schools.

During the visual observations, elongate shape schools have been frequently observed. It is estimated that there were much continuous immigrations from the outside of the small fishing area during before and after the surveys.

Schooling is a prominent characteristic of pelagic fishes. Besides early planctonic life stages, such as egg and larval stages, all life stages of Japanese sardine *Sardinops melanosticta* are conducted within schools. Schooling behaviours have been published by numerous authors. Methods to study the schooling behaviour can be classified into laboratory studies and observations in nature. Furthermore, the observations in nature is divided into three classes: aerial observations, hydroacoustic measurements, and underwater observations. Each of these methods have limitations. For example, the aerial observation is under certain restraints, such as water transparency, illumination and reflection of the sea surface. The method of the aerial observations, however, is a better way to observe Japanese sardine school, since the schools in natural condition can be observed directly by sight and measured later by photographing them. Moreover, Japanese sardine usually stayed in shallow layer in the surveyed area, the waters off southeastern coast of Hokkaido.¹⁾ HARA²⁾ reported that the school shapes of Japanese sardine in this area are usually elongate and slender, but they are classified

into three types, such as oval, crescent and elongate. The changes of shape and the movement of sardine schools were not observed, since all of them looked like stationary in the absence of comparative objects.

It is very important to study how to make school move in a certain direction and to recruit to a fishing ground. Then, the moving direction of Japanese sardine schools on the basis of aerial surveys are discussed here.

Materials and Methods

The work was planned to be undertaken in the area where big catches of sardine have been taken by 24 commercial purse seiners since 1976. The site was chosen in the waters off the southeastern coast of Hokkaido as sardine schools are observed in great quantity during summer and autumn seasons there.

The flight surveys using Cessna U-206G aircraft were conducted five times under the calm sea conditions during the day hours with the two spotter pilots and the author himself during September 19-23, 1984. The flight surveys are classified into visual observations and the experiment. Figs.

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Fig. 1. The transect of the visual observation on Sept. 19, 1984. The number shows sardine schools in number sighted. The crescent mark expressed the elongate shape and the elongate shape school moves towards the head of the crescent. The ellipse mark expresses the rest.

Fig. 2. The transect of the visual observation on Sept. 20, 1984.

1-4 show the plan of the four visual observations. The areal coverages were broader than commercial fishing grounds (Fig. 6). The aerial observations were taken at an altitude of 500 m above the sea. The shape of the schools was observed directly by sight or was measured later from photo and the number of schools was counted. We can not distinguish each fish in a school which were easily sighted only distinguished with dark blue against

lighter background of the sea.²⁾ At the survey altitude of 500 m, the swathe of sighting was approximately 1,000 m wide.

To examine the moving direction of school, the experiment was conducted near the fishing ground (Fig. 5). In the experiment it was carried out that floaters attached a seamarer were airdropped near a school and after relative changes between the school and the seamarer were compared each

Fig. 3. The transect of the visual observation on Sept. 22, 1984.

Fig. 4. The transect of the visual observation on Sept. 23, 1984.

other by means of photography. Since the sea-marker contains fluorescein sodium salt (uranin), it diffuses yellow-colored particles after a while airdripped into the sea.

Results

Area Surveyed and Fishing Ground

Japanese sardine have an annual cycle of migration obviously expressed by the southward to the northward as the seasons progress. In summer

(July to September), sardine schools migrate toward Hokkaido from the southern part along Pacific coast of Japan, and migrate to the southern part in Autumn (October). The sardine fishing ground was formed of the southeast coast of Hokkaido during July to October. Commercial fishing is conducted during the day. The catches are only sardine and another species is nothing. In the beginning of the fishing season, the fishing ground was formed offshore and shifted gradually

Fig. 5. The area that the flight experiment was done using seamarkers on Sept. 21, 1984.

Fig. 6. The fishing grounds before and after the surveys. The number in grid shows efforts of commercial purse seiners.

from the offshore to the nearshore. The fishing grounds just before the surveyed periods were formed at the northeast part of the area, and after that they were formed along the nearshore off Kushiro over a long time, about 3 weeks as shown in Fig. 6. Under such conditions and the flight range of the aircraft, the plan of observation transects were decided (Figs. 1-4 and 5).

Moving Direction of School

In order to monitor the schooling behaviours, the experiment was done near the fishing ground shown in Fig. 5. The flight survey was conducted once under the calm condition: the sea was calm, the weather was fair, the direction of wind was SSW, and the velocity of the wind was 3 meters per second. In the experiment three types of the

schools were chosen: oval, elongate, and intermediate shape between these (Figs. 7, 8), since the school shapes usually observed in this area were classified three types.²⁾ The observation was conducted shuttling among them, and was taken at altitude between 200 m and 500 m to airdrop the floaters and to take photograph.

Fig. 7 shows the changes of the oval shape school. A floaters airdropped is expressed by a dot, and a yellow plume from a seamarker is expressed by two thin lines from the dot in this figure (same as in Fig. 8). The oval shape school moved back and forth at the beginning (time 11:18-11:35), and after elongated at 12:12. The size of the school in the greatest dimension was ranged from 50-100 m. Later, it broke into two schools (time 12:17-12:30).

The changes of elongate and intermediate shape schools are shown in Fig. 8. The elongate shape school in the right side in Fig. 8 is ranged from 150-200 m in the greatest dimension. It is observed that the school was moving to the north, because of the observation of the relative changes between the school and the diffusion of the seamarkers (time 11:39-12:10). That is to say, the movements of three floaters, which were airdropped to parallel with the elongate school, show the same manner of the school with time. Moreover, it is supposed that the floaters were drifted to nearly north by the effect of the wind. The reasons why the floaters were drifted by the wind are as follows; (1) Sea condition was calm

Fig. 7. The changes of the oval shape school sketched from the vertical or oblique photographing. The number shows the time of the observation. The dot shows the floater airdropped and two thin lines from the dot expresses a yellow plume from a seamarer fixed to the floater.

and the current or flow did not exist there, (2) Generally, a diffusion in a speedy stream shows a state of plume, if its source is fixed in the stream, (3) Since the diffusion of seamarkers show plumes, their sources might move themselves, (4) During the survey, the direction and the speed of wind was SSW and 3 m/s respectively.

The intermediate shape school in the left side in Fig. 8, which is ranged from 100–150 m in the greatest dimension, was shown at time 11:37, 11:57 and 12:10. At first, the floaters and the school were closely each other and one of the floaters was in the school (at 11:37). Later, the floaters and the school tend to separate each other (at 11:57 and 12:10). During the observation, the school kept to the similar shape. In order to compare the relative movements, the condition at time 11:37 and 11:57 overlapped each other are shown in the left side of upper part in Fig. 8. As a result, it is estimated that the school moved to nearly the northeast. The reasons of this are as follows; (1) The floaters were moving to the north

Fig. 8. The changes of the elongate and the intermediate shape schools expressed in the same manner as Fig. 7. The arrow shows a moving direction of school.

because of the same reasons described above, (2) The floaters and the school were getting to separate with time, and (3) The relative changes between them described above.

From the results of two moving schools, it is concluded that the front of the school, which indicates the direction of movement, is dark blue and the rare is watery blue. Namely, the leading and the trailing edges of the school are shown as the thick and the thin line in Fig. 8 respectively. Then, by observing a shape and a tone or shape of color of a school, we can easily estimate a moving direction of school.

General Movement in the Surveyed Area

The results of the visual observations around the fishing ground are shown in Figs. 1–4. The shapes of schools are roughly classified into two types: the majority of schools were mostly elongated expressed by the crescent mark, the rest were oval like shape expressed by the ellipse mark in the figures. A large number of the elongate schools were ranged from 100–150 m in the greatest dimension and were about 15 m in the smallest

Fig. 9. The moving directions estimated from the records of 24 commercial purse seiners. S, W, N, and E express a compass direction.

dimension. The movements or behaviours of schools and the number of schools sighted, however, change with time, especially at the route from off Cape Erimo to off Kushiro. They were divided roughly in the following two trends: namely in the morning schools are stagnant and small quantity, and in the afternoon schools are numerous and active move to the north. From the experiment described above and the visual observations, in which shape and size of school were observed, it can be said that sardine schools successively move toward the north, namely from off Cape Erimo to off Kushiro. As mentioned above the elongate shape schools have been frequently observed. In sardine schools the greatest dimension is usually the leading edge observed by dark blue color, namely the school moves in line. This could be a characteristic moving formation in this surveyed area.

On the other hand, fishing grounds were formed along the nearshore off Kushiro before and after the surveys as described above. During the period the daily catches were highly kept on three weeks (about 15,000 t/day) and 24 purse seiners intensively operated in the small area everyday such as shown in the efforts 290 or 190 in Fig. 6. It is estimated that there were much continuously immigration from the outside of the small fishing area.

There is another information about the movement of schools in the records of 24 commercial purse seiners. That is to say, when a school is intercepted its moving direction by purse seine,

fishermen record the moving direction called "IREKOSHI" in Japanese everytime in operation. Fig. 9 shows the directions before and after the observation. The directions, NE-E are dominant during Aug. 28-Sept. 6, when the fishing grounds were formed at the northeast part of the area and after the schools emigrated from the fishing ground. This conforms well to the movements of the fishing ground obtained by the records of operations. During the period, when the fishing ground continuously stayed off Kushiro or the period of the surveys, the dominant directions of the movements of the schools are NE-E.

It is concluded from these results that before schools immigrant to the fishing ground, they migrate from the south part of the area to the north (fishing area), and after recruitment to the fishing ground, they move to the eastward, namely along the coast. The reasons why the fishing ground kept on off the Kushiro for a long time, a great many schools continuously immigrated from off Cape Erimo to off Kushiro.

Discussion

The moving directions and the general movement of schools around the fishing ground has been described on the basis of aerial observations. The shape of sardine schools observed by an aircraft was already reported by HARA²⁾ that the shapes of sardine in this area were classified into three types. On the shapes, the results almost coincide with the fact reported by SQUIRE,³⁾ CRAM and HAMPTON,⁴⁾ and HAMPTON *et al.*⁵⁾ on pelagic fish schools. However, there is little work on the moving directions of the schools in nature. The schools so far observed from the air did not like moving, but almost stationary in general. HAMPTON *et al.*⁵⁾ reported that the direction of the movement of African pilchard schools that the crescent-shaped school moved toward the head of the crescent. They explained that this could be a characteristic moving school formation. However, they did not explain how to take the result. In the present study, the moving directions were obtained by the experiment compared the relative changes between a school and sea-markers. The results support the conclusion by HAMPTON *et al.*⁵⁾ but not by PITCHER and PARTRIDGE.⁶⁾

Namely, from the result of HARA²⁾ and the present study, the relative dimensions of sardine schools in the surveyed area were valued of 33~50:5:1 (breadth:length:height). The greatest

dimension (breadth) is usually the front or the leading edge of a school. It is concluded that the sardine schools sized relatively described above, continuously recruit to the fishing ground. This is one of the reasons why the daily catches were highly kept on a long time.

In the visual observation it is observed once among many as a special case that the two moving schools were facing each other. Unfortunately, it was not observed what had become of the schools since. Through the present study, it became clear that the aerial survey is effective to study behaviours of schools in nature, but a speed of moving schools was not taken, so this may be the subject for a future study. In order to study this it is necessary to establish a synchronized system of air- and ship-borne observations.

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