CRUISE REPORT OF THE FLYING SQUID SURVEY BY THE

WAKATORI MARU IN JUNE/JULY, 1990

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A survey of flying squid was conducted by the *Wakatori maru* at 22 stations which were fixed at 37° to 44°N and 172°E to 177°W in the North Pacific Ocean in June and July, 1990 with the following objectives: (1) a survey of the distribution of flying squid and the conditions of incidental take of salmonids, marine mammals and sea birds, (2) comparison of the catch of flying squid by jigging and driftnet, (3) comparison of fishing efficiencies between the cases when a jig was attached at about 1 m interval as normal operational style and when a pair of jigs was attached at about 1 m interval; and (4) to determine the depth at which the organism was entangled and to know the conditions which marine mammals were incidentally caught. At each station, the driftnet operations were conducted using driftnets of 116 to 123 tans in total, 50 tans of the non-selective research nets (5 tans each of 10 different mesh sizes from 48 mm to 157 mm) and 50 tans of the commercial net (115 mm in mesh size), and 16 to 23 tans of the modified commercial net (115 mm in mesh size, the net which one or two ropes or plastic tapes were attached horizontally). The squid jigging operations were conducted by 10 automatic jigging machines and hand jigging. In the driftnet operation, nets were set before sunset and started to haul immediately before sunrise, and the jigging operations were conducted from before or after sunset to midnight. At three stations, only jigging operations were conducted. The total catch (in number), excluding the dropouts, from 19 driftnet operations using 2,231 effective tans, was 3,821 in total including 2,170 flying squid and 1,163 Pacific pomfret. The catch (in weight) of flying squid was 3,323 kg. Of these, the catch (in number) of salmonids, marine mammals and sea birds was as follows: 213 coho salmon, 30 chum salmon, 2 pink salmon, 1 chinook salmon, 1 northern fur seal, 1 laysan albatross, 11 sooty shearwater (2 alive and 9 dead), 1 short-tailed shearwater (dead) and 1 horned puffin (dead). In addition, the following momentary entanglements were observed: 10 northern fur seal, 4 laysan albatross and 1 leach’s storm petrel. The momentary entanglement is defined as marine mammals and sea birds that were near the vessel were sometimes entangled in the nets when they touched the net, fish or squid during the net retrieval, but they escaped by themselves without any help or when the net was loosened artificially. When the same individual was entangled several times, each entanglement was counted as one entanglement. No sea turtles were entangled. The number of squid caught by 22 jigging operations (number of fishing line x minute = 98,680) was 2,932 flying squid, 222 boreal clubhook squid, 194 eight-armed squid, 6 luminous flying squid and 1 *Moroteuthis*. The catch (in weight) of flying squid was 4,266 kg. The surface water temperature at each station ranged from 10.3°C to 19.1°C, and flying squid were caught at all stations excluding the northernmost station.
High CPUE of flying squid at several stations of 11°C to 12°C in surface water temperature, which we have never known, were obtained by drift net and jigging. Salmonids were caught in waters of the surface water temperature of 12.3°C and under in area north of 40°30'N in June and north of 42°30'N in July. When two jigs were attached closely, the dropout rate was about one half that of ordinary jigging gear (jigs were attached at about 1 m intervals), however, attack (a behaviour which the jigs were seized by tentacles or arms) of flying squid to jigs were reduced and as a result the catch rate became about one half. The mantle length range of flying squid was 15-46 cm by the research net and 28-49 cm by the commercial net, 16-47 cm by the automatic jigging machine, and 17-48 cm by hand jigging. Although the mantle length composition of flying squid by the commercial net and by jigging varied by station, the modes were observed in three places, 19 cm, 26 cm and 35-36 cm. Groups with a mode around 36 cm were distributed mainly in waters north of 39°30'N and groups with a mode around 19 cm were distributed mainly in waters south of that. One hundred and nine flying squid were tagged. The depth at which the catch was entangled are being analyzed.
1. Introduction

The National Research Institute of Far Seas Fisheries conducted a survey on flying squid using four research vessels in the North Pacific Ocean in 1990, as a continuation of the previous year (Hayase et al. 1990). The objectives of the survey by the Wakatori maru, which was conducted around the northern boundary of the western fishing grounds for the Japanese squid driftnet fishery, were as follows: (1) a survey of the distribution of flying squid and the conditions of incidental take of salmonids, marine mammals and sea birds; (2) comparison of the catch of flying squid by jigging and driftnet; (3) comparison of fishing efficiencies between the cases when a jig was attached at about 1 m interval as normal operational style, and when a pair of jigs was attached at about 1 m interval, and (4) to determine the depth at which the organism was entangled and to know the conditions which marine mammals were incidentally caught, one or two ropes or plastic tapes were attached horizontally to the commercial nets. The fourth objective was jointly conducted by the National Institute of Fisheries Engineering and Nihon University. The details are scheduled to be reported in a separate paper. The arrangement of survey stations was quite similar to the survey by the Wakatori maru in 1989 (Yatsu 1989).

In conducting the surveys, I sincerely express my gratitude for the cooperation provided by captain Shun-etsu Takada and his crew and two scientists, Mr. Kojima and Dr. Wing.

2. Method of Survey

1) Research Vessel

Wakatori maru (Tottori Prefectural Sakai Fisheries High School, Fishery Training Vessel), 273 GT, 48 m in length.

2) Scientists

Akihiko Yatsu (National Research Institute of Far Seas Fisheries)

Takato Kojima (Nihon University)

Bruce Wing (Auke Bay Laboratory, Alaska Fisheries Science Center, U.S.A.)

3) Crew

Captain Shun-etsu Takada and 18 others

4) Period

Departure from Hakodate: June 9.
Fishing survey and oceanographic observation: June 15 to July 7.

Arrival in Hakodate: July 13.

Date used for this report is Japan time.

5) Area

North Pacific Ocean (37°30'N to 43°30'N and 172°30'E to 177°30'W).

Number of survey stations: 22 (Fig. 1).

Stations 0 and 21 were added because we had spare time during the cruise.

6) Survey Items

(1) Oceanographic Observation

At each station, weather condition and transparency were recorded and water temperature and salinity from surface to depth of 300 m or 1,000 m were measured by CTD. In addition, during the cruise, surface water temperature was recorded every hour using an electric thermometer.

(2) Driftnet Survey

The driftnet surveys were conducted at 19 stations except Sts. 0, 13, 21, owing to stormy weather or the cruising schedule. As the fishing gear, a total of 116 to 123 tans was used: 50 tans of non-selective research net (5 tans each of 10 different mesh sizes: 48, 55, 63, 72, 82, 93, 106, 121, 138 and 157 mm, hereafter referred to as the research net), 50 tans of commercial net (115 mm in mesh size), and 16 to 23 tans of modified commercial net (115 mm in mesh size, one or two ropes or plastic tapes were attached horizontally). The net was cast one to two hours before sunset, and hauling of the net was started around sunrise. Therefore, soaking time of the gear was about 10 hours.

The number in the catch was reported as the number of animals landed on the vessel. Animals entangled in the nets, but that dropped off the net in visible range were recorded as the number of dropouts. Marine mammals and sea birds were recorded by condition such as momentary entanglement, alive and dead. The definition of momentary entanglement was as follows: marine mammals and sea birds that were near the vessel were sometimes entangled in the nets when they touched the net, fish or squid during the net retrieval, but they escaped by themselves without any help or when the net was loosened artificially. When the same individual was entangled more than one time, each entanglement was counted as one entanglement. No sea turtles were entangled.
(3) Squid Jigging Surveys

The squid jigging surveys were conducted at all 22 stations. As the fishing gear, 10 automatic squid jigging machines (double reel) and hand jigging were jointly used, and the number of fishing lines and number of persons was increased or decreased according to the oceanographic conditions, etc. In the automatic jigging machine, (1) 10 air tube elastic jigs (common name: Oppai Bari (soft plastic)) and 10 hard plastic jigs, both were the jigs for flying squid fishing, were attached in one line (the jigs were attached one by one to the line at 1 m interval, which was an ordinary operational style, and hereafter referred to as a single jig), and (2) 20 each of both type of jigs were attached in one line (a pair of jigs of the same kind were attached to the line at 1 m interval, and hereafter referred to as a double jig). The maximum depth reached by a jig was about 120 m. The details of hand jigging gear varied by each person, but a person usually used one to three of Emaki jig, about 20 cm length jig wrapped by squid mantle, several of various small-sized jigs and one small-sized underwater light with a dry battery were equipped at about 1 m above the jigs. The fishing depth of hand jigging was estimated to reach a maximum of about 130 m. Twenty-five fish luring lights (a mercury lamp of 2,000 watts) were used. The operation period ranged from before or after sunset to midnight (0245 local time), the operation hour and number of fishing lines used varied by oceanographic condition and fishing condition, but a minimum of 110 minutes, 7 jigging machines, and 1 person for hand jigging.

(4) Sampling

Frozen samples of flying squid which were collected from a part of the catch of each operation were brought back to the Faculty of Fisheries, Hokkaido University, National Research Institute of Far Seas Fisheries, and the U.S. All dead sea birds were brought back to the Faculty of Fisheries, Hokkaido University as frozen samples. We also brought back scales of salmonids to the National Research Institute of Far Seas Fisheries. Some fishes were brought back to the U.S. as frozen samples.

(5) Body Measurement

The mantle length of flying squid, the total number of catch by driftnet and about half of the catch (usually the catch obtained before 00:00 local time) by jigging, was measured by sex as much as possible. For salmonids, fork length, sex and gonad weight of the entire catch was principally measured in the research net and commercial net, and scales were taken. Regarding the other major species, the entire number in the research net and a part of the catch in the commercial net was sampled randomly and the fork length was measured.
(6) Tagging

When possible, a white anchor type tag was attached to the basal part of the fin of flying squid, which were caught by jigging, and were released after the measurement of mantle length was made.

3. Results

1) Oceanographic Observations

Surface water temperature at each station was a minimum of 10.3°C (St. 7) and a maximum of 19.1°C (St. 13). Judging from the horizontal distribution of surface water temperature (Fig. 2), warm water was distributed in the southern part of east longitude area, and isothermal lines of 13°, 14° and 15°C were close with one another, and they were distributed in a progressively lower latitude in the east. There was a time lag of about 3 weeks between Sts. 0 and 21 (Fig. 1). The vertical distribution of water temperature and salinity are shown in Fig. 3. The Subarctic boundary in the North Pacific Ocean in the summer is represented at 34.0% of salinity (Mishima 1981). According to this, the Subarctic boundary was recognized at near 42°N in 172°30'E line, but in waters west of that, it was not definitive.

2) Results of Catch by Driftnet

The total catch in number (including the catch in weight of flying squid) and the number of dropouts is shown in Table 1 by kind of net and by species. Of the numbers caught, flying squid was dominant, followed by Pacific pomfret, and these two species accounted for 87% of the total number of animals. Because one dead northern fur seal was returned by mistake to the sea, we could not make biological measurements. Because of a storm after the net was cast at St. 8 and the hauling was begun after midnight, the driftnet operation was conducted again. The first operation at St. 8 was omitted in this report.

3) Distribution of Flying Squid and Salmonids obtained by driftnet

Flying squid were caught at all stations except St. 10 (Figs. 4 and 5). Flying squid were caught by jigging at St. 10. Salmonids were caught in waters north of 40°30'N in June, and north of 42°30'N in July (Fig. 6). The northern boundary for the Japanese driftnet fishery in the survey area was at 40°N in June, and 42°N in July, and salmonids were not caught on the south side of the northern boundary. The areas which had high CPUE values of flying squid were at Sts. 3, 5, 6, 9 and 20, and of these the isothermal lines of 13° to 15°C of surface water temperature were aggregated at Sts. 3, 9 and 20 (Fig. 2).

The relationship between surface water temperature and CPUE is shown in Fig. 7. Although CPUE of flying squid with the commercial net had a peak at the 11°C level and tended to decrease in the area with higher water temperature, CPUE for flying squid with the research net had peaks at the 11°C.
level and the 18°C level. The peak at the 11°C level was dominated by the large-sized flying squid of 35 cm and larger in mantle length and the peak at the 18°C level was dominated by the small-sized flying squid which had a mode of 18-19 cm (described later). According to the surveys which were conducted at almost the same stations in July and August, 1989, flying squid and salmonids were distributed separately, almost to the border of water temperature of 13°C (Yatsu 1989). The CPUE of flying squid at water temperatures of less than 13°C in 1989 was 10 fish/50 tons and under for both the commercial net and research net, and contrasted with the results of this survey. However, the survey was not conducted this year at the 14°C level which was the level at which the maximum CPUE was obtained by the commercial net in 1989.

4) The Fishing Results and Distribution of Flying Squid Obtained by Jigging

The number and weight (flying squid only) of squids caught by jigging is shown in Table 2 by method and by species. Flying squid were caught in all stations except Sts. 7, 16 and 21 (Figs. 4 and 5). Flying squid were caught by driftnet at Sts. 7 and 16, and the driftnet operation was not conducted at St. 21. Station which had a high CPUE of flying squid were Sts. 3, 5, 6 and 9. Murata et al. (1983) mentioned that an isothermal line of water temperature of 7°C which reached a depth of 50 m and deeper or near the ocean front was an index of flying squid fishing grounds in the northwestern Pacific Ocean in August and September, and high density in June was observed when water temperature at a depth of 100 m was 10°C and up and surface water temperature was 16° to 21°C. At Sts. 3 and 9, an isothermal line of surface water temperature was aggregated densely, and water temperature at a depth of 100 m layer at Sts. 5 and 6 was about 10°C.

The relationship between surface water temperature and CPUE of flying squid is shown in Fig. 8. This relationship was similar to that by the commercial net (Fig. 7, top), but CPUE by the commercial net at St. 3 in which a high CPUE was obtained by jigging was not so high. It is worthy of special mention that high CPUE values of the large-sized flying squid was obtained from Sts. 3 and 9 at water temperature of 11°C where good catches had never been known in the past.

5) Comparison of CPUE of Flying Squid by Jigging Method

The dropout rate (the percentage of the number of dropouts to the total number of catch and dropouts) with a double jig of the automatic jigging machine was about half of that of a single jig, but an attack by flying squid (a behaviour which the jigs are seized by tentacles or arms) against a double jig was less frequent that for a single jig and consequently CPUE of a double jig was about half of that of a single jig (Table 3 and Fig. 9). The results obtained from this survey supported the results in the past (Murata et al. 1981) which reported that the tentacles of flying squid were weak and the dropout rate by jigging was high, and on the other hand, it was apparent that a double jig was effective in reducing the dropout of the large-sized flying
squid. In the future, it would be desirable to modify a double jig to increase an attack of squid against a double jig. The CPUE of flying squid with hand jigging was very effective when the CPUE with a single jig of the automatic jigging machine was about 3 or less, however, when the CPUE was higher, the CPUE with hand jigging was less than half of that of a single jig on the automatic jigging machine (Fig. 9).

6) Mantle Length Composition of Flying Squid by Driftnet

The mantle length composition of flying squid for the combined stations which were caught by the research net and commercial net is shown in Fig. 10. In the research net, the mantle length ranged from 15 cm to 46 cm, and the modes were found at 19, 26, and 36 cm. In the commercial net, the mantle length ranged from 28 cm to 49 cm, and the mode was found at 38 cm. Judging from the selectivity of driftnet mesh, it is considered that the mantle length composition of flying squid which were caught by the research net reflects nearly the natural composition of flying squid of about 18 cm to 50 cm in mantle length at a depth where nets are set (Kubodera and Yoshida 1981), while it is recognized that the mantle length composition of flying squid which are caught by the commercial net are selective for catches of the large-sized squid.

In the mantle length composition of flying squid which were caught by the research net at each station is shown in Fig. 11. Groups which had the mode around 36 cm were mainly distributed in waters north of 39°30'N and groups which had the mode around 19 cm were distributed in waters mostly south of 39°30'N, where the surface water temperature was 17.0°C and up.

In the mantle length composition of flying squid which were caught by the research net and were obtained from almost the same stations in July and August, 1989, the range was 15 cm to 48 cm, and the mode was found at 18 cm and 43 cm, and the mode by the commercial net was found at 42 cm (Yatsu 1989). The mode of the large-sized group for the research net in 1989 was 7 cm larger and for the commercial net it was 5 cm larger and it may indicate growth of flying squid for a month. Existence of the middle-sized group was not apparent based on the composition in 1989. Although the mode of the small-sized group was found at almost the same size, the catch of the small-sized group was more abundant than the catch of the large-sized group in the 1989 survey. Therefore, the small-sized group obtained from the 1990 survey was considered to be the composition of more restricted range (further northern part of its distribution or early part in the northward migration), as compared with the 1989 survey.

7) Mantle Length Composition of Flying Squid by Jigging

The mantle length composition of flying squid which were caught by single jig and double jig of the automatic jigging machine and by hand jigging is shown by the mean CPUE of all stations (number of squid/line/hour) in Fig. 12. Although the shape of composition varies by jigging method, the mantle length range and mode was similar with one another in all kinds of jigging
methods, and was also similar to that by the research net. We found that a single jig was much more effective for catching small-sized flying squid than the double jig and hand jigging. Since the dropouts of the small-sized flying squid of about 20 cm in mantle length was low, it was considered that these small-sized flying squid hardly attacked the double jigs.

We examined the mantle length composition of flying squid at each station, assuming that only one line of a single jig and a double jig of the automatic machine and one line of hand jigging were used for the operation (Fig. 13). As a whole, they were similar to that by the research net (Fig. 11). However, a number of the large-sized flying squid were caught by jigging (mainly by hand jigging) at stations south of 38°30'N, but were seldom caught by the research net. As the persons who were conducting the jigging at these stations said that flying squid were caught at a depth of about 100 m, it is considered that the above differences depend upon the depth of distribution of large-sized flying squid.

8) Tagging

One hundred and nine flying squid were tagged and released at St. 3 (Table 4).

9) Marine Mammals

Marine mammals which were incidentally taken by driftnet were as follows: one dead northern fur seal, dropout at St. 4, one momentary entanglement at St. 5, 3 momentary entanglements at St. 9, and 6 momentary entanglements (same individual) at St. 20. No cetacean entanglement was observed.

10) Sea Birds

Sea birds which were caught incidentally by driftnet were as follows: laysan albatross, one dead at St. 10; sooty shearwater, one live and one dead at St. 2; two dead at St. 3; two dead at St. 4; one dead at St. 7; one dead at St. 9; one live and one dead at St. 19; and one dead at St. 20; short-tailed shearwater, one dead at St. 7, and horned puffin, one dead at St. 6. Momentary entanglement of laysan albatross occurred twice at St. 4, once at St. 6, and once at St. 8. Momentary entanglement of leach's storm petrel was once at St. 10.

References, Tables 1 to 4 and Figs. 1 to 13 are in English in the Japanese document.