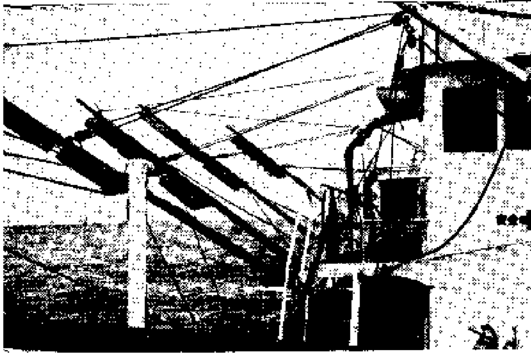

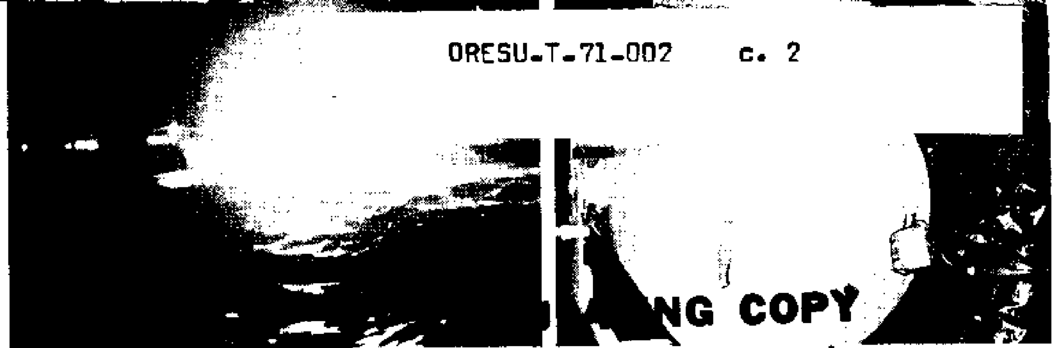

PACIFIC SAURY *(Cololabis Saira)*

A review of stocks, harvesting techniques, processing methods and markets

by Michael Shigeru Inoue, Ph.D.
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U. S. Department of Commerce

Engineering Experiment Station
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INTRODUCTION

Since the beginning of this century, scientists and fishermen have become increasingly aware that an undeveloped Pacific saury resourse exists off the west coast of North America. This awareness has come through the observations of commercial fishermen, particularly those in the albacore tuna fishery and the California-cased seine fisheries, and fishery assessment surveys by the Soviet Union, Japan, and the United States. No American fishery for saury has been established, but, on the Asian side of the Pacific, Japan, South Korea and the Soviet Union have developed large saury fisheries.

The Japanese fishery, which has been in existence since the 17th century, was revolutionized just before World War II by the introduction of new fishing geqr and techniques. Japanese landings of saury reached a high of 575,000 metric tons in 1958 but declined to approximately 52,000 tons in 1969 (Table 1). The Soviet Union entered the Asiatic saury fishery in 1958 and has operated a large saury fleet since 1960. Recent Soviet landings of saury have been around 40,000 metric tons annually although their 5-year plan had a 160,000-ton goal, for 1970. South Korea also has a fishery on Pacific saury in Asian waters, landing between 20,000 and 50,000 metric tons annually.

Wtih the decline in saury landings by Japan, the price of saury has increased severalfold since 1967. During the 1970 season, the average price to fishermen for all sizes of saury landed was $290 per ton. Fish of prime size for tuna bait often commanded ex-vessel prices of $400-$500 per ton. Freezer plants in American Samoa were reportedly

Table I.--Total Japanese catch and approximate catch composition from 1952-1969 saury fishing seasons (in metric tons)1/

Year	Total catch	Approximate catch composition 2/ Small	Medium	Large
1952	225,727	20,000	160,000	50,000
1953	253,661	25,000	210,000	25,000
1954	292,717	20,000	140,000	130,000
1955	497,002	15,000	210,000	190,000
1956	327,813	25,000	180,000	25,000
1957	421,530	20,000	185,000	170,000
1958	575,087	15,000	230,000	215,000
1959	522,567	10,000	290,000	220,000
1960	287,071	10,000	110,000	160,000
1961	473,732	35,000	370,000	80,000
1962	485,160	15,000	170,000	290,000
1963	384,548	30,000	255,000	90,000
1964	210,687	30,000	65,000	115,000
1965	230,300	15,000	200,000	15,000
1966	237,776	25,000	155,000	60,000
1967	217,261	20,000	165,000	30,000
1968	120,000			
1969	52,000			

1/ This table has been compiled from Hotta (1964c) and unpublished Japanese catch data (All Japan Saury Association, unpublished data, 1968). It is realized that the categories of approximate catch do not always add up to the total tonnage harvested because of omission of some data and possible reporting errors.

2/ Saury classified as "small" measure from 20 to 24 cm (KL) and weigh about 45 grams, "medium" from 26 to 28 cm (KL) and 85 to 95 grams, and "large" saury measure from 29 to 33 cm (KL) and weigh 100 to 155 grams. (Japanese scientists have selected knob length (KL) as a standardized length measurement for saury. Knob length is measured between the tip of the lower jaw and the posterior tip of the muscular knob of the caudal base, Kimura, 1956a).

selling 10-kg bait packs of frozen saury for about $600 per ton.

The increased value of saury has stimulated interest, both domestic and foreign, in the saury resource off the American Pacific coast.

Because it occurs well offshore and was of slight value, little research was conducted on eastern Pacific saury before 1967. A program has since been initiated by the National Marine Fisheries Service (NMFS) to study the biology of saury and to investigate factors which are likely to be important to possible U.S. participation in an eastern Pacific saury fishery.

The first step in the new program was to become fully informed on the Japanese saury fishery and to review research studies. In July 1968, NMFS contracted with the senior author to investigate Japanese saury industry and research facilities. The junior author made a survey of Japanese, Soviet, and domestic scientific literature. Accordingly, this report contains information on the Japanese saury fishery, summarizes biological studies on the western Pacific saury stock, and considers the less well-known central and eastern Pacific stocks.

PACIFIC SAURY STOCKS

POPULATION STRUCTURE AND LIFE CYCLES

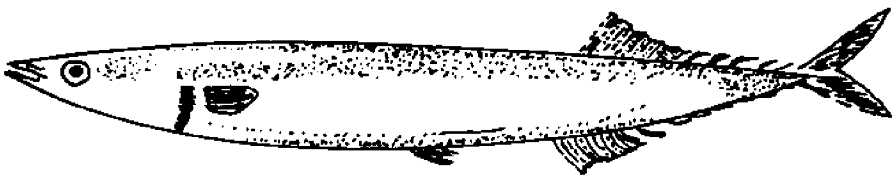
Cololabis saira (Brevoort), commonly referred to as "saury" or "needlefish" in English and "sanma" in Japanese, is one of three species belonging to the family Scomberesocidae, order Beloniformes.[1/] It has an elongate, slender body, dark greenish-blue dorsal surface, silverish ventral surface, projecting lower jaw, and a single dorsal fin far back on the body (Figure 1). Adults, superficially resembling flying fish without wings, grow to a length of 35.5 cm.

Although members of Scomberesocidae may be found in most temperate waters of the world (Figure 2), the Pacific saury is generally restricted to the waters of the Pacific Ocean between 19 and 58 degrees N. latitude (Hotta, 1964c: Kobayashi et al., 1968). The species is "homogeneous" (Sokolovskii, 1969) but appears to be separated geographically into three groups designated here as the western, central and eastern Pacific stocks[2/] (Figure 3). Soviet studies have indicated that eastern and western Pacific saury intermix at times but some Japanese investigators believe that the stocks do not overlap (Hotta, 1964c; Kobayashi, 1968).

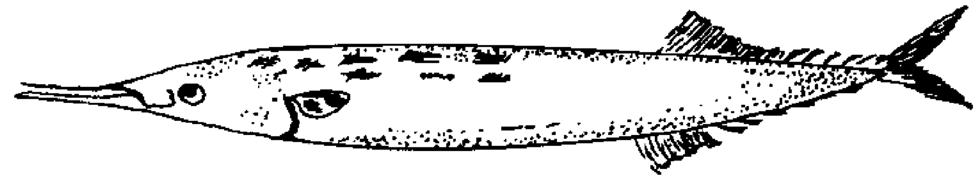
1/ Other Japanese names are Bansho (local name in Sado, Japan), Banjo (Niigata, Japan, Kado (Mie, Japan), Marukado (Mie, Japan), Saira, Saire, Sairenbo, Saera (Kansai, Shikoku and Kyushiu, Japan), Tamanosayori (Awaji, Japan), Sayori (Wakayama and Toyama, Japan), Saza (Goto Archipelago), Sazameio, Sairaiwashi, etc.

2/ As used here, the term stock is defined as a population segment that has geographical affinities and may or may not be genetically distinct.

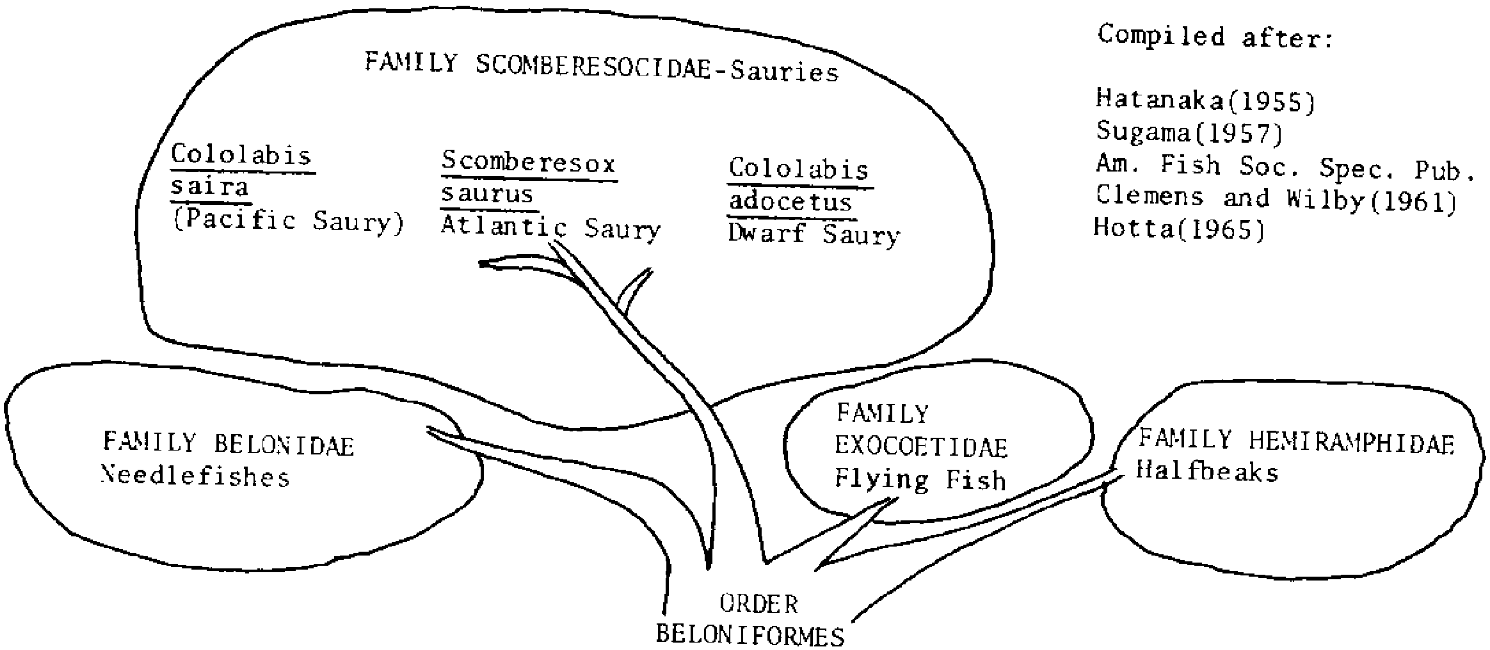
	Pacific saury Cololabis saira	Atlantic Saury Scomberesox saurus	Dwarf saury Cololabis adocetus
Jaws	somewhat protruded	Protruded	similar to C.saira
Mouth	short	elongated but soft	short
Vertebrae	63 to 66=(38~40)+(25~26)	64 to 66=(39~42)+(24~25)	54 to 58=(33~35)+(21~23)
Pectoral fin rays	13 to 14	14	9
Gill-rakers (first lower gill-arch)	35 to 38	45	17-20
Distribution	Entire North Pacific	North Atlantic, South Australia	off Peru



Pacific Saury



Atlantic Saury



Compiled after:

Hatanaka(1955)
Sugama(1957)
Am. Fish Soc. Spec. Pub. No.2(1960)
Clemens and Wilby(1961)
Hotta(1965)

Figure 1.--Phylogenetic relationship of the Scomberesocidae within the Beloniformes and principal morphological and geographical factors characterizing the three species of saury.

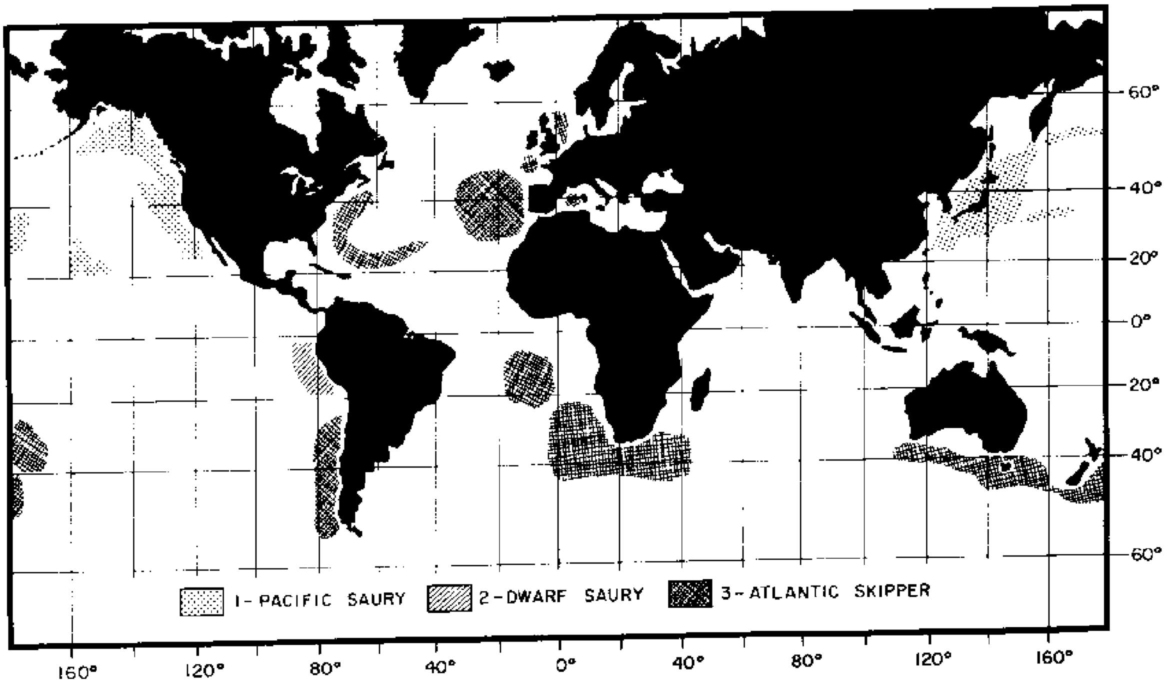


Figure 2.-- Geographical distribution of species within the Family Scomberesocidae: (1) Pacific saury, Cololabis saira; (2) Dwarf saury, Cololabis adocetus; (3) Atlantic saury, Scomberesox saurus. From Hotta (1965) and Zusser (1967a).

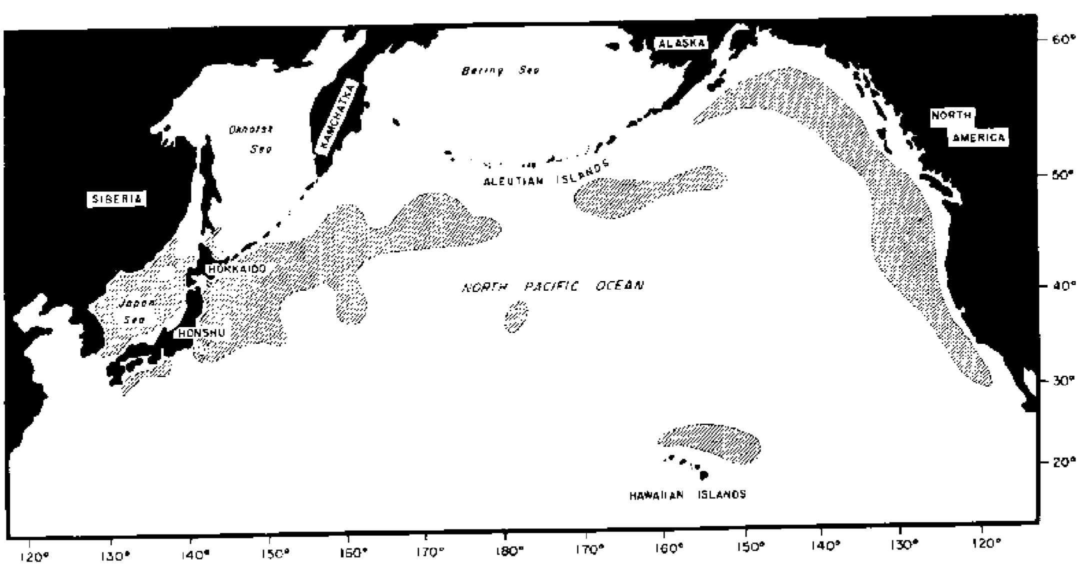


Figure 3.-- Distribution of Pacific saury, Cololabis saira. After Kobayashi et al. (1968).

Although the western Pacific stock has been fished for over two centuries, apparent changes in stock size only recently occurred as landings and fishing effort peaked. The combined saury catch by Japan, the Soviet Union, and South Korea exceeded 600,000 metric tons in 1958 but has since declined to about 130,000 metric tons in 1969 (Figure 4). Although fishing effort has decreased somewhat since its maximum in 1958-62, authorities agree that this stock has diminished (Shin Suisan Sokuho, 1969). As a result of the reduced supply and continuing demand for saury, the unexploited central and eastern Pacific saury stocks may become economically important. Domestic interest has been shown by numerous tuna companies who buy Japanese bait saury to supply leased longline vessels. During the late summer and fall of 1969 and 1970, the Japanese Government and fishing companies funded extensive exploratory fishing operations in the central and eastern Pacific. During 1970, at least 15 Japanese vessels operated off the west coast of the United States and Canada.

Western Pacific Stock

The western stock is distributed over three general areas: the Northwest Pacific Ocean, the Okhotsk Sea, and the Japan Sea (Hatanaka, 1956a,b). A large portion of the saury in the western Pacific is believed to enter the Okhotsk Sea through the Kuril Islands in mid-summer and leave there to join other western Pacific fish in late fall (Figure 3) (Hatanaka, 1956a,b, and Kobayashi et al., 1968). Although Kimura et al. (1956) have shown a substantial number of saury to enter the Sea of Japan north of Hokkaido Island and through the strait between Honshu and Hokkaido for spawning in the late summer and autumn, it is believed that the Japan Sea saury is at least partially separated from the Pacific group (Odate, Tohoku Regional Research Laboratory, personal communication, 1968).

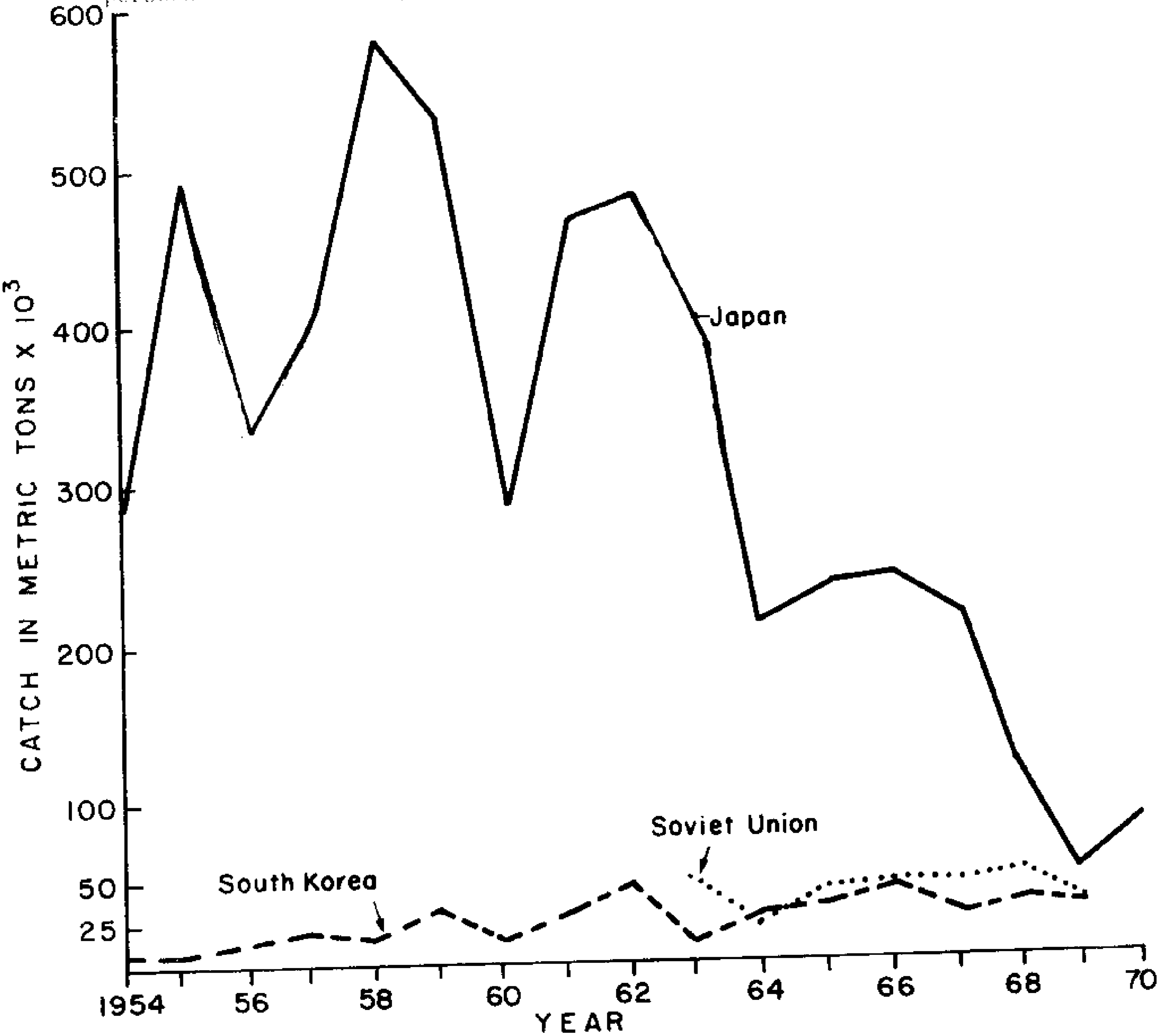


Figure 4. - Western Pacific saury landings by Japan, South Korea and Soviet Union, 1954-70.

Soviet and Japanese scientists have published many articles on the biology of the Pacific saury. Unfortunately, they have not been able to agree on certain key issues. In an attempt to minimize confusion, the Japanese theories will be presented first followed by Soviet theories with important points of disagreement summarized in table form.

The first significant theories on saury growth, reproduction, and migrations were presented by Hatanaka (1956a, 1956b). These initial studies indicated the Sea of Japan and the Pacific coast of the Japanese Archipelago from latitude 25°48' N. to 43°19' N. were the two major spawning areas. Eggs were collected nearly 1,000 miles at sea. Hatanaka's work indicated that spawning in the Sea of Japan occurred mainly in May and June whereas spawning in the Pacific Ocean occurred throughout the year. Hatanaka reported that the saury attained sexual maturity at 3 years and that a few survived to spawn at 5 years. The smallest ripe females measured 25 cm in length (KL); however, females usually attain sexual maturity at a length of 26 to 30 cm (KL). Young saury were reported to congregate around the southern Japanese islands, while adults migrated north during spring and summer and returned to the south during late summer, fall, and early winter.

Later studies by other Japanese scientists indicated that some of Hatanaka's conclusions were apparently incorrect. The most recent and widely accepted Japanese theories on saury biology (Naito, 1967-presented at Annual Japanese Saury Symposium) are described below.

The western Pacific saury stock is divided into two distinct populations, one spawning in the spring and the other spawning in the fall (Hotta, 1960). A mature female spawns from 1,000 to 4,500 eggs several times during a reproductive season (Hatanaka, 1956a; Japan Saury Study Group, 1968; Kimura et al., 1961). The eggs are fertilized and float near the surface where they typically become attached to seaweed, feathers, or each other by filamentous threads. Investigations in the Sea of Japan and Pacific coast of Japan suggest the eggs hatch into actively swimming and feeding larvae in about 10.5 days in water of 20°C (Hotta and Fukushima, 1963). Newly hatched larvae average 7.2 mm in body length (Yusa, 1960; also see Figure 5). The larval stage is considered to end when a length of 6 cm is reached about 180 days after hatching. Hotta (1958) demonstrated in his rearing experiments that juvenile saury measuring about 6 cm in length grow to 20 cm within 6 months.

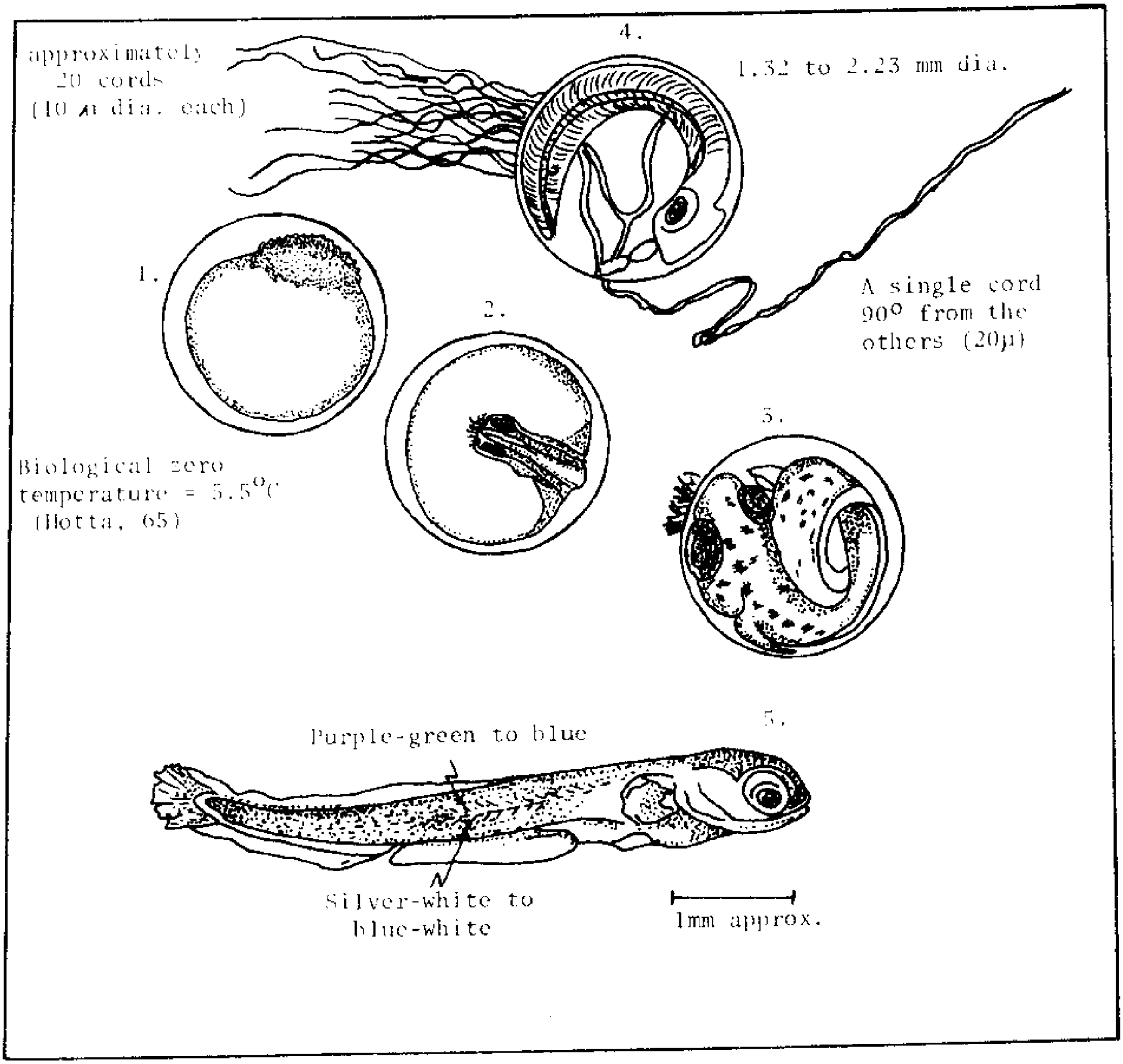


Figure 5.--Four stages of embryonic development and newly hatched larva of the Pacific saury (after Hatanaka, 1956a).

Most Japanese scientists (Annual Japanese Saury Symposium, 1967) presently believe that the spring-spawned saury become sexually mature at about 2 years of age, spawn several times during the spring of their second and third year with complete mortality following soon after the last reproductive season. The fall-born saury also spawn at 2 years of age, but do not survive to spawn a second season. These conclusions are supported by age-length studies of commercial catches taken during the fall (Figure 6-a). Commercial catches were found to be composed of 1½-and 2½-year-old spring-born fish and 1- and 2-year-old fall-born fish (Hotta, 1960; Odate, 1962). The range of length and weight measurements of the four groups that make up the marketable catch are as follows; 1-year-old fish (mostly 20-24 cm in length, about 45 g in weight); 1½-year-old fish (mostly 26-28 cm and 85-95 g); 2-year-old fish (mostly 29-30 cm and 135 g); and 2½-year-old fish (mostly 31-33 cm up to 155 g) (Table 1). The flow diagram in Table II summarizes the latest Japanese theories of saury growth and development.

Age determination is considered extremely difficult. Most Japanese scientists (Annual Japanese Saury Symposium, 1967) presently agree with the conclusions about the age of saury described above. Additional evidence supporting these hypotheses was obtained by Sugama (1957) and the Japanese Saury Study Group (1967). Based on scale and otolith readings from saury caught during the fall fishing season, two separate growth patterns have been detected (Figure 7). The "Type-1" otolith is found in small and large fish (believed to be 1- and 2-year-old fall-spawned saury, respectively), while the "Type-2" otholith is found in medium and extra large fish (believed to be 1-1/2 and 2-1/2-year-old spring spawned saury). Scale readings also support these theories on age and growth.

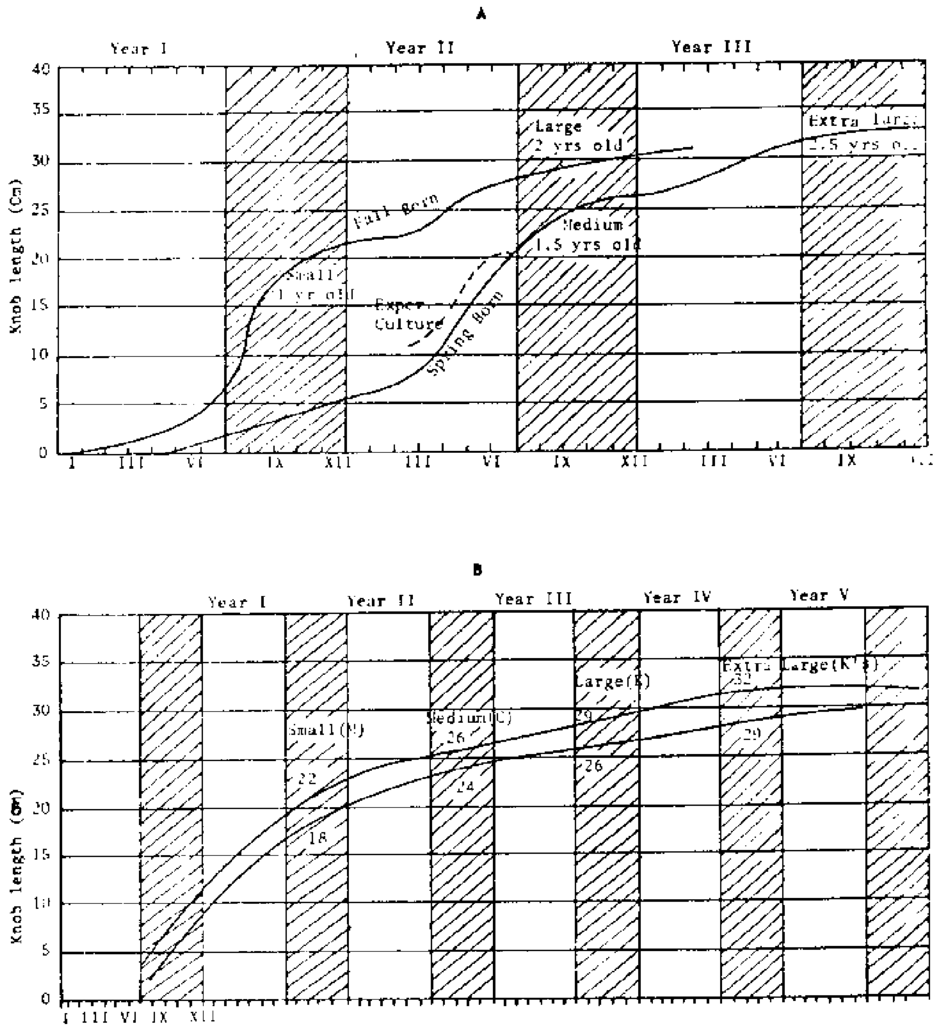


Figure 6.-- Growth in length of Pacific saury as interpreted by (A) Japanese and (B) Soviet scientists. Shaded months correspond to fishing seasons. The two lines in (B) indicate range of growth. (After Hotta, 1969c and Naito, 1967 unpublished manuscript)

Hypotheses advanced by Japanese scientists to explain seasonal improvements of saury off the Pacific coast of Japan are complex (Kobayashi et al., 1968) (Figures 8 and 9). The spring- and fall-born saury both occupy coastal waters but the fall-born saury occur further offshore. As previously mentioned, Kimura et al. (1958) reported that large numbers of saury enter the Sea of Japan north of Hokkaido and through the strait between Houshu and Hokkaido to spawn in the Sea of Japan.

Table II.--Flow diagram summarizing the general development stages of the Pacific saury (after "Japan Saury Study Group," 1968).

EGG - 1,000 to 4,500 eggs spawned by individual females at each of 6 to 7 spawnings.

- Eggs have a dozen cords on one end and a longer cord on the side vertical to the longitudinal axis, which typically become entangled in or attached to floating or fixed objects.
- Eggs are oval, 1.73 to 2.33 mm in length, 1.51 to 2.00 mm in diameter, and are typically transparent and colorless in their earlier stages, becoming green-violet in their last stage. They are slightly buoyant in seawater, having a density of 1.055.
- The incubation period varies from 15 days at 15° C. to 10.5 days at 20°C. Eggs will not develop in waters below 5.5°C. (biological zero).

↓

LARVAE

Pre-larval stage: 5.3 mm to 7.8 mm in length. For 3 to 4 days, nutrient is derived from yolk.

Post-larval stage: 8 to 25 mm in length. Fin-rays and bones reach adult numbers.

↓

JUVENILE

- 25 to 60 mm in length.
- Otoliths are formed and the first ring appears.
- Adult number of gill-rakers formed.
- Heads are shorter than adults.
- Swimming ability develops.

↓

YOUNG

Youth stage: 6 to 10 cm in length. Adult in external appearance but gonads are immature.

Pre-adult stage: 10 - 23 cm in length (KL). Gonad weight fluctuates seasonally when size reaches 20 cm Known to carry eggs when 22 to 23 cm long. Sexes can be identified by the gonad weight (GW) when fish measure over 10 cm in length.

↓

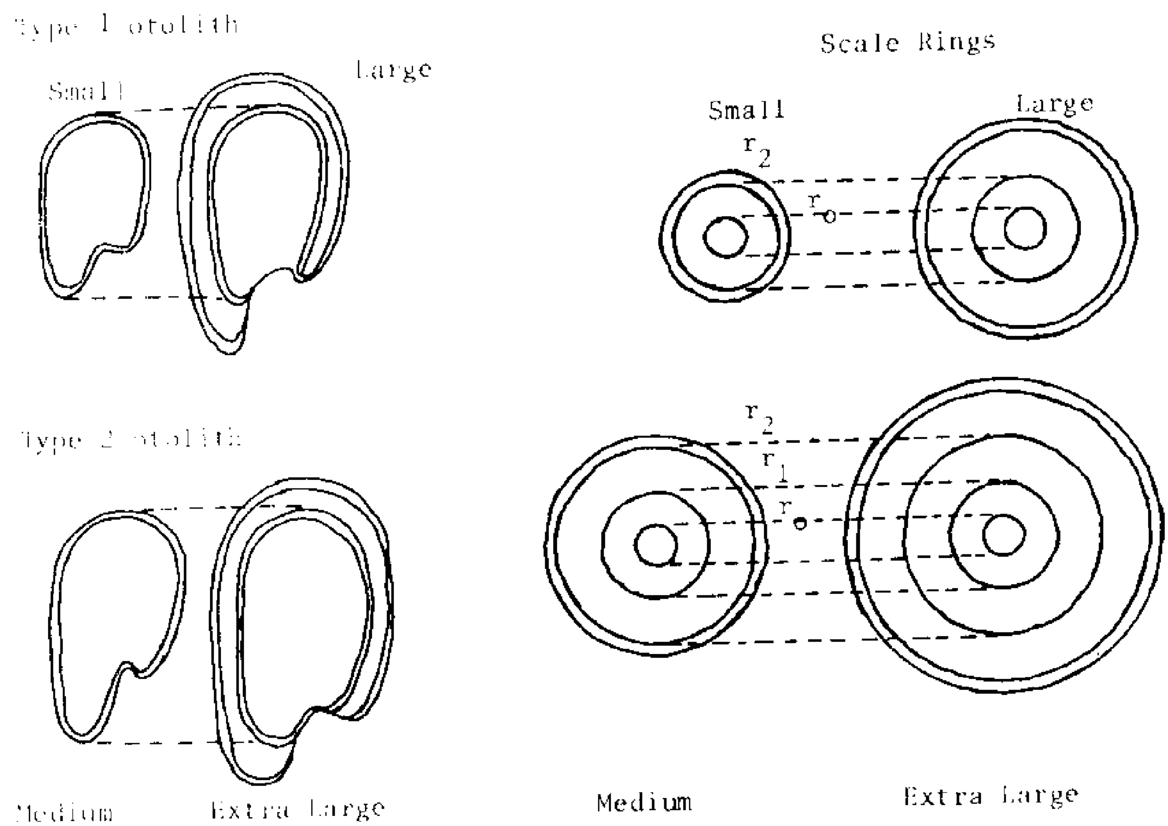
ADULT

Food-seeking stage: Fish feed heavily and grow rapidly, condition factor shows considerable variation between schools.

Pre-spawning dispersal stage: Saury lose weight as GW increases. Concentration of Vitamin A is translocated to reproductive organs. Poor attraction to artificial lights noticeable in fish 28 to 30 cm long (KL).

Spawning stage: 29 to 30 cm in length. Mortality is high after spawning.

(→ returns to EGG)



	Fall-born saury		Spring-born saury	
	Small (cm)	Large (cm)	Medium (cm)	Extra Large (cm)
First transparent band in otolith formed	17.06	17.16	24.22	24.43
Second transparent band in otolith formed	---	27.52	---	32.05
r_o in scale formed	6.38	5.90	6.11	6.55
End of first ridge (r_1) formation	---		13.45	12.57
Start of r_2 formation	---	22.43	24.80	27.39
Start of r_3 formation	---	---	---	32.54

Figure 7.-- Comparison of scales and Type 1 otoliths from small (1-year-old) and large (2-year-old) fall born saury with scales and Type 2 otoliths from medium (1.5-year-old) spring-born saury. The table correlates fish length (cm) with scale ring and otolith band formation for fall- (small and large) and spring- (medium and extra large) born saury. (After Hatanaka, 1956a; Sugama, 1957, 1959; Hotta, 1965: and Hokkaido Saury Group, 1966)

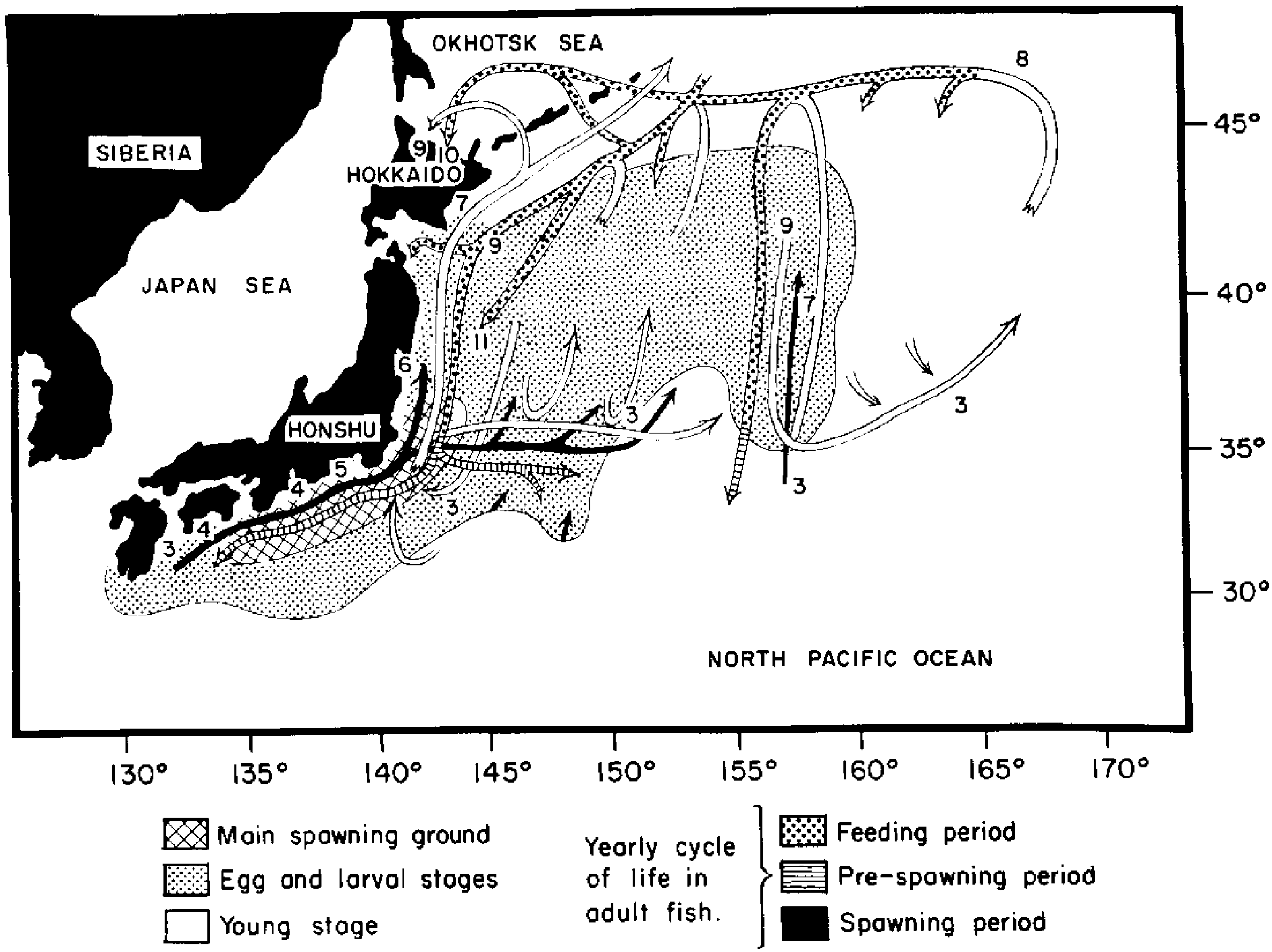


Figure 8.-- Hypothetical Migration Routes of Fall-Spawning Saury. The numbers indicate months of the year. After Kobayashi et al. (1968).

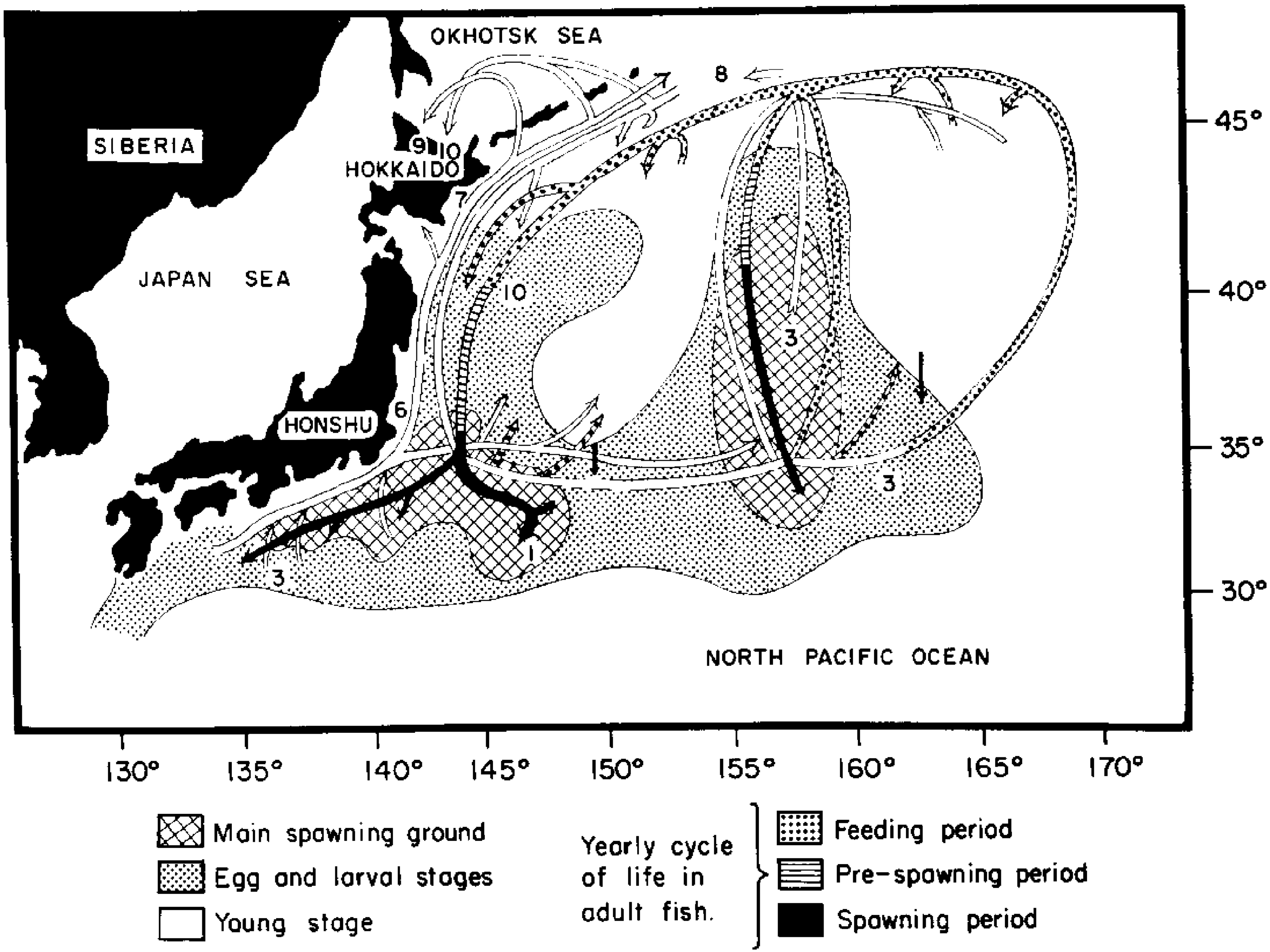


Figure 9.-- Hypothetical Migration Routes of Spring-Spawning Saury. The numbers indicate months of the year. After Kobayashi et al. (1968).

During the southerly migration in the late summer and fall, large saury may, but do not always precede the small fish because water temperature conditions may temporarily disrupt the size-segregated migration, resulting in a mixed southward migrating population (Kimura, 1956b).

Recent Soviet reports on saury growth, reproduction, and migration patterns are similar to the early theories and findings of Hatanaka but usually lack the details of the Japanese studies (for annotated bibliography of Pacific saury studies, see Hughes, 1970). Studies by Novikov (1960) indicate that spawning occurs throughout the year with peak activity in spring and fall. Novikov states, however, that the spring- and fall-born fish do not constitute two separate populations. He also reported that saury reach sexual maturity at 3 (2 +) or 4 (3 +) years of age. Saury captured from August through November 1958 are mostly 2 + and 3 + years of age fish with smaller proportions of 1 + and 4 + fish. Commercial catches were mainly 25- to 31-cm fish. (Compare Figures 6a and 6b for Japanese and Soviet age-length interpretations). Evidently, much of the difference between Japanese and Soviet theories on growth arises from difficulty in ageing this species.

The Soviet explanation for saury migration patterns (Figure 10) is less complex than the recent Japanese concept and more closely resembles the early theory presented by Hatanaka. Novikov and Klyuev (1958) reported that between August and November the saury gradually move southward and concentrate off central Honshu. Studies by Parin (1960) indicated that adult fish winter in the waters adjacent to southern Honshu Island and migrate north to the middle Kuril Islands during the summer. Recent studies by Novikov (1966) indicated that saury migrate north from the southern grounds to the south Kuril Islands from June to August, and commercial concentrations formed near the southern tip of Hokkaido in September 1964. The latter observation was interpreted as being part of the southerly migration down the coasts of Hokkaido and Honshu.

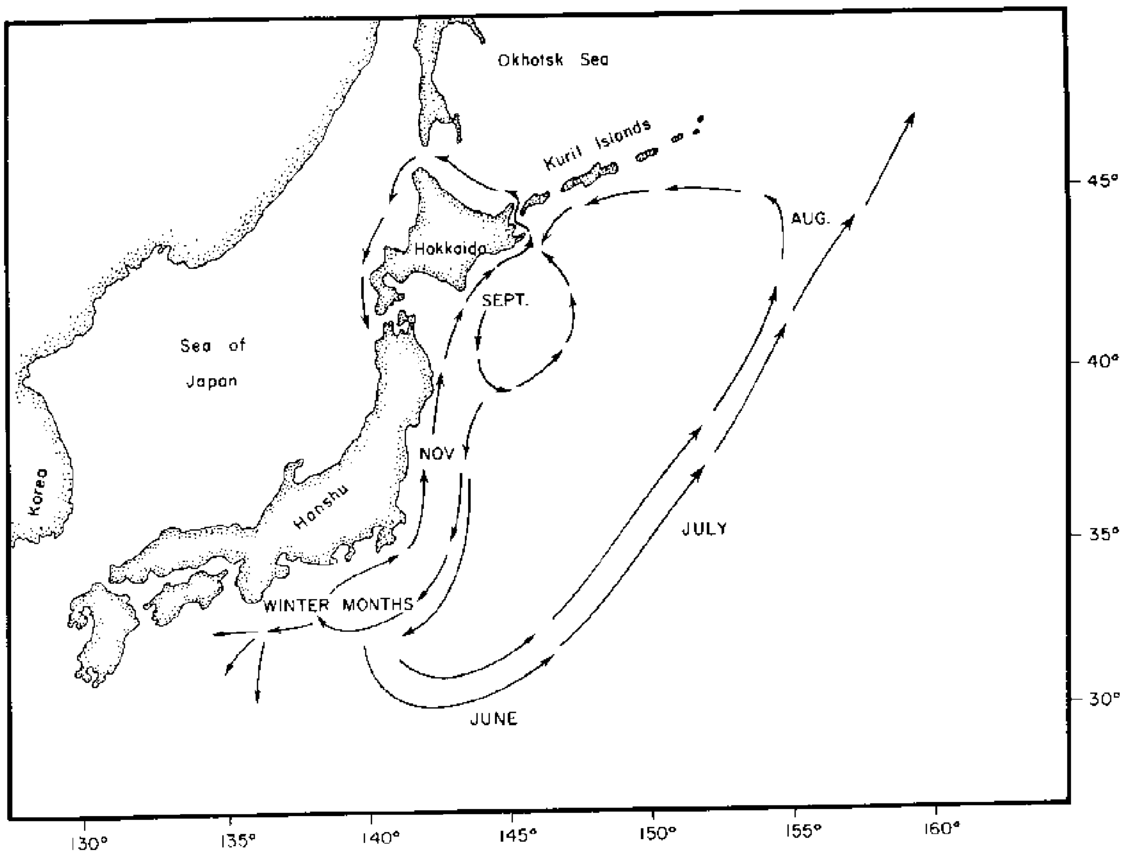


Figure 10.-- Soviet hypothesis of saury migration. Dates from Novikov and Klyeuv (1958); Parin (1960); and Novikov (1966).

Table III summarizes the noted contrasting theories on the biology of the western Pacific saury which have been presented by various Japanese and Soviet authorities.

Table III. Summary of contrasting theories on the biology of saury presented by Japanese authorities prior to 1960, after 1960 and by Soviet authorities.

	Original Japanese	Current Japanese	Soviet
Population Structure	Homogenous	Spring spawning Fall spawning	Homogenous
Time of spawning	Throughout year	Spring and fall	Throughout year with peaks of activity in spring & fall
Years of age at maturity	3	2	2+ or 3+
Years of age at spawning	3-5	2 and 3 (spring) 2 (fall)	2+ - 5
Age composition of commercial catches taken during late summer and fall	————	1;1.5;2;2.5	1+ - 5+
Life span (years)	4 to 5	3 (spring) nearly complete mortality following 2nd spawning season 2 (fall) nearly complete mortality following 1st spawning season	4 - 5+

Central Pacific Stock

The following information summarizes existing knowledge of the central Pacific saury stock.

Between 1955-59, research vessels of the National Marine Fisheries Service's Honolulu Biological Laboratory (unpublished data) collected information on the distribution, abundance, and size of Pacific saury occurring in the North Pacific (30° N. to 47° N. latitude) from mid-ocean (180°) to the west coast of the U.S. These data indicated the abundance of saury in the central sector (135° W. to 165° W.) to be relatively low compared to western (165° W. to 180°) and eastern (135° to west coast) sectors. Observations in the central sector where information was collected from May through October revealed scattered concentrations composed mostly of small fish (2.5-17.5 cm). Most of the large fish encountered in this sector were along longitude 160° W. The presence of very small fish (2.5-7.5 cm) suggests that spawning occurs from May through October. In the western sector (165° W. to 180°) observations made from March through August indicated large numbers of saury. Throughout this study period, between 1,000 and 3,000 fish were collected during 1-hour night-light stations. Size of available fish showed a more definite seasonal trend in this sector as smaller fish, 2.5-15.0 cm predominated in spring and early summer, and fish of 25.4-30.8 cm predominated in late summer and fall.

Eastern Pacific Stock

Although better known then the central Pacific stock, little serious attention has been devoted to the eastern Pacific saury stock. The literature discussed below gives some insight into its distribution and biology but few conclusions may be made at this time.

Soviet research ships surveyed the eastern Pacific saury stock during 1958-59 (Parin, 1960). In winter, concentrations of saury were observed along the Pacific coast of North America between latitude 33° N. and 38° N., and a small concentration was observed 450 miles west of the Oregon coast at latitude 45° N., longitude 137° W. (Figure 11). From egg and larva tows, this survey indicated that coastal waters between latitude 26° N. and 40° N. constitute the main spawning grounds, and spawning occured chiefly from April to July.

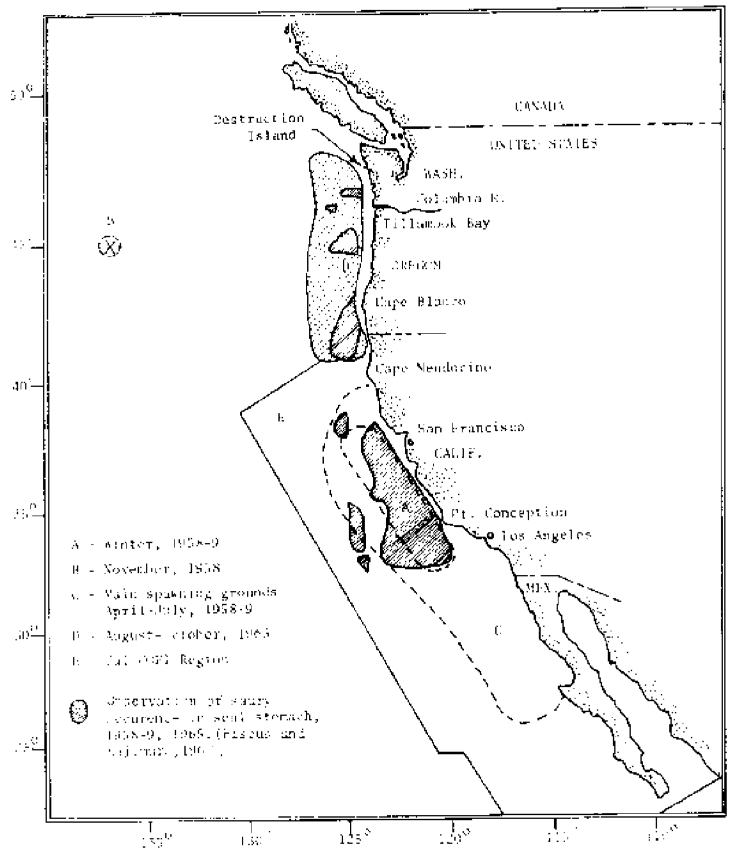


Figure 11.-- Eastern Pacific stock survey

Another survey of the eastern Pacific stock was made by the Soviet vessel, <u>Ogon</u>, from February through October 1965 off the coast of the United States and Canade between latitude 40° N. and 54° N. (Novikov and Kulikov, 1966). No saury were located in June, only small individuals were caught in July, and commercial quantities were taken in August From August through October, between latitude 41° N. and 48° N., saury were found in an area averaging 50 to 70 miles in width (Figure 11). Saury distribution within this area was described as "irregular." The more dense concentrations of sexually mature fish (26-30 cm) were found, between latitude 42° 18' N. and 44° 22' N. in water temperatures of 12.5 to 13.5° C. North of latitude 44° 22' N., large saury (28-31 cm) were found, but concentrations were less dense. South of latitude 42° 18' N., separate schools of small fish (18-22 cm) were located. In October, adults were found in commercial quantities throughout a 13,000-square-mile area. The investigators described distribution and behavior as similar to that of saury off Japan and the Kuril Islands.

The NMFS research vessel, John N. Cobb, made a survey of saury off Oregon, Washington, and southern British Columbia during August and September 1967 (unpublished NMFS cruise report). An abundance of large fish, mean length 23.2 cm, was encountered 30 miles west of Destruction Island, Washington (Figure 11). On this occasion, a dense concentration of fish was observed continuously over a 3- to 4-mile band. Saury schools were also found 5 to 10 miles west of the Oregon-California border.

Eberhardt (1954), Ahlstrom and Casey (1956), and Ahlstrom (1968) have reported on saury within the (California Cooperative Oceanic Fisheries Investigations) area off California and Mexico. Eberhardt's study, from 1950 to 1952, indicated that a large population was present and was most abundant during fall and winter. Ahlstrom and Casey have reported a detailed, month-by-month study of the distribution and abundance of saury eggs and larvae, as well as visual sightings of adults. Their data suggest that off California, adult saury are most abundant in November (Ahlstrom, NMFS, La Jolla, Calif., personal communication, 1969). Correspondingly, Smith, Ahlstrom, and Casey (in press) report that in the CalCOFI area saury are most abundant from late August to December.

In the CalCOFI area, saury eggs are present throughout the year, but 92 percent of the total were collected during February to July and 65 percent during April, May, and June (Ahlstrom, 1968). Based upon egg data, Ahlstrom estimates the adult saury population in the eastern North Pacific to be at least 450,000 tons. However, he notes that visual evidence of abundance and stomach analyses of predators suggest that the population actually may be several times larger than estimates made from egg data. No estimate of maximum sustainable yield is available. However, if the population structure of the eastern Pacific stock is similar to the western Pacific stock, where the Japanese have estimated the maximum age to be 3 years, then one would expect the natural mortality rate to be quite high. This being the case, MSY of the eastern Pacific stock (based on Ahlstrom's estimate of population, size) would be at least 200,000 tons (Pereyra et al., unpublished planning document)).

The NMFS Honolulu Biological Laboratory cruises conducted in the eastern sector of their study area (135° W. to North American west coast) included the period from spring through late fall.

During the summer (July-August), corresponding with the northward shift of the 13° to 18° C isotherms, the locations of saury observations also shifted northward. The bulk of the observations as well as the larger concentrations of fish were between 40° N. and 47° N. latitude. Most of the sightings were of fish 2.5 cm to 10.0 cm long, but a few fish in the 25.0 cm - 35.0 cm size group were also present. In late fall (November and December) the sightings were concentrated between 32° N. and 43° N. latitude. Saury of the 30 cm size group were most prevalent during the fall. The data suggests that spawning occurs between 32° N. - 43° N. and 135° W. to the North American west coast at least from May through August.

ECOLOGY AND BEHAVIOR

Japanese and Soviet authorities (Annual Japanese Saury Symposium, 1967 and 1968) indicate that the distribution and behavior of saury are strongly influenced by environmental conditions, particularly water temperature. Knowledge of the saury's reactions to changes in water temperature is important in predicting general migration patterns and short-term movements.

Effects of Water Temperature on Migration

Saury are sensitive to water temperature gradients throughout their life cycle (Hatanaka, 1956a). Larvae less than 29 mm in length are usually found in waters of 15 to 25° C (average 17° C), whereas larvae larger than 30 mm occupy waters of 14 to 18° C. Saury larger than 60 mm occur in water temperatures of 7 to 23° C; however, large concentrations usually occur at temperatures of 17 to 18° C. Spawning takes place at temperatures of 10 and 22° C.

Temperature gradients, both horizontal and vertical, largely determine the geographical range and depth of saury concentrations (Fukushima, 1962, and Zusser, 1967b). The maximum depth in which saury are found is regulated by prevailing currents and thermal stratification, but Pacific saury usually are not found deeper than 60 meters. This species also prefers to congregate in waters near sharp thermal gradients such as the California and Davidson Currents in the eastern Pacific (Novikov and Kulikov, 1966; Parin, 1960) and the two branches of the Okhotsk Current in the western Pacific (Zusser, 1967b). This preference may be related to the abundance of food in these areas resulting from upwelling, rather than thermal conditions (Parin, 1960; Zusser, 1967a). Sharp thermal gradients that temporarily bisect migration routes, however, often stop or severely impair fish passage (Kimura, 1956b). This phenomenon has been noted several times in the western Pacific and is a very important factor in forecasting fish abundance in an area (Fukushima, 1958, and Zusser, 1967b).

Strong winds which create the upwelling conditions responsible for the sharp thermal gradients affect the location of feeding grounds and migration patterns (Parin, 1960). Such winds often result in highly concentrated aggregations of saury, whereas weak winds or winds that dissipate existing thermal gradients result in widely dispersed saury schools. The catch rates of Soviet and

Japanese vessels have been shown to be related to wind intensity, direction, and to the resulting thermal gradient patterns. Steep thermal gradients resulting from prevailing south winds in the Japanese and Soviet fishing areas are believed responsible for high catch rates (Fukushima, 1958; Novikov, 1966).

Daily Vertical Migrations

Studies in the western Pacific have indicated that adult saury generally are found at depths between 30 and 70 m during daylight (Zusser, 1967a). Stomach analyses have indicated that during this period the fish feed mainly on copepods, fish eggs, and larvae, and the megalops larvae of crustaceans (Hotta and Odate, 1956). At sunset, the feeding rate diminishes and the saury migrate to surface waters, where they stay during darkness (Zusser, 1967a; Hotta and Odate, 1956). Numerous small aggregations often merge near the surface during the early hours of darkness to form masses of fish that may cover several square miles. If food has been abundant during the previous day, the fish do not feed at night (Zusser, 1967a). At sunrise, the fish again descend into deeper waters, the aggregations may break up, and the fish resume feeding.

Schooling and Predators

Although saury may form dense schools under natural conditions, this is not considered a typical behavioral characteristic of the species. During hours of darkness, saury more typically form rather "loose" aggregations on surface waters. Such concentrations are often of a single year class (Hotta, 1964c). Japanese fishermen characterize saury concentrations in the following manner:

(1) Nagashi (Cruising): Fish swimming in a same direction in a well-coordinated manner. These groups are easily spotted even in daytime, and are preferred by fishermen for harvesting.

(2) Shirami (White Spots): Fish observed by the white spots on the surface of the ocean due to sporadic uncoordinated fish movement at the surface level. More difficult to observe during the day and usually yielding marginal amount of harvest.

(3) Hane (Jumping): Excited groups of saury jumping into the air.

(4) Soko (Bottom): Groups near the sea bottom. Usually observed by Sonar or echo sounder only. Other names: Bochi, Tsubo, etc. 30-70 m deep.

(5) Hamonomawashi (chased by Jack-knife): Groups of saury being chased by predators. Easily attracted and caught.

In the eastern Pacific, marine mammals and predatory fishes have been observed to feed on saury. Gill and Hughes (in press) observed a 44-foot sei whale (Balaenoptera borealis) feeding on surface schools of saury during daylight hours off Point Reys, California. The whale was subsequently killed and examined. Its stomach was filled with saury along with a small quantity of unidentified euphausiids. Individuals, from the estimated 500 pounds of ingested saury, ranged in fork length from 6 to 29 cm. Fiscus and Kajimura (1965) reported that saury ranked sixth in importance as a food species for the fur seal Callorhunus ursinus off California. Stomach contents of 32 marlin caught near San Diego in late summer of 1951 showed that Pacific saury constituted about 75 percent of their diet (Hubbs and Wisner, 1953). Clemens and Wilby (1961) reported that albacore tuna feed on saury, and fishermen report that captured halibut and mackerel often "spit up" saury.

Grinols and Gill (1968) observed coho salmon (Oncorhynchus kisutch), jack mackerel (Trachurus symmetricus), and sablefish (Anoplopoma fimbria) foraging for saury that had concentrated at night beneath floodlights off the Washington-Oregon coast during August-September of 1967. The stomach contents from representatives of the three predatory species confirmed the observation.

Response to Artificial Light

At night, at the surface, saury will form dense schools under artificial lights. In the western Pacific, saury are apparently attracted to lights only during their late summer and fall southerly migration. The horizontal and vertical areas of attraction are dependent on light intensity and color. Saury show a positive response to an intensity as low as 0.01 lux; they remain for a long time in the zone of 150 to 200 lux; they remain for a few seconds in the zone of 600 to 800 lux; and they avoid zones of more than 800 lux (Sidel'nikov, 1966).

Saury were observed to be sensitive to wavelengths between 390 millimicrons and 770 millimicrons. The response to light, however, may be partly because of the availability of food (copepods, amphipods, euphausiids, etc.) under or near light. This is based on the observation that saury that are not hungry are said to have poor "hitsuke" (attraction to light) and also by the fact that below certain depths, light does not seem to attract saury as readily as might normally be expected. The experiments upon which these observations are based were conducted by Ibaragi Prefectural Experimental Station in 1967.

Owing to the absorption coefficient of light in water, white and blue lights penetrate farther than red light. By the use of white, blue, and red attraction lights, saury can be lured into respectively smaller areas and closer to the surface, thus increasing school density (Chiba Perfectural Fishery Research Base, personal communication, 1968).

Behavior During Spawning Period

Although sexually mature saury continue feeding during the spawning period (Kotova, 1958), ripe fish are not attracted to alluring lights (Yamamura and Muto, 1962). This phenomenon is believed to be related to a lack of Vitamin A content in the eyes during the spawning period.

Saury that are ready to spawn actively seek floating algae and debris in the open sea. Ayushin et al. (1967) showed a direct relation between the abundance of floating debris and the abundance of spawning saury on the spawning grounds. In an attempt to improve the reproduction conditions for saury, Soviet investigators scattered bundles of straw on the sea surface in a spawning area. They noted saury laying eggs in the straw-covered area during the day. After 12 hours, the bundles were retrieved, and as many as 4,000 eggs per 500 g of damp straw were counted. Saury have been observed to spawn during the entire 24-hour period with peaks of activity at midnight, early morning, and midafternoon (Kimura et al., 1958).

HARVESTING TECHNIQUES

Most of the information presented in this section was provided by Japanese research institutes and industry representatives which the senior author visited during his stay in Japan. Much of this information is unpublished. It was provided verbally and as informal reports and blueprints.

BRIEF HISTORY OF SAURY FISHING GEAR

Japanese fishermen and scientists have developed most of the harvesting techniques employed in Asian saury fisheries. Such techniques were usually designed to take advantage of one or more of the following behavioral characteristics of this species (Fishing Vessel Research Laboratory, Tokyo, personal communication, 1966).

(1) Formation of surface concentrations at night.

(2) Attraction to floating objects (during spawning period).

(3) Ability to hear predators and other saury feeding.

(4) Attraction to artificial lights (during part of their life cycle).

Hachida-Ami (1673-1680).--This first known commercial saury fishing gear was a trawling lift-net constructed of cotton fiber (Figure 12). It measured 100 to 200 meters (corkline length) and was pulled by two Japanese-style wooden boats. This technique (Fujinami et al. eds., 1958) utilized many of the basic concepts presently employed in the popular stick-held dip net.

Straw-Mat Method (1793-present).--In 1793, a method of catching spawning saury by hand, known as the "straw-mat method," was invented in Japan. Although this harvesting technique is used only for spawning fish, it is still seen practiced in the Japan Sea during the spring when more modern techniques are not useful.

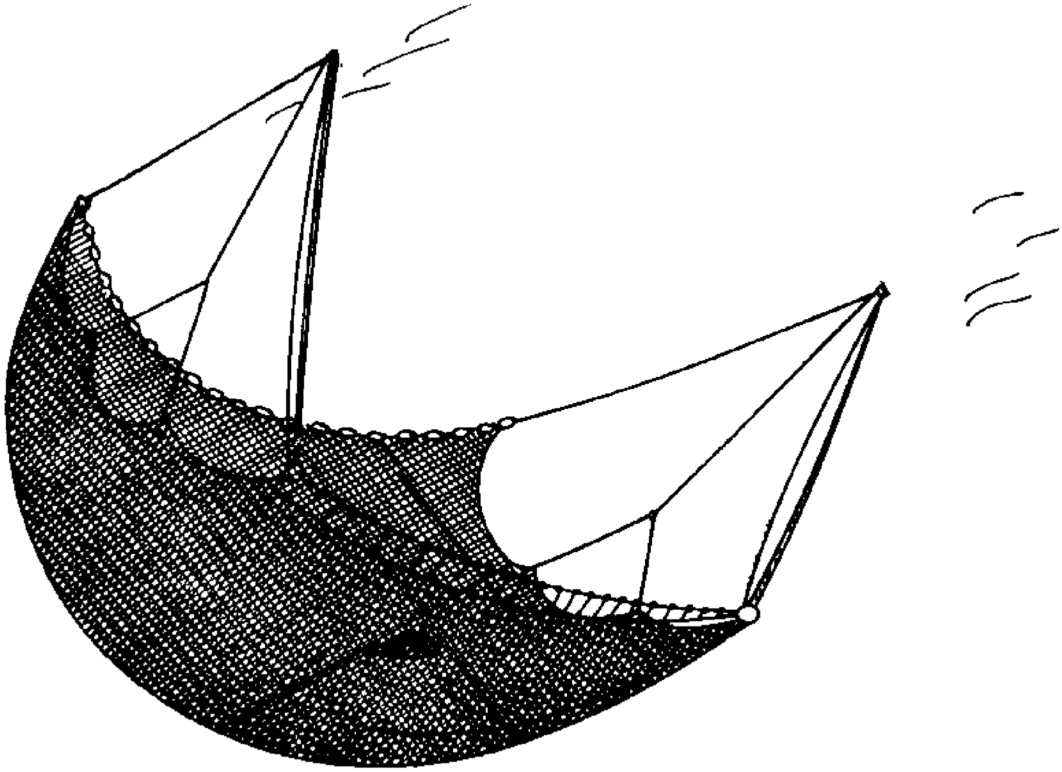


Figure 12.-- Hachida-Ami

Fishing is conducted from a small boat anchored in the spawning grounds. The mat, measuring about 3 m. by 1 m. is floated beside the boat and supports seaweed which hangs in the water to create a favorable spawning environment. Fishermen grab saury through holes cut in the mat as the fish lay their eggs on the seaweed (Hotta, 1964c). According to Naito (Kushiro Prefectural Fisheries Laboratory, personal communication, 1968), a fisherman may catch up to 5 fish each time he reaches through the holes. A small scoop net made of a blue nylon fiber, 45 cm. diameter scoop and a 1 to 1.5 m. long handle has now replaced bare hands.

The commercial quantity of saury harvested by this method has never been significant. Their quality is also considered inferior to fish caught during feeding season.

Saira-Oami, or Agri-Ami (1820).--This gear was an improved model of the Hachida-Ami and more closely resembled a purse seine (Dr. Fukushima, personal communication, 1968). It was operated from two 10-ton wooden vessels, each manned by 3 to 4 persons. The cotton net measured over 1,300 m. in total length and was composed of three parts: (1) the wings (Michi-Amis), the bunt (Kama-Ami) and a reinforced section of the bunt (Uodori) from which the catch was brailed (Figure 13).

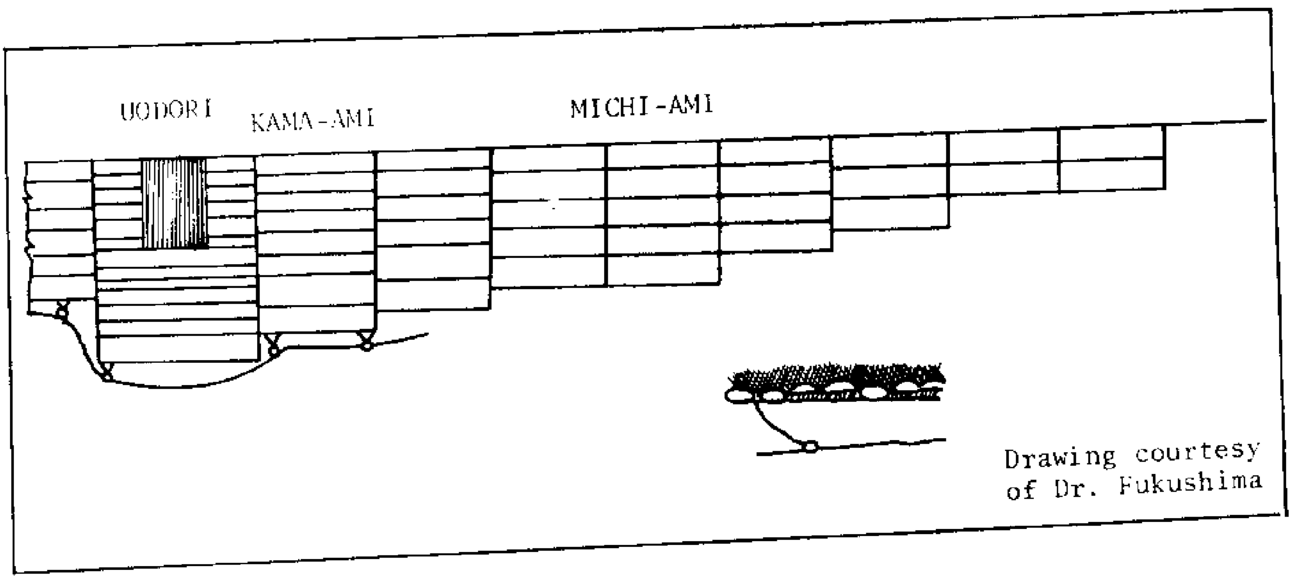


Figure 13. Agri-Ami (20 sections, 43 m. each).

Nagashi-Ami (1898-present).--A commercial saury gill net was developed by the Chiba Prefectural Fishery Experiment Station in 1898. It's construction and operation is similar to American commercial salmon gill nets (Figure 14). Originally, nets were composed of several sections

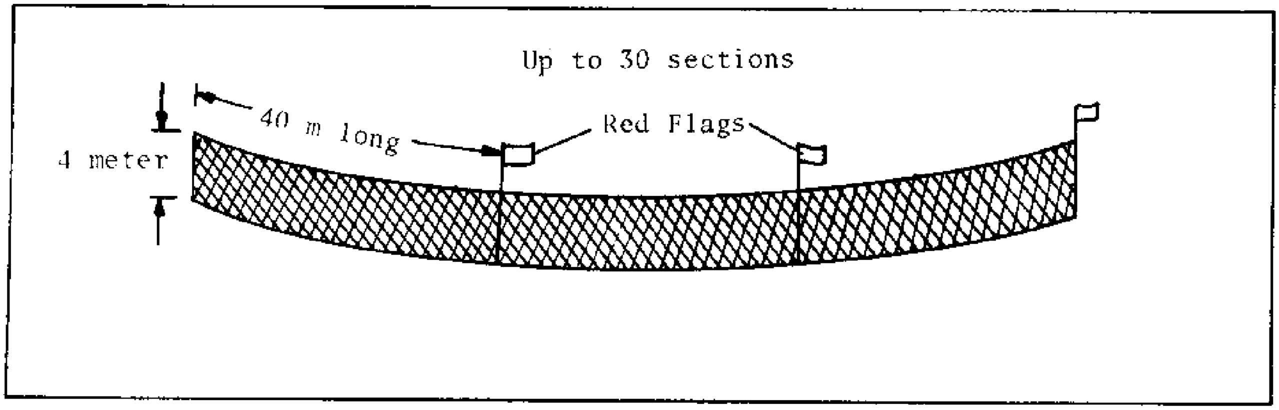


Figure 14. Nagashi-Ami (Japanese saury gill net)

and measured approximately 4 meters by 900 meters. Porcelain or lead was used to weight the bottom edge, while pieces of paulownia-wood (Aba) 20 cm. by 6 cm. served as flotation for the corkline.

Nets were operated from small (15 ton) motorized vessels, which fished 2 to 30 miles off the coasts. This gear was set at sundown and recovered shortly after sunrise. Catches of saury averaged about 1 ton per set. During years of peak fishing effort, the annual Japanese gill net harvest ranged up to 10,000 tons.

Improved nets of synthetic fiber called "Amilon" and foam plastic floats are still being used today to catch saury in some regions of Japan, and in South Korea.

Fish-Alluring Lights (1901-present).--The saury's strong attraction to artificial light was accidentally discovered by gill-net fishermen when lanterns replaced flags as net markers. Because unusually large catches were taken in the lighted areas, much effort was devoted to refining light attraction techniques.

The utilization of fish-alluring lights for attracting fish is attributed to Yoshiro Murakami of Chiba Prefecture. The technique was first used commercially for sardines but was later adopted for saury fishing.

Experiments with submersible fish-alluring lights have been conducted by the Ibaragi Prefecture Fishery Research Laboratory. Experiments conducted in 1967 demonstrated that while submersible alluring lights do attract saury, schools fail to surface when the lights are raised. (Alluring light systems presently used by Asian fishermen are discussed below).

Boke-Ami (1937-present).--The Boke-ami or stick-held dip net method of saury fishing was invented by fishermen in Chiba Prefecture in 1937 and was first used commercially in 1938 (Figure 15). It is most effective when used with alluring lights. World War II regulations prohibited the use of lights, and it was not until 1949 that this method became widely accepted. However, the method was so superior to older methods that by 1950 nearly all Japanese saury vessels were equipped with boke-ami gear. The gear and its operation will be discussed in detail below. Figure 16 shows the six basic steps of boke-ami fishing.

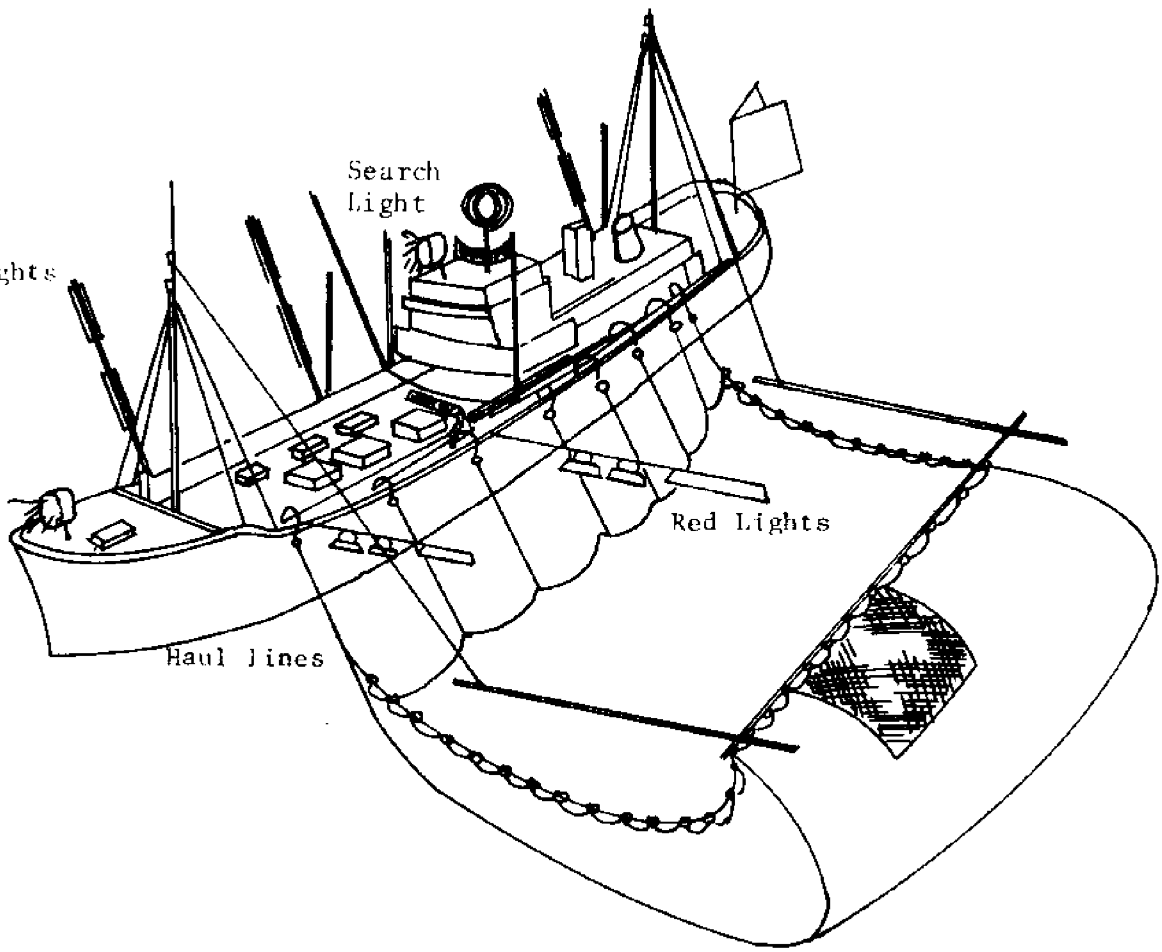
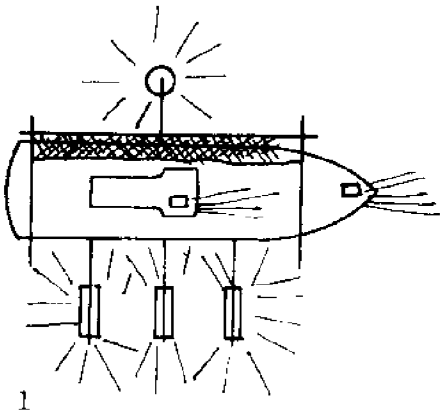
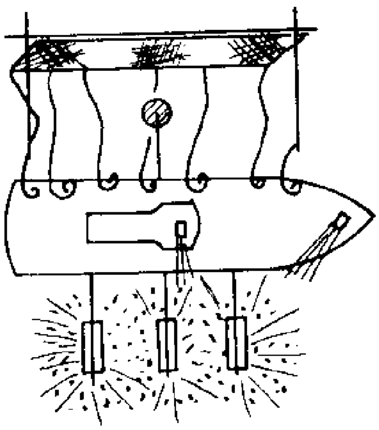


Figure 15.-- Stick-held dip-net (boke-ami) shown in a partially hauled position beside a Japanese-style saury vessel.



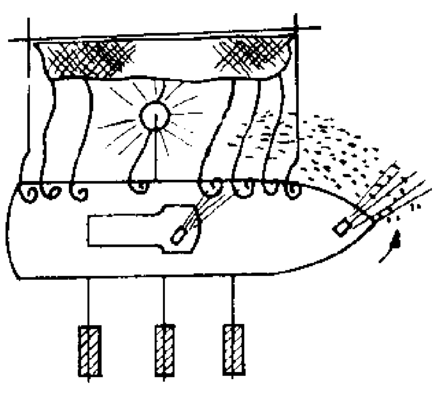
Step 1

<u>Searching for schools</u>
All lights on. Net up.



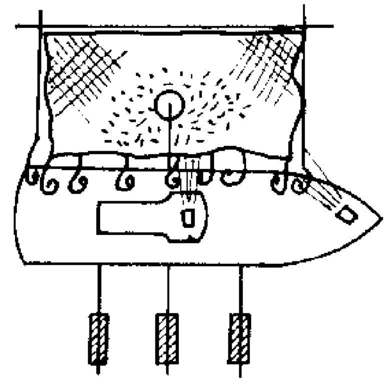
Step 2

<u>Gathering schools on starboard</u>
Fishing and search lights on.
Net lowered.



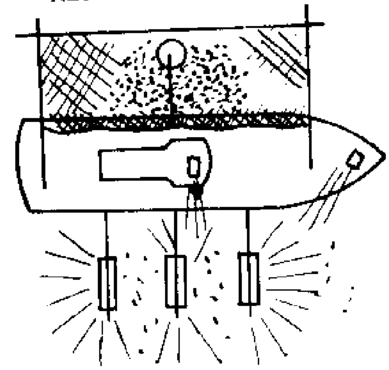
Step 3

<u>Guiding schools into net</u>
Lights on and off in sequence
around the vessel.



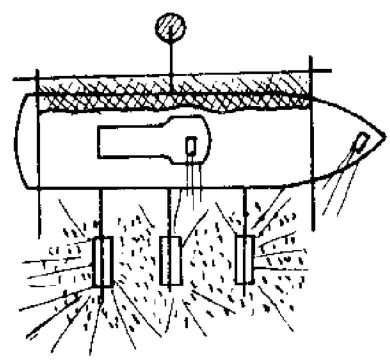
Step 4

<u>Enclosing the schools</u>
Net side lights on.
Pursing the net.



Step 5

<u>Hauling in net while gathering other saury</u>
Lights on for new schools.
Net pulled toward the vessel.



Step 6

<u>Bailing the catch aboard</u>
Fish concentrated on starboard
ready again for step 2.

Figure 16. Six basic steps followed in the boke-ami fishing operation.

"Improved" Boke-Ami Methods.--An "improved" stick-held dip net was proposed and patented by Fukuhara, 1947 (Figure 17). It consisted of a bag-shaped dip net with sticks joined to the vessel via universal joints. Operation of the gear is easy but not recommended in rough weather.

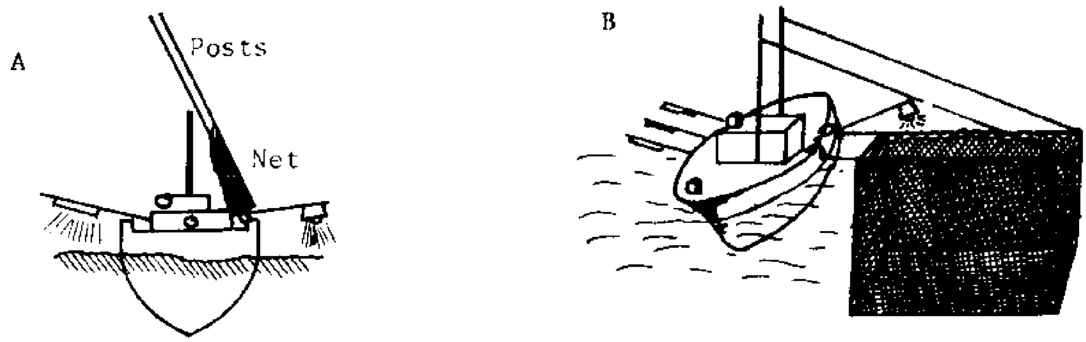


Figure 17. Fukuhara Boke-Ami. (A) Net secured while vessel searches with fish alluring lights and searchlights on. (B) In fish harvesting position with net lowered in waters.

Since 1967, Ibaragi Prefectural Fisheries Research Laboratory has also been experimenting with their so-called "curtain-type" dip net which can be drawn together to the center before being lifted on board the vessel. This labor-saving net has been implemented on their 200-ton vessel.

Other recent improvements include nets of nylon instead of cotton, fluorescent lamps where incandescent lamps alone are too inefficient, use of hydraulic side-rollers to dry up the catch, improved navigation equipment (3-station Loran, sonar, facsimile, radar, etc.), and the use of fish pumps and automatic fish sorting machines.

Electro-Fishing.--Soviet fishermen have recently designed and tested an electro-fishing technique for capturing saury (Commercial Fisheries Review, 1965a). The gear includes: (1) alluring lights, (2) a suction pump, and (3) a direct current electric field (Figure 18). When a school of saury is encountered, the suction pump is placed in the water alongside the vessel. The alluring lights (500 w. red lights) are positioned 0.5 to 1 m. above the water directly over the center of the pump. When the saury are

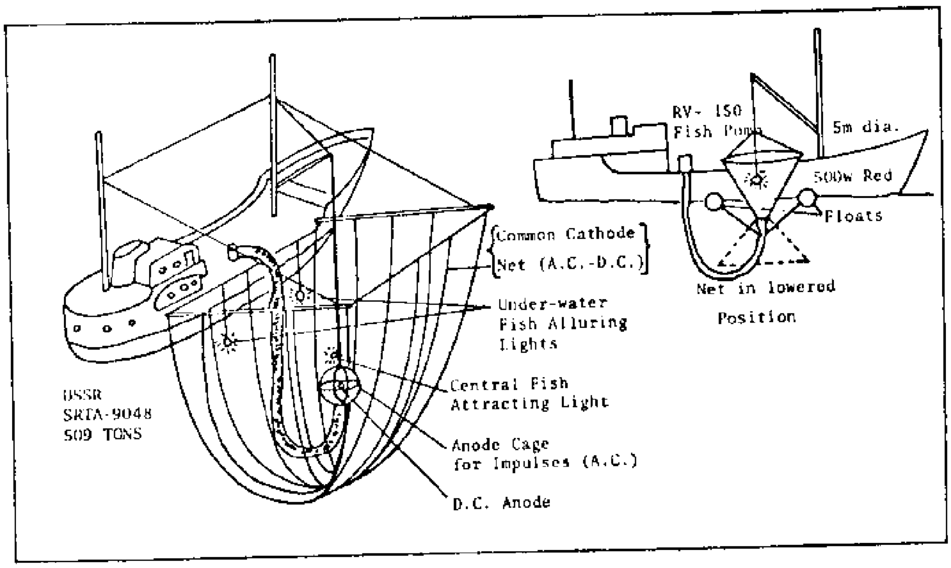


Figure 18. U.S.S.R. Electro-Fish-Pump Fishing
(a) With Electric Field (Sakiura, 1968)
(b) With a Lift-Net

attracted under the lights, direct current is applied between two steel cathodes and the suction pump which serves as the anode. The saury respond toward the anode of the direct current pulsed system and are pumped aboard. It was reported that a medium-sized Soviet trawler took more than 50 tons of saury in 12 days and 20 tons in one night using the above method. Although this experiment was reported nearly six years ago, reports of further development are not available. Despite suggestions that the electro-fishing technique is operational, the Soviet saury fleet still uses the stick-held dip net as its standard gear.

JAPANESE BOKE-AMI VESSELS AND GEAR DESCRIPTION

Boke-Ami Vessels.--Japanese vessels which fish with boke-ami gear during the saury season usually participate in several seasonal fisheries. The particular choice of activities undertaken by a vessel depends on its design, gear, and home port. To exemplify this diversity, the off-season activities of 206 vessels from Hokkaido (the northern island of Japan) were surveyed. The analysis indicated that 84 percent of the Hokkaido saury vessels also participated in salmon fisheries, a figure considerably greater than the national average of 46 percent.

Most salmon-saury fishing vessels restrict their activities to salmon and saury, but others may participate in three or more fisheries. Table IV illustrates the typical fishing schedules followed by saury fishermen in four different regions.

Table IV. Typical fishing schedules of Japanese vessels from four prefectures which engage in saury fishing

Date	Prefecture			
	Ibáragi	Kushiro	Fukushima	Kushiro
Aug.-Nov.	Saury	Saury & squid	Saury	Saury
Nov.-Dec.	N.Pacific tuna	Saury, squid & tuna	Albacore	Tuna
March	Bonito	Pacific mackerel	--	--
Apr.-July	Bonito 25°N. 150°E.	Pacific mackerel	Bonito	Salmon

Eight years is the average economic life expectancy of wooden saury vessels, while over 15 years service is expected from steel vessels. However, in the Japanese saury fleet vessels more than six years old are rare. For example, Mito-Maru (the saury research vessel of Ibaragi

Prefecture, constructed in 1962), was the oldest of 45 saury fishing vessels (all over 150 tons) based in Nakaminato in 1967.

Because of competition for good crews, a modern and large saury vessel is often equipped with a crew's dining room (a legal requirement), a recreation room with TV and stereo, and improved living quarters with baths, washing machines, etc. Advanced electronic equipment (3-station Loran, horizontal and vertical sonar, etc.) and new hydraulic labor-saving machinery (such as a side-power roller, and an 8-gang line hauler) are also standard on newer vessels. These, in addition to higher wages (salary plus commission) and various fringe benefits are needed to maintain an adequate crew.

Vessel construction and specifications.--Since 1960 steel has begun to replace wood in hull construction because of its greater resale value and reduced maintenance (Dr. C. Doke, Mitto Shipyard Co., Miho, Japan, personal communication, 1968). Wood construction, however, is favored for smaller vessels (40 tons or less) and is very popular among the combination coastal saury and squid jigging vessels. Constructing wooden vessels of 170 tons or more is becoming financially impractical because of new marine safety and labor regulations.

A 1965 survey of 16 randomly selected vessels from Ibaragi and Fukushima Prefectures, revealed that 10 were steel vessels which averaged 1.4 years old, and 5 were wooden vessels which averaged 5.0 years old. The Japanese fleet stays modern because three to six-year old vessels are usually sold to other Asian countries.

In 1967, 942 vessels totaling 60,151.86 tons, obtained permits to fish saury in Japan (Table V). Hokkaido had the most vessels, but

Fukushima Prefecture led in total tonnage. Ibaragi Prefecture had the highest average tonnage per vessel (127).

Table V. Size composition of Japanese vessels which were licensed to fish saury during the 1967 season. Numbers in parentheses indicate number of vessels that actually fished.

Prefectures	Hokkaido	Fukushima	Ibaragi	All-Japan
No. of vessels	220(186)	140(136)	66(63)	942(828)
Total tonnage	10,830	11,539	8,371	60,152(55,332)
Av.tons/vessel	49	82	127	64(67)
No. of vessels				
10-20 tons	27 (15)	1 (1)	0 (0)	41 (22)
20-30 tons	5 (5)	0 (0)	0 (0)	44 (34)
30-40 tons	29 (27)	7 (6)	0 (0)	206 (170)
40-50 tons	99 (85)	8 (7)	1 (1)	217 (183)
50-80 tons	26 (22)	22 (20)	0 (0)	92 (83)
80-100 tons	34 (32)	102 (102)	35 (33)	307 (302
100-150 tons	0 (0)	0 (0)	4 (3)	8 (7)
over 150 tons	0 (0)	0 (0)	26 (26)	27 (27)

The number of vessels which have actually engaged in saury fishing is shown in parenthesis in Table V. Of the 41 vessels in the 10-20 ton class which obtained permits, only 22, or 53.6 percent, actually profited by fishing saury. On the other hand, 100 percent of the vessels larger than 150 tons profited. The 12 Hokkaido vessels which registered but did not engage in saury fishing, probably turned to pole-and-line fishing for squid.

Commercial licenses and season opening dates vary, depending on vessel tonnage. No permit is required for a vessel smaller than 10 tons. Opening dates were moved ahead in 1967 because of the earlier opening date in the Russian saury fishery. However, the Japanese saury season now opens between August 1 and 20, depending on vessel size. Regulations allow small vessels to begin fishing earlier than large vessels.

Because saury fishing is conducted by combination vessels, considerable variation is found in their design and specifications. The following data are characteristic of most such vessels.

Size:

- Length: 9-45 m (typically 25 m)
- Tonnage: 10-250 tons (typically 100 tons)
- Carrying Capacity: 60-6,000 $m.^3$ (4,500 $m.^3$ typical)

Power Plants:

- Main Engine: 60-1,000 HP
- Auxiliary Engines: 2 x 50 HP diesel or over
- Electric Power Generators: 2 x 30 KVA or over
- Speed: 9-14 knots

Deck Layout (Figure 19)

- Fish hatches on forward deck
- Bridge at the center of the vessel
- Crew quarters near stern

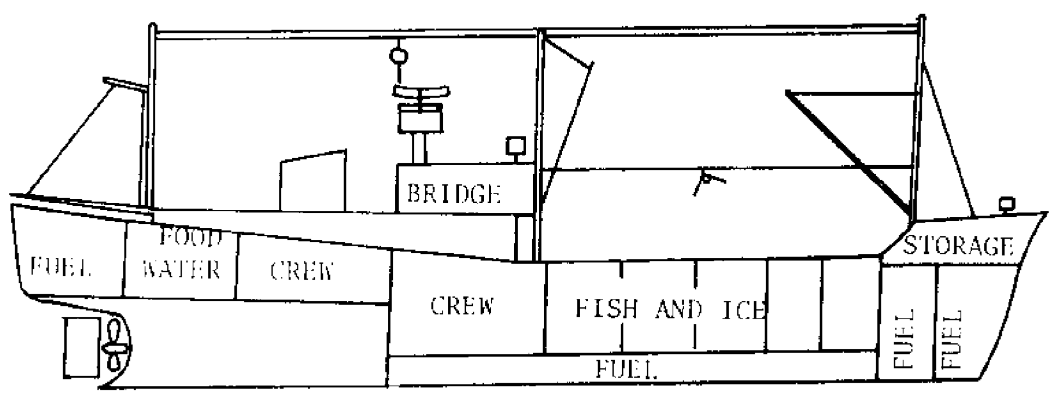


Figure 19. Space utilization on a typical Japanese saury vessel

The minimum vessel requirements for stick-held dip netting are:

1. Adequate space on deck to maneuver the dip net.

2. Provisions for installing fish alluring lights.

3. Adequate storage space for the catch. The fish hold is usually sectioned into compartments and refrigerated.

4. Two searchlights (5 kw and 3 kw, though a 7.5 kw and 5 kw combination is preferred on large vessels.

5. A spanker.

6. A sea anchor.

7. Auxiliary engines and generators for alluring light requirements (the legal wattage limit on alluring lights is 30 kw).

8. Radio communication.

9. Masts.

   -Bow: Tripod or Torii (Japanese Shinto shrine gate) with one boom.

   -Stern: Single mast.

   -No boom but with provisions for using a spanker (there may be a separate spanker mast).

Many Japanese saury vessels are equipped with the following navigation and communication instruments:

Electronic Equipment:

Two or three station Loran (600 miles day range; 1,000 miles night range).

Thirty to forty-mile range Radar

27 MHz radio direction finder

Automatic Radio Direction Finder, 250 KHz to 3 MHz or above

Sonar

Electric Temperature Gauge

Communication Equipment:

Main Transmitter and Receiver with 14 or more channels

Secondary Single Side Band 8-channel Transmitter Receiver

One or more multi-band Receiver and Facsimile Band Receiver

Single Side Band Transmitter and Receiver

Facsimile Receiver for weather map, fishing area forecast and other news.

Intercom, Walkie-Talkie, etc.

Fish Alluring Light System.--Lighting equipment and techniques for attracting saury have been highly refined for use in the Asian lift net (boke-ami) fisheries. Specifically, various lighting techniques are used to locate surface schools of saury, attract them to and concentrate them around the vessel, and finally to position and hold the fish for capture. Accordingly, the success of this harvesting system is dependent upon successful light-alluring procedures.

Although the type and placement of lights varies considerably with vessel design (Figure 20), all vessels operate under the same basic concept. Lights are evenly spaced along one side of the vessel, which

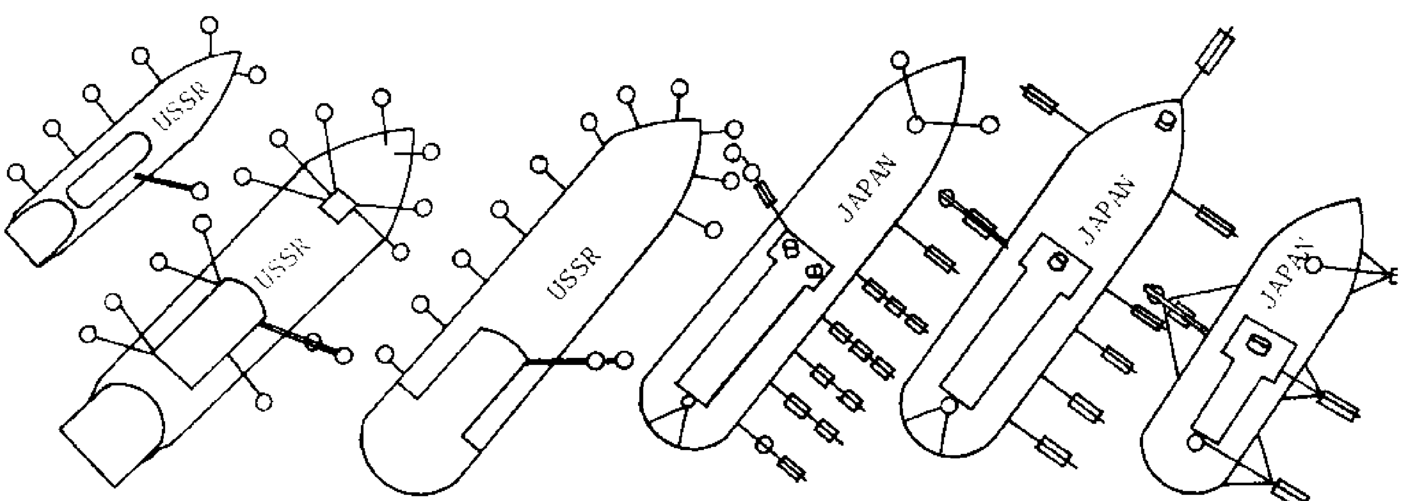


Figure 20. Light arrangements in Soviet and Japanese saury vessels.

serves as the fish gathering area, and amidships on the opposite net side. On larger vessels, additional lights are usually placed on the forward quarter of the net side. Thus, fish can be more easily led from the fish gathering side to midships on the net side by sequentially turning lights on and off.

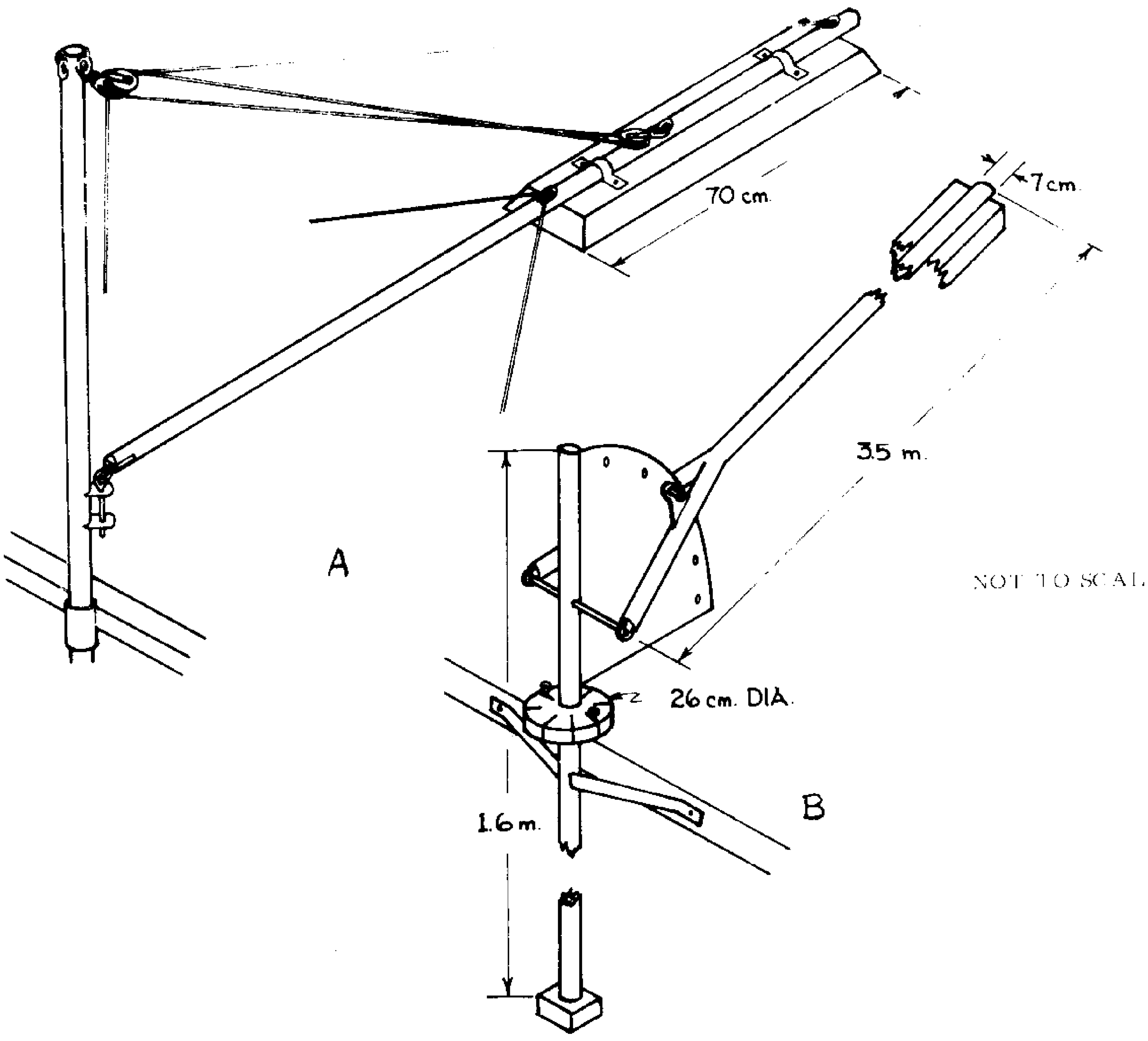


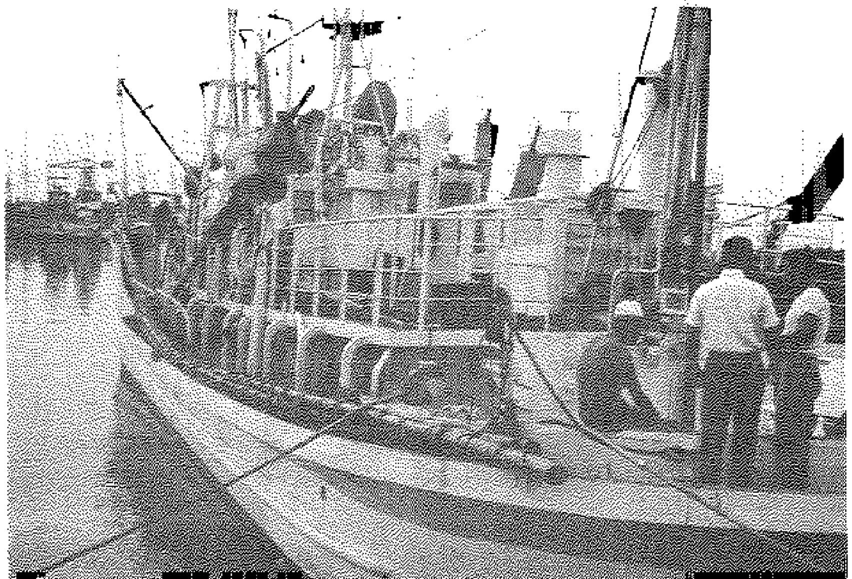
Figure 21.-- Light standards typically used on (A) Japanese and (B) Soviet saury fishing vessels.

On larger vessels, power for the lighting systems is sually supplied by two 60 KVA generators. A 220-volt system is used on most Soviet vessels, but Japanese vessels prefer to drop the voltage down to 100 volts in the lighting circuits for safety reasons. The Japanese government is attempting to enforce a 30 KW limitation for fish alluring lights used at any one time, regardless of vessel size. All lighting circuitery is controlled from a master switchbox mounted on deck and controlled by the fishing master.

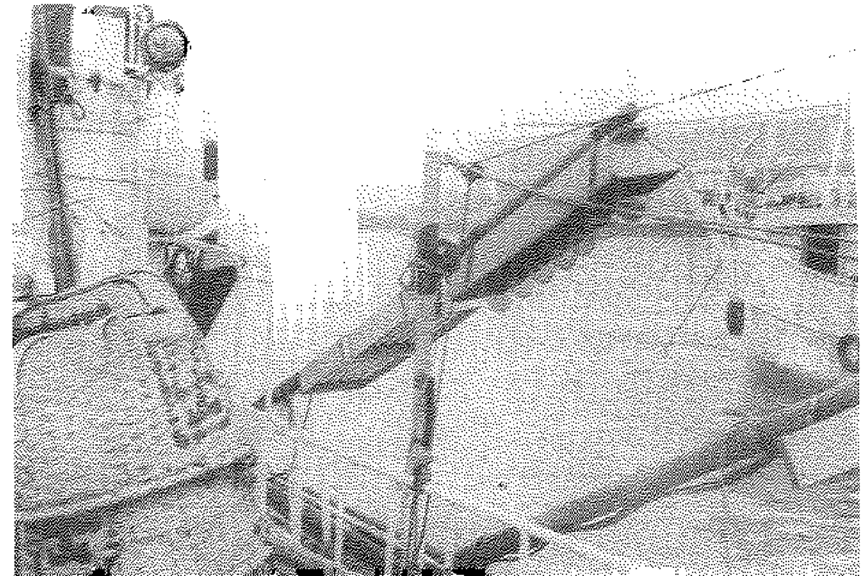
Various types of alluring lights are wired in banks and attached to light booms (Figure 21). Booms are of wood or steel and range up to 30 feet in length. When fishing, the booms are oriented outboard from the vessel at an angle of 30° to 45° above the horizontal which usually places the lights 9' to 12' above water.

The most popular fixtures on Japanese vessels include 500-watt, 100-volt incandescent lamps mounted in reflectors and blue or blue-green 20-watt, 100-volt fluorescent lamps. Because of the 30 KW lighting limitations placed by the government to avoid unnecessary competition, the more efficient fluorescent lamps are gaining popularity. Fluorescent lamps also have a shorter wave-length and thus can penetrate the water deeper because of lower absorption coefficient. Vessels equipped with incandescent lamps have been observed to switch on both auxiliary generators to increase the voltage and obtain a higher color temperature: however, this shortens the bulb life.

Figure 22 illustrates various lighting equipment used on Japanese saury vessels. Sealed beams similar to automotive headlights and mercury vapor lamps have also been considered for possible adoption. The arrangement of fish alluring lights on a typical Japanese vessel and the maximum potential wattage of each light bank is presented in Figure 23.

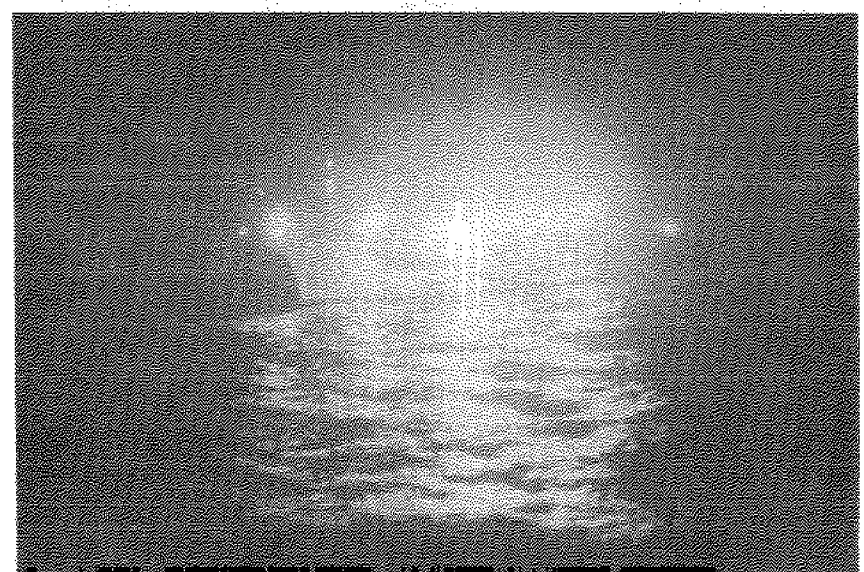


a. Vessel with alluring lights in stored positions. The light bank on the portside is composed of blue and red incandescent lights to surface the fish as the net is pulled.



b. Combination of fluorescent and incandescent lights are often used on one bank.

c. Saury searchlight (5 KW) used to scan surface waters for saury schools.



d. Vessel searching for saury with lights on.

Figure 22.-- Examples of lighting equipment used on Japanese vessels.

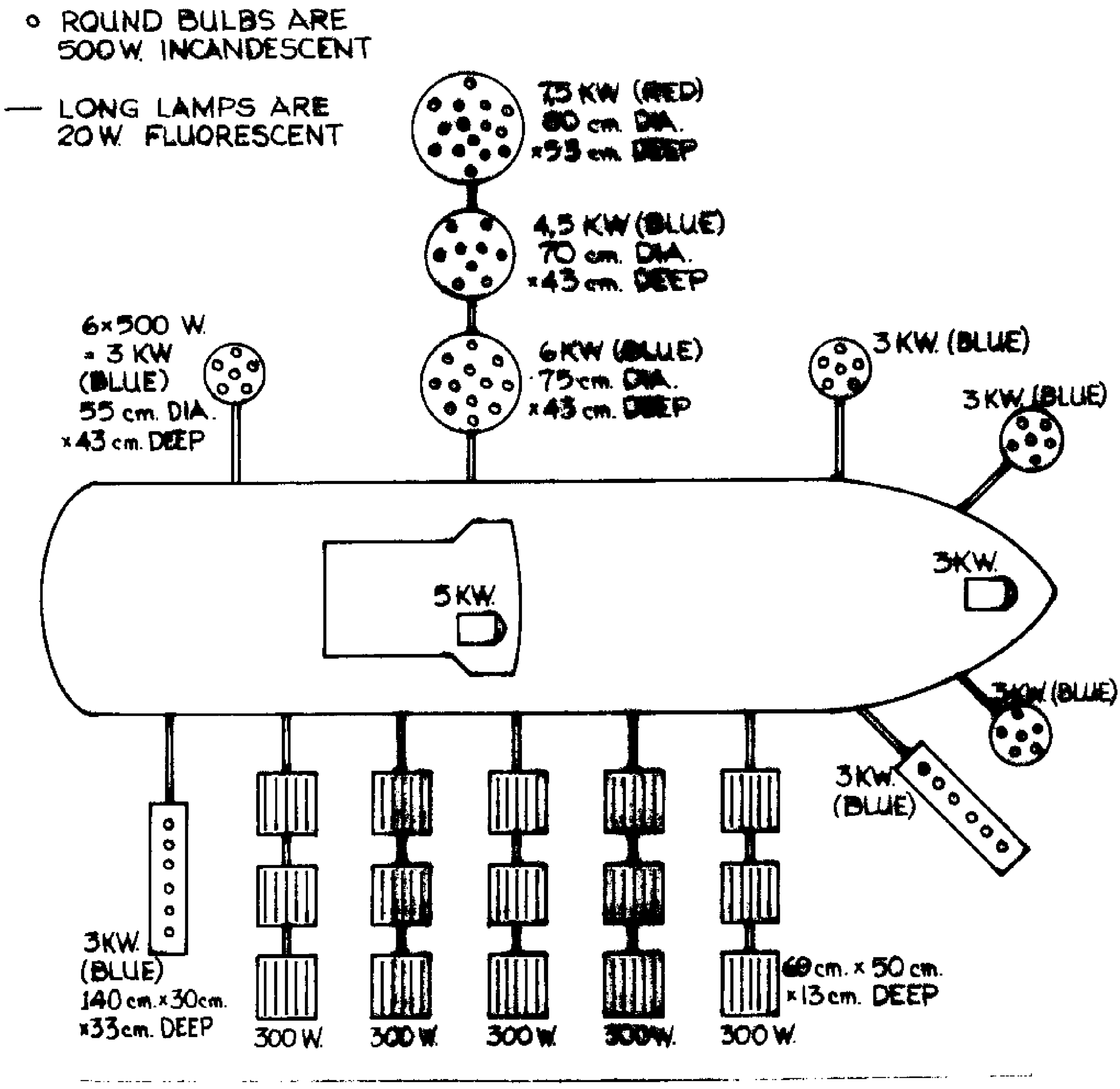


Figure 23.-- A typical arrangement of fluorescent and incandescent lamps on a saury fishing vessel.

Although the sum of the power required for all lamps does not exceed the 30 kw legal limit, all the lights are rarely on at the same time. The red lights on the dip net side (portside on most Japanese vessels, and starboardside on most Russian vessels) are used to bring to the surface saury which have been attracted, since the absorption coefficient in water is greater for red color than for blue-white colored lights.[1/] Some vessels use dimmed blue lights in place of red lights. The requirement, in any case, is to hold the fish near the surface between the net and the vessel as the web is hauled under and around them.

The arrangement of fish alluring lights used on the Russian R/V PT Peramyda and the position of the boke-ami as it relates to the location of fish alluring lights is shown in Figure 24.

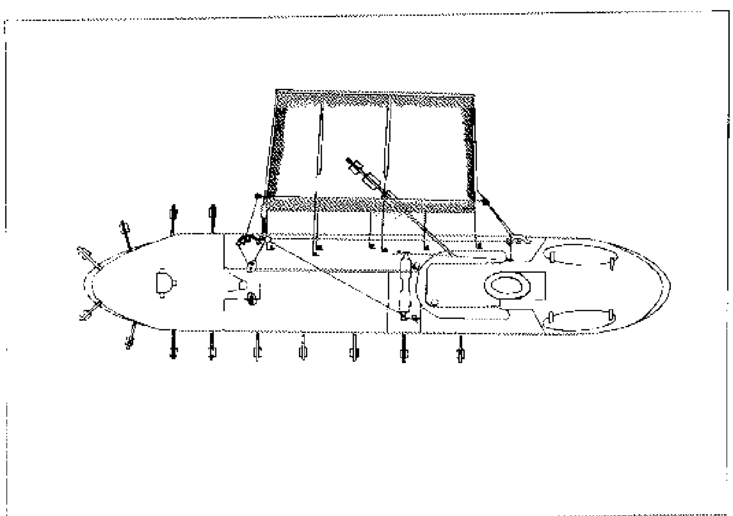


Figure 24. Arrangement of fish alluring lights used on Soviet R/V PT Peramyda.

1/ The absorption coefficient for red light in fresh water (650-700 milimicrons) is about 0.5 per meter, while that of blue light (450-500 milimicrons) is only about 0.04 per meter.

The Boke-Ami and Auxiliary Gear.--The boke-ami or stick-held dip net system is used by all nations involved in the Asian saury fisheries. Some of the other harvesting techniques previously mentioned are still employed, but their use is very limited. At least 98 percent of the total Asian landings are made with the boke-ami. Although this gear is relatively inexpensive and easily installed on many classes of vessels, the fishing operation itself is extremely labor intensive.

A cost estimate for equipping an 88-ton saury vessel using Japanese equipment purchased in Japan is given below.

Boke-ami dip net and brail	¥ 1,150,000 ($3,194)
Fish alluring lights (not incl. the generators)	¥ 600,000 ($1,667)
Power side-roller	¥ 800,000 ($2,222)
Six-gang winch	¥ 350,000 ($ 972)
TOTAL:	¥ 2,900,000 ($8,055)

The above figures are based on the official exchange rate of ¥ 360 to $1.00.

The size and to some extent the materials and design of boke-ami nets vary with vessel size and class. A simply constructed net, used mostly on small vessels, is shown in Figure 25. A more elaborate net commonly used on larger vessels is shown in Figure 26, and a Soviet boke-ami (Andreev, 1962) constructed of two mesh sizes, is shown in Figure 27. Photographs in Figure 28 show a Japanese net attached to the bamboo float poles, purse rings used along the ends of the net, the leadline, and various sized meshes and strips of web in a boke-ami.

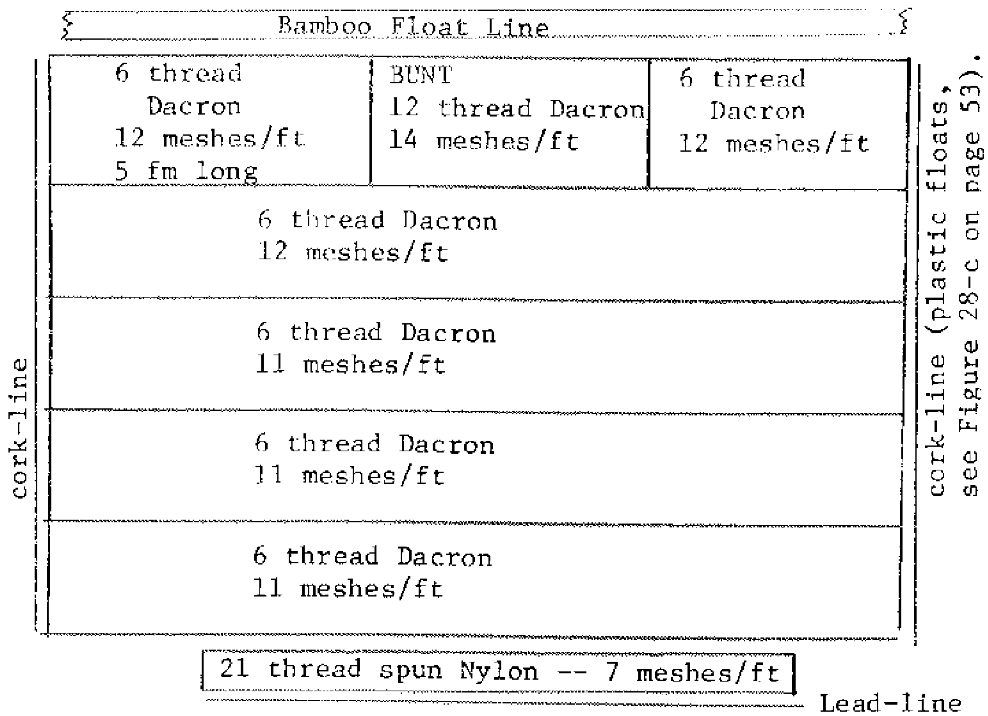


Figure 25.-- Design of a small, simply constructed Japanese stick-held dip-net for use on small vessels.

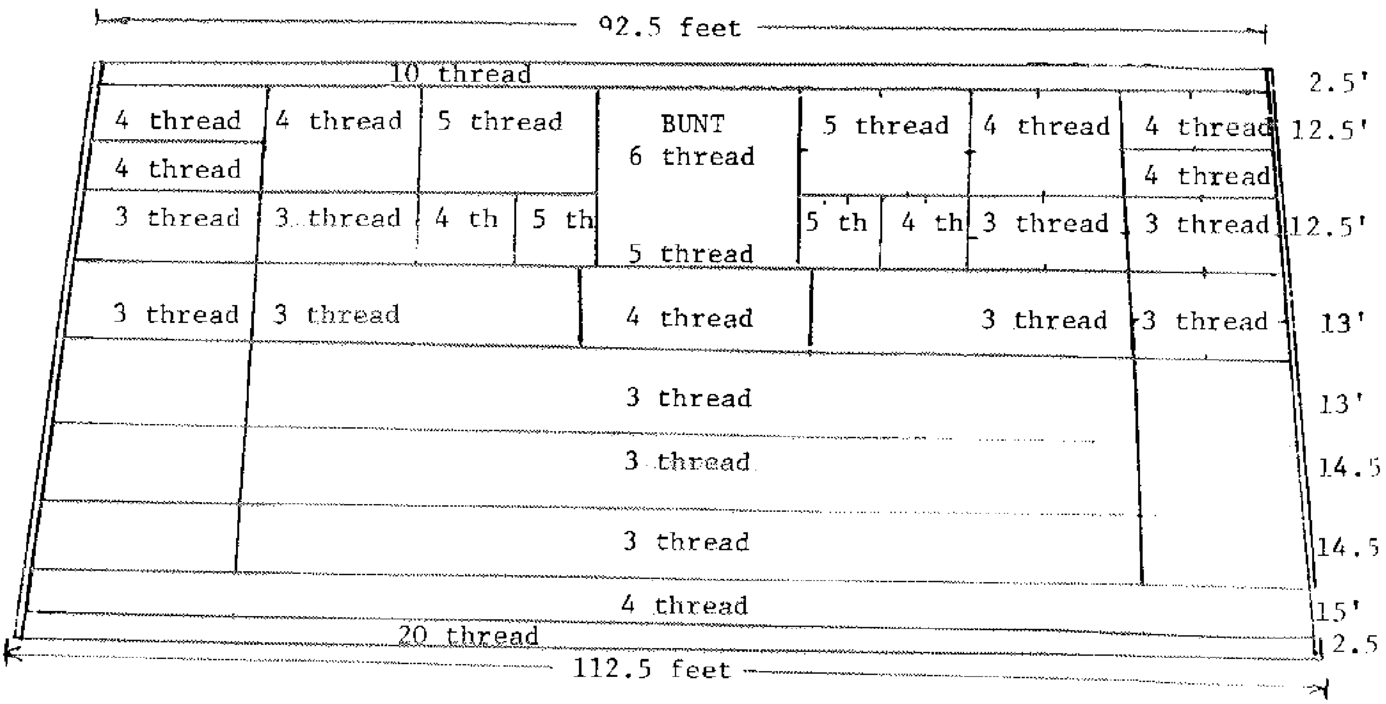


Figure 26.-- Design of a typical Japanese dip-net for a 96-ton vessel.

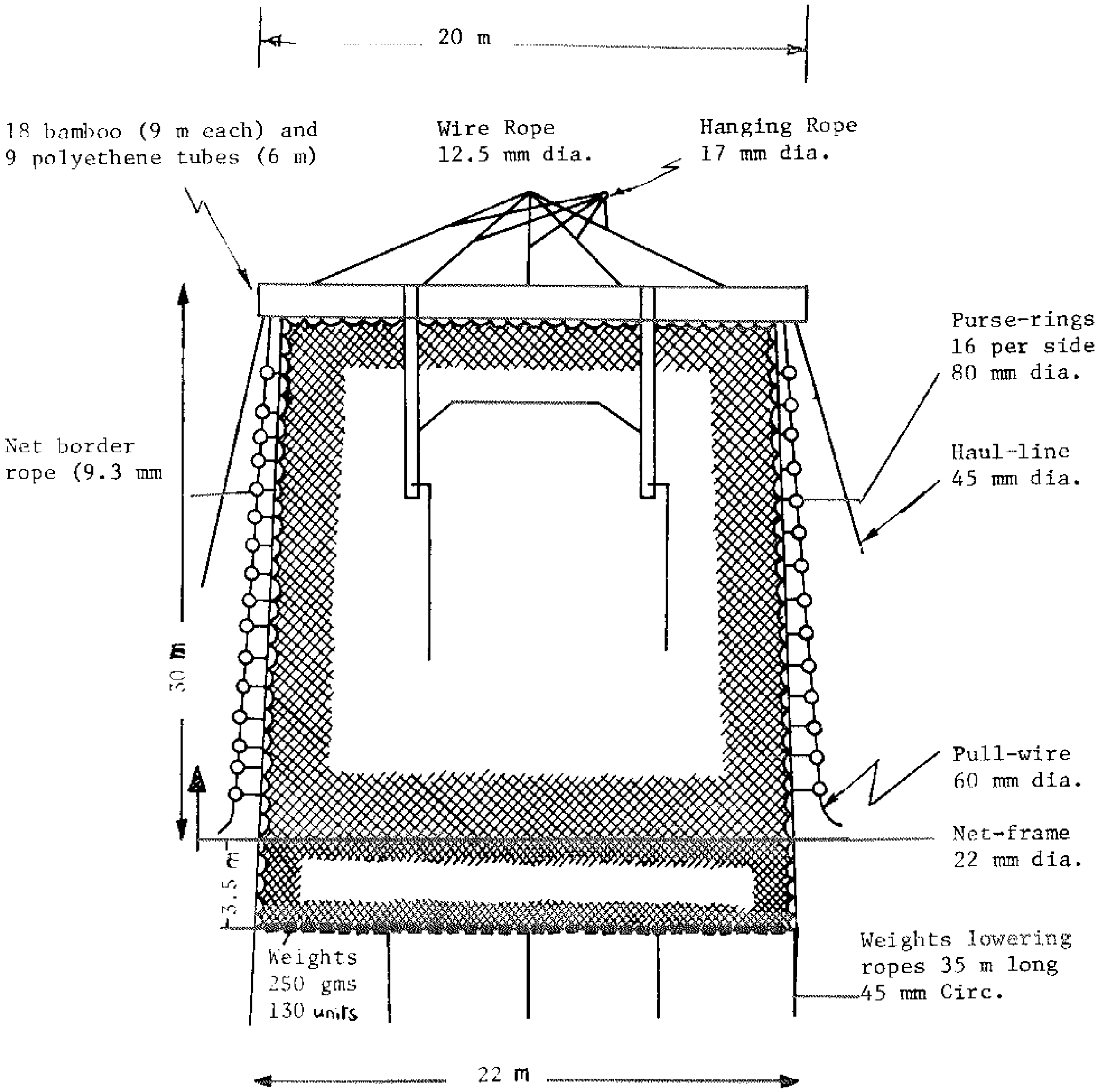
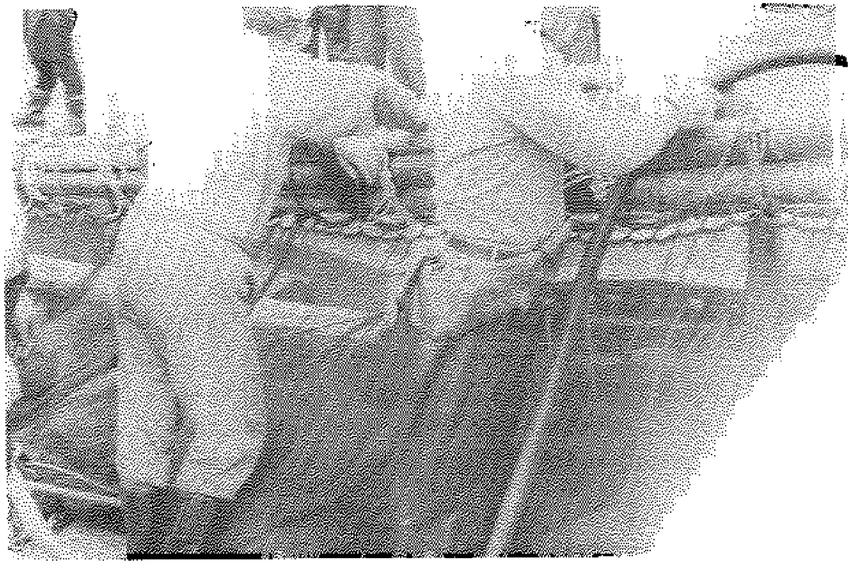
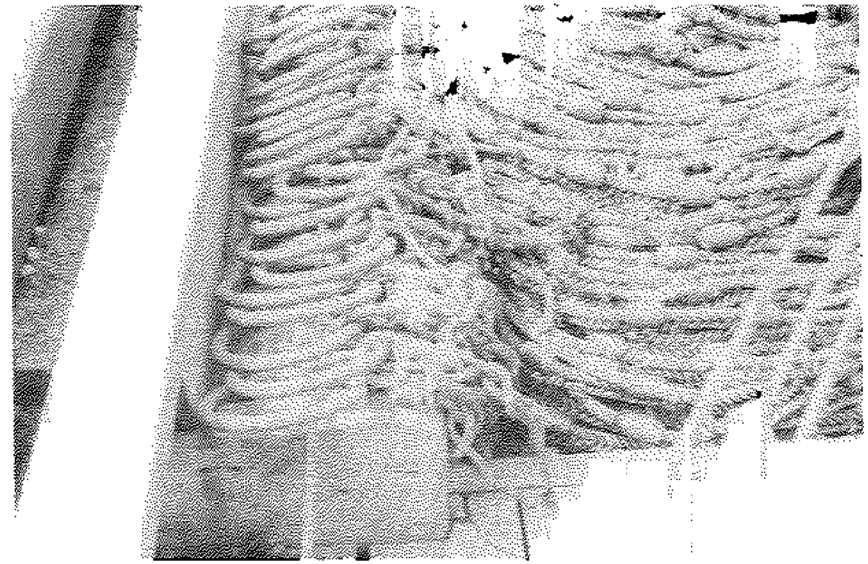


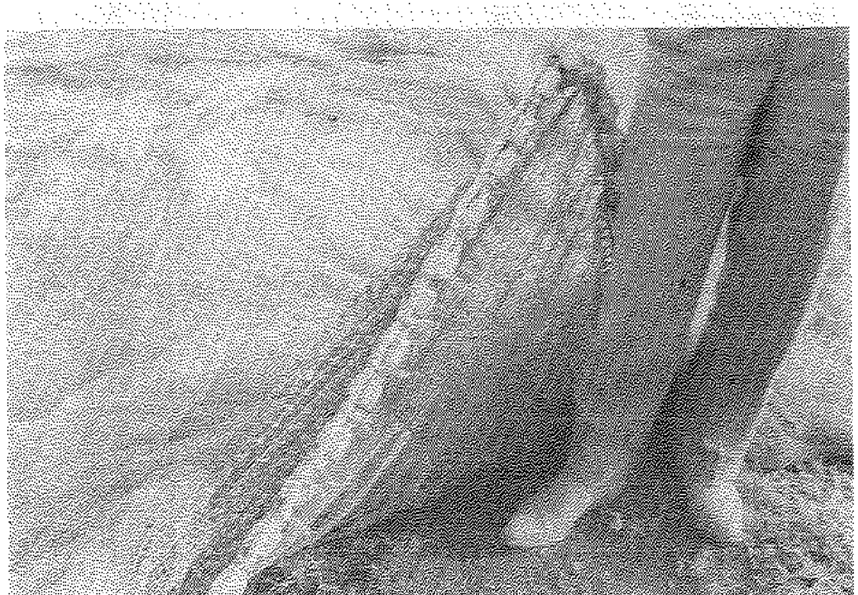
Figure 27.-- Design of the boke-ami used on the Soviet research vessel <u>PT Peramyda</u>.



a. Dipnet attached to the main bamboo float poles (Mukodake). The top of the net is laced to these poles which provides a rigid framework as well as flotation.



b. Rings assembled on a vessel. A purse line passes through rings (shown above) lashed to the ends of the net (fore & aft), allowing the ends of the net to be quickly puckered and closed during hauling operations.



c. A section of the cork-line is shown.

d. Three different mesh sizes employed in body of the net.

Figure 28.--Various components of the Japanese stick-held dip net.

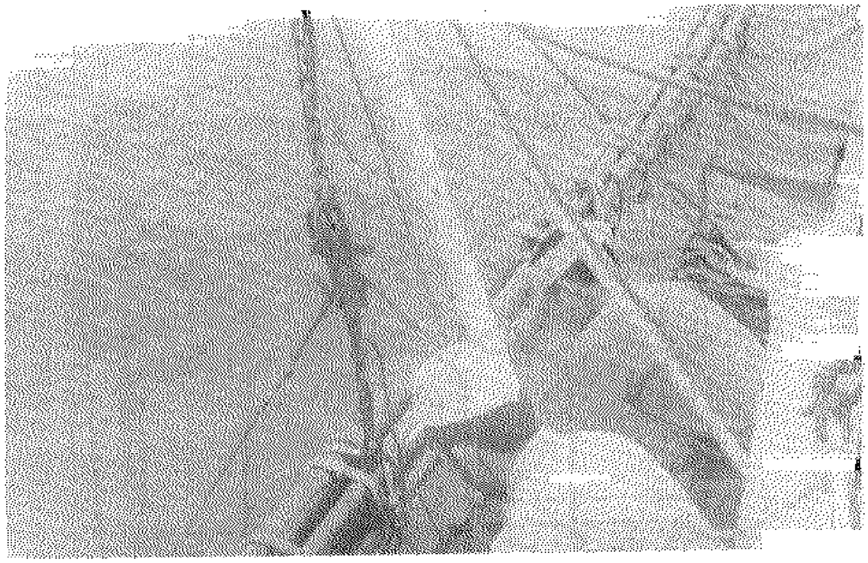
When the boke-ami is set, the bundle of bamboo poles[1/] (Figure 28a), supports the weight of the net which hangs vertically in the water as a curtain of web. When not in use, these poles and the attached net are secured along the vessel's rail by a pair of snatch hooks supporting the ends of the poles (Figure 22a). From its stored position, the boke-ami can be quickly set by releasing the snatch hooks. Figure 29a shows the hook in position.

Additional gear used with this harvesting system may include a 6-8-gang line hauler, a net side roller and the brailer. The line hauler and net roller are mechanical labor-saving devices which have only recently been employed in this fishery (Figure 29b,c).

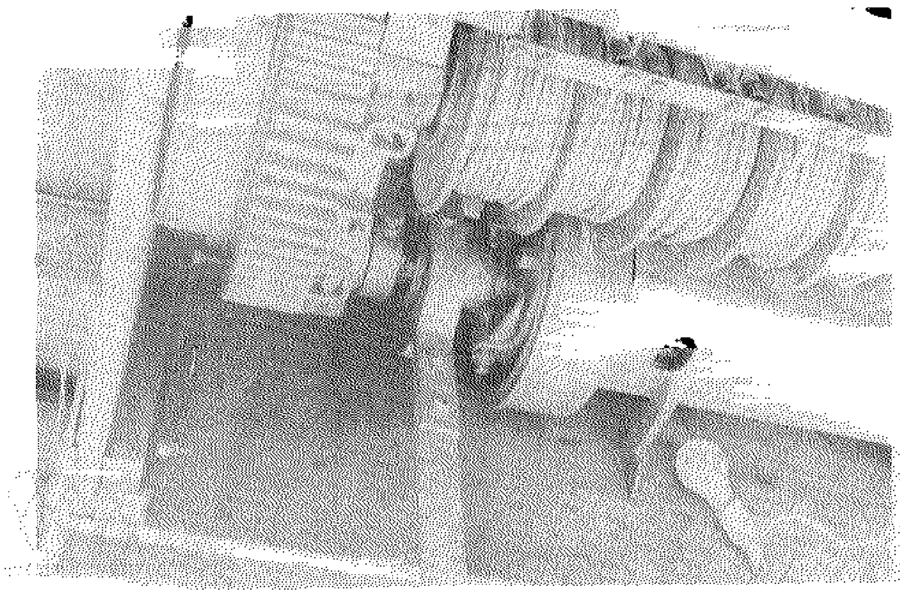
After the net is set and pushed away from the vessel's side, the leadline is pulled up and toward the vessel by a series of lines to form a blanket of web between the bamboo poles and the vessel. Although these lines are still hauled by hand on some vessels, a 6- or 8-gang line hauling winch is faster and reduces labor requirements (Figure 30). An even more laborious task is pulling most of the net aboard the vessel, thus confining the catch to a small pocket of web for brailing between the bamboo poles and the vessel. Labor requirements for this task have been reduced by the use of the power side-roller (Figure 31).

1/ Plastic pipe has been used experimentally by both Japanese and Soviet fishermen.

a. Snatch hook.



b. Eight-wire winch.



c. Power side roller.

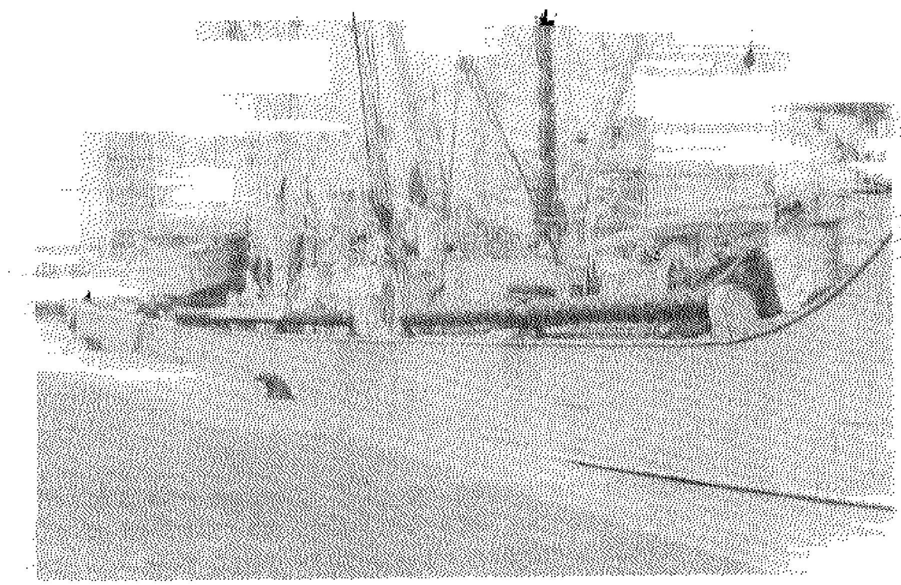
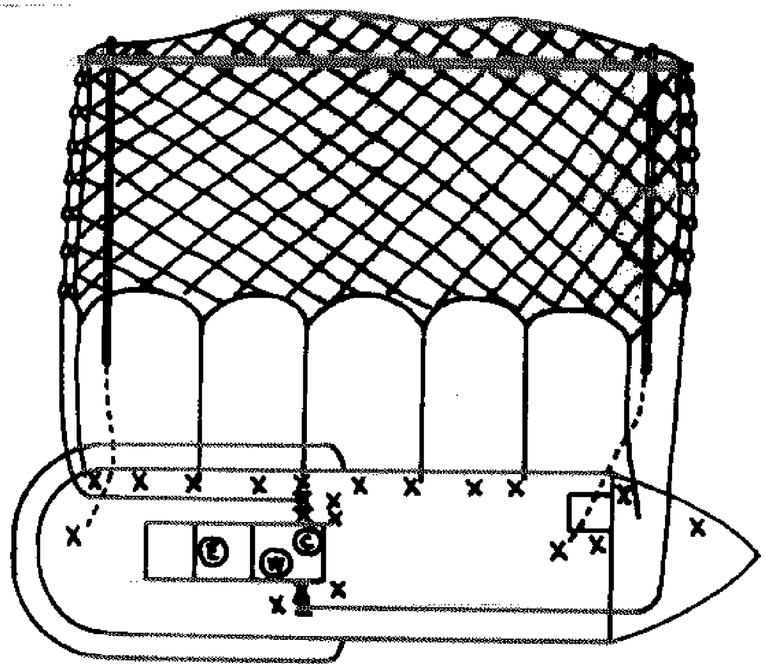


Figure 29.-- Various auxiliary gear used in boke-ami fishing.



X: crew member

C: Captain or fishing master

W: deck watch

E: engine-room watch

Figure 30.-- Labor required to pull the leadline of an average sized boke-ami up and to the vessel with the aid of an 8-gang line hauler.

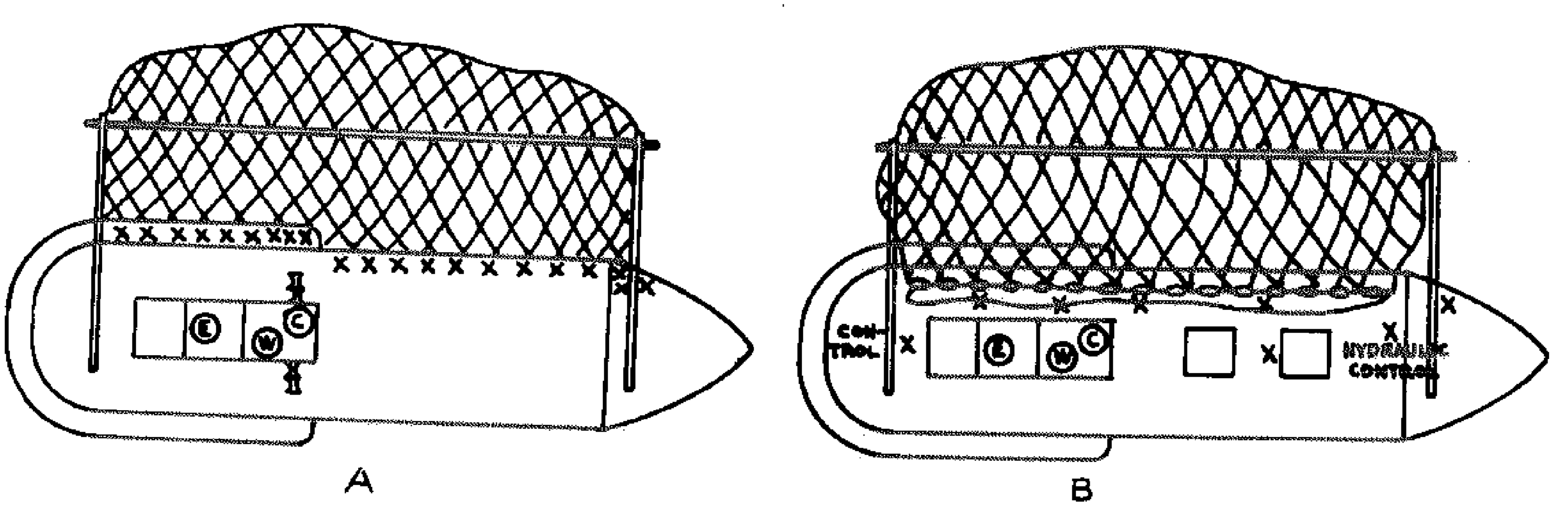


Figure 31.-- Labor required to pull excess web aboard prior to brailing (A) without and (B) with the aid of a side power-roller[1]. Manufacturers claim this unit reduces crew requirements up to 40%, decreasing hauling time by 40-50% and prolonging net life expectancy at the same time.

[1] Asahiyo Sangyo Kabushiki-Gaisha, 1-1 Nihonbashi-honcho, Chuo-ku, Tokyo, is one of the makers of side-rollers especially designed for saury vessels. The reversible hydraulic system costs about 1,450,000 yen for a 30-50 ton vessel.

The final piece of auxiliary gear required in the boke-ami fishing operation is the brailer or Tamo. As in many other fisheries, this brailer is operated from a boom and is used to transfer the catch from the net to the fish hold. Japanese saury brailers are usually 1-2 m. in diameter and are tied off with a puckering string.

BOKE-AMI FISHING OPERATION

Although fishing is conducted only at night, saury vessels run during daylight hours, recording surface temperatures in an attempt to locate areas of sharp thermal gradients. Plankton sampling can also help locate saury since they feed primarily on certain forms. The presence of several copepods (Calanus plumchrus, C. cristatus, C. fenmarchicus, Pseudocalanus sp., Paracalanus parvus, Corycaeus sp., Labidocera sp., Omcaea sp.) and amphipods (Corophium crassicorne, Thermisto sp.) are considered favorable signs (Hotta, 1964c; Kobayashi, 1966). Flocks of sea birds and other saury vessels drifting may also serve to indicate the presence of saury. At sundown, the fishermen prepare for the night's fishing.

Several procedures are followed during the searching, detecting and harvesting operations. The vessel cruises with the alluring lights on and uses 7.5 and 5 kw spotlights mounted on the bow and aft bridge to scan the sea surface for jumping saury. On most Japanese saury vessels, the fishing master (FM), not the captain, is in charge of these operations. From the upper deck the fishing master controls all alluring lights and steers the vessel with a hand-held remote rudder control. Other personnel active during scouting include the captain, two engineers, a radio man, two spotlight operators, and an assistant to the fishing master who watches the sonar and records sea surface temperatures every five minutes.

When a concentration of jumping fish is seen in the spotlight, the vessel is stopped to eliminate propeller noise.1/ As the vessel drifts toward the school, the alluring lights attract the fish toward the vessel. Usually the school can be most rapidly drawn to the vessel lights by slowly sweeping a spotlight beam from the fish toward the vessel. When the saury near the vessel the fishing master examines the school size, composition and behavior. If judged adequate for harvesting, the remaining crewmen are ordered to their stations.

When possible, the gear is set so the wind drifts the vessel away from the net while the current moves the net away from the vessel. Under adverse current-wind conditions, it is sometimes necessary to use the spanker, a small sail, and occasionally maneuver the vessel with the main engine to keep the net properly oriented to the vessel.

Assuming the net is operated from the portside, fish attracted under portside lights are relocated to the starboard, prior to setting the gear, by turning off all lights on the net side of the vessel. The main bamboo float poles (Mukodake) with net attached are then released from the snatch hook, and drift away from the vessel. Other bamboo poles (Oshidake) are used to push the main floats and net away from the vessel (Figure 32). Figure 33 shows the net hanging vertically in the water and attached to the vessel by the 6 or 8 lines which run from the net leadline to the vessel's line hauler and by lines which are attached to the poles previously used to push the net away from the vessel. The net is now ready for the fish schooled under the starboard alluring lights.

1/ Saury will react to propeller noise (approximately 1 kc), so the surface of the propeller is often smoothed to minimize noise in this frequency. However, it is still recommended that the main engine be stopped when a school is located.

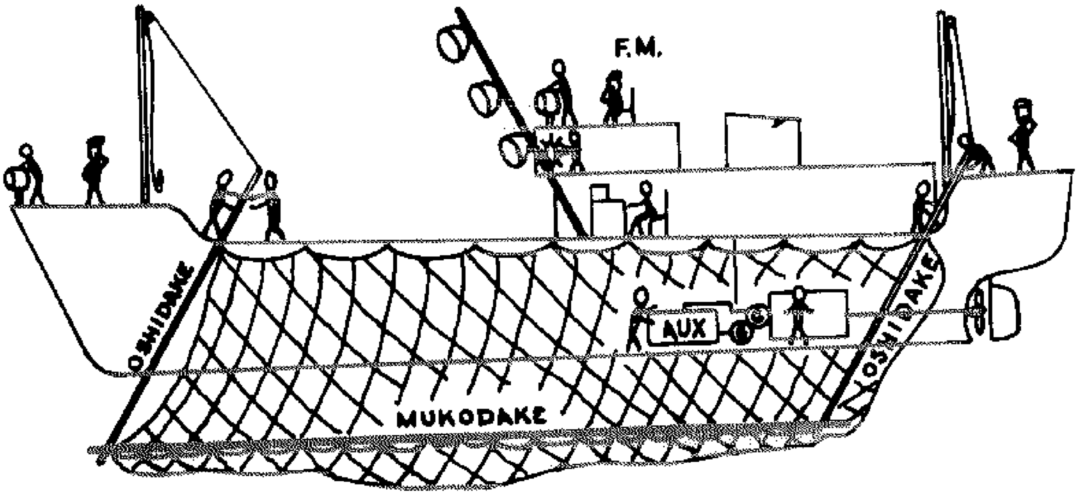


Figure 32.-- The bamboo float poles (Mukodake) and attached net are dropped from the vessel's snatch hook and pushed outboard by two other poles (Oshidake).

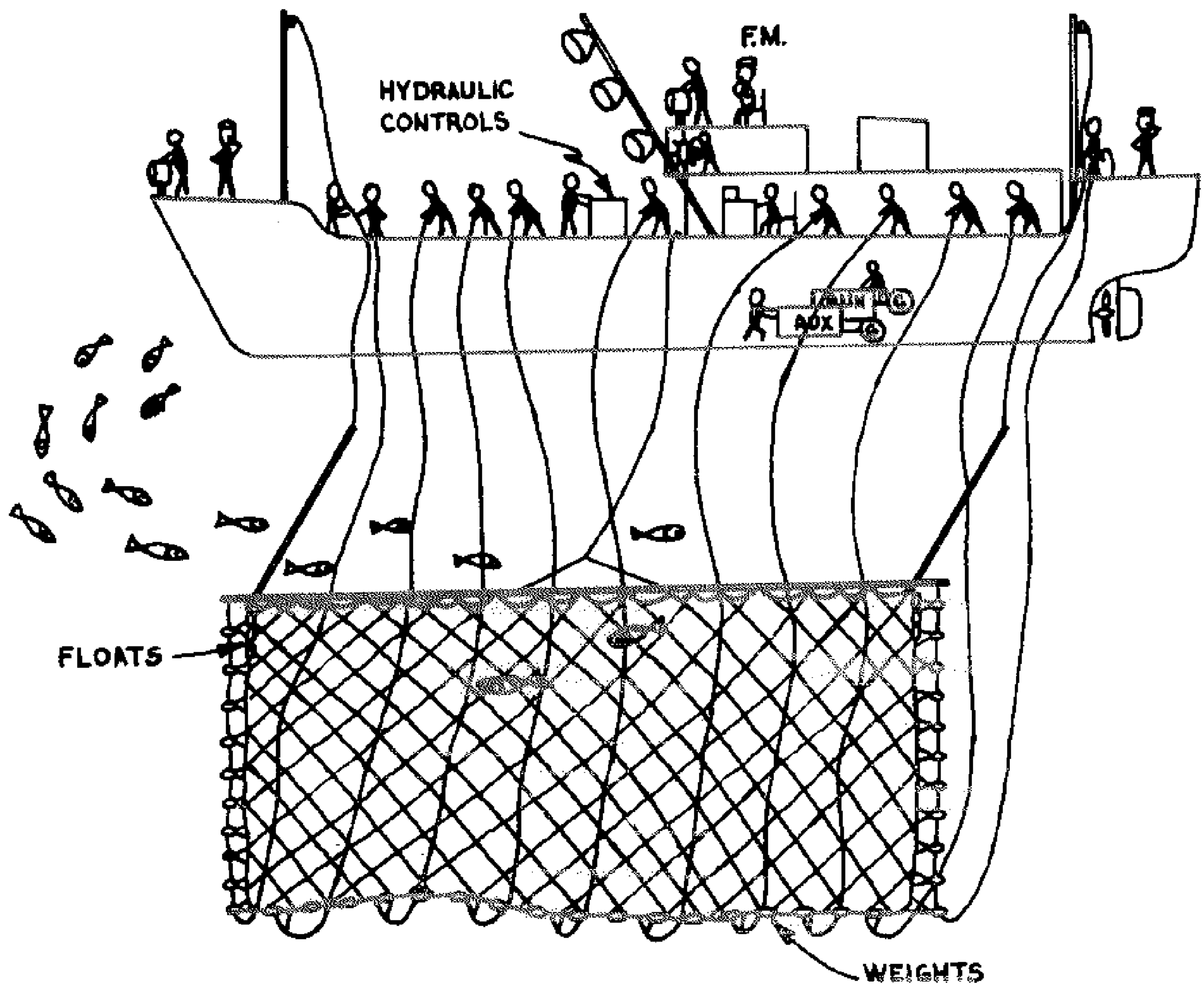


Figure 33.-- Once away from the vessel, the net hangs vertically and is attached to the vessel by 6 or 8 lines which run from the net's leadline to the line hauler. The bamboo poles previously used to push the net from the vessel, now float on the water. Next, the fish are attracted between the net and the vessel.

Because the saury prefer lighted waters, it is possible to move the school from starboard to port (between the net and vessel) by sequentially extinguishing all starboard lights in a counter-clockwise fashion (looking forward). Port lights are again turned on and off until the entire school has been moved under the bank of lights located amidship which illuminates that area between the vessel and net. Before pulling the leadline up and toward the vessel, it is usually necessary to lure the school to the surface where they are most susceptible to capture. The principle used to move fish from port to starboard can also be used to surface the school. Red light is absorbed by water much faster than white or blue light. Thus, the school will usually rise to the surface as white or blue lights are extinguished and red lights turned on. At this point the net is hauled (Figure 34).

Approximately two minutes are needed to haul the net from its position in Figure 33 to that in Figure 34. Most of the web is then pulled aboard in order to confine the catch to a small pocket. This procedure takes about 5 minutes, and is the most laborious part of the operation (Figure 35). Time required to brail the fish aboard once confined to a web pocket (Figure 36) ranges from about 5 minutes for a 600-pound catch to about 15 minutes for an 8,000-pound catch. Brailerfuls of fish are emptied into the hold. Handling procedures aboard ship will be discussed in the next section.

If only part of the available fish are captured, it is usually possible to regroup the remainder under the starboard alluring lights and hold them for another set. Even if all available fish are enclosed,

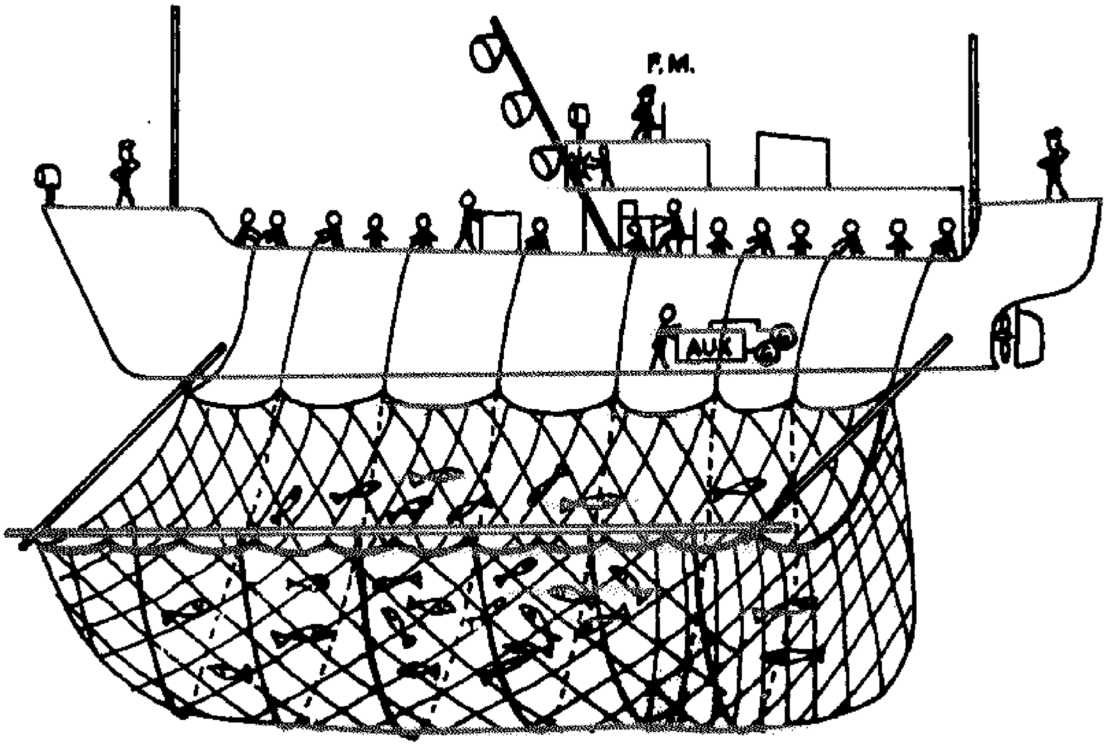


Figure 34.-- After the fish are moved to and held between the curtain of web and the vessel by alluring lights, the leadline and end lines are hauled, thus, enclosing the catch.

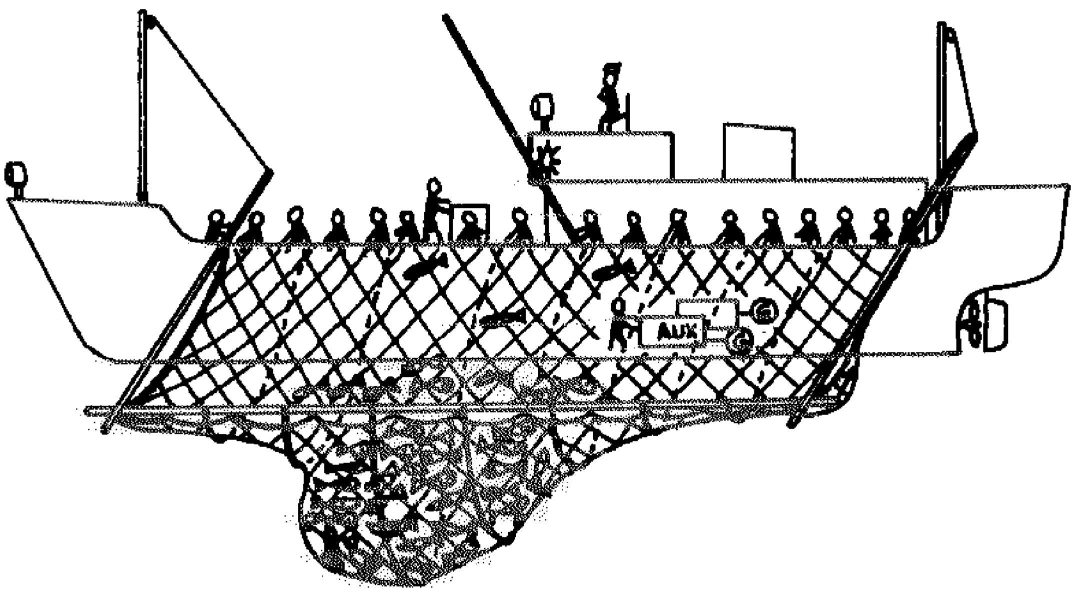
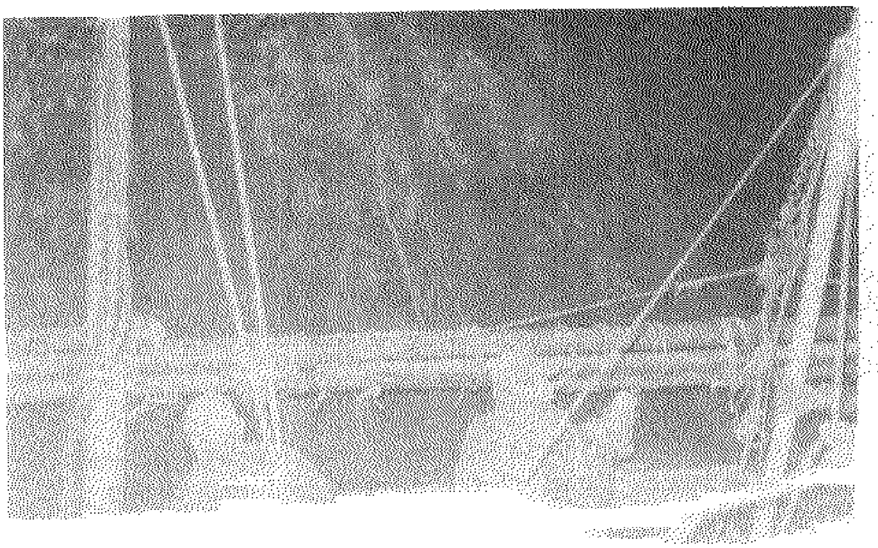


Figure 35.-- To confine the catch to a small pocket for brailing, most of the web is pulled aboard. During this phase, the end poles previously used to push the net from the vessel are taken aboard which also help draw the net to the vessel.

the starboard lights are usually turned on while the catch is being brailed, in an attempt to attract other schools to the vessel. When schools are plentiful, it is often possible to make several sets without additional searching. Under such circumstances, a well equipped vessel may complete up to 14 hauls per night.



(A)

(B)

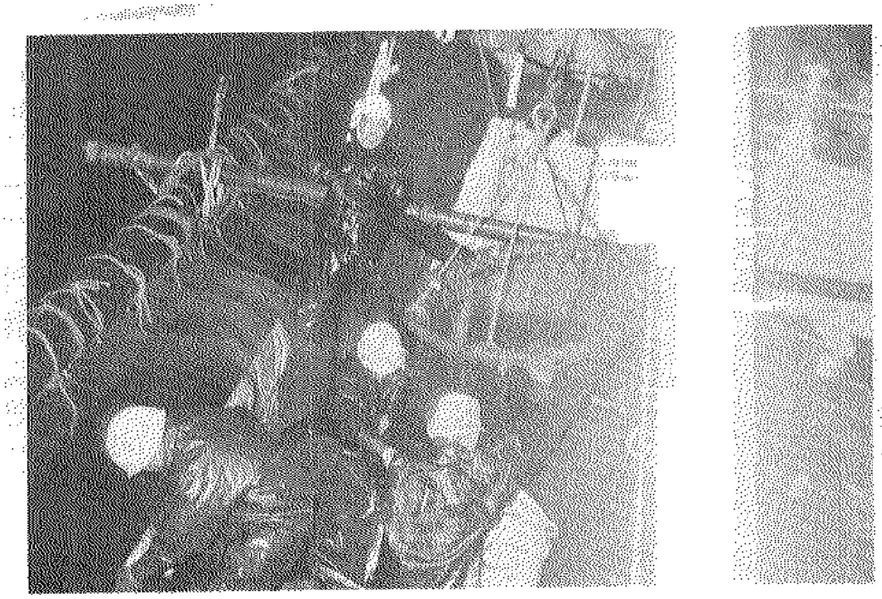


Figure 36.--Final stages in the fishing operation are shown (A). The catch is worked into a web pocket, and (B) brailed directly into the fish hold.

HANDLING CATCH ABOARD SHIP

The procedures for handling catches on a typical Japanese vessel are summarized in the flow diagram showing the operation of the boke-ami harvesting system (Figure 37). Aboard commercial Japanese saury vessels, handling procedures are precise and carefully controlled. As might be expected, selling prices are largely determined by size composition of the catch, freshness and general appearance. Fish pumps have not replaced brailers because it is believed they are more damaging to the product. Excessive loss of scales has been the main complaint. Before the catch is stored below, samples are routinely collected, measured and weighed (Figure 38). Such data are included in the vessels log and transmitted by radio to a fishermen's information center. In the hold, saury are moved about by shovel. The hold is refrigerated and sectioned into individual compartments that may be equipped with automatic refrigeration controls (Figure 39). Fresh fish in the fish hold are held in a mixture of 2°C. salt water and ice. Sufficient water is held in the hold to partially float the catch and reduce squashing and flattening. The bloody brine solution is replaced in 5 to 10 hours with a solution of fresh sea water and preservatives. The temperature is then decreased to 0°C. Japanese fishermen believe these carefully controlled thermal conditions preserve the bright color and flavor of the fish. If the fresh catch is immediately cooled to 0°C., both color and flavor deteriorate. Saury are not usually kept aboard the vessel more than 3 days. When fishing is good, the fish will usually be unloaded in port the following day.

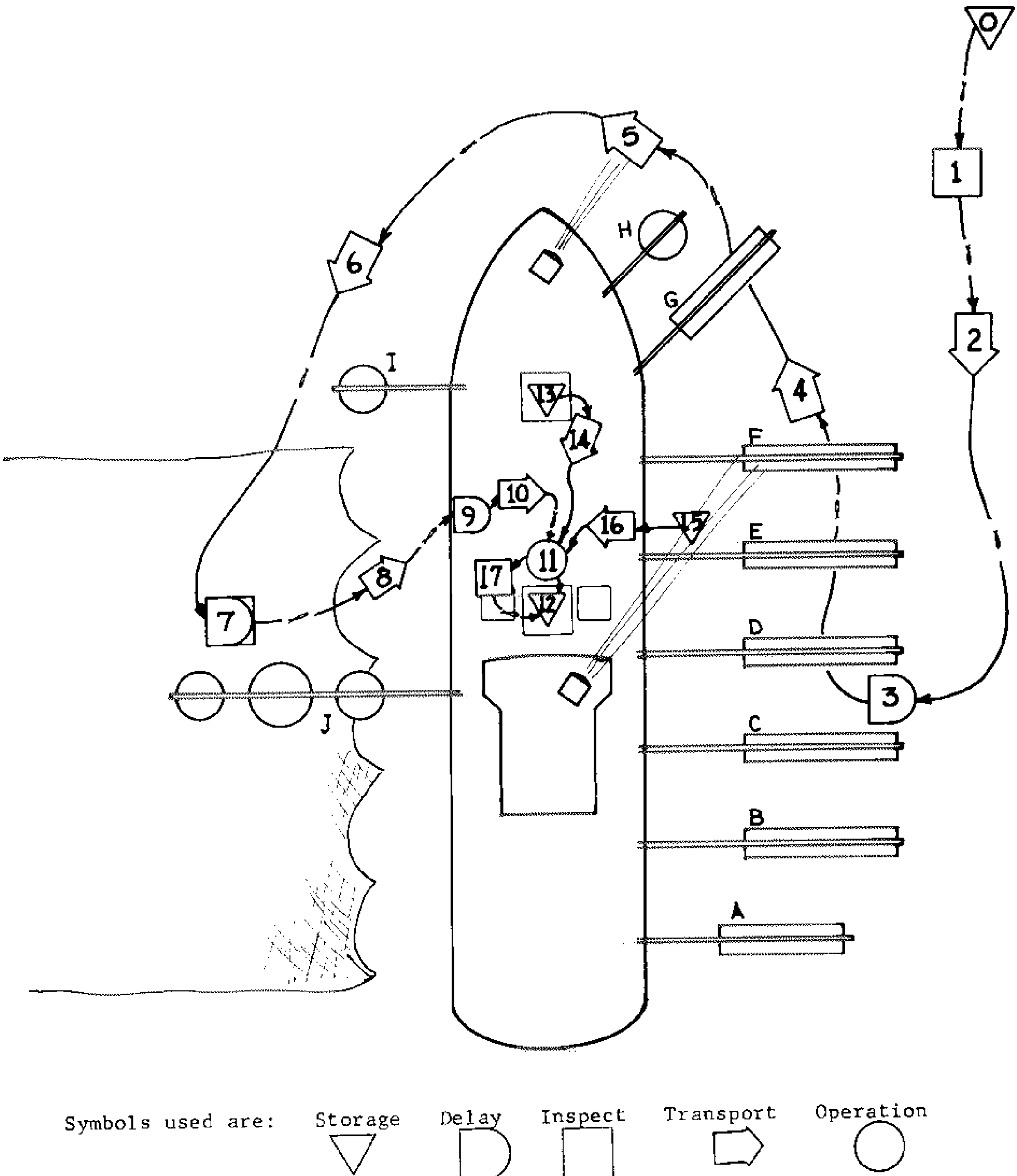


Figure 37. Flow diagram summarizing operation of the Japanese boke-ami harvesting system. (Explanation of steps is summarized on page 63).

0 School of saury near surface.

1 The school is discovered by the searchlight operator spotting a few fish jumping under the light. The school size is judged by the fishing master (FM) as adequate or inadequate for harvesting.

2 The school is attracted to the vessel's alluring lights. The lights on the net side are turned off and the vessel will coast around the school in a clockwise direction to attract as many saury as possible.

3 The school gathers and starts to circle (usually in a random but somewhat clockwise manner) under the fish alluring lights while the net is set on the portside.

4 The school is guided from the starboard to portside by sequentially extinguishing lights in a counterclockwise direction and by turning on all lights on the portside.

5 With lights A, B, C, D, E, F, G, and H off, and lights I and J (both red and blue) on, the 3 kw searchlight is rotated clockwise (light hitting the water only when the motion is from right to left, and the beam aimed toward the sky in the return trip from left to right) to guide the school from the starboardside to the net side.

6 By turning off light I, the school is moved under the blue and red lights of support J.

7 The school keeps circling under lights J and surfaces as the blue lights are turned off and the red lights are kept on. The net is pulled when the FM decides that the school can be contained within the net.

8 The school is contained and further confined to the net's fish-gathering section.

9 Catch ready for brailing.

10 Saury are brailed and slid down into the fish hatch.

15 Sea water.
16 Pumped

13 Ice in hatch.
14 Crushed ice moved into the fish hatch.

11 Ice, saury, and sea-water mixed. (Preservatives are usually added after fishing activities are over.)

17 Samples are inspected and measured for the saury survey.

12 Hold saury are kept at 0 to 2°C. by refrigeration. (Freezing saury on board is discouraged.)

Information concerning the handling of saury on Soviet vessels is limited. Apparently saury are simply transferred to factory ships by saction pumps where the fresh product is canned (Fillmonova, 1965).

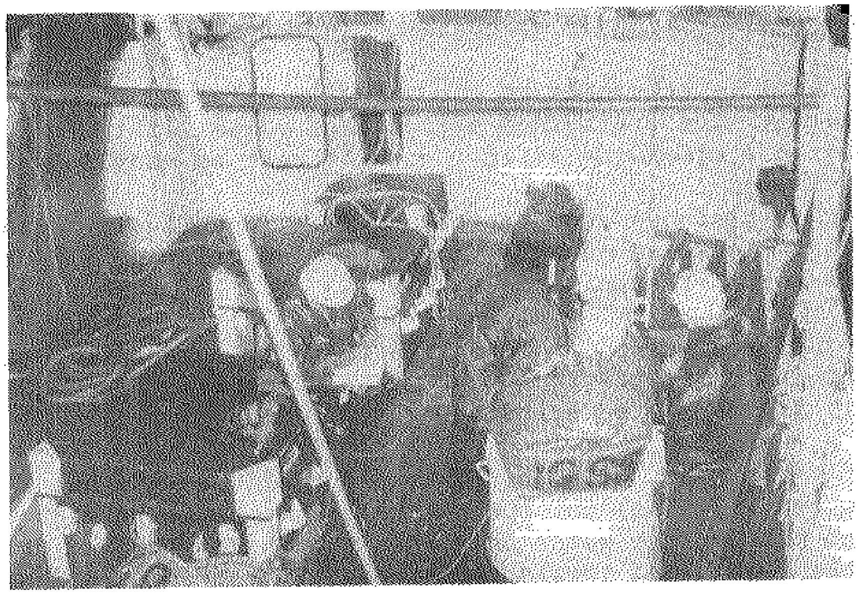


Figure 38.-- On Japanese vessels, samples are routinely collected and size composition determined. This data plus weight, location, and date and time of each landing is broadcasted to a central data exchange center for the benefit of all fishermen and research agencies.

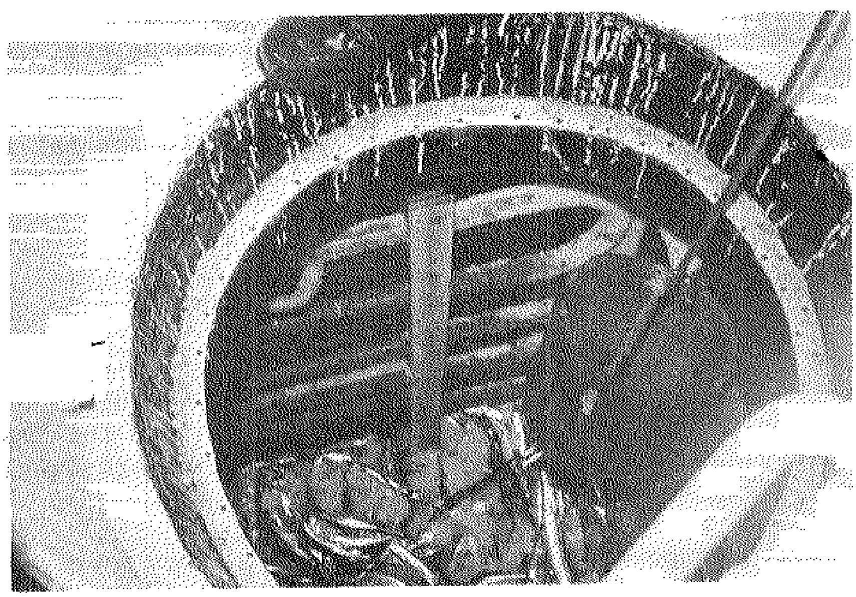


Figure 39.-- Fish holds on Japanese vessels are divided into small and usually refrigerated compartments. Fish are placed in a sea-water-ice mixture, which minimizes damage to the product. Thermal conditions are carefully controlled to preserve color, texture and flavor.

METHODS OF PROCESSING SAURY

The reduction in Japanese saury landings during the last decade has altered prices and product demands. During the late 1950s and early 1960s most saury were prepared for human consumption, and a lesser percentage was frozen for tuna bait. The situation gradually changed until 1969 and 1970, when nearly all saury which met bait size requirements were purchased by the tuna industries at inflated prices (see Table VI for 1962-1967 data).

Table VI. Approximate product distribution of 1962-1967 Japanese saury catches. (Figures are presented in tons of whole fish and percentage of total catch by year).

Product	1962	1963	1964	1965	1966	1967
Fresh (tons)	75,667	53,449	37,410	40,927	49,401	22,883
(%)	16.4%	14.5%	17.8%	17.8%	20.8%	10.5%
Frozen (tons)	171,556	181,953	123,350	130,784	150,350	140,636
(%)	37.1%	49.9%	58.8%	56.9%	63.2%	64.8%
Canned (tons) or bottled	54,867	40,262	19,837	25,926	10,232	10,277
(%)	11.9%	11.0%	7.9%	11.3%	4.3%	4.7%
Processed food (tons)	63,391	41,523	16,639	25,209	16,609	15,971
(%)	13.7%	11.4%	7.9%	11.0%	7.0%	7.4%
Fish meal (tons) oil soluble	96,963	47,069	12,470	6,846	11,184	27,450
(%)	20.9%	13.1%	5.9%	3.0%	4.7%	12.6%
Total (tons)	462,444	374,256	209,716	229,690	237,776	217,217

The following information extracted from Suisan Tsushin (1970b) summarizes current trends for utilization of saury products:

"The Saury Association has recently announced the following uses for saury in 1969:

Amount of Saury Used (in metric tons)

Product	Hokkaido		Honshu		Total	
	Quantity	%	Quantity	%	Quantity	%
Fresh	6,599	31.6	2,152	6.9	8,751	16.8
Frozen	12,860	61.6	28,877	92.2	41,737	80.0
Canned	22	0.1	124	0.4	146	0.3
Processed	9	0.0	160	0.5	169	0.3
Meal and oil	1,394	6.7	0	0.0	1,394	2.6
TOTAL	20,884	100.0	31,313	100.0	52,197	100.0

Due to a marked reduction in the total catch of saury in 1969, the proportion used for canning and processing declined while that for frozen bait for tuna fishing accounted for 80 percent of the total catch. The ratio of fresh saury for human consumption did not change much (10.5% for 1967, 19.4% for 1968 and 16.8% for 1969) but the quantity was only 8,751 tons (22,883 tons for 1967 and 25,264 tons for 1968). The ratio of frozen saury increased from 64.8 percent for 1967, 65.6 percent for 1968 to 80 percent for 1969, but the quantity also dropped from 140,636 tons for 1967, 85,400 tons for 1968 to 41,737 tons for 1969.

For the major prefectures in Honshu, the total catch for Miyagi Prefecture was 14,957 tons (94.3% frozen, 5.2% fresh and 0.5% canned), Iwate Prefecture 13,890 tons (93.8% frozen, 5.6% fresh and 0.4% canned) and Aomori Prefecture 450 tons (80.7% fresh and 19.1% frozen)."

Even though saury products are now quite restricted by resource supply, the following section summarizes methods of processing saury which have been recently employed.

FRESH FISH

Prior to 1967 saury was considered "the best" of the inexpensive fishes. Fresh saury was prepared in many ways, although barbecuing them whole over an open fire was most popular. Baking was also popular. Saury sashimi, or saury cut into strips and soaked in vinegar, was also a common dish. The preparation of saury fresh fish dishes and other Japanese delicacies are described in "Processing Saury" by the Hokkaido Sea-Product Research Group (1956).

FROZEN PRODUCTS FOR HUMAN CONSUMPTION AND TUNA BAIT

Saury has several qualities that make it a desirable frozen product for human consumption and for tuna bait. It is especially muscular and firm-fleshed, oily, and has practically no stomach during the adult stage. Because of the firm texture and lasting bright color after freezing, saury is one of the most effective tuna longline baits, as well as an attractive food fish.

When fresh fish are purchased for freezing and storage, the eventual destiny of the product is usually undetermined. Most of the packing procedures for a frozen product satisfy both tuna bait and other industry requirements. Thus, procedures outlined below apply for all saury which are frozen for later use.

Prior to packing in 10 kg boxes (22.4 lbs.), fish are sorted by size. Size categories correspond to numbers of uniformly sized fish which are required to fill the 10 kg boxes. Such procedures are especially important to the bait industry, since a pack of uniform sized fish minimizes squashing and the size category indicates the number of bait pieces contained within each box.

Traditionally, sorting was done manually, but two types of mechanical sorters are now widely used. One is a chute constructed of gradually diverging bars. Fish are slid down the chute and fall out between the bars by size. The second device sorts by centrifugal force. Saury are rotated on a disk and thrown through the air. Fish of varying weights are separated by the distance traveled. This device has an added advantage for packaging because sorted fish are lined with the heads pointed the same direction. Fish of fairly uniform size are then layered in the 10 kg boxes, tails in and heads out. The pack shown in Figure 40 contains 120± 5 pieces. Common packs of bait-sized fish range from 110± 5 count up to 180± 5 count. Packs containing the smaller fish, 160, 170, and 180 count, are usually used for albacore bait rather than for larger tunas. After boxing, the pack is quick-frozen, glazed, covered with plastic and held at -30°C to -40°C for 24 hours.[1/] Packs are then transferred to cold storage where -20°C temperature is maintained.

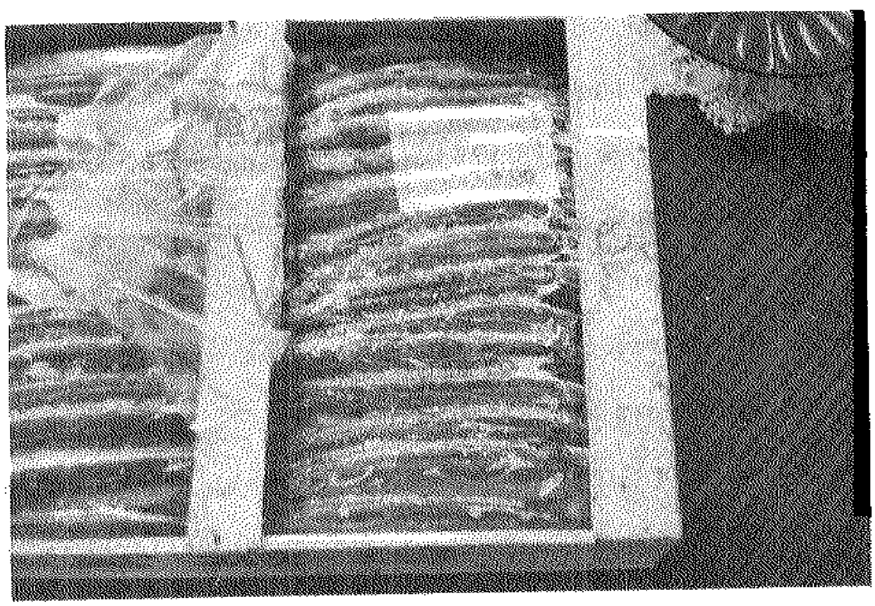


Figure 40. Saury, frozen for later use as either tuna bait or for human consumption, are sorted by size and layered in 10 kg boxes. This pack contains 120± 5 pieces arranged in two rows, heads out and tails together.

1/ At times, the antioxidant BHT (Butylated hydroxytoluene) is applied to prevent oxidation during freezing.

The quality of the product is periodically checked by random sampling (1 sample if the lot size is less than 500, and 10 if 500 or more). The samples are subjectively evaluated for appearance, odor and uniformity of glaze. Measurements are made of internal temperature, micro-biological contamination, pH (acidity or alkalinity), volatile base nitrogen, tremethylamine-nitrogen and volatile reducing substances. It is not recommended that storage exceed one year. Table VII indicates how the 1967 stock of frozen saury was utilized during 1968.

Table VII. Utilization of frozen saury during 1968

	Planned Usage (Metric Tons)				
Month	Human consumption	Processing	Tuna Bait	Others	Total inventory on hand
March	15,138	4,363	14,445	1,048	34,994
April	10,864	3,522	13,006	343	27,735
May	6,839	2,865	9,210	864	19,778
June	5,394	1,628	7,365	601	14,988
July	5,128	1,627	6,202	64	13,021
August	4,389	939	4,458	490	10,276
Sept.	5,301	4,480	14,405	368	24,554
Oct.	8,283	8,017	24,789	419	41,508
Nov.	6,541	10,417	32,741	1,441	51,140

CANNED SAURY [1]

Frozen saury which are to be canned are first thawed and separated. After inspection, the heads and viscera are removed. The fish are then cut transversely into two or three pieces, or pre-cooked by steam, split into fillets and the backbone removed. Transverse sections are usually soaked in brine prior to packing. The packed cans are then steam-cooked at 100-103°C for 30-50 minutes, depending on the size of

1/ Most of the information in this section was obtained from Tanikawa (1965).

the can, after which excess liquid is discarded. Tomato sauce, soy sauce, or oil is then added for seasoning. Next, the cans are sealed and processed at 113-116°C for 70-110 minutes. Saury fillets are often dry-salted for later use to prepare a cold-smoked and canned product.

During the 1950s and early 1960s, large quantities of saury were canned. This was a good outlet for poorer quality fish because many of the sauces would mask a slight stale odor and size was of little importance.

Canned saury products and the Japanese canner codes for product identification are summarized in Figure 41.

Saury	MP
Saury boiled in water	MPN (salt is the only seasoning)
Saury fillet	MPF
Seasoned saury	MPC (soy sauce, sugar, ginger, MSG)
Small saury (Nangking) boiled	MPCN
Roasted (broiled) saury	MPK "sanma kabayaki" (dried)
Smoked saury in oil	MPS (95°C smoked then cooked)
Saury in tomato sauce	MPT
Saury in t.s. sardine style	MPTB (packed in tomato sauce)
Saury in red pepper	MP5)
Saury in mustard	MP6)
Saury in curry	MP7) Pickled
Saury in pepper	MP8)
Saury in other mixtures	MP9)

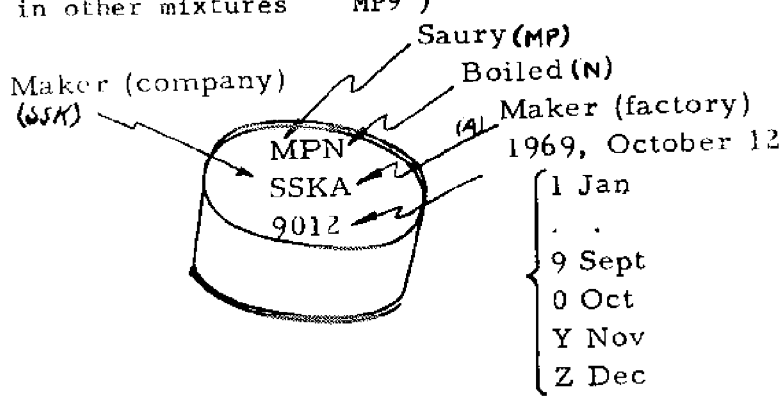


Figure 41. Japanese canner codes for popular saury products.

OTHER PRODUCTS

In Japan, several by-products have been produced from that portion of the saury which is considered waste (30 percent by weight), and inedible for human consumption.[1/] By weight, the waste portion is composed of 7% viscera (intestines and gonads) and 23% scraps (fins, heads and backbones). Depending upon fish size, 3% to 10% oil (by weight) may be rendered from the composite waste portion. Fish scraps can be pressed, dried and used as fertilizer, or processed into fish meal for animal feed. "Stick water," the liquid fraction which is a product rendered when fish scraps are processed into meal, is also a potential food source. Valuable constituents include minerals, vitamins, oil, and soluble protein.

1/ Compared to other species of similar size, saury are high-yield fish.

MARKETING

Japan is the primary supplier and consumer of fresh and frozen saury for human consumption and of frozen saury used for tuna bait. In the past, Japan also was a primary supplier of canned saury to world markets. Presently, the tuna bait market for saury is the most lucrative and largest in volume. The decline in Japanese landings in recent years is responsible for this trend. Extensive export markets for canned saury have diminished since 1966-67 because of limited supply and the high cost of fish. Rising costs of fresh fish or fresh-frozen fish for human consumption have also limited its use to wealthier people in Japan. Unconfirmed reports indicate that the Japanese Government may have recently placed restrictions on the sale of bait-sized saury to markets other than tuna bait. Figure 42 shows the trend in landings and prices in the Japanese saury fishery.

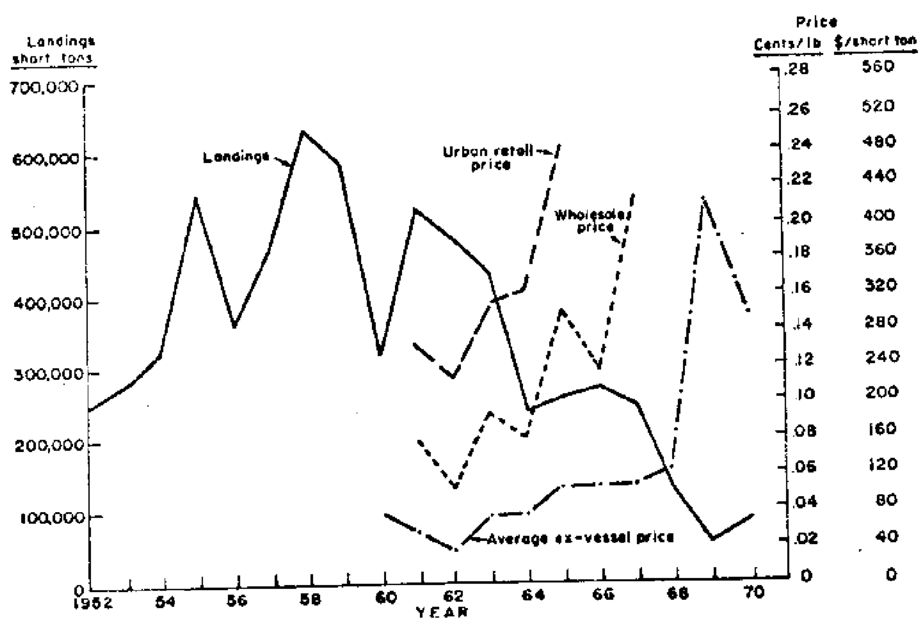


Figure 42. Trend in landings and prices--Japanese saury fishery, 1952-1970 (Ministry of Agriculture and Forestry, 1966 and unpublished Japanese data).

FACTORS AFFECTING LANDINGS AND EX-VESSEL PRICES

Because of the saury's pattern of migration during the fishing season, catches are usually landed in northern ports. Prior to 1962 when freezer storage was extremely limited, northern Japanese ports would be over-supplied with fish, while areas to the south would be in need of more fish to sustain processing operations. Consequently, price fluctuations were a function of local distribution channels and processing facilities. Such circumstances often caused small vessel owners financial hardship, since their limited holding capacity and minimal refrigeration restricted their landings to nearby over-supplied ports. Although ex-vessel prices throughout Japan have since been considerably stabilized by the construction of hundreds of freezer plants, prices are usually lowest in Hokkaido and progressively increase to the south. This trend and other pertinent data are shown in Table VIII.

Table VIII. Catch, effort and price data for three prefectures and the all-Japan average during 1967 (Zensanma, 1967).

	Hokkaido	Fukushima	Ibaragi	All-Japan
No. of saury vessels	186	136	63	828
Total tonnage (1,000 tons)	9,467	11,302	8,054	55,332
No. of trips	4,328	3,020	1,094	17,465
Avg registered tonnage/vessel	50.90	83.10	127.85	66.83
Avg crew/vessel	16	22	36	23
Avg No. landings/vessel	22.3	22.2	17.4	21.1
Catch/vessel (kgms)	206,184	319,894	285,550	227,904
Catch/vessel (million yen)	6.555	17,482	15.682	10,656
Avg. price (yen/kg)	31.8	54.6	54.9	46.8
Avg price (cents/lb)	4 cents	6.9 cents	6.9 cents	5.9 cents

The relationship of vessel size (tonnage) to coast and earnings also reflects the value of a vessel which can land in ports where supplies are low and prices high. For example, during 1967 the average price per kilogram paid for saury to the largest vessels was nearly three times that paid to the smallest vessels, and the total expenses, in percent of gross income, were 11 percent lower for the largest vessels.

Other important factors which influence ex-vessel prices are the availability of fish and size composition of catches. Although raw fish has been in short supply since 1967, and freezer plants have improved market stability, the monthly variation in landings during the season still affects ex-vessel prices. Generally, prices are highest during the early season when the catch is low and decline as landings peak during mid-September to mid-October. Prices may rise again during the late season depending on previous landings and demand. Figure 43 shows the variation in catch during 1962, 1963, 1966 and 1967 seasons.

One aspect which indirectly affects landings and prices at Japanese ports is the marine information system. Because saury are highly migratory, fishermen have found an information exchange system between vessels and portside data centers to be beneficial to all. The system's purpose is to reduce searching time and increase the probability of productive fishing. The system has two parts. Vessels (usually from 20 to 40) which belong to one union, exchange coded data every 4 to 6 hours. Typical reports include vessel location, direction and speed, observation of other vessels, birds, information on last catch (tonnage, catch composition and behavior), water temperature and expected port of landing.

Severe penalties are placed on those vessels which do not provide accurate data.

The second system provides more long-term "public information data" which is broadcast daily for the benefit of the entire saury fleet. Information provided includes catch data (one day old), forecasts of where new grounds are expected to develop, and current ex-vessel prices at major ports. Information is originally provided by commercial vessels and research bases which have ships at sea. Figure 44 shows the complex nature of the saury fishing data communication network which is but a part of the Japanese Marine Information System.

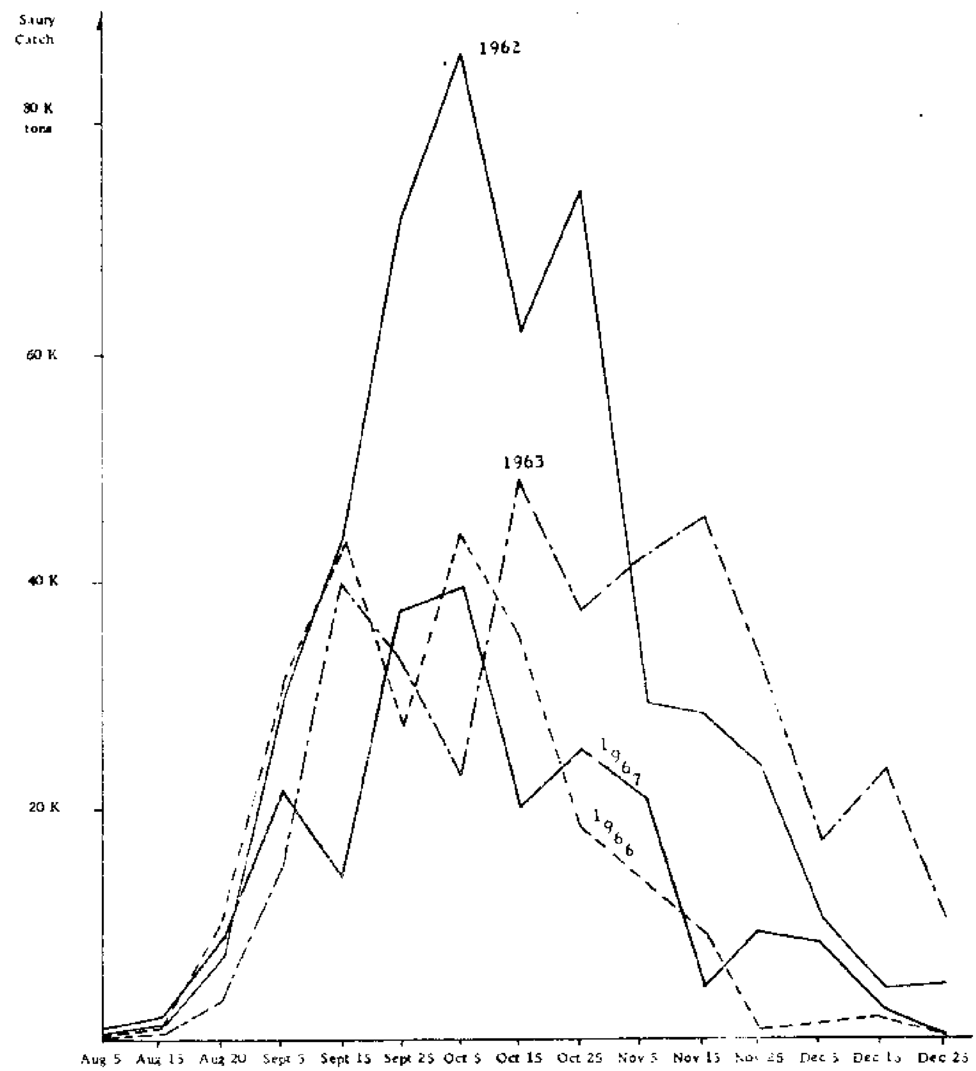


Figure 43.-- Variation in Japanese landings (metric tons) during four typical seasons (1962, 63, 66, and 67).

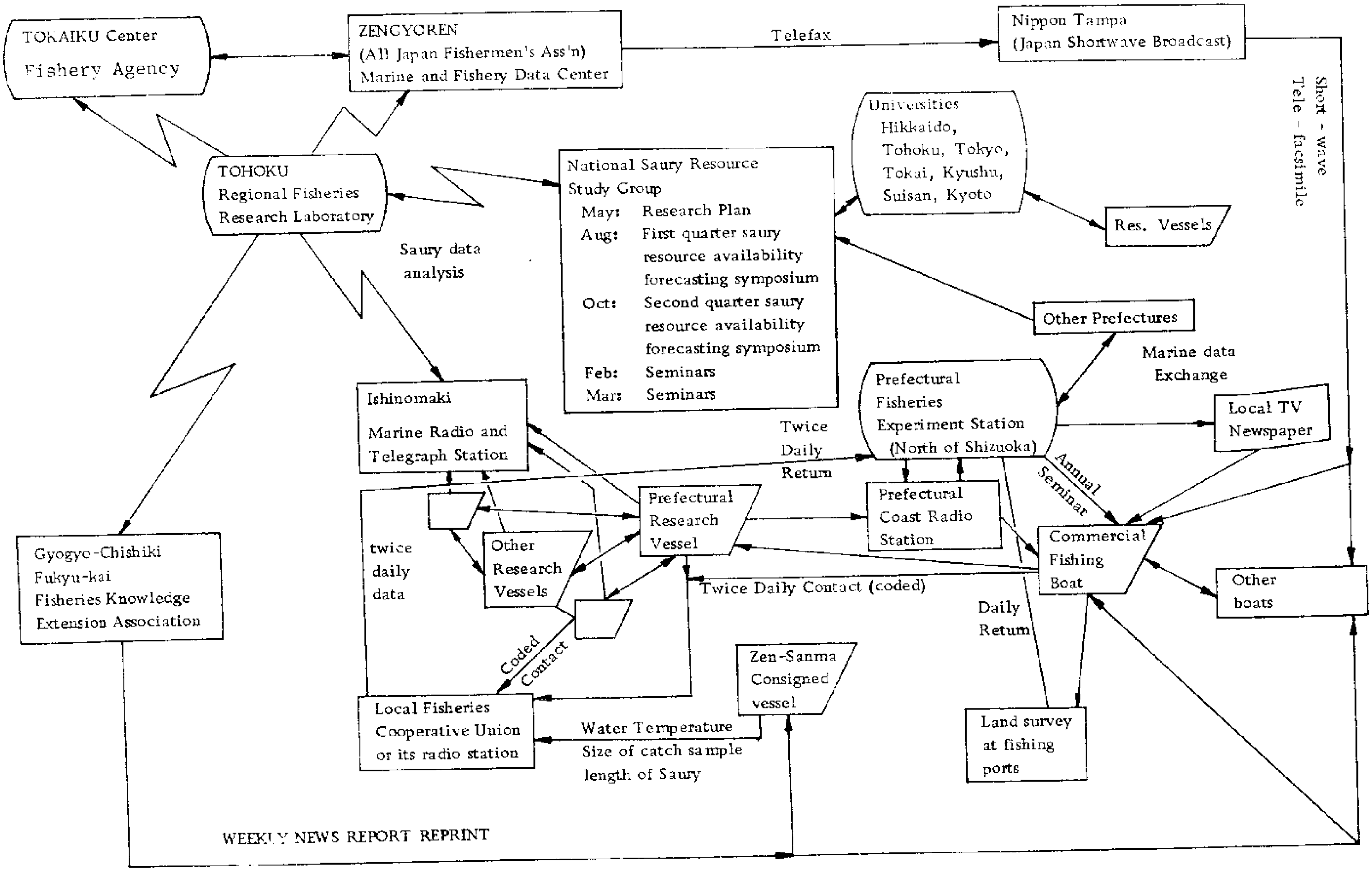


Figure 44.-- Saury fishing data communication network in Japan.

DISTRIBUTION OF JAPANESE SAURY PRODUCTS

Saury landed in Japanese ports are sold through a broker who is contracted by the vessel to sell its catch for its best use and highest price. The broker may deal through personal contacts, or several prospective buyers (tuna bait companies or fish wholesalers) may examine the fish for appearance, quality and size and bid competitively.

Channels of distribution of fresh and fresh-frozen fish in Japan resemble those in the United States. Fish purchased from a vessel by a wholesale company for eventual retail as fresh fish, are packed in 10 kg boxes as previously described, and shipped by rail to retail markets for public sale. Wholesale companies may freeze the boxed fish for later sale to retail markets.

The majority of all saury landings is channeled to the frozen bait market. Frozen bait saury held in storage by Japanese bait suppliers is shipped by outward-bound tuna vessels to various storage plants near major tuna grounds. Figure 45 shows points around the world where bait saury are distributed to tuna longline fleets. The world longline fleet consists primarily of Japanese, South Korean, and Formosan vessels. Japanese concerns handle more than 75 percent of the world's supply of tuna bait. U.S. tuna canners, in both the Pacific and Atlantic, purchase bait to supply the needs of longline vessels (foreign) under contract to them. The rapid increase in world longline tuna fishing effort has resulted in estimated requirements of 65,000-80,000 short tons of bait in 1971. Worldwide average prices paid by tuna vessels for bait saury during 1968, 1969 and 1970 are shown in Table IX.

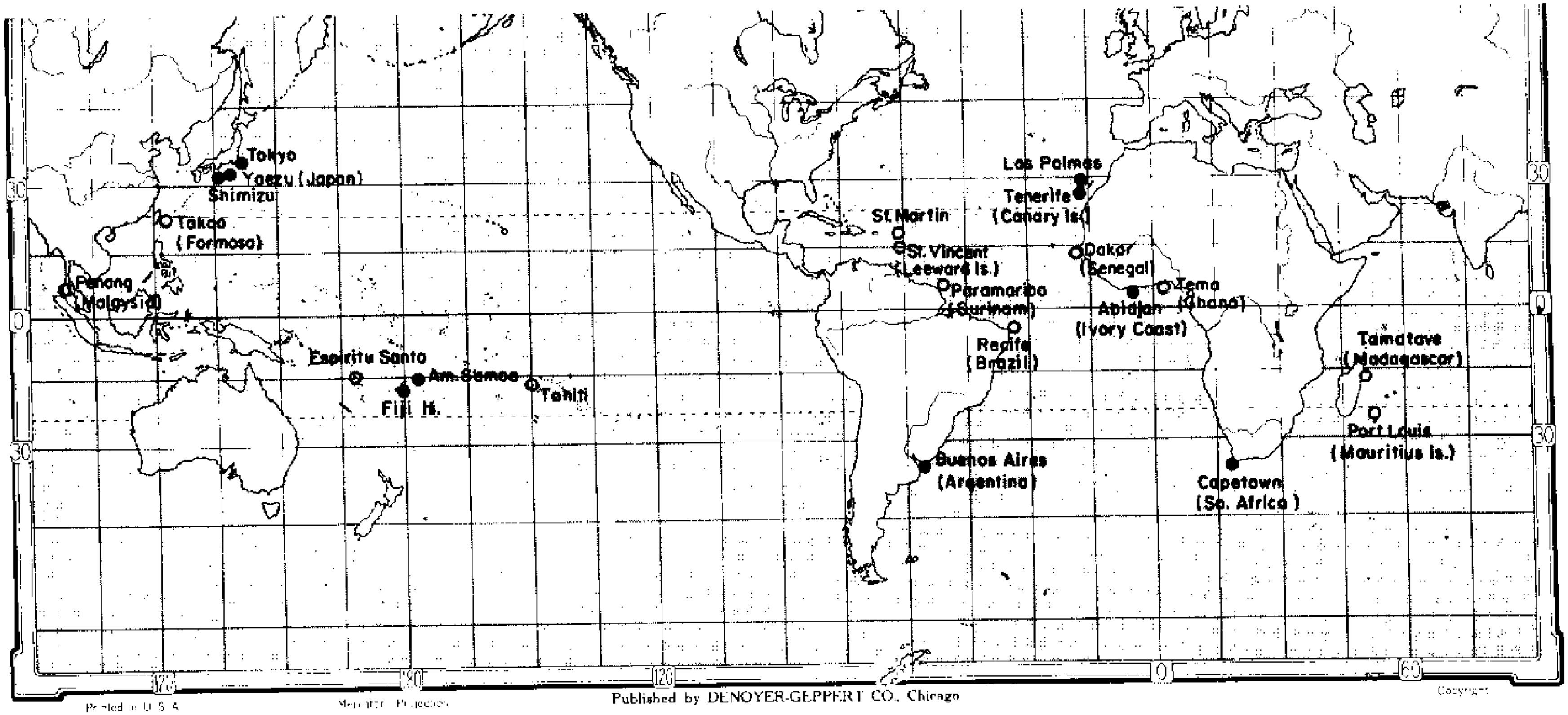


Figure 45. Distribution points for tuna bait (after Pereyra, et al., unpublished MS.
Dark circle = major distribution points.
Open circle = minor distribution points.

Table IX. Average worldwide price paid for bait saury by tuna longline vessels for 1968-1970

Period	Price per 10 kg carton 1/	Price per short ton 1/
1968	$3.89-4.17	$354-379
1969, March	$5.00	$455
September	$8.33 (high)	$757
1970, early	$8.89-9.16	$808-833
May	$7.78-8.06	$707-733
late	$5.50-6.50	$500-590

1/ Price includes cost of product, insurance, and freight from manufacturing point to consumption point.

Presently, production of canned saury commodities is very low relative to that of 6-10 years ago. A small amount of saury, mostly of poor quality or of undesirable size for bait or fresh fish, is canned for domestic use and limited export to high-income countries. However, extensive export markets for many canned saury products did exist during the 1950s and early 1960s. The total canned production, export figures and destination of various export products during 1962 have been tabulated in Table X. Japanese saury landings during 1962 totaled about 462,444 tons, of which 11.9 percent or 54,867 tons of fresh fish were canned in addition to an unknown amount of the 171,556 tons of fish frozen for later use.

Table X. Production of canned saury for domestic use and export during 1962 (after Tanikawa, 1965). Numbers shown in parentheses are equivalent numbers of 48 pound cases

Saury product	No. of cases produced for domestic use	No. of cases exported	Export market
Prepared in tomato sauce	169,061 (113,285)	87,469 (77,442)	Burma, Singapore, Malaysia, New Guinea, Oceania, Hongkong, Belgium, Switzerland, West African nations
Prepared in oil	286,199 (118,948)	211,980 (97,404)	Lebanon, Philippines, Ceylon, Holland, Belgium, Switzerland, Italy, Greece
Prepared in soy sauce	1,343,331 (684,702)	924 (311)	
Boiled	756,705 (656,337)	552,733 (465,371)	Philippines, Ceylon, New Guinea, Egypt, Oceania
Broiled and canned (Kabayaki)	454,741 (144,799)		
Other	2,007 (957)		
TOTAL:	3,012,044 (1,719,028)	923,106 (640,528)	

DISCUSSION

Those who will be involved in the research and possible development of a U.S. eastern Pacific saury fishery can profit from the experience of the Asian countries. Biological studies of the western Pacific stock furnish a background for similar studies of the central and eastern Pacific stocks. A knowledge of Japanese fishing techniques has already proven valuable to U.S. scientists studying the eastern Pacific saury resource (Ellis and Hughes, 1971).

The sharp reduction in Asian landings during the past 12 years has resulted in more cooperative research between Japan and the Soviet Union. A mutual concern over the decrease in annual yields is obvious. During the 1969 Japan-Soviet Union saury meeting, the two countries agreed that coastal stocks have decreased (Shin Suisan Sakuko, 1969). More recently, the Japanese Ministry of Agriculture and Forestry reported that the 60 percent decrease in the saury catch between 1968 and 1969 was because of a decline in stocks and a decrease in the numbers of vessels (Suisan Tsushin, 1970). There is also concern over change in the size composition of Japanese saury landings. The percentage of large fish seems to be decreasing and Suisancho Nippo (1969) predicted from the trend that the 1969 catch would be composed mainly of medium- and small-sized fish. Perhaps the most pessimistic report concluded that "saury fishing off Japan this year was so poor (total 51,000 tons in 1969) that little can be expected in the future" (Suisan Tsushin, 1970). However, the 1970 Japanese landings totaled about 80,000 tons.

Both Japan and the Soviet Union have conducted surveys of the saury resource off the west coast of North America and Japan has carried out limited commercial fishing operations. Obviously the potential for rapid development of a saury fishery exists if the resource is available in sufficient quantities. Therefore, it is important that information on the status of the resource be acquired rapidly so that a basis for rational utilization can be developed.

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2/ Presently an Asst. Professor, Department of Industrial Engineering, Calif. State Polytechnic College, Kellogg-Voorhis, Pomona, Calif.

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APPENDIX

JAPANESE AGENCIES AND KEY PERSONNEL ASSOCIATED WITH THE WESTERN PACIFIC SAURY FISHERY

<u>Japanese Fisheries Agency, Tokyo, Japan</u>

Dr. K. Tanaka, Director of the Research Division
Dr. Tomonari Matsushita, Special Assistant to Director of the Research Division

<u>All-Japan Saury Fishing Cooperative Association (Zen-Sanma), Tokyo, Japan</u>

Mr. Shigeo Tanaka

<u>Far Seas Fisheries Research Laboratory, Miho, Japan</u>

Dr. Hiroshi Yabe, Director
Dr. Tamotsu Yonemori
Dr. Hajime Yamanaka
Dr. Ichiro Yamanaka
Dr. Osamu Kibezaki
Dr. Akira Suda

<u>Miho Shipyard Co., Miho, Japan</u>

Mr. C. Doke, Managing Director

<u>College of Marine Science and Technology, Tokai University, Miho, Japan</u>

Dr. Mitsuo Iwashita, Assistant Dean
Dr. Minoru Nishikawa
Dr. Motoo Inoue

<u>Yaizu Fish Market, Yaizu, Japan</u>

(The largest tuna landing port in the world, with a 2-mile long waterfront)

Mr. Warashina (Far Seas Research Laboratory)

<u>Shimizu Shokuhin Kabushiki-Gaisha (SSK), Shimizu, Japan</u>

(Canning factory specializing in saury)

Mr. Era, Production Manager

Tohoku Regional Fisheries Research Laboratory, Shiogama, Japan

Dr. H. Sato, Director
Dr. Rikiichi Ishida, Director of the Propagation Department
Mr. Shinichi Fukushima, Head of the First Research Section of the Marine Resource
Mr. Shigeru Odate, Fishery Biologist
Mrs. S. Odate, Biologist

Tairin Industry, Shiogama, Japan

(Net and alluring light fabrication)

Mr. Koichi Isogarashi, Factory Manager
Mr. Takeo Ujiya, Business Manager

Hakodate Seimo Co., Hakodate, Japan

(Net manufacturer)

Mssrs Morita and Akaoka

Hokkaido Gyo-Gyo Kosha, Hakodate, Japan

(Canning factory)

Mr. Takano

Kushiro Prefectural Research Laboratory, Kushiro, Japan

Mr. Akira Fukuhara, Director
Mr. M. Naito, Head of the Marine Resource Research
Dr. S. Kawakamo, Head of Fish Culture and Farming Research
Mr. K. Toriyabe
Mr. K. Tsuda, Captain of the research vessel Hokko-Maru

Hokkaido University, Sapporo, Japan

Dr. E. Tanikawa
Dr. M. Ishida

Nippon Kagaku Shiryo Fish Meal and Fish Soluble Mfg. Co., Kushiro, Japan

Mr. A. Hino, Director

Hokkaido Central Fisheries Laboratory, Sapporo, Japan

Mr. Makoto Wako

Kushiro Kamaboko Manufacturing Cooperative Association, Kushiro, Japan

(Food processing)

Mr. A. Ishioka
Mr. A. Shibuya

Ibaragi Prefectural Fisheries Research Laboratory, Matsushima, Japan

Mr. Tachisaburo Okada, Director
Mr. Saruya, Head of the Fisheries Department
Mr. M. Misono, Captain of the research vessel *Mito-Maru*

Tohoku University, Sendai, Japan

Dr. M. Hatanaka
Miss Keiko Takahashi, Research Assistant to Professor Hatanaka
Dr. N. Mitsugi
Dr. T. Suzuki
Dr. F. Mitani

Tokai Regional Fisheries Laboratory, Tokyo, Japan

Dr. T. Hitaka, Director
Dr. Y. Maniwa, Fishing Vessel Research Laboratory
Dr. N. Yokoyama, Fishing Vessel Research Laboratory

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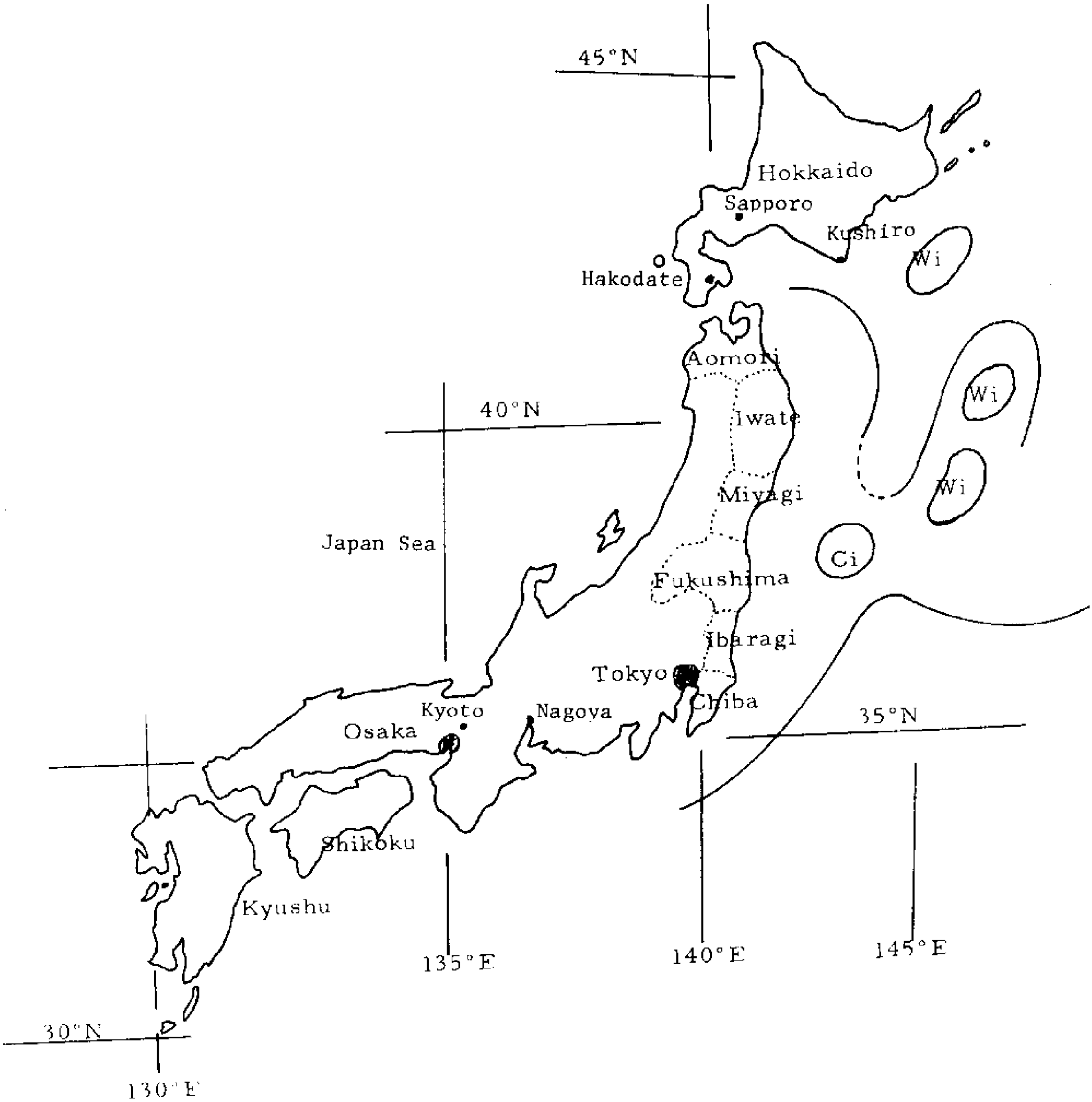

Prefectural Map of North-East Japan.