SQUIDS AS THE FOOD OF SPERM WHALES IN THE BERING SEA AND ALASKAN GULF

TAKASHI OKUTANI* AND TAKAHISA NEMOTO

It is well known that sperm whales, *Physeter catodon* (Linnaeus), feed on squids in the world seas. There are many reports on the feeding of sperm whale and squids found in the sotmach of that whale (Mathews, 1938: Mizue, 1950: Clarke, 1955: Betesheva & Akimushikin, 1955: Clarke, 1962). Betesheva & Akimushkin (1955) described the food species of sperm whales in the waters of Kurile Island, and Pike (1950) and Rice (1963) reported the food animals of whales in the west coast of America.

The pelagic whaling by Japan and U.S.S.R. have been operating in the Aleutian waters and Bering Sea, and sperm whale is one of the important species of the catch therefrom. However, the foods of the sperm whales caught in the northern North Pacific have seldom been examined, although a report on the stones and other aliens found in the stomachs of the whales was published by Nemoto and Nasu (1962).

The stomach contents of the sperm whales from the waters around Aleutian Islands, Bering Sea and Alaskan Gulf were collected in 1963. These specimens were examined taxonomically, and their occurrences were studies in viewpoint of distributions of the squids and the predators in the north Pacific. Here this report deals with the preliminary results of the investigation, and this study will be continued to contribute the knowledge on distribution and taxonomy of squids in the North Pacific.

MATERIALS

The present samples were collected through the survey carried out in the North Pacific on board the factory ship. This investigations are mainly carried out in the waters around Aleutian Is., Alaskan Gulf and the Bering Sea. The field observations are made on all sperm whales caught, and the contents of stomachs are descriminated as squids, fish and other items. The observation was made on the first stomach content which is in fairly better condition than that elsewhere. However, sometimes second stomach was erroneously dissected for examination. The content found in the first stomach in worse condition might be the second stomach content surged back into the first. The squids have been preserved in 10% formalin sea water, and they are tentatively classified into types A,B,C,D,E and G. A part of samples taken out from the whale stomach was brought home for close examination.

* Tokai Regional Fisheries Research Laboratory, Tokyo.

SYNOPSIS OF THE SPECIES IDENTIFIED

As was mentioned in the preceding section, at the field observation six forms discriminated were classified into A, B, C, D, E and G. On the basis of the samples brought home, each group was found to be composed of the species as follows:

A: *Moroteuthis robustus* (Verrill, 1876)

B & D: *Gonatopsis borealis* Sasaki, 1923, *makko*, n. subsp.

C: *Mastigoteuthis* (?) sp.
Stigmateuthis sp.
Galiteuthis armata Joubin, 1898
Taonius pavo (Lesueur, 1821)

E: *Gonatus* (*Berryteuthis*) *magister* Berry, 1913

G: *Gonatus fabricii* (Lichtenstein, 1818)

Only C-Group was found containing four species. This is because these species have gelationus integuments which are easily matilated badly when taken by the predators. Sometime fragments of transparent pens of some unidenified Cranchiids were remained undigested.

Synoptic notes on the results of examination on the specimens are present in the following lines.

OEGOPSIDA

Onychoteuthidae

Moroteuthis robustus Verrill, 1876

Because of huge size, reddish variegation and rippled skin, this species is easily discriminated at the field observation on board the factory ship. One of the specimens brought home was measured about 700 mm in dorsal mantle length. Both tentacles were removed, but other characteristics are quite agreeable to the description by Sasaki (1929). Another specimen of head-foot part (mantle and visceral parts lacking) is much larger than the other, and the tentacular club is well preserved as is illustrated in Fig. 1 a. The specimens examined for the present study are generally gigantic in size, but a unique example of 300 mm-individual was found in the course of field observation. (see p. 118.)

Histioteuthidae

Stigmateuthis species

A badly matilated specimen was examined. The mantle length measured 100 mm and the longest arm, 300 mm. A part of the integument with some photophores is preserved. But identification to the species cannot be made because of lack of tentacle.

Gonatidae

Gonatus (s.s.) *fabricii* (Lichtenstein, 1818)

A single specimen brought home presented a very large size: Dorsal mantle length, 300 mm; width of the mantle, 56 mm; length of the fin, 170 mm; width of the fin taken together, 150 mm.

Mantle is robust, purplish in color in preserved state, elongated cylindrical and length is about five times diameter. The fins are muscular and rhomboidal in outline. They seem to present more elongated shape than those of younger specimens taken from the North Pacific on other occasions. Arms have two series of hooks on inner rows and two series of small suckers on outer rows. Arm formula is 3, 1, 2, 4.

The distal parts of both tentacles which may be the most important key of identification, were already lost when the specimen was taken out from the whale stomach. However, rows of small fixing pads disposed on both margins of sucker-bearing face of the tentacualr carpus were observed. These rows of pads in *G. fabricii* reached far proximally than those in the next species. From such character and shapes of locking cartilages led the present authors to the conclusive identification of the present specimen.

Gonatus (*Berryteuthis*) *magister* Berry, 1913

Specimens examined are mostly adults measured about 200–250 mm in dorsal mantle length. They are seldom found broken into the body and head-foot parts, as their locking apparatuses may be fairly tighter than those of other species.

This species is readily identified by muscular and broad fin and moderately squat body. At a glance, it may be taken as Ommastrephids, if four-series of brachial armatures and peculiar tentacular armatures are overlooked.

Nothing could be added to the careful descriptions by Berry (1912 as a part of *G. fabricii*; 1913, an amendment of the name) and Sasaki (1929).

Gonatopsis borealis Sasaki, 1923 *makko**, n. subsp.

Oegopsida of moderate size; integument soft in touch and smooth all over. Mantle loligiform, soft, subcylindrical, tapering gradually posteriorly to an acutely attenuated point; anterior margin truncated, projecting very slightly at the mid-dorsum, broadly emarginated ventrally leaving rounded lateral angles on both sides of the funnel; the widest part of the mantle about one-third the dorsal mantle length. No sculptures and color patterns present externally but dark violet internally (in preserved state).

Fins muscular but rather soft with thinned margins, one-thirds as long as the dorsal mantle length, subrhomboidal, length equal to the width of both fins taken together, obtusely angulated at three-tenths posterior from the anterior margin.

Head as broad as the mantle opening. Neck moderately constricted, probably marginated by a circum-nuchal ridge, which is indistinct in the type specimen. Nuchal locking cartilage elongated rectangular with rounded corners, feebly narrowed at the middle, width a quarter long. Funnel excavation demarked by depressed nuchal folds on both sides. Funnel moderate in size, semilunar valve presents inside. Dorsal funnel organ V-shaped, the posterior tips of rami reach as far as the anus. Ventral organs small and ovoid. Funnel locking cartilage lanceolate, slightly curved, tapering anteriorly and widened posteriorly and then

* The subspecific name, *makko*, means sperm whale in Japanese.

rapidly narrowed to an angulated posterior end; groove very shallow, widened posteriorly ending an open end. Mantle locking cartilage very weak and ridge-like in shape.

Arms robust, very powerful in appearance; the ventral pair decidedly shorter than the others and as long as two-thirds the longest arm; the arm formula 2, 3, 1, 4; the longest arm attains two-thirds the dorsal mantle length. All of the arms nearly the same strength, gradually tapering distally; the sucker-bearing faces flat meeting with the side faces in a rectangle; the aboral side roundish. Integumental keel poorly developed on the third lateral arms. Web not well developed except at the proximal portion of the ventral arm. Armatures of arms composed of hooks and suckers. In the ventral pair, they present only suckers with several teeth at the distal margin of the horny rings. In other pairs of arms, the proximal several rows are loosely arranged suckers, there followed about thirty transverse rows of two small suckers outer side and two large hooks of inner side each. The outer suckers are borne on the thick and long pedicels and bear horny rings with few triangular teeth at the distal margin. The inner hooks are very sharp with vestigial sucker-like structure proxiamally. Tentacle completely absent. Buccal membrane papillated and dark violet in color (in preserved state) with seven projections on the margin, each suspended by long rib.

Gladius slenderly penniform, about one-fifteenth as broad as long.

Radulae not examined.

*Types**: Holotype, male, found from the stomach of a sperm whale; the integument is somewhat matilated probably by action of digestive fluid of the whale. Dimensions of the type specimen are as follows: dorsal mantle length, 350 mm; width of the mantle, 55 mm; length of the fin, 100 mm, width of the fin taken together, 100 mm; length of the dorsal arm (right), 200 mm; second lateral arm (right), 210 mm; third lateral arm (right), 225 mm; ventral arm (right), 170 mm.

Another specimen (paratype) with the dorsal mantle length 300 mm long is also matilated and separated into two parts. The third specimen (catch number 39: 52°26N, 175°11E) was only head-foot part remained and was the largest of all. The longest arm measured 300 mm in length and the arm formula was 2, 1=3, 4.

Remarks: At a glance, the present new subspecies is very similar to the typical *Gonatopsis borealis* Sasaki which is abundant in the northern North Pacific. However, some external morphological characteristics do not coincide with those of *G. borealis*, unless *G. borealis* presents a remarkable individual changes in proportion of various parts of the body.

An abridged comparison of those two types are as follows:

	typical *borealis*	*makko*, n. subsp.
General shape of the mantle	Cylindrical, somewhat squat; skin thick	Cylindrical, very slender; skin thin
Fin length	2/3 total breadth or 2/5 mantle length	The same as the total breadth or 2/3 mantle length

* Deposited in the National Science Museum, Tokyo, Reg. Nos: Mo. 13311 (Holotype), Mo. 13312 (Paratype).

Nuchal locking cartilage	Panduliform, with a gentle constriction near the middle	Elongated rectangular
Funnel locking cartilage	Panduliform, 1/3 as broad as long	Curved lanceolate, 1/4 as broad as long
Arm	2/5 the mantle length 3, 1=2=4	2/3 the mantle length 2, 3 (=) 1, 4

The criteria common to both forms are armature of arms which composed of four series of suckers and hooks all the way through and the sagittate outline of the fins. In contrast to these, another known *Gonatopsis*, *G. octopedaus* Sasaki has 8–12 series of small suckers on the distal parts of the arms and a reiniform fins. *Distribution:* Probably a bathyelagic zone of the northern North Pacific.

Mastigoteuthidae

Mastigoteuthis (?) sp.

A single strange specimens in a half digested state is taken to be a Mastigoteuthid. The specimen has degenerated tentacles which present only muscular short appendages between the third lateral and ventral arms. Degeneration of tentacles are hitherto known on *Gonatopsis* (Gonatidae) and *Octopodoteuthis* (Octopodoteuthidae) and none on any other families. Therefore, it is still inconclusive whether the present specimen belongs to Mastigoteuthidae.

Cranchiidae

Taonius pavo (Lesueur, 1821)

Galiteuthis armata (Joubin, 1898)

Two above-mentined Cranchiids were found mixed with the preceding species and *Stigmateuthis* sp. As they have very delicate and gelationous integuments, they are found to be completely destroyed.

DISTRIBUTIONAL IMPLICATION

The catch of sperm whales have been concentrated to the coastal waters of the Aleutian Is., the Bering Sea and Alaskan Gulf. This is corroborated by Clarke (1956) who described that sperm whales congregate to the neighborhood of the islands in the mid oceans and continental shelves. The distributions of sperm whales and their foods are illustrated in Figs. 1 and 2 based on the results in 1960 and 1963, respectively.

The male whales occupy the major part of the catch, and very small number of females were caught as are so for the Antarctic catch of sperm whales. Matthews (1938) suggests the difference in food between the male and fameal is possibly present as the males are usually large in size and more powerful in catching preys by deep sea diving. But no clear difference between the size of food squids intaken by male and female has been proved. (Matthews, 1938: Clarke, 1956).

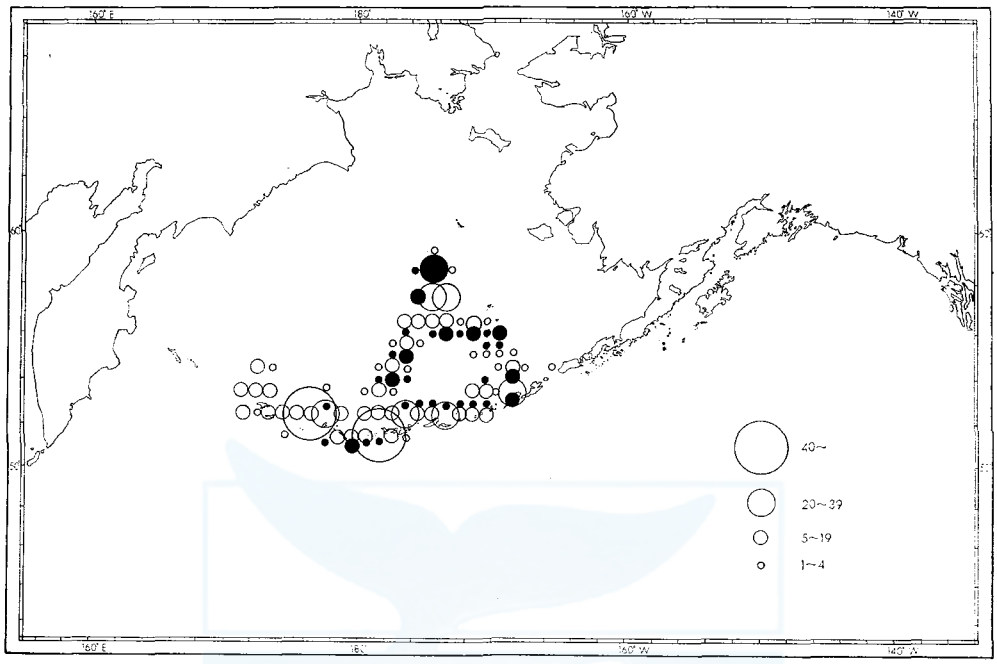


Fig. 1. Distribution of squids and fish in the stomachs of sperm whales from the Bering Sea, 1960. White—Squids, Black—Fish.

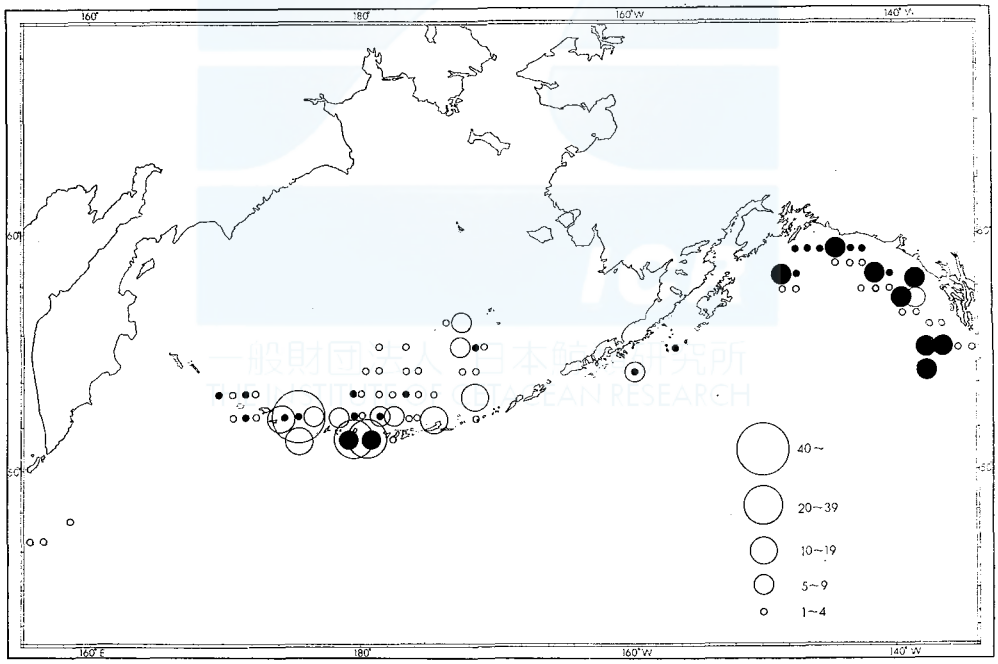


Fig. 2. Distribution of squids and fish in the stomachs of sperm whales from the Bering Sea and the Alsakan Gulf, 1963. White—Squids, Black—Fish.

It is evident from the Figs. 1 and 2, squids dominantly occur in the western part of the coastal waters around the Aleutian Is. Fish as the food of the whale are, on the contrary, mostly predominate in the eastern waters along the Alaskan Gulf and the east Bering Sea. This tendency was also noticed by Ohsumi (personal communication, 1956) for the Bering Sea. In 1960, the dominant occurrences of squids were observed in the waters around 176 °E longitude and fish are mostly found in the northern area of the Bering Sea.

The 1963 catch of sperm whales was taken from the Alaskan Gulf where the sperm whales feed on fish in larger quantity than squids. For the foods of sperm whales in the other parts of the North Pacific Ocean, there are some reports available:

Mizue (1950) described squids and fish as the foods of sperm whales in the adjacent waters to Japan without classifiying them. Betesheve & Akimushkin (1955) described foods of sperm whales from the Kurile waters. The foods species of sperm whales in the east Pacific along the American coast were described by Rice (1963).

TABLE 1. OCCURRENCES OF SQUIDS AND FISH IN THE STOMACHS OF SPERM WHALES FROM THE NORTHERN PART OF THE NORTH PACIFIC, 1960 AND 1963

		Bering Sea & Aleutian coast -180°	Bering Sea & Aleutian coast 180°-160°W	Coast of Alaskan Gulf 160°W-130°W
1960	Squids	240	434	—
	Fish	16	178	—
1963	Squids	129	116	45
	Fish	19	9	94

According to Betesheva & Akimushkin (1955) and Sleptozov (1955), the most important species of suqids as the food of sperm whales are *Gonatus magister* and *Gonatus* sp. followed by *Gonatus fabricii*, *Galiteuthis armata*, *Taonius pavo*, *Chiroteuthis veranyi* and *Meleagrotheuthis seperata*. They presented few occurrences of giant sqids, *Moroteuthis robustus* and *Architeuthis japonica*, from the Kurile waters. On the other hand, *Moroteuthis robustus* occupied 41% of the total food of sperm whales caught off America (Rice, 1962), although the materials are rather poor. *Gonatopsis borealis* stood the second rank of the foods reported by him.

From the materials treated here, the following patterns of distributions by species are observed:

Type A: *Moroteuthis robustus*

This was the most important squid in the waters around Aleutian Is. and the occurrences of this species are illustrated in Fig. 3. *Moroteuthis robustus* was found in the coastal areas of Alaskan Gulf as far as the Canadian coast. This squid was reported to be found from the stomachs of sperm whales taken off the west coast of British Columbia (Pike, 1950: Robbins, Oldham & Geiling, 1937). These obserbation suggest that *M. robustus* is also common in the California Current area.

There was found no diurnal change in occurrences as is shown in Fig. 5. Matsushita (1955) stated that the sperm whales in the Antarctic feed on squids in the early or the late hours of the day when those squids come up to the surface of the sea. Thus, whales need not to dive so deep in the sea to feed on large squids. At feeding, sperm whales in the Bering Sea may reach at the sea bottom sometimes, as some stones and other sedimentary aliens are found in the stomachs of sperm whales caught there (Nemoto, & Nasu, 1962). But, the ocean depths are generally not so large there as in the Antarctic waters.—The coastal waters of the Aleutian Is. are shallow enough for sperm whales to reach at the bottom, so that *Moroteuthis robustus* may be fed by them even in the mid-day at or near the bottom.

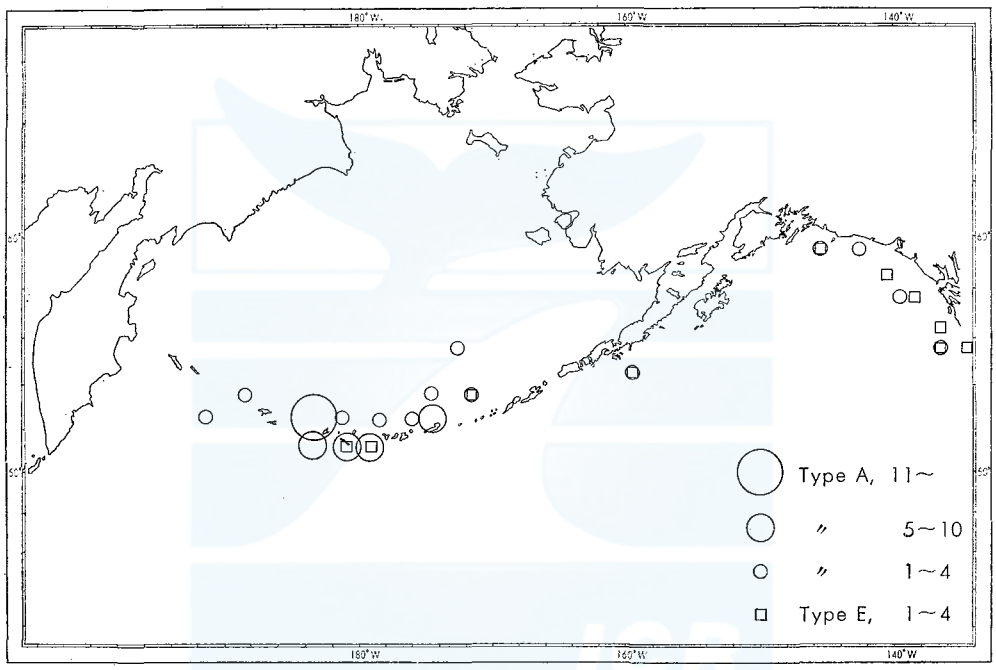


Fig. 3. Distribution of squids found in the stmaches of sperm whales from the Bering Sea and the Alaskan Gulf: Type A (*Moroteuthis robustus*) and Type E (*Gonatus magister*).

The specimens of *M. robustus* reported by Betesheva & Akimushkin (1955) were mostly ranging in size from 100 *cm* to 140 *cm* in total length including the foot. The largest one reported by Pike (1950) and Robbins, Oldham and Geiling (1937) measured 250 *cm* in length. In the present study, the large six specimens of *Moroteuthis* were found in the stomach of a single sperm whale, and thirty specimens of 100 *cm* or smaller were found from another sperm whale.

Type B & D: *Gonatopsis borealis makko*

The position for the largest specimen (Type B) found together with *Moroteuthis* was the west Aleutian waters. Other small specimens could not be identified on the

occasion of field observations. They were described as type D and were found in the central part of the Bering Sea and the adjacent waters to the Aleutian Is. This species was also found in the comparatively high latitudes of the Bering Sea. A single occurrence was also observed in the coast of Alaskan Gulf.

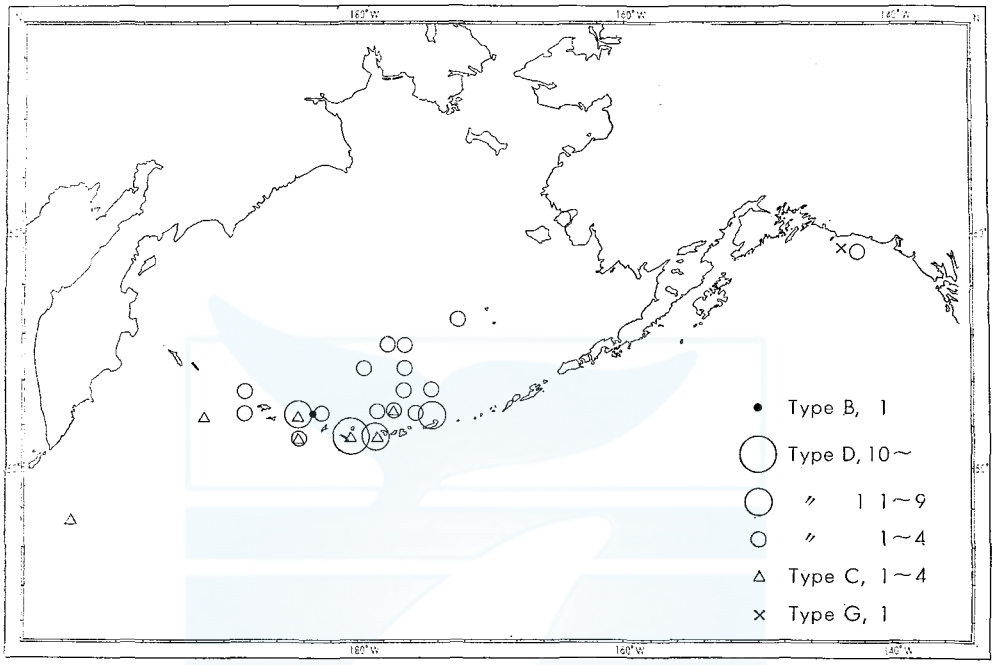


Fig. 4. Distribution of squids by type found in the stomachs of sperm whales from the Bering Sea and the Alaskan Gulf: Type B (*Gonatopsis borealis makko*), Type D (the same), Type C (*Mastigoteuthis* (*?*), *Stigmateuthis*, *Galiteuthis* and *Taonius*), and Type G. (*Gonatus fabricii*).

Type C: *Mastigoteuthis?* sp., *Stigmateuthis* sp., *Galiteuthis armata,* and *Taonius pavo*

Above four species are described as type C on the field note although the shape and other taxonomical criteria are different. These species were mainly found in the central part of the Bering Sea as shown in Fig. 4. From the occurrences of fragmental integument in the stomachs of sperm whales, these squids were suspected to be distributed mostly the central part of the Bering Sea.

Type E: *Gonatus magister*

This species was observed in the coastal waters of Aleutian Is. and Alaskan Gulf as in Fig. 3. This species is considered to be very common in the north-eastern Pacific.

Type G: *Gonatus fabricii*

Gonatus fabricii was recorded as the main food of the toothed whale (bottle nose) in the Atlantic (Hjort & Ruud, 1929). Betesheva & Akimushkin (1955) des-

cribed considerable numbers of occurrences of this species from the adjacent waters to Kurile Is. Pike (1950) also found this species from sperm whales taken off the Birtish Columbia coast. In the present survey, only a single large specimen was found from the Alaskan Gulf.

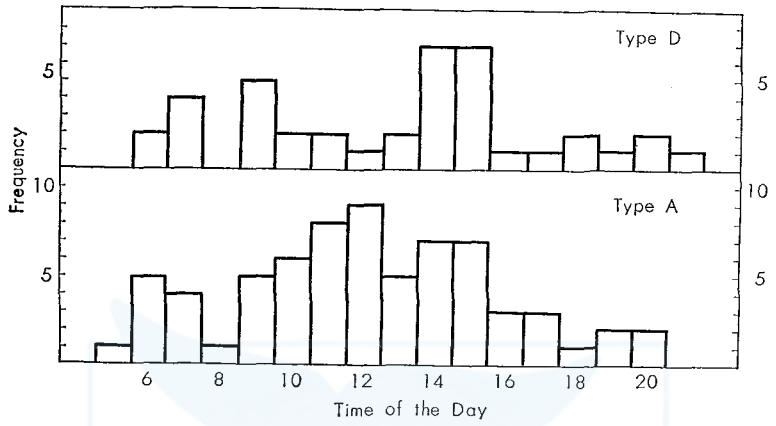


Fig. 5. Occurrences of Type A (*Moroteuthis robustus*) and Type D (*Gonatopsis borealis makko*) in the stomachs of sperm whales from the northern part of the North Pacific by hours of a day.

It is interesting to note that none of Myopsida, mostly coastal and benthonic forms, was found in the stomachs of sperm whales. Myopsida is generally tropic and temperate water forms and they are naturaly not distributed in the waters of high latitudes.

SUMMARY

The squids specimens found in the stomach of sperm whales taken from the northern part of the North Pacific (Bering Sea and Alaskan Gulf) were examined.

1. *Moroteuthis robustus*, *Mastigoteuthis ?* sp., *Stigmateuthis* sp., *Galiteuthis armaa*, *Taonius pavo*, *Gonatus magister*, *Gonatus fabricii*, and a new subspecies, *Gonatopsis borealis makko*, were found in the stomachs of sperm whales as their foods.
2. The distributions and occurrences of those squids are discussed.

Moroteuthis robustus, which is considered to be the most important squid for the food of sperm whales, is common in the adjacent waters to Aleutian Is. *Gonatopsis borealis makko* is also common not only in the central part of the Bering Sea, but also in the northern part. *Gonatus magister* is found along Aleutian Is. and Alaskan Gulf, while *G. fabricii* is found in the Alaskan Gulf. Cranchiids are discovered from he central part of the Bering Sea.

3. The distribution of those food squids is considered to be concentrated to the central part of the Bering Sea along the chain of Aleutian Is. This coincides with the major distributional area of sperm whales. On the other hand, fish as the food of sperm whales, are mainly found in the waters of the northern part of the Bering Sea and Alaskan Gulf.

REFERENCES

AKIMUSHKIN, I.I. (1955). The feeding of the Cachalot. *C.R. Acad. Sci., U.S.S.R.* 101(6) : 1139–40.

BERRY, S.S. (1912). A review of the cephalopods of western North America. *Bull. Bur. Fisher.* 30, Doc. 761 : 267–336. 25pls.

—— (1913). Notes on some west American cephalopods. *Proc. Acad. Nat. Sci. Phil.* 65 : 72–77.

BETESHEVA, E.I. & AKIUMSHKNI, I.I. (1955). Food of the sperm whale (*P. catodon*) in the Kurile Islands. *Trans. Oceanogr. Inst., Moscow* 18 : 86–94.

CLARKE, R. (1955). A giant squid swallowed by a sperm whale. *Norsk Hvalfangst-Tid.* 44(10) : 589–93.

—— (1956). Sperm whales of the Azores. *Discovery Rep.*, 28 : 237–98. 1pl.

CLARKE, M.R. (1962). Stomach contents of sperm whales caught off Madeira. *Norsk Hvalfangst-Tid.*, 51(5) : 173–91.

HEEZEN, B.C. (1957). Whales entangled in deep sea cable. *Deep Sea Res.*, 4 : 105–15.

HJORT, J. & RUND, J.T. (1929). Whaling and fishing in the North Atlantic. *Rapp. Proc. Vverb. Ré.* 56 : 5–123.

MATTHEWS, L. H. (1938). The sperm whale (*Physeter catodon*). *Discovery Rep.* 17 : 93–168. 9 pls.

MATSUSHITA, T. (1955). Daily rhythmic activity of the sperm whales in Antarctic Ocean. *Bull. Japan. Soc. Sci. Fish.*, 20(9) : 770–3.

MIZUE, K. (1950). Food of whales (in the Adjacent waters of Japan.) *Sci. Rep. Whales Res. Inst.*, 5 : 81–90.

NEMOTO, T. & NASU, K. (1962). Stones and other aliens in the stomachs of sperm whales in the Bering Sea. *Sci. Rep. Whales Res. Inst.*, 17 : 83–91.

RICE, D.W. (1963). Progress report on biological studies of the larger cetacea in the waters off California. *Norsk Hvalfangst-Tid.*, 52(7) : 181–7.

PIKE, G.C. (1950). Stomach contents of whales canght off the coast of British Columbia. *Prog. Rep. Pacific Cosat St.* 83 : 27–8.

ROBBINS, L.L., F.K. OLDHAM, & E.M.K. GEILING (1937). The stomach contents of sperm whales canght off the west coast of British Columbia. *Rep. British Columbia Museum* 1937 : 10–20, 1pl.

SASAKI, M. (1923). On a new eight-armed squid from Hokkaido, Gonatopsis borealis n. sp. *Ann. Zool. Jap.* 10 : 203–207

—— (1929). A monograph of the dibranchate cephalopods of the Japanese and adjacent waters. *J. Coll. Agr., Hokkaido Imp. Univ.*, 20 : 1–357. 30pls.

SLEPTOZOV, M.M. (1955). On the biology of cephalopod molluscs of the far-eastern seas and the north-western Pacific. *Trans. Ocenolog. Inst., Moscow*, 18 : 69–77.

EXPLANATION OF THE PLATES

PLATE I

Fig. 1. *Moroteuthis robustus* (Verrill), dorsal mantle length 700 mm.
1a. Tentacular club of another specimen.

PLATE II

Fig. 2. *Gonatus* (s.s.) *fabricii* (Lichtenstein), dorsal mantle length 300 mm.
Fig. 3. *Stigmateuthis* sp. (*separata* Sasaki?), dorsal mantle length 100 mm.

PLATE III

Fig. 4. *Gonatus* (*Berryteuthis*) *magister* Berry, dorsal mantle length 250 mm.
Fig. 4a. Tentacular club of the same specimen.

PLATE IV

Fig. 5. *Gonatopsis borealis makko*, n. subsp., dorsal mantle length 350 mm. (Holotype)
Fig. 5a. Left lateral arms of the same specimen.
Fig. 5b. A funnel locking cartilage.
Fig. 5c. Nuchal locking cartilage.

PLATE V

Fig. 6. *Taonius pavo* (Lesueur), anterior part of the mantle torn out, dorsal mantle length 250+x mm.
Fig. 7. An unidentified squid, probably *Mastigoteuthis* sp.

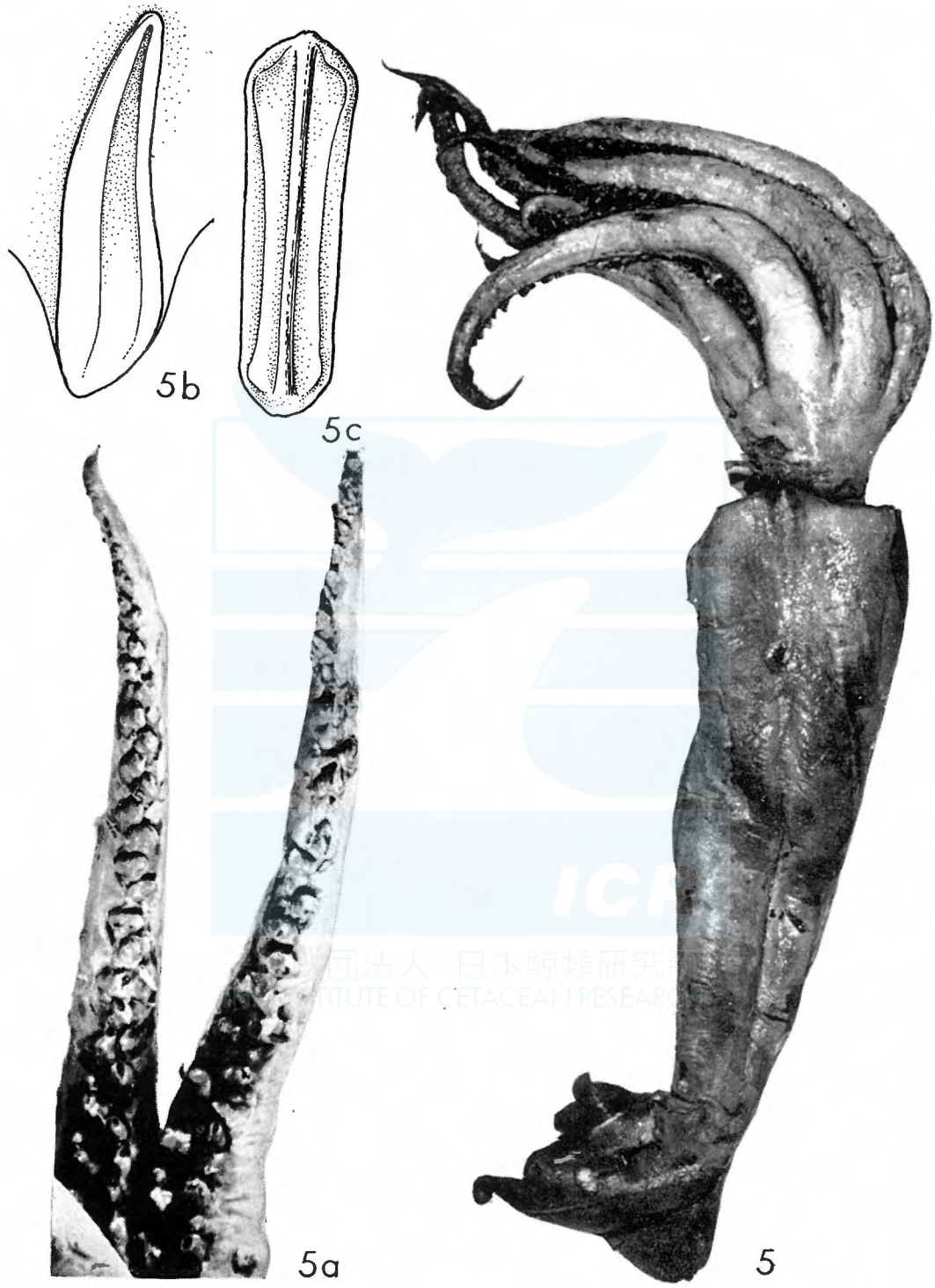

1
1a

2

3

4

4a


5b
5c
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6 7