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Foreword

During an extended visit, as consulting oceanographer, at the Fisheries Research Board of Canada, Biological Station, Nanaimo, B.C., September, 1958 to May, 1959, Dr. Uda, Professor of Oceanography, Tokyo University of Fisheries, prepared and delivered to the scientific staff a series of ten seminars on the fisheries of Japan.

Because of the general interest in the widely-distributed and well-organized fishing operations of the Japanese in all oceans of the world but primarily, of course, in the waters off Japan, it has been deemed desirable to reprint the seminar outlines for wider distribution. The relationship of the fisheries to oceanographic features is of particular importance and in many instances the Japanese findings in this regard are not available in the English language.

A similar series of seminars on oceanography has also been prepared and distributed as No. 51 of the Manuscript Report Series (Oceanographic and Limnological) of the Fisheries Research Board of Canada.

For their suggestions and assistance in preparing the outlines, the author is indebted to Drs. R.E. Foerster, F. Neave, W.E. Ricker, F.H.C. Taylor, M. Waldichuk and Messrs. J.I. Manzer and G.C. Pike.

THE FISHERIES OF JAPAN

by

Michitaka Uda

Seminar 1. General outline of the fisheries in Japan, their development and fishing methods

In the waters surrounding Japan many kinds of marine resources (fishes, shellfish, whales, seaweeds, etc.) occur in abundance as a result of the complex environments caused by the intermingling of cold and warm ocean currents, rich land drainage and volcanic topography.

Although the Japanese fisheries had their origin in the very distant past, as long ago as the Stone Age, they were limited, up until a century ago, to coastal waters and were carried out by non-powered fishing craft such as oar-manipulated boats or small sailing vessels and by beach seine, angling (rod, hook and line), long line, square lift nets, set nets and drag nets. However, just prior to the present century, due to the activities of foreign (English and American) fur-seal and whaling vessels in the waters adjacent to Japan, the Japanese pelagic fisheries began to develop rapidly.

In Europe, fur-seal fishing and whaling had commenced about the 8th century and the cod-line fishery between the 8th and 14th centuries (in the U.S.A., in the 17th century). While the sailing drift-net fishery had begun in the 13th century, and the sailing beam trawl in 1688, the purse seine did not come into use until around 1820, the steam trawl in 1865, the steam drift-net fishery in 1872 and the steam long-line in 1879. In Japan the high-seas fishing commenced as an exploratory whaling venture in 1887 in the waters near the Idu Islands by M. Sekizawa. In 1905 the first oil-burning fishing boat was built for the skipjack fishery. At that time more than 400,000 oar-propelled fishing boats were in operation in Japan, fishing in areas which were limited to about 30-40 sea miles from the coast. Sea disasters were all too frequent due to the inability of the wooden vessels to withstand the force of typhoons in summer and autumn and the high winds and monsoons of winter.

The modern steel motor vessel came into general use around 1910, from which time the off-shore and high-seas fishing areas began to be exploited. These were extended year by year off the coasts of Hokkaido, Sakhalin, Kurile, Kamchatka, Korea, Formosa and in the China Sea. A rapid increase in the fish catch resulted. Although fisheries statistics are available since 1894, the present-day statistical survey system, with margin of error ± 5-20%, was established in 1946 (T. Yamamoto, 1956; N. Oka, 1956).

Table 1. Yield of fisheries in Japan

Year	Catch in 10^8 Kan (266,667 Kan = 1 ton = 1,000 kg.)
1894	1.3
1910	2.2
1912	3.2
1916	4.4
1923	5.0
1925	6.0
1926	7.2
1927	9.0
1933	10.9
1941	11.8
1945	5.4
1952	12.0
1957	16.0

Japan's fisheries suffered greatly during World War II and the catch declined to less than one-half of the pre-war yield. In the post-war reconstruction, the fishing vessels, which were equipped with wireless telegraphy and telephone, increased from 1077 in 1940 to 5078 in 1954. In 1953 there were in operation 135,084 powered vessels (913,965 tons) and 308,151 non-powered boats (296,112 tons). There were 900,000 persons engaged in the fisheries of whom 620,000 were full-time fishermen, and the total family population involved in the fisheries was 2,916,766 or nearly 3% of the total population of Japan.

Fishing efficiency was much increased by the improvement of gear, such as the use of synthetic fibres, and the use of new equipment such as radar, fish finders, fish lamps, etc., and by the extension of the fishing areas out into the open ocean. Consequently, Japan's fisheries production recovered quickly and gained appreciably over the pre-war peaks of 3,562,000 tons in 1938 and 4,116,000 tons in 1940 and reached around 6,000,000 tons in 1957, or about 18% of the world total catch of 2996 × 10^4 tons. Japan occupied first place in world fish production, followed by U.S.A., China, U.S.S.R., Norway, India, U.K., Canada, in that order.

To meet the increasing demand for sea food to supply the necessary proteins for their country's dense populations, Japanese fishermen exploited various kinds of marine edible forms, such as seaweeds, squid, octopus, sea urchins, etc., and extended their fishing operations off shore and to a depth of about 1,000 m. Daily fish consumption per capita in Japan varied from 42 g in 1937, to 26 g in 1946 and to 52.9 g in 1952. Thus the Japanese, like the Norwegians, are the greatest fish-eating nation in the world.

The composition of fish species varied greatly, however, before and after World War II. In the pre-war years, sardine, herring, cod, salmon and trout were the principal species; in the post-war period, while the catches of sardine, herring, salmon and trout declined, the catches of anchovy, mackerel, horse mackerel, Pacific saury, squids and tunas increased markedly. According to our studies the causes seem to be related to a change in the oceanic environmental conditions, similar to the case of the California sardine, Norwegian herring or Arctic cod fisheries (e.g. Uda, 1952, 1956). In spite of the exploitation of the high seas, the main yields of fish in Japan come from the extensive and varied coastal fisheries.

Table 2. Principal fisheries production in Japan in 1956 and 1957 (unit - 10^3 Kan = 3.75 metric tons)

Species	1956	1957	Species	1956	1957
Herring	9,482	12,604	Yellow tail	11,418	11,245
Sardine	55,014	59,597	Cod	9,387	17,514
Round herring	15,986	14,084	Alaska pollack	62,639	74,371
Anchovy	92,455	114,723	Atka mackerel	32,310	28,150
Skipjack	26,127	31,441	Horse mackerel	65,711	83,369
Spanish mackerel	6,913	---	Pacific saury	87,417	112,468
Blue-fin tuna	9,845	9,129	Squid	79,863	97,168
Albacore	15,641	20,726	Sea weed	87,405	107,681
Big-eyed tuna	12,553	16,081	Shellfish	103,567	119,178
Yellow-fin tuna	20,500	26,537	Whaling: Antarctic	6,462	8,092
Mackerel	70,981	73,421	: Subarctic	3,186	4,816
Black marlin	6,272	7,942	: Coastal	4,494	(3,109+)
Flatfish	40,040	40,568	Salmon (Subarctic)	24,765	26,667
			South China Sea trawl	2,086	3,197
			Crab	5,934	5,675

Fishing gear and fishing methods

The first compilation on Japanese fishing operations was published in 1912 as "Nihon Suisan Hosai Si" (Japanese Fisheries Book) and "Nihon Suisan Seikin Si" (Japanese Fisheries Products) by the Japanese Fisheries Agency (in Japanese). Recently (1958) "Illustrations of Japanese Fishing Boats and Fishing Gear", edited by the Japanese Fisheries Agency, has been published in both English and Japanese (price, $6.00) by the Japanese Association for Agriculture and Forestry. Another excellent reference book, written in English, is "Japanese Fisheries", compiled by the Japanese Fisheries Agency in 1955.

During the last one hundred years, many new developments have taken place in fishing gear and related equipment. Mechanization proceeded swiftly from 1900-1915 and after World War II (1946-55). New chemical net fibres were developed and electronic instruments used, such as:

Fish finder (S. Kawata, 1956, 1957).

The Fishing Boat Research Laboratory of the Japanese Fisheries Agency (Y. Ōtu, T. Hasimoto and others) contributed greatly to the improvement in fish-finders (commonly 10-100 kc., more recently 200-400 kc.). Herring, sardines, anchovies, mackerels, horse mackerels, squid, Alaska pollack, kelp, corals and even bottom inhabitants (king crab, trawl fishes) and large fish such as tunas, yellow tail and whales (by sonar) were detected by their peculiar echo-traces. Even the position of the DSL (deep scattering layer) could be determined, this being the area of concentration of the fish's planktonic animal food. In 1953 there were 3500 fishing vessels in Japan equipped with supersonic fish finders.

Fish lamps (T. Sasaki, 1955; S. Takayama, 1956; N.Y. Kawamoto, 1956; Z. Nakai, 1956).

Fish lamps developed from the torch lights (10-100 W. in luminosity) which had been used prior to 1900. In 1920 electric lights were used and in 1932 their luminosity ranged from 1-10 KW, the limits set by government regulation. Such lights are used to attract schools of sardine, mackerel, horse mackerel, Pacific saury, squid, etc., into large concentrations so that they can be encircled by nets and caught.

The catch increased almost in proportion to the square of the light power used. Taking 1948 as a standard, the increased catch in 1954 has been approximately 4 times while the increase in light power has doubled. A stick-held dip-net fishery for Pacific saury using a fish light has, since 1948, replaced the former drift gill-net fishing and since 1932 the purse seine fishery for sardine and mackerel has developed, especially off the west and north coasts of Kyusyu since 1946. Phototaxis for sardine schools occurs within the range of around 10^{-2} lux daylight. Phototaxis of ecological groups, as revealed by observation and sampling, shows zooplankton responding first, followed by small fish and finally large fishes, i.e. in the order corresponding to the food-chain (prey - predator) relationship. Fish schools at the breeding or spawning season have, in general, no phototaxis. It was found that usually underwater lights produce greater illumination and thus are much more effective in the transparent southern waters.

<u>Synthetic fibres</u> (H. Miyamoto, 1956)

Since 1948 the introduction of synthetic fibres for fishing nets and ropes has led to a rapid development of the fisheries of Japan. Used first for gill nets in 1952, then for set nets in 1953 and successively thereafter for seine nets, trawl nets, and long lines and now making up an active export business, they consist of polyamid compounds - Amilan (similar to nylon), polyvinyl compounds (Cremona, etc.,) and vinylidane chloride (Saran, Kurehalon, etc.).

<u>Search for favourable fishing grounds by oceanographic methods</u> (refer to Dr. Uda's Oceanographic Seminars, 2 to 10)

The oceanographic surveying of existing fishing grounds and exploratory expeditions into new areas to discover new fishing districts have aided very materially in increasing the efficiency of fishing and have contributed greatly to the tremendous yield of recent years.

<u>Conservation, regulation, protection of fisheries resources and fisheries forecasts</u>

The effect of environmental conditions on the early stages of the life cycle of fishes is a very important factor.

<u>Reference books on Fisheries Science published in Japan</u> (in Japanese)

(1) Fisheries physics (M. Tauti, 1953) - physical application, such as thermostat incubator, drying of fishmeat, the strength, elasticity and fouling mechanism of fishing rope and twine, dynamics of the swimming of fish-shoals against set net, etc.
(2) Electric fishing method (T. Kuroki, 1956) - experiments by means of electric pulse.
(3) Fish population dynamics (I. Kubo, T. Yoshihara, 1958).
(4) Manual of general fisheries resource (H. Aikawa, 1949).
(5) Ichthyology (Y. Suehiro, 1951).
(6) History of fisheries economy in Japan (M. Habara, 1952-58).
(7) History of Japanese fisheries (K. Yamaguchi, 1947).

(8) Set net fishery (H. Miyamoto, 1952).
(9) Whale and whaling (H. Omura *et al*., 1942; K. Maeda *et al*., 1952).
(10) Tuna fisheries and tuna resources (H. Nakamura, 1951).
(11) Fisheries statistics and sampling method (T. Yamamoto, 1957).
(12) Aquiculture Science (T. Tamura, 1957).
(13) Trawl fishing (Ichiro Saito, 1957).

Trawl fishery

To supplement and largely replace the native trawls (Utase, Teguri nets of Japan), European trawls and trawling methods were introduced from Britain in 1903 by M. Simoda. Steam trawling commenced in 1909 and since 1912 the number of trawling vessels has increased to 139. The Fisheries Agency regulated the number of such vessels and many were used to exploit new fishing grounds in the East China Sea and Yellow Sea. In 1933 operations were extended into new fishing grounds in the Bering Sea (off Bristol Bay) and also in the South China Sea, off Australia, Argentina, Mexico and along the Siberian coast of U.S.S.R. From 1945 fishing was carried out in the waters adjacent to Burma, India, Pakistan, the Persian Gulf and South America. Conservation of the bottom fish resources was studied biologically by the Fisheries Agency after 1946.

In 1917 the Nihon Suisan Company was established and founded a Research Laboratory. Under its auspices a rapid freezer which could be installed in fishing vessels was invented. Bottom fishing grounds and their resources (shrimps, etc.) were studied by K. Kunisi, T. Kumada *et al*. In 1927 the first diesel-powered trawler in the world, the "Kusiromaru" (311 tons, 750 H.P. and capable of remaining at sea for 40 days) was built. In 1938, H. Hayasi invented a new extension device for trawl nets.

Set net fishery

Though this fishery has declined year by year, it is still the mainstay of the Japanese fisheries. Among the species caught by set net along the coast are yellowtail, sardine, anchovy, tuna, squid, sea bream. This fishery commenced in the 17th century but has been greatly developed and modified. Dr. M. Tauti, H. Miyamoto have carried out many model experiments based on the principle of dynamical similitude.

Whaling

Hand harpooning was practised prior to 1600; since 1676, whale netting has been conducted. Coastal whaling by gun (M. Sekizawa, Manziro Nakahama) has been practised since 1887. The first steam whaler ("Tyosyu Maru", 122 tons) was operated by Zyiuro Oka in 1899. Captain Tokusuke Sino, S. Idumi and others developed Japanese whaling scientifically.

The first age determinations of whales were undertaken by Captain Tasuke Amano by using the teeth of sperm whales and the fin plates of finbacks and in 1910 he initiated whale marking. In 1934 Japan entered into Antarctic whaling. In 1950 Professor Morizo Hirata invented the flat-headed harpoon. Biological studies of the stocks of whales have been made by H. Omura, S. Matsuura *et al*. and Professor Teizo Ogawa *et al*. have made anatomical studies of sea mammals.

Subarctic fisheries

In 1897, S. Gunzi initiated cod fishing in North Kurile waters by sail boat. The salmon fishery by the Japanese along the Kamchatka coast began in 1905 and continued to 1929. The motherboat system of salmon fishing was initiated in 1914 by the "Unyomaru" (444 tons, a training vessel of the Imperial Fisheries Institute) and at that time the first successful gill-net sets were made. The salmon fishery off the northern Kurile began in 1931 and since 1952 a mothership fishery has operated in the Bering Sea and in Aleutian waters. Because of the international aspect of these fisheries in the North Pacific, conferences are held annually by INPFC (Japan, Canada and U.S.A.) and also between Soviet Russia and Japan.

King crab fisheries

In 1914 the "Unyomaru" initiated trial fishing operations in the Okhotsk Sea and in the Bering Sea, carrying out the canning operations right on board. In 1920 the "Kurehamaru" (Toyama Prefecture Fisheries Institute) initiated the canning of king crab after boiling in sea water.

Herring fisheries

In 1798 the Etorohu fishing grounds of the South Kurile Islands were first exploited for herring, salmon and kelp and since 1795 the Sakhalin fishing areas have been fished by the Japanese for herring and salmon

In 1801 Dyuzo Kondo surveyed the Sakhalin-Amur coasts as fishing areas. The herring fishery in Hokkaido (Hakodate) waters has been in operation since 1447.

Skipjack fisheries

From inshore angling in ancient times this fishery now extends from the subtropical seas near Formosa, Ryukyu, Kyusyu in winter and spring to offshore waters several hundred miles from northern Japan (Hokkaido, Sanriku) in summer and autumn. Live bait (anchovy, sardines) are used.

In 1909, the "Fujimaru" (belonging to the Siduoka Prefectural Fisheries Experiment Station) was built, the first skipjack motor-powered vessel. A fisheries wireless telegraph system was developed by Dr. Y. Torigata and subsequently became the Association of Fisheries Wireless Telegraphy by incorporating all local Fisheries Telegraph Stations.

Tuna Fisheries

At the present time this pelagic fishery embraces the North and South Pacific Oceans, the Indian Ocean and the Atlantic, especially in the Equatorial regions and near the polar front areas where long line vessels are used. These have specially-invented line-hauler devices and rapid-freezing systems. Tagging experiments and hook detection, plus taxonomic and biometric studies are now providing interesting data on tuna. In view of the declining hook rate (catch per 100 hooks in long line) as a result of heavy exploitation, a basic study of the conservation of the deep-sea tuna resource is being actively continued by the scientists of the Nankai Regional Research Laboratory, Koti, etc., as well as by the Inter-American Tuna Commission (M.B. Schaefer et al. and POFI).

Moreover, recently the sardine and mackerel purse-seine fisheries, mackerel and skipjack angling and the Pacific saury dipnet fishery have all become very active over broad areas of the ocean.

Arahura sea pearl

This shell fishery was started in 1874 by Japanese divers and has continued ever since then.

Aquiculture

As early as 1716-71 a system of salmon protection had been begun by the then feudal administration in the streams of Niigata Prefecture and since 1894 artificial propagation of salmon has been practised in hatcheries in Hokkaido (Y. Handa et al.)

Smelt transplantation techniques have been developed by Professor Chiyomatsu Ishikawa and S. Nakano.

Artificial propagation of sea bream was initiated by T. Kitawara and from 1922 to 1933 was conducted by E. Kaziyama.

Since 1939, after the very poor catch of Hokkaido spring herring in 1938, artificial propagation of herring has been experimented with at the Hokkaido Fisheries Experiment Station.

Oyster culture began in Hirosima Bay in 1681. The method of collecting oyster spat on hanging strings of cultch and rearing the oysters in this way was developed by Dyuzo Hori and Hidemi Senoo in 1930-40. Physiological and ecological studies on seed oysters, removal of natural enemies, etc., have been made by Professor Takeo Imai.

The artificial pearl oyster culture was initiated in 1904 by Kokichi Mikimoto, with the cooperation of Professors K. Mitsukari and T. Nisikawa.

Clam propagation was introduced in 1660 by Kenzan Nonaka.

Laver culture began in 1751 in Hirosima Bay and in Tokyo Bay some 300 years ago.

Physiological, histological and ecological studies of seaweeds (laver, kelps) were undertaken by Drs. Kintaro Okamura (1867-1940), Saburo Ueda, Kingo Miyabe, K. Endo, Kunieda, Arasaki and others.

The horizontal floating net seeding method for laver was invented and developed by M. Kaneko, Saburo Fujimori, D. Kusakabe and others. Now, however, water pollution is a very serious problem in Japan.

Food technology and utilization of marine products

Problems such as the protein content and vitamin A and D liver oil content, fish-skin tanning, toxicity, canning and manufacture of fish fillets, fish cakes, fish balls, fish meal, etc., have been investigated physiochemically by many scientists.

Mechanical problems involved in fish food preservation by means of freezing, radio-active treatment using isotopes, drying, etc., have also been studied.

Commercial organizations and educational institutions for fisheries

The Japanese Fishermen's Association was founded in 1884.

The original Imperial Fisheries Institute, now the Tokyo University of Fisheries, was established in 1889 (S. Matsubara *et al.*), while the Department of Fisheries at the University of Tokyo was started in 1910 by Drs. Kishinone and Ishikawa.

The Department of Fisheries of Hokkaido University was founded in 1872.

The first Fisheries High Schools (Obama, Miyako) were set up in 1895.

The first Prefectural Fisheries Experiment Station (Aichi) was established in 1894.

Seminar 2. The herring and sardine (pilchard) fisheries

From ancient times, fish of the herring family (Clupeidae) have formed a very important seafood resource. This family includes, besides the herring, the sardine or pilchard, the anchovy, the menhaden and the shad. All are subject to violent fluctuations in abundance due to oceanographic conditions.

I <u>Herring</u> (<u>Clupea pallasii</u>)

A. In the Orient, herring are found along the east coast of Korea, from Peter the Great Bay to near Pusan, along the Japan Sea coast from Yamagata Prefecture to Hokkaido, in the Okhotsk Sea, along the Pacific coast from Hinuma Lake in Ibaragi Prefecture to the south coast of Hokkaido (Kusiro, Akkessi from June to August) and off Kamchatka (Anadir Bay). (See Ishida, 1952)

While the herring of the eastern Pacific (Stevenson, 1955 and F.H.C. Taylor, 1955) are considered to form a number of local populations which undertake comparatively short inshore-offshore migrations, the Hokkaido herring form one population which, in its young stages, migrates north into the Okhotsk Sea, south of Hokkaido in the Pacific and to Kamchatka, and returns to spawn along the west (Japan Sea) coast of Hokkaido (Kuragami and Kazita, 1936).

In northern Japan (Hokkaido) and Sakhalin, herring approach the coast in great shoals in spring, from March to May, to spawn in the intertidal zone. The water temperature at this time varies from 3 to 4°C to 6 to 8°C. The spawning herring are mainly 3, 4 and 5 years old, with some reaching an age of more than 10 years. Dominant year-classes occur and may last for sometimes ten years or more ("Vital Statistics", J. Hjort, 1914).

The Hokkaido Fisheries Experimental Station forecasts the yield and the date of the start of the fishery. This forecast is based on surveys of the relative strength of the year-classes, of oceanographic conditions (temperature, salinity, currents, plankton, etc.) and of weather conditions. Hardy (1957 and 1958) has also demonstrated that herring spawning grounds are affected by oceanographic conditions. He showed that the greater intrusion of Atlantic water from August to December caused a shift not only of the most productive fishing grounds (determined by records from the Hardy Plankton Indicator) but also of the spawning grounds of the North Sea herring.

Herring in Hokkaido are fished by set nets, gill nets and trawls. In its 500-year history, the herring fishery has shown great fluctuations (Tables I and II) with a cyclic occurrence of poor years.

B. In both the western Pacific and eastern Atlantic, the herring fisheries have declined in recent years. In the western Pacific, the Hokkaido herring fishery has been a complete failure in recent years. The Sakhalin herring catch, although remaining at an average level from 1938 to 1950, has also declined in the last few years (Moiseev, 1956). This decline has been attributed to the warming of the Sea of Japan. In the eastern Atlantic, the East Anglian herring fishery declined sharply after 1951. Hodgson (1957, 1958) reported that the fish grew bigger and matured earlier. He believed that excessive fishing, particularly trawling, was responsible for the decline in the fishery and for the greater proportion of three-year-old fish in the commercial fishery. Cushing and Burd (1957)

Table 1. The success of the Hokkaido herring fishery (Uda, 1957)

Years	Hokkaido herring	Minimum interval (years)
1447	Fishery founded	
1596-1614	Poor years	
1661-1681	Good years	90
1688-1703	Poor years	
1716-1762	Good years	88
1775-1791	Poor years	
1814-1840	Good years	70
1847-1857	Poor years	
1858-1898	Good years	54
1900-1912	Poor years	
1913-1920	Good years	32
1938	Very poor year	
1944-1945	Good years	17
1955-1958	Very poor years	

Table 2. Japanese herring catch

Years	10^3 Metric tons	Dominant age group	Years	10^3 Metric tons	Dominant age group
1927	653.3		1949	186.3	Age 10
1934	383.2		1950	172.7	11
1938	43.4		1951	187.4	12
1942	200.6	Age 3	1952	320.9	13
1943	312.1	4	1953	275.2	14
1944	370.6	5	1954	275.2	15
1945	317.6	6	1955	46.9	
1946	324.9	7	1956	37.0	
1947	172.8	8	1957	47.3*	
1948	192.0	9			

* Increased by open ocean gill net fishery.

state that the advance in maturity noted brings the herring into the fishery sooner in their life history and that makes an appreciable reduction in the older age groups. But an increase in total mortality has made this reduction more noticeable. Their data indicate that fishing has also reduced the abundance of older age groups directly:

(a) because the reduction in recent years is more than would be accounted for by the advance in maturity;

(b) because apparent total mortality has been relatively high in two periods of high landings, one of which, 1935-38, was before the change in maturity.

On the other hand, Parrish (1958) considers that natural factors are more important than man-made factors in explaining the changes that have occurred in this fishery. He believes that the growth change, itself naturally induced, has resulted in a change in the prespawning distributions and behaviour, which in turn may account for the increase in apparent total mortality rate and the decline in catch. L.H. Cooper (1957) has pointed out that, due to a change in the deep circulation or in internal waves, there has been a decrease in the amount of nutrients (phosphates) supplied from the deeper zone near the shelf edge. He suggests that this decrease in nutrients may have reduced the plankton food supply on which the autumn-spawned juvenile herring are dependent. The fluctuations in the European herring fishery as shown by Otto Pettersson (1926) appear to be generally in phase with the fluctuations in the Oriental herring fishery.

Table 2a

European herring	Good years	1660-80	1752-1810	1876-97
Hokkaido herring	Good years	No record	1748-76 Peak 1764-71	1877-1905
	Poor years	No record	1777-83-91 Minimum 1784	1906-43

In the eastern Pacific, however, herring fisheries have not declined to the same extent. The Alaska fishery showed a maximum in 1938 and declined to a minimum in 1952-54. The British Columbia herring catch on the other hand has increased steadily, reaching a maximum in 1955-56.

C. In the Hokkaido herring fishery it has been noticed that years of low yield are preceded by:

(i) a period of unstable and declining catch, especially in the southern fishing areas, e.g. the centre of fishery has shifted northward.
(ii) years in which the older age classes dominate the fishery (see Table 2).
(iii) years in which the fishing season is shortened and occurs earlier.
(iv) years with poor kelp harvest.
(v) years in which warmer-water southern fishes (Yariika and Kōnago) appear on the herring fishing grounds.

D. Studies have shown that the decline in the Japanese herring fishery can be attributed to a decrease in recruitment caused by cyclically occurring changes in the environmental conditions. Reproductive potential appears to be higher:

(i) when the annual hours of sunshine are longer.
(ii) in warmer and less stormy years.
(iii) when water temperatures do not fluctuate greatly (Kuragami and Kazita, 1925).

Kuragami and Kawana (1934) and Kawana (1948 and 1949) have shown that the years of abnormally successful survival occur in the periods between the years of maximum and minimum sunspot numbers, a 6-9 year cycle. S. Sato (1949) has shown that when the Soya Warm Current is stronger, the yield of seaweed increases, but that in the following spring the herring yield decreases. Thus, there is a relationship between the herring yield and recruitment and sunspot number and oceanographic conditions. Years of poor catch correspond to years when the Tusima and Soya Currents are strongest.

E. (i) Uda (1952) found a marked correlation between years of poor catch in the Hokkaido herring fishery and the years when water temperatures were abnormally low. Poor catches can be expected 4 years (sometimes 3 years) after an extremely cold year (a bad rice crop year). The poor breeding conditions in the extremely cold years produced adults that migrated to the spawning grounds as four-year-old fish.

Table 3

Cold year	Interval in years	Year of minimum catch
1866	4	1870
(1869)	4	(1873)
1884	3	1887
1902	4	1906, 1907
1905	4	1909
1913	4	1917
1926	4	1930
1934 (1935)	4	1938 (1939)
1944 (1945)	4	1948
1953 (Hokkaido)	(4)	1957

(ii) In some years the Kuroshio Current produces a westerly current near Cape Sionomesaki and a strong onshore current near Sima Peninsula. In these anomalous years, the skipjack fishery off the coasts of Wakayama and Mie Prefectures is exceptionally good, but the Hokkaido spring herring fishery is very poor. Such years were 1906-07, 1917-18, 1937-39, 1956-57.

(iii) The Hokkaido herring and sardine catches seem to vary inversely to one another (Figs. 1 and 2). In 1937 and 1938 the northward flowing warm current prevailed, the Hokkaido sardine catch was excellent, but the herring catch was one of the poorest on record. In 1944 and 1945, years of low water temperature, there was a sharp decline in the sardine catch but an improvement in the herring catch.

The mechanism by which natural fluctuations are produced, especially those occurring in the early years of life in relation to environmental factors, remains a problem still to be solved.

II Sardine

1. The sardine fishery

In Japanese, the word "Iwasi", sardine, is used to cover several species of clupeoids, including the sardine or pilchard (Sardinops melanosticta), the anchovy (Engraulis japonica) and the round herring (Enumeus micropus).

Fig. 1.

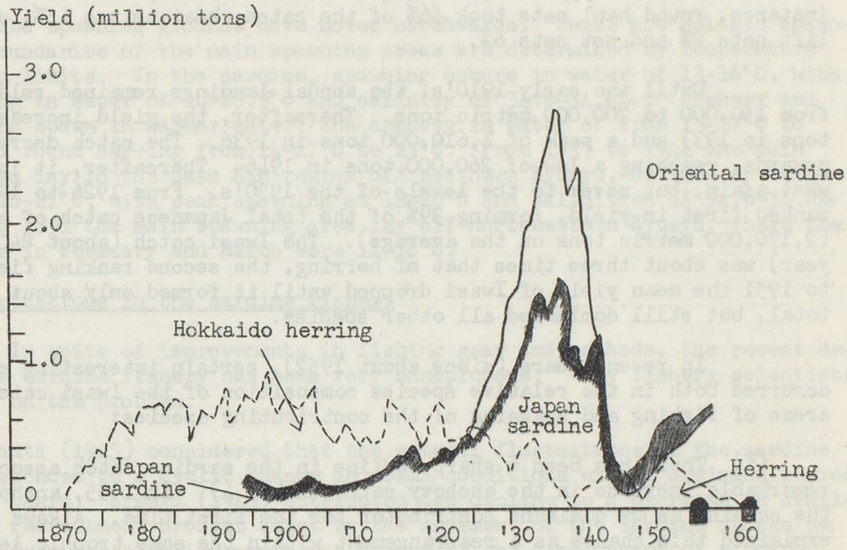
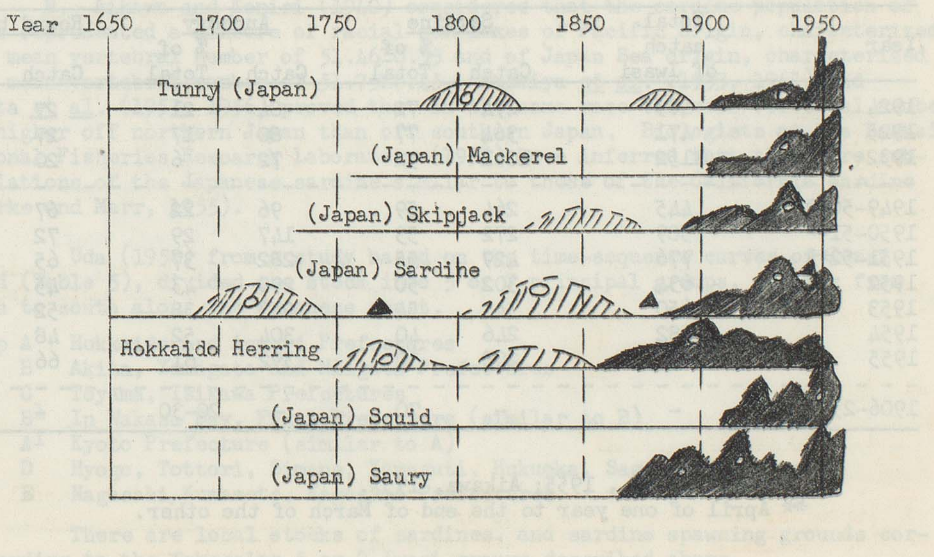


Fig. 2. Long period trends of catches



Because of their great abundance, Iwasi form an important source of animal protein in Japan. These fish are found around almost all of the warmer parts of the coast of Japan and have contributed to the economy of the fishing villages for more than 1000 years (Nakai _et al_., 1955).

Various types of fishing gear are used to capture Iwasi. In 1951, for instance, round haul nets took 56% of the catch, boat seines 15%, drift nets 9%, lift nets 8% and set nets 6%.

Until the early 1910's, the annual landings remained relatively low, from 150,000 to 200,000 metric tons. Thereafter, the yield increased to 750,000 tons in 1933 and a peak of 1,610,000 tons in 1936. The catch decreased from 1941 onwards, reaching a low of 260,000 tons in 1946. Thereafter, it increased somewhat again, but never to the levels of the 1930's. From 1926 to 1951, Iwasi ranked first in yield, forming 39% of the total Japanese catch of all fish (2,170,000 metric tons on the average). The Iwasi catch (about 840,000 tons a year) was about three times that of herring, the second ranking fish. From 1949 to 1951 the mean yield of Iwasi dropped until it formed only about 25% of the total, but still dominated all other species.

In recent years (since about 1952), certain interesting changes have occurred both in the relative species composition of the Iwasi catch and in the areas of fishing and spawning of the contributing species:

(i) There has been a sharp decline in the sardine catch associated with a remarkable increase in the anchovy catch (Table 4). In 1955, anchovy displaced the sardine as the dominant contributor for the first time. Aikawa (1957) has explained this change as a rearrangement within the same trophic level as a result of competition for food.

Table 4. The Iwasi catch and its composition* (in metric tons)

Year	Total catch of Iwasi	Sardine		Anchovy		Round herring	
		Catch	% of Total	Catch	% of Total	Catch	% of Total
1924	405	294	72	84	21	27	7
1925	471	364	77	80	17	27	6
1932	1152	1061	92	72	6	20	2
1949-50**	445	264	59	96	22	67	4
1950-51**	509	272	53	147	29	72	4
1951-52**	776	429	55	282	37	65	-
1952	634	302	50	290	43	45	7
1953	650	344	54	243	38	52	8
1954	582	246	40	304	52	48	8
1955	697	208	30	392	61	66	9
1906-25	-	-	70	-	20-30	-	4-5

* Nakai _et al_., 1955; Aikawa, 1957.
** April of one year to the end of March of the other.

(ii) The fishing grounds have changed. From 1925 to 1938 the main sardine fishing grounds were off Hokkaido and Tohoku (northeastern Japan) and off the east coast of Korea and the USSR Maritime Province. Off Korea mostly large-sized fish were caught. In 1951 the main fishing grounds shifted southward to off the west coast of Kyusyu.

(iii) The spawning grounds have moved northwards. Iwasi are pelagic spawners. The boundaries of the main spawning areas are determined by temperature and salinity limits. In the sardine, spawning occurs in water of 13-16°C, with peak spawning in water of 14-15.5°C and salinity of 34.0-34.4‰. Anchovy and round herring spawn in warmer water; the anchovy in water of from 13-17°C to 20-23°C, and round herring from 14-17°C to 23°C. From 1937 to 1941 the main spawning area lay in the Satu Nan region off southern Kyusyu, defined by temperatures of 16-21°C, with peak spawning at 18-20°C and salinities of 34.6-34.8‰. From 1947 to 1951 the main spawning area lay off northwestern Kyusyu, where the temperatures in February and March were 14-16°C.

2. Fluctuations in the sardine fishery

A. In spite of improvements in fishing gear and methods, the recent decline in the sardine fishery has been very conspicuous. Many fishery scientists have worked on the problem.

Tauti (1943) considered that the natural fluctuations in the sardine stock corresponded to a cyclic change in ocean conditions with a dominant period of about 33 years. Kimura (1943) attributed the decline to a decrease in availability and recruitment brought about by the movement of the sardine stocks to some region from which their return was barred by the development of a cold coastal current. Aikawa (1943) first postulated that the decline was probably the result of overfishing (the peak Oriental catch was over 3 million tons). Later, in 1957, he modified this view, taking into consideration the effect of changes in natural environmental conditions on recruitment.

B. Aikawa and Konisi (1940) considered that the sardine population of Japan represented a mixture of racial complexes of Pacific origin, characterized by a mean vertebral number of 51.46±0.55 and of Japan Sea origin, characterized by a mean vertebral number of 51.75±0.45. Amemiya et al. (1933, 1941) and Yokota et al. (1953, 1956) proved that in the same race the mean vertebral number was higher off northern Japan than off southern Japan. Biologists at the Hokkaido Regional Fisheries Research Laboratory (1958) have inferred that there are subpopulations of the Japanese sardine similar to those of the California sardine (Clarke and Marr, 1955).

Uda (1958) from a study based on the time-sequence curves of Iwasi yield (Table 5), divided the stock into 5 or 7 principal groups, running from north to south along the Japanese coast.

Group	A	Hokkaido and Aomori Prefectures
	B	Akita, Yamagata and Niigata Prefectures
	C	Toyama, Isikawa Prefectures
	B¹	In Wakasa Bay, Fukui Prefecture (similar to B)
	A¹	Kyoto Prefecture (similar to A)
	D	Hyogo, Tottori, Simane, Yamaguti, Hukuoka, Saga Prefectures
	E	Nagasaki, Kumamoto, Kagosima Prefectures

There are local stocks of sardines, and sardine spawning grounds corresponding to the foregoing 5 or 7 Iwasi groups described above.

Table 5. Fluctuations in Iwasi catch in Japan

Years	Fishery
About 1500-1600	Iwasi fishery developed
1660	Good year near Tyosi
1680-1730	Good years
(1716-1724)	Very good years
1736-1789	Poor years
(1768-1780	Extremely poor years
1818-1859	Good years
(1830)	Extremely good year
1864	Very large catch at Tyosi
1870-1890	Poor years
(1884-1888)	Extremely poor years
1917-1921	Good years in Japan Sea
1929-1939	Very good years
1941	Start of decline
(1941-1947)	Poor years in Japan Sea
1951-1957	Poor sardine fishery, very good anchovy fishery

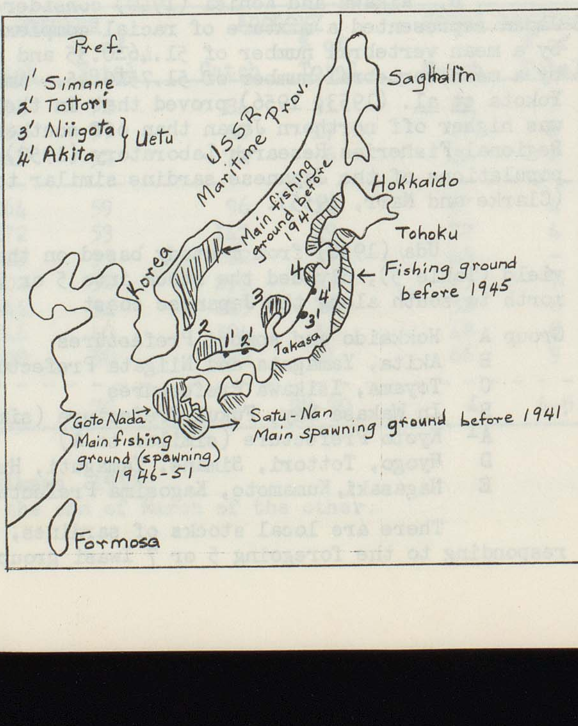
Sardine spawning areas along the west coast of Japan are concentrated in the following 6 regions (Nakai, 1938-1958, Ito et al., 1956) shown in Fig. 3.

(i) Satu-Nan area
(ii) Goto Nada, Amakusa Nada areas
(iii) The area off Yamaguti Prefecture
(iv) The area off Noto
(v) The Uetu coastal area
(vi) The Tugaru area

Fig. 3.

Sardine

1. Off Nagasaki
2. Off Yamaguti
3. Off Noto Peninsula
4. Off Aomori, Tugaru
spawning ground
(3,4,5 -- 1949-58)



Aikawa (1957) recognized these principal spawning centres and added two others on the Pacific side, (i) off southern Kyusyu in February and March and (ii) in the northern Kuroshio area in April, May and June.

During the period of the decline in the sardine catch (1941-1947), the centre of fishery shifted progressively farther south each year. During the periods of growth from 1930 to 1938 and 1949 to 1956, in the Sea of Japan, the centre of fishery moved progressively farther north each year. The northerly shift of the centres of spawning and of fishing and the north-south changes in the distribution of the yield from these migrating sardines, corresponds well with the changes in oceanographic conditions.

3. Decline of the Oriental sardine fishery since 1941

A. The Oriental sardine fishery in the northern part of the Japan Sea and the Pacific prospered from 1923 to 1940, but from 1941 onwards declined rapidly, particularly off the coast of Hokkaido and North Korea. Kurita (1957), from computations of the total weight of the stock at the start of any year and the annual rate of increase during that year, concluded that the successive failure of recruitment from 1938 to 1941 was responsible for the decline in the sardine catch after 1941.

B. Nakai (1943, 1949, 1956) was convinced that the primary cause of the decline was a decreased production of post larvae in the Kuroshio area due to the presence there of abnormally cold water (1936-1945). The centre of heavy spawning moved from the Satu Nan area to northwest Kyusyu. Over 70% of the total spawning in 1937 to 1941 occurred in the former area in February and March in water of 16-21°C, with peak spawning in 18-20°C water, and salinity of 34.6-34.8‰. Since 1943, the centre of spawning has been in the latter area and off Noto in water of 14-16°C.

C. Uda (1958) showed that years of good sardine catch were warm and of poor sardine catch were cold (Table 6).

Table 6

Period	Sea Temperature	Years	Sardine fishery
I	Cool	1902, 1905-09	Sardine poor, herring good
II	Warm	1917-21	Sardine good (1915-21), herring and squid poor
III	Cool	1923-31	Sardine poor (1929-30), squid good
IV	Warm	1932-40	Sardine good, herring poor
V	Cool	1941-47	Sardine poor, herring and squid fairly good
VI	Warm	1949-55	Fairly good, herring poor, squid (1949-52) good, anchovy, mackerel and horse mackerel increased, sardine poor in south, good in north

The alternative cool and warm periods seem to be on a 7-8 year interval and on a longer 25-30 year interval. These intervals correspond to the fluctuations of cold currents and of the Tusima Warm Current, flowing from the East China Sea into the Japan Sea. Examining the changes in the local yield of sardine, Uda also found that from 1917-1939 catches were good in the north and poor in the south, but from 1941-1950 the catches were poor in the north but good in the south.

D. Uda (1956 and 1958) also noted that the north-south decrease in sardine catch since 1946 was correlated after a phase lag with the southerly intrusion of cold current from the Sea of Okhotsk. This intrusion also caused the sardine fishery areas to contract southward for several years.

In explaining the depletion of the sardine stock, Uda presumed that during the warm period from 1932-1940, the limits of the sardine range and also the fishery extended much farther north than in the cold periods. Thus in warm periods the return migration of adults to the winter spawning grounds to the west and southwest of Kyusyu was not only considerably longer than in cold periods, but was also hindered to a significant extent by the greater strength of the warm, northward-flowing Tusima current. Some sardines may have spawned in unfavourable areas in the southern Japan Sea, where the eggs and larvae were destroyed by the sudden cold in autumn and winter. The southward intrusion of cold water that occurred after 1941 also caused increased mortality among eggs and larvae.

The bluefin tuna fishery showed the same trend. Good catches were made of large, old tuna from 1933 to 1940, but not thereafter.

Since 1941, the prevalent cold water circulation has resulted in increased spawning populations of saury in waters of 16-18°C in the Japan Sea. Long-line samples from depths of 50-200 meters have shown pollack (another cold water species) to be plentiful in the zone of upwelling of cold water of 1-3°C. Swarms of Euphausia pacifica appeared from 1943 to 1948 in 12-14°C water along the coast of the Japan Sea, from Nagasaki Prefecture to Wakasa Bay (Uda, 1952, Matue and Komaki, 1958).

4. Recent warming of the Japan Sea in relation to the sardine fishery

A. Smooth temperature curves for the period 1945-1955 show a general upwards trend with, however, low temperatures occurring in some winters. In cold winters the herring and yellowtail fisheries are generally good, whereas in mild winters they are generally poor. The general upwards trend in temperatures have led to a northward shift in the sardine fishing areas, a declining catch in the southern areas and to northerly extension of the spawning grounds.

B. To the west of Kyusyu in 1944 and 1945, a cold current intruded from the north, and there followed from 1947 to 1951 a period of good sardine fishing. However, in 1951 and 1952, conditions changed rapidly and there was a remarkable inflow of warm water from the south. This resulted in a northward shift of the central plankton blooming area, and rearing and fishing grounds, and to a decrease in importance of the southern fishing grounds.

C. During this same warm period, enormous numbers of horse mackerel (Azi) appeared and spawned further north than usual. There was a marked increase in catch along the whole eastern coast of the Japan Sea south to Hokkaido.

At the same time, there was a similar occurrence of the porcupine-puffer, a tropical species (Nishimura, 1958). The growth of the warm southern current from 1952 to 1956 led to the northward extension of such warm water species as sardine, mackerel, horse mackerel, bluefin tuna, flying fish, jack mackerel, warm water cuttle and jelly fishes.

D. The centre of the sardine fishery has moved north year after year. In 1954 it was off Niigata Prefecture, in 1956 off Yamagata Prefecture and in 1956-57 off Akita and Aomori Prefectures. The sardine catch fluctuates with the intensity and direction of the Tusima Current (T. Shimomura, 1954). The best sardine fishing areas are located in the frontal zone or in eddies formed at the head of the cold water intruded in the meandering Tusima Warm Current and at the coastal front. When high salinity water masses from the Tusima Current approach the coast, good sardine fishing seasons occur and when these water masses occur only well offshore, poor seasons occur (Kozima, 1958). In 1954 to 1957 there was a relative failure of the fishery for large-sized sardines in waters northwest of Kyusyu. The unduly high temperatures resulting from the abnormally strong warm current probably precluded the southward migration of fish from the Japan Sea (see Nakai, 1956).

5. Basic studies of fishery forecasts

A. In the Japan Sea let us consider a species such as the sardine or the mackerel. The spawning populations (N) of this species are found in the winter and mainly in the south. A northwards migration in summer occurs along the Tusima Current (the x direction) with a velocity (c). The rate of fishing (f), of natural mortality (m), and of escapement from the area (d) are constant along the migration route. Then,

$$\frac{dN}{N} = -(m + f + d)dt$$

$$\therefore N = N_o e^{-(m + f + d)t}$$

If the catch (n) is proportional to the population (N) and x = ct, then $n = n_o e^{-kx}$; i.e. the yield decreases exponentially as you move downstream. However, because in fact fronts (convergences), upwelling (divergences) and eddies concentrate the fishing areas, the smooth mean curve will correspond to this exponential decrease (Uda, 1958). This was proved by the Japan Sea Regional Fisheries Research Laboratory (Miyata, 1958). The reproductive potential and the extent of migration varies from year to year with oceanographic conditions.

B. The optimum temperature for sardines lies between 10-18°C. Sardines will therefore migrate earlier in warm years and later in cold years. Uda and Okamoto (1936) were able to forecast the fishing season in each locality from data on water temperatures using the following formula:

$$y = a + bt$$

where y = the first day of fishing, a and b are constants determined for each locality, and t is the number of days between the date of occurrence of a convenient arbitrarily chosen standard temperature and the forecast date of occurrence of the temperature corresponding to the average temperature on the first day of fishing in preceding years. This latter date is forecast from the comparison of the annual temperature curve to the mean temperature curve of preceding years. At Senzaki, in Yamaguti Prefecture, the standard temperature is 19°C, the average temperature on the first day of fishing 15°C, a is 4.5 and b, 0.61. At Hirasawa, in Akita Prefecture, the standard temperature is 8°C, the average temperature on the first day of fishing, 10.8°C, a is 24.7 and b is 0.67. At Senzaki, the first day of fishing can be forecast with an accuracy of 90% ± 9 days, at Hirasawa with an accuracy of 84% ± 5 days.

6. World-wide fluctuations of the sardine fisheries

A. Uda (1952), Marr (MS 1955) and Walford (1954) have all commented on the similarity in the pattern of growth and decline shown by the sardine fisheries in the northern hemisphere (Japan and Korea, California and Spain). In the southern hemisphere the southwest African pilchard has nearly the same temperature requirements for spawning as the Japanese and California sardines. The fishery for this newly exploited species is growing rapidly. Research on the California sardine has made great progress in recent years (Clarke and Marr, 1956, Reid et al., 1958). The California fishery was at a peak from 1936 to 1942, but declined rapidly after 1944 to a minimum in 1952 and 1953. The decline was accompanied by a southwards shift and shrinking of the spawning grounds to off northern Baja California. Since 1954, the catches have improved somewhat; there has been a northerly shift in spawning grounds and an increase in survival rate, accompanying the northerly extension of warm water (1957 was warmer than the years 1949 to 1956). These features coincide well with the trends off Japan. We should study the fluctuations of fisheries in relation to world-wide weather conditions and fluctuations in ocean currents.

B. Abnormal mass mortality in the sardines has been observed at various periods in the growth and decline of fisheries. Such mortalities occurred along the northwest coast of Korea in October 1923 (Nakai, 1939), along the southern coast of Hokkaido in November 1933 (M. Kuragami and Kawana, 1934) and also in 1918 and 1919 (Aikawa, 1957) and among young pilchards in Saanich Inlet and Pender Harbour, British Columbia in January 1941 (Foerster, 1941), several years before this species disappeared from the British Columbia coast. These phenomena appear to be caused mainly by the intrusion of unfavourably cold water during periods of instability in the sea.

Seminar 3. The salmon fisheries

1. A. Japanese salmon fisheries are very important in relation to international problems.

Four genera of Salmonidae are present in the Far-Eastern sea region, as shown in Table 1. However, the commercially important species belong to <u>Oncorhynchus</u>. (For statistics of Japanese high-seas salmon catches see Pacific Fisherman Yearbook and FAO Fishery Yearbook.)

Table 1.

	Genus	Species	English	Japanese
Salmonidae	Oncorhynchus	keta (Walb.)	Chum, Dog	Sake, Sirozake Tokisirazu, Akiazi
	Salmo	gorbuscha (Walb.)	Pink, Humpback	Karahutomasu Sepparimasu
	Salvelinus	nerka (Walb.)	Red, Sockeye, Blueback	Benizake Benimasu
	Hucho	tshawytscha (Walb.)	Spring, King, Chinook	Masunosuke
		kisutch (Walb.)	Coho, Silver, Medium red	Ginzake
		masou (Brevoort)	Trout	Masu, Sakuramasu (Cherry trout)

Yield of salmon and trout in Japan in 1957 $= 49{,}752 \times 10^3$ kan
$= 18.7 \times 10^4$ ton
$= 8.7 \times 10^4$ + restricted mothership yield 10×10^4
in 1958 $= (7 + 11) \times 10^4$ tons
(USSR $= 7.3 \times 10^4$ tons)

Estimated world yield (including USSR) of Salmonidae in 1955 was about 600×10^3 tons (2.2% of total world fisheries yield).

Salmonid fishes are distributed in sub-Arctic cold waters (which coincide pretty well with the area of dichothermal water) and are fished by gill-net, set-net or trap-net, purse-seine and trolling (sometimes by long-line). In the northern Pacific Ocean, within the zone of cold, low-salinity sub-Arctic water, around 50°N (adjacent to Polar Front except on the American continental side and the Asiatic side near the Japanese Islands) the young salmon grow to adults and migrate from their feeding and wintering grounds toward their mother streams on the Asiatic and American coasts respectively. Salmon are generally scattered in sub-Arctic waters (characterized by summer water temperatures below 20°C and salinity below 33.8‰) as far south as 42°N but not in the sub-tropical waters (summer temperatures warmer than 24°C and salinity greater than 34.2‰). However, this southern boundary of salmon distribution moves northward in late spring and summer.

B. Salmon begin their spawning migration towards the mother river when the maturing of the gonads is accelerated by the rise of water temperature in spring in the high seas. Their migration routes may be correlated with an orthogonal line across a favourable temperature zone (2°C - 6°C for chum and sockeye). The salmon approaching the Asiatic continent from Aleutian waters separate into two groups, one migrating northwestward toward the Kamchatka, Sakhalin and Siberian coasts, the other migrating toward the Kuriles, Hokkaido and Japan proper.

C. Of the salmon entering Japanese streams the chum is most important and has been fished from ancient times. Summer chums, called "Tokisirazu", are fished in July and August, mainly along the coasts of northern Hokkaido on the Okhotsk Sea side. Autumn chums, called "Akiazi" are fished on the warmer southern coasts of Hokkaido and adjacent parts of Honsyu from September to December (Japanese Fisheries Agency, 1954). Chum salmon spawn in shallower upstream gravel beds, a favourable temperature being 5°C - 8°C (Sano, 1952) and the young go downstream to the sea in spring (March to May).

The pelagic migration of salmon was investigated by tagging experiments. (During the period 1917-1942 a total of 59,161 fish were liberated and 3,379 were recaptured, i.e. 5.7%. Y. Hirano, 1953; R. Sato, 1937.) The results (I.N.P.F.C. Bull. No. 1, pp. 75-78, 1955) indicate that salmon migration routes have a close relation to oceanic currents (see Uda, 1958, Oceanographic Seminar No. 6). Moreover, the wintering grounds and migration routes of salmon originating in Asia and America can be explained in the light of oceanographic researches (see Uda, 1958, Oceanographic Seminar No. 6).

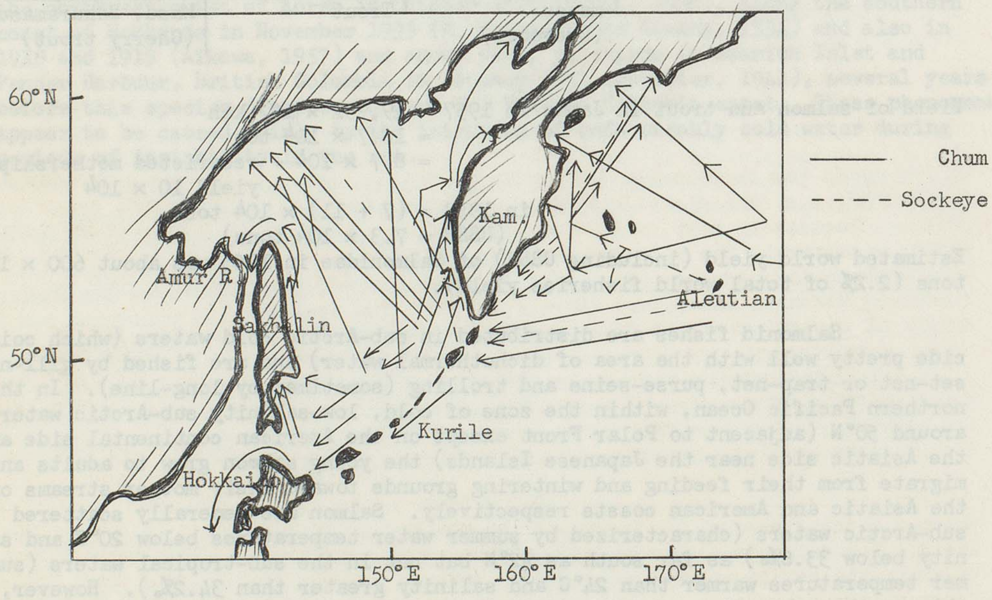


Fig. 1. Tagging Experiments of Salmons
(refer to Hirano, 1950)

2. Water temperature favourable to salmon

A. In Aleutian waters in early May, at the beginning of the fishing season, considerable quantities of chums and small quantities of sockeye congregate in areas where the water temperature is approximately 2°C (K. Yamahira, 1954) at about 165°E and near 48°N, 172° - 178°E (K. Taguchi, 1957). In early June they are found in southwestern Aleutian waters of 4°C (K. Taguchi, 1957).

On the basis of pre-war salmon investigations, Y. Hirano (1953) reported the favourable temperatures for salmon fishing as follows.

Table 2.

Species	Beginning period °C	Prosperous period °C	End of fishing °C
Chum	1-1.5	5-7	12-13
Pink	3-4	6-9	12-13 or more
Sockeye	3-4	6-8	(13)
Coho	5-6	8-10	(12-13)

Later figures: K. Taguchi (1957), sockeye 4° - 6°C; chum (I) 3° - 4°C; chum (II) 4° - 5°C; pink 6° - 8°C. H. Kosugi and Z. Oyake (1955), for waters south of 47°N in summer, chum 4° - 6°C; pink 7° - 13°C but minimum down to 4°C.

Salmon caught in the Gulf of Alaska were in water with temperature of 7° - 14°C (sockeye 9°-11°; pink 11°-12°; chum 11°-12°; coho 11°; spring 12°) and salinity of 31.9‰-33.7‰. No salmon were found in water temperatures higher than 14°C.

It has been proven that chum salmon are distributed over a broader area, including parts of the Arctic Ocean, because of their greater thermal range (2° - 13°C). They appear earlier than sockeye, pinks and cohos in places where very cold water is warming. The evidence suggests that the lower limit of favourable temperature for salmon is near 2°C. On the other hand the water temperature of the fishing grounds adjacent to Kamchatka in late July (11° - 13°C) is near the upper limit of favourable temperature for salmon in the high seas. Chums prefer a lower water temperature than any other species of salmon, whereas coho prefer the highest. In general, the fishable temperature for chums is lower than 12°C and the best catches are made at a temperature of around 6°C (Kosugi and Oyake, 1954).

B. The heaviest concentration of salmon takes place near 4° - 8°C. A close relationship between the vertical distribution of water temperature and that of salmon has been observed. At the lower temperatures prevailing near the beginning of the fishing period, fish were gilled mostly in the upper part of the drift gillnets. The catch in the lower part of the nets increased with the rise of temperature as the season approached an end. However, salmon tend to stay away from the deeper layers since the catch was always greater in the upper than in the lower part of the net even at the end of the salmon fishing season.

Salmon have diurnal vertical migrations, swimming deeper in daytime than at night (Y. Hirano, 1954). It is reasonable to infer that salmon stay out of the Okhotsk Sea and the Bering Sea in winter, since the very cold water would not be at all favourable to them.

3. Current patterns and water masses in relation to salmon migration and feeding grounds

A. By means of drift-bottle experiments K. Taguchi (1957) showed that the migration of salmon in summer from offshore waters toward the coast of Kamchatka coincides well with the direction of currents in conjunction with the shifting of an isotherm of about 3°C.

B. H. Aikawa and G. Okamoto (1942) reported that the front of the warm branch current approaching the North Kuriles from the south in summer corresponded with the most favourable salmon fishing locality in this area. Similarly in the southern offshore waters of Hokkaido during the fishing season from March to July the concentrated fishing grounds for salmon are found in the favourable temperature zone of 2° - 10°C (centre 5°) for chum and 4° - 12°C for pink at the head of the warm branch current (Sugi, 1942). Off the southern part of west Kamchatka at about 52°N concentrated sockeye grounds are also found near the front of cold and warm waters (K. Ogaki and Ikeda, 1935).

Dominant foods for salmon are crustaceans (Copepoda - Calanus plumcrus, C. finmarchicus, C. cristatus, etc.; Euphausiacea - Euphausia thysanoessa, E. themisto, etc.; Amphipoda); also forms higher in the food chain such as the fry of Gadidae, Hexagrammidae, small-sized fishes (Clupeidae, Myctophidae) and squid. Occasionally, in addition to the above, considerable amounts of crustacean larvae and pteropod larvae are taken, according to studies of the stomach contents of adult salmon (Y. Hirano, 1943; T. Tamura and S. Kawai, 1953; Z. Nakai and K. Honjo, 1954).

Concerning the feeding migration of concentrated salmon, it is important to find how, where and when areas of abundant food supplies are produced. In general, the frontal zone, where the cold waters of the East Kamchatka Current meet the warm waters belonging to the North Pacific Drift, forms remarkably rich feeding grounds (Beklemishev and Burkov, 1958; P.A. Moiseev, 1958; R.S. Semko, 1958) and fishing grounds (K. Taguchi, 1957) for salmon.

C. By associating records of catches per boat per day with temperatures, Taguchi reported the following:

(i) Favourable fishing grounds for sockeye and chum are found in May in waters of 3°C - 4°C located at about 49°N (165°E - 172°E) with southern limit estimated as 45° - 46°N. In June-July there is a northward shift to waters off southeastern Kamchatka at about 51°N. In this shift chum fishing ground always precedes sockeye fishing ground.

(ii) Favourable fishing ground for pink salmon in mid-June at about 163°E - 168°E is in water of about 6°C south of 48°N (in comparison with chum and sockeye, pinks are located more to the south). From this area pinks move in late June and early July in a northwest direction towards North Kurile waters, with a northern limit at about 51°N.

(iii) Coho salmon appear in mid-July in relatively warm water of 8° - 10°C. In early August the main dense group appears at about 158°E - 163°E, with a northern limit near 51°N. Immature small-sized chums and sockeyes inhabiting 8° - 10°C water to the east of the cohos follow the latter in their westward movement.

D. The southern limit of salmon distribution in summer was assumed by Burodovsky (1955) to be near the 12° - 13°C isothermal zone (less than 15°C) where the food biomass is greatest.

The migration route may be determined by the connected line of food-abundant localities corresponding to eddies in the frontal zone. These vary year by year in their time of development as well as in their north-south and east-west positions, according to sea conditions in relation to climate.

Approaching the coast of Kamchatka the adult spawning population separates from the immature fish populations. I.V. Birman (1958) inferred that the 5°C isotherm was the approximate northern wintering (feeding ground) limit of pinks of Kamchatka origin along the Polar Front, these being located mainly southeast of Kamchatka and the North Kuriles, west of 170°E. Chum and sockeye feeding grounds in the summer of 1956 were found in regions from the Kuriles to the Aleutians at temperatures lower than 13.5°C.

E. On the basis of NORPAC data (summer of 1955) J.P. Tully and A.J. Dodimead (1956) discussed "salmon waters" in the Northeastern Pacific. Salmon are distributed in the region along the Aleutians and in the Gulf of Alaska (10° - 12°) north of 48°N and vertically in the homogeneous upper zone 10-20 meters in depth. South of 38°N in sub-tropical water (temperature warmer than 24°C, salinity higher than 35‰) no salmon exist. On the other hand salmon in the North Pacific prefer surface temperature from less than 5°C up to 14°C, and the young in fresh water prefer 12°C - 14°C (F. Neave, 1958). (Refer to J.R. Brett, 1952).

We may conclude that spawning salmon are attracted from the high seas to low-salinity coastal waters on the Asiatic side near Kamchatka and on the American side near Alaska, British Columbia and California.

4. <u>Mechanism of environmental effects on salmon</u>

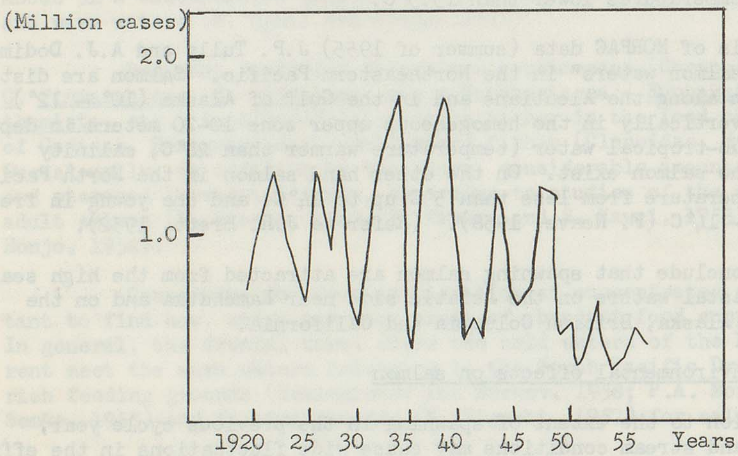
In addition to the extent of spawning in the previous cycle year, climatic, oceanic and stream conditions may cause wide fluctuations in the efficiency of production (Foerster, 1955).

Rheotaxis is predominantly positive at low temperatures but frequently becomes actively negative at higher temperatures. A positive response was usual at temperatures normally prevailing during the seaward migration (Foerster, 1955). The use of meteorological and oceanographical records for estimating the return of adult fish (commercial catch or catch plus escapement) should be studied more closely (e.g. W.J. Menzies, 1949, p. 71). Mention can be made of studies such as those of F. Neave and W.P. Wickett (1949) in which the amount of precipitation in July and August is correlated with the success of the next generation of returning pink salmon adults in B.C.; also the experimental physiological approach by J.R. Brett (1957). F. Neave (1958) showed a close correspondence between the catches of adult Cowichan River cohos (per unit of effort) and the minimum summer flow of the river two years previously.

5. <u>Fluctuation of salmon yields</u>

A. The Far-Eastern salmon yields along the Kamchatka and Siberian coasts have declined in recent years as have the Alaskan salmon fisheries (P.A. Moiseev, 1958; Pacific Fisherman Yearbook, 1957). It has been prematurely supposed by some that the main cause was overfishing by the Japanese high-seas salmon fisheries. However, by inspection of graphs it can be seen that the declining trend began before the Japanese high-seas fishing. The peaks of sockeye pack yields were in 1930-1940 in Bristol Bay, Alaska, in 1890-1910 in central Alaska and in 1925-1935 in the Kamchatka River, Ozernaya River and Amur River of USSR. The North Atlantic salmon yields provide a similar case. The fluctuation of natural environmental conditions such as the falling of water levels and freezing of spawning redds due to climatic change, together with deforestation, water pollution, dam obstruction, effect of natural enemies, predators, etc. and changes in survival or mortality due to changes in ocean climate, may be mainly responsible for such a broad change in sub-Arctic waters.

Fig. 2. Pinks



Sockeye pack in Bristol Bay similar to Pink, Herring (Alaska) fluctuation

B. Long-term changes in oceanographic conditions (water temperature, salinity, currents and planktonic food biomass) may initiate higher mortality or lower survival in marine life and consequently may result in the decline of salmon resources.

Whether there has been a general decline and northward shift of salmon stocks or fishing grounds in conjunction with the sub-Arctic warming is a question. In Kamchatka waters the early salmon resources declined remarkably during the latter half of the 19th century and afterwards recovered rapidly to the maximum of 1925-35, with another decline since about 1940 (USSR authors, Krogius, Krochin, 1953, 1956). In the Ozernaya River (West Kamchatka) the salmon yield declined from about 1940 but in 1944-53 it rapidly increased again. The yield of Kamchatka River salmon during the period 1942-47 was stabilized at a lower level than formerly; after 1948 it declined rapidly.

According to Semko (1954) the decline of Kamchatka sockeye began in 1948, when the climate became warmer. P.A. Moiseev (1955) noted that the Anadir zoogeographical barrier which determined the northern limit of boreal fishes (cod, Alaska pollack) in 1931-33 disappeared in 1953. These fish moved north and afforded dense new commercially available populations.

Concerning sockeye salmon resources, the varying mortality during their long life in lakes and in the high seas (the latter hitherto not well known) should be more closely studied in relation to natural environmental conditions as well as artificial influences including fishing, management and conservation.

C. R.E. Foerster (1955) remarked of B.C. salmon: "Analysis suggests that either the environmental conditions are becoming progressively less favourable or the fishing pressure is too great, especially on the declining catches of chums in the northern areas".

D. How can we account for the alternate high and low yields shown by odd- and even-year pink salmon (or by certain sockeye cycles) and the changes in relative magnitude of these cycles which sometimes occur after a number of years, e.g. in Japan in 1926-32, the big pink salmon runs were in even years while in 1935-57 they were in the odd years. In the Fraser River, B.C., from 1897-1925 the big sockeye runs were in odd years, but from 1930-58 they were in even years. Statistics of the pack of Skeena River sockeye from 1902-57 show that even-year catches have nearly always been greater but a few maxima have occurred in odd years. (Refer to F. Neave, 1953 a and b).

Pink salmon populations have declined remarkably in recent years, perhaps because of climatic changes affecting broad areas, since this species increases when cold water circulation is prevalent and decreases when warm water circulation is prevalent (A.G. Kaganovsky, 1949). Extremely cold years (such as 1941) delay the growth and maturity of sockeye of Asiatic origin. According to G. Svärdson (1958) a significant correlation was found between the area of maximum ice-cover of the Baltic Sea and the salmon yield five years afterward. Two or three years after a mild winter another peak in salmon yield is found.

E. It is inferred that the main wintering grounds of chum and pink salmon of Asiatic origin are in the waters south of the Aleutians (mainly for fish of Kamchatka origin) and in the waters southeast of Hokkaido-Kurile Islands, where water temperatures may be from 2°C to 13°C, commonly 6°C - 10°C, near the cold cores in the sub-Arctic waters (Uda, 1958, Oceanographic Seminar No. 6).

F. Reviewing the racial studies of sockeye salmon based on scale pattern, parasites, morphological and serological investigations, United States investigators (I.N.P.F.C., 1957) postulated that sockeye salmon in the waters east of 175°E are 90% of North American origin. However, in 1957 (warmer than 1955 and even than 1956) a higher percentage of salmon of Asiatic origin was found between 175°E and 175°W (Japan Fisheries Agency 1958). It seems that in conformity with the oceanographic pattern which is related to year-by-year changes in weather conditions, the pattern of intermingling of salmon of Asiatic and American origin may fluctuate year by year and should be established by long-continued surveys.

6. A. The heavy catch of sockeye in the high seas of the North Pacific and Bering Sea in 1957, in contrast with a poorer than expected catch in Alaska, may be attributed to the abnormal meteorological and oceanographic conditions of that year, which were in marked contrast to those of 1958. In 1957 the water temperature in the Aleutian and Bering Sea areas was about 2°C warmer than in recent previous years, while the waters of the Oyashio along Kamchatka and the Kurile Islands were 2°C below normal. The strengthened South Aleutian Warm

Current against the strengthened Oyashio Cold Current formed a conspicuous oceanic front in the western central sub-Arctic waters and changed the migration route of salmon (especially sockeye) and the areas in which the fish were concentrated - consequently the fishing grounds. As a result the restricted high-seas fishery made a big catch in the northwestern sea region against a poor catch in the southern region. Weather conditions were also abnormal in 1957.

(i) The high atmospheric pressure system of middle latitudes of the North Pacific was weaker, whereas the Northern Arctic high pressure system was stronger. In consequence, easterly winds developed and the cyclone path was pushed farther south than usual.

(ii) Fishing areas were covered by the high pressure area, with weaker winds, calm weather, less cloud cover and more warming of the sea by insolation. Fishing operations were helped by absence of storms and the heavy fish population became available in a high degree.

B. In 1958 the sea and weather conditions were completely changed from the previous year.

(i) Drift ice was seen abundantly even in July in the southeastern waters of Kamchatka. Water temperature was lower than normal. The persisting dichothermal water obstructed the South Aleutian Warm Current and consequently the migration route of salmon was pushed to the south. The front (Siozakai, Siome) was very obscure and fishing grounds were not well developed.

(ii) This was a poor year for high-seas sockeye and also for pink salmon in northern Aleutian waters. However, relatively good pink salmon catches were made east of Hokkaido at 44°N to 45°N, west of 165°E. In 1958 the fishing areas were south of 48°N and did not extend to the normal 51°N.

(iii) The year was stormy and colder. The Pacific high pressure area, although weak, shifted to the east and NW or W winds prevailed. Temperature rise was remarkably delayed.

C. In conclusion, in the interests of conservation and management of salmon resources and fisheries, closer investigation of the ever-changing environmental conditions should be promoted.

7. Problems of finding useful prediction indices

A. Long-term fluctuations of North Pacific fisheries (salmon, etc.) and oceanographic conditions, with reference to world-wide fisheries and climatic changes.

(i) Can a general northerly shift of favourable or unfavourable fishing grounds be seen in the fluctuations of the various regions?

(ii) Can long-period cyclic changes be recognized?

B. Causes of the remarkable fluctuation of North Pacific fisheries (salmon, etc.) and especially the so-called decline of salmon fisheries in recent years.

(i) In relation to natural environmental conditions.

(a) Natural changes. Heavy larval mortality due to dry weather, flood, freezing, abnormal high temperature, stream flow, natural enemies, etc.
(b) Man-made environmental changes. Deforestation, water pollution, dam construction, destruction of redds, etc.

(ii) Overfishing problem. Fishing intensity.

C. Natural mortality in the oceanic life of salmon, compared with freshwater life, and the environmental causes. (Refer to R.E. Foerster, 1955; F. Neave and R.E. Foerster, 1955; W.J. Menzies, 1949, pp. 71, 94; J.I. Manzer, 1958.)

(i) Marine mortality due to shortage of food in the sea.

(a) Growth rate (size, weight).
(b) Abundance of plankton and small food fishes.
(c) Rate of recovery from ocean tagging.

(ii) Natural mortality during the spawning migration toward rivers.

D. Relation between fluctuations in abundance and catch in the past and natural environmental changes.

(i) Instability of fisheries from year to year, corresponding with variations in sea and weather conditions, which affect availability and fishing operations (e.g. the contrast between salmon fisheries of 1957 and 1958).

(ii) Causes of "odd"- and "even"-year salmon runs and 4-year or 5-year cycles, and of changes in these cycles.

E. Distribution of salmon and its variation in relation to water masses and their boundaries (borderlines, fronts or frontal zones).

(i) "Salmon water", its characteristics (refer to Tully and Dodimead, 1956).

(ii) Existence of "salmon water" for different populations of each species.

(iii) Changes in the location of these waters due to fluctuation of sea and weather conditions.

(iv) Intermingling and mixing ratio of salmon populations of Asiatic and American origin in relation to the characteristics of water masses. Results of tagging, parasitological, serological and morphometric studies.

(v) Localities, extended areas and seasonal variations of salmon feeding grounds, including wintering grounds, in relation to their environmental conditions. Especially, in spite of stormy weather conditions, the life of each species of salmon should be studied in the unknown wintering period by sampling and by oceanographic surveys in relation to eddies, gyrals, etc.

F. Migration routes of salmon, as determined by tagging and marking experiments, biological studies and fishing ground statistics, in relation to currents and extended water masses.

(i) The effect of cumulative water temperature on the start of salmon migration (where and when do concentrated schooling and dispersal occur?).

(ii) Changes in the migration pattern of salmon in relation to environmental sea conditions.

G. The oceanographic structure responsible for the areas of concentration (favourable fishing grounds) of salmon. The oceanographic and weather conditions correlated with heavy upstream runs of salmon.

H. Fluctuations of salmon fishing operations due to weather and sea conditions (increased escapement due to stormy weather, etc.).

I. Salmon runs, rate of oceanic survival and fishing conditions in relation to occasional occurrence of great schools of albacore, pilchard, mackerel, herring, etc., associated with warm and cold intrusions.

Seminar 4. The Pacific saury and the squid fisheries

1. Pacific saury (Cololabis saira Brevoort) or "Sanma" in Japan

A. The Pacific saury is distributed in the waters of the East China Sea, Japan Sea and the Pacific Ocean from off the Kurile Islands and Hokkaido in the north (50-45°N) to off Okinawa and the Bonin Islands in the south (25°N) and between 126°E and 160°E longitude, i.e., in waters of from 12° to 20°C in temperature. (Refer to H. Kasahara and N. Otsuru, 1952.)

Its annual production at present (1957) amounts to 400,000 to 500,000 tons (Table 1) and the catches made by the stick-held dip-net fishery using fish lamps have contributed greatly to the Japanese seafood supplies since World War II. In Figure 1 are shown the Pacific saury fishing areas and an inset graph shows the trend in yield since 1946. The post-war fishing capacity of saury fishing boats has been greatly increased by the utilization of larger vessels and modern gear and equipment (Table 2). However, when catches are large, difficulties arise in distributing the fish products to the local markets, storing them and maintaining good quality. Prices decline. This matter of distribution to consumers is now a serious problem. In 1958 the Russian fishing fleet also participated in this fishery in the waters adjacent to northeastern Japan, using powerful fish lamps.

Table 1. Saury yields in Japan (Unit 10^3 Kan = 3.75 tons

Year	Tons	Year	Tons	Year	Tons
1894	1176*	1912	15952**	1947	6134
1896	1474**	1913	9354	1948	17599*
1898	79	1916	6434	1949	16996
1901	137	1921	5867	1950	33696
1902	327	1925	17093**	1951	34998
1903	579	1926	10009	1952	60194
1905	202	1930	5610	1953	67643
1907	1196	1935	4605	1954	78058
1909	3946	1940	7111**	1955	132534**
1910	3720	1945	823	1956	874147
1911	4853	1946	2737	1957	108243
				1958	(rich year)

* Since 1948 drift gill-net fishing changed into highly efficient stick-held dip-net fishery, using fish lamps.

** The catch maxima in 1896, 1912, 1925, 1955 show a cyclic interval of nearly 15 years.

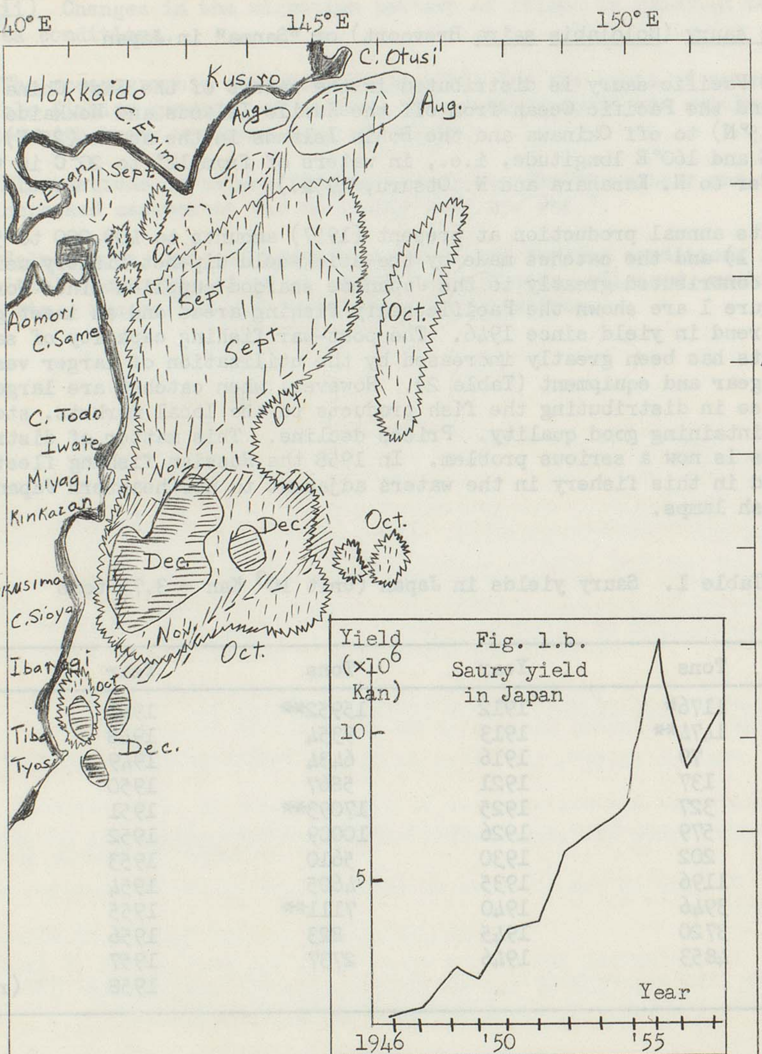


Fig. 1. Saury Fishing Grounds and Catch.

Table 2. Saury fishing boats in 1957, 1909 in number (41,076 cruises).

Vessel size (tons)	Number	Days out	Catch × 10^3 Kan	Catch per cruise (Kan)
10	362	1.0	1953	333
10-20	384	1.2	849	903
20-30	272	1.6	12724	1589
30-50	305	2.9	20565	3243
(20-50)	(577)	-	(33290)	(2320)
50-100	487	3.4	50777	5007
100-200	99	4.4	14212	8618

(1 boat/cruise out to sea on an average of 2.2 days)

The fishing areas extend practically from the waters in the vicinity of the Polar Front (Oyashio Front or Sub-Arctic Convergence) to the Kuroshio Front in the northwest Pacific but the fish are distributed broadly much further to the south, north of this Sub-tropical Convergence where they spawn in December to May (mainly during the winter in the Kuroshio Counter Current area). Sometimes tangled eggs are found attached to tuna long lines or other gear.

As for saury distribution in the Eastern Pacific, information is still being collected. Canadian fisheries scientists have already reported, on the basis of exploratory fishing operations, on the possibilities of developing important fisheries for saury and the tasty pomfret (Brama raii or Ray's Bream) on the high seas off North America. The recent USSR Oceanographic Expedition of the "Vityaz" has reported large aggregations of saury present in high-seas areas of the North Pacific during a cruise from October 5 to November 15, 1958. Also refer to U.S. Fish and Wildlife Service, Special Scientific Report, Fisheries No. 190, 1956 and California Co-operative Fisheries Investigation Progress Report (July 1956 - July 1958), p. 11.

B. Saury reach maturity at the end of the third year, at a body length of around 27 cm, and may spawn several times, each female fish releasing from 700-5,000 eggs during the spawning season. Spawning occurs from November to June, in northern waters the dominant periods being November and June whereas in more southern areas the main season is March. The reproduction potential of the saury and its spawning brood strength is reported to be extremely high.

The eggs and larvae are transported and dispersed northward by the Kuroshio and Tusima Currents and their northward extensions and, during the northward feeding migration in spring and summer (May, June and July) in the offshore waters of the west, south and east coasts of Japan, the saury are caught in small quantities by set nets and certain primitive types of gear. The northward migration follows an optimum temperature zone of 16°-18°C, which is also the zone used subsequently by the southward spawning migration. Fish of the '0' age group tend to approach close to the coast and migrate to sub-Arctic waters.

Biological studies of saury and their population dynamics have been conducted by M. Hatanaka (1955) and others at the Tohoku Regional Fisheries

Research Laboratory (Siogama). Success or failure in the yearly production of young, which depends largely on natural environmental conditions, determines the abundance of the adults appearing on the fishing grounds which are chiefly off the northeast coast of Japan.

The main food of saury appears to be the pelagic crustacea (copepods, euphausiids, chaetognaths, etc.) and fish eggs.

Saury, when chased by the larger predators such as the tunas, marlin, porpoises, fur seals, etc., skip along the surface of the water, hence the common name, "Skipper".

By making use of the strong phototactic response of the saury, which exists at all stages except when near spawning time, fishing is done by using electric fish lamps, as already mentioned above. The size and power of these lamps is controlled by Government regulation.

C. During their migration from north to south in the autumn of each year, the large-sized saury appear first, then the medium-sized ones and finally the small ones. When the migrating schools are stopped by the intense Polar Front the composition of the sauries landed shows a bimodal length frequency curve, the modes usually lying at 26-29 cm for the most abundant adults of the III-year class and some IV-year, and at 30-33 cm for the IV- and V-year groups. Early in the fishing period there may also be a mode at about 23 cm. When, however, the saury schools migrate quickly and are not obstructed by fronts, the length-frequency curve is unimodal.

D. Saury fishing grounds. As shown in Figure 1, the main saury fishing grounds move monthly during the autumn from north to south. They develop in the contact zone of the warm and cold currents (Oyashio Front), i.e. in the area (36°-43°N, 141°-147°E) around the Polar Frontal Zone within 300-600 sea miles of the Japan coast.

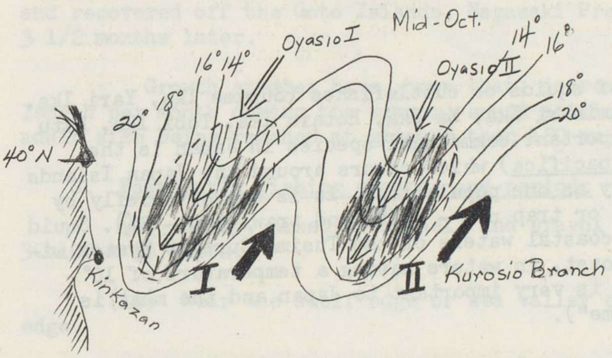
The availability during a prosperous season (fishing efficiency or number of cruises) depends on the sea conditions resulting from the fluctuations of the Oyashio and Kuroshio Currents. In 1955 the Polar Front approached closer to the coast and greatly increased the availability. This produced denser concentrations of saury and resulted in large catches (Table 3).

Table 3. Seasonal variation in Pacific saury fishery in 1955 (biggest year).

	Days out to sea per boat	Fishing days per boat	Number of hauls/day	Landings per boat (Kan)	Catch per haul (Kan)
Mid Sept.	3.1	1.5	11.4	7840	470
Late Sept.	4.2	2.0	11.2	11140	505
Early Oct.	2.3	1.6	11.3	7120	408
Mid Oct.	2.2	1.6	10.2	6620	428
Late Oct.	3.6	2.2	9.7	5240	255
Early Nov.	2.6	1.9	10.5	9100	479
Mid Nov.	3.0	1.9	10.5	5210	276
Late Nov.	3.0	2.9	9.9	3520	186
Early Dec.	3.2	1.7	9.9	5080	303
Mid Dec.	2.8	1.9	6.5	1310	122

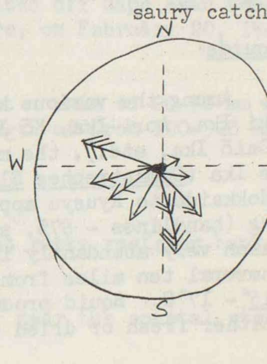
M. Uda (1930, 1936) first pointed out the correlation between the monthly movements of the saury fishing grounds and the shift in the optimum (15°-18° C) temperature zone due to the growth of the Oyashio Current. The two migration routes appeared to be determined by the offshore and coastal distribution of the Oyashio Cold Current. Furthermore, he showed that the core of the fishing area was located at the head of the Oyashio Current near the Oyashio Front, forming somewhat easterly eccentric elliptical contours of iso-catch curves, their main axis coinciding with the current axis (M. Uda, 1936, 1938). These features are shown in Figures 2 and 3. In Figure 2 the catch per net haul was greatest in the direction of the southward current. During the mid-October period Fishing Ground II vanishes and amalgamates with I. In November and December, Fishing Ground I continues to move southward. In the current rose of Figure 3, the length of the arrow is proportional to the saury catch.

Fig. 2. Saury grounds off Kinkazan



Late Oct. II vanishes or amalgamates to I.
In Nov., Dec. I only moves southward.

Fig. 3. Current-rose and saury catch



Length of arrow is proportional to the square of saury catch.

M. Uda and N. Watanabe (1938) have referred to the relation between the sudden and rapid movement of the saury fishing grounds and the passage of cyclones in autumn, accompanied by a temperature drop of 1°-3° C in the water. Passage of typhoons in autumn tends to scatter the saury schools and brings about an earlier termination of fishing.

S. Ikeda (1931, 1933) has reported that, within the range of favourable water temperatures, 13°-20° C for saury fishing, the optimum temperature gradually drops as the fishing season progresses. H. Aikawa (1933) noted the variation in favourable water temperature month by month - Sept., 14°-20° C; Oct., 13°-21° C; Nov., 12°-22° C. These optimum temperatures vary greatly in some years, e.g. in 1949, to 13°-15° C, which is much lower (around 3° C) than normal (Reports of the Iwate and Ibaragi Prefectural Fisheries Experiment Stations, 1950).

E. According to K. Kimura and S. Fukusima (1956, 1958) the tremendous catch in 1955 was due to the peculiar sea conditions resulting from the extension of the Oyashio Front from the north off Hokkaido and Aomori directly to the southwest. As a result, the fish schools were concentrated closer to the coast.

At the beginning of the saury fishing season south of Hokkaido and the Kurile Islands young immature fish, called "Nankin Sanma", are abundant. As the fishing season progresses the large and middle-sized sauries cover the area.

When the Polar Front varies in a latitudinal E-W direction (Tugaru and Kuroshio Currents stronger) the saury fishing grounds remain for a longer time off Hokkaido, providing abundant catches in the Hokkaido area but poor ones in more southern waters. When the Polar Front varies in a meridional (N-S) direction the fish move southward earlier, resulting in poor catches in the Hokkaido region. Along the north coast of Hokkaido (Okhotsk Sea side) the saury catches are very sporadic due to the abnormal sea conditions, e.g. in the autumn of 1951.

During the summer the Japan Sea groups of saury pass through Tugaru Strait and mingle with the Pacific saury groups (K. Kimura, 1957).

2. Squids

A. Among the various kinds of squids or cuttlefishes (Surume Ika, Yari Ika, Kensaki Ika, Aori Ika, Kō Ika, Kaminari Ika, Ma Ika, Hotaru Ika, Tobi Ika, Matu Ika, Daiō Ika, etc.), the most important commercial species in Japan is the Surume Ika (*Ommastrephes Slaanii pacifica*) which occurs around the Japan Islands from Hokkaido to Kyusyu apparently as one population. It is caught chiefly by angling (handlines - 87%, set net or trap net - 7-8%, and trawl net - 3%). Squid are taken very abundantly in the coastal waters of the Tusima Current System within several ten miles from the coast, in waters having a temperature of 10° - 14° - 15° - 17° C. Squid production is very important to Japan and the meat is used either fresh or dried ("surume").

Table 1. Statistics of squid catches

Year	Catch metric tons	Year	Catch metric tons
1905	30,000	1945	108,495
1910	37,900	1946	129,150
1911	44,060	1947	254,378
1913	82,400	1948	301,328
1915	54,700	1949	257,464
1916	94,400	1950	268,204
1919	33,100	1951	517,328
1921	52,000	1952	656,445
1925	203,400	1953	467,925
1930	60,000	1954	443,299
1933	114,760	1955	434,500
1935	41,100	1956	354,500
1941	172,900	1957	435,000
1943	155,300		

The yield in 1952, the peak year in squid production, was 656,000 tons or 15% of the total fishery in Japan. In recent years, fishing methods have been improved (e.g., many hooks now attached to the handline, called "Suzuran Duri") and larger vessels with increased horsepower have been used. Electric fish lamps have been also more widely utilized. However, the principal cause of the increase in catch must be attributed to the increase in populations of squid generally, resulting from favourable environmental conditions in recent years.

B. Squid (Surume Ika) have a south to north feeding migration in spring and summer seasons whereas in autumn and winter a reverse north to south spawning migration occurs, often over long distances (Fig. 4). The migration route and the speed of travel have been determined by tagging experiments made by the Hokkaido Fisheries Experiment Station. From 1928 to 1932, a total of 10,584 squid were liberated (T. Isahaya, T. Kawana) and, from 1946 to 1951, some 56,577 (J. Soeda) in the waters off Hokkaido. Recaptures have been made along the coasts of the Japan Sea (Sado, Oki, Tusima, Goto Islands, etc.) and on the Pacific sides of Japan (Iwate, Miyagi, Siduoka and Wakayama Prefectures, etc.). For example, on November 6, 1946, tagged squid were liberated off Cape Esan (Hokkaido) and recovered off the Goto Islands, Nagasaki Prefecture, on February 20, 1947, 3 1/2 months later.

Growth studies have shown that, increasing at a rate of 20-30 mm mantle length per month during the summer, squid attain a length of from 100-320 mm, adult size being reached at greater than 180 mm.

C. <u>Favourable fishing grounds and periods</u>

(i) Sandy, mixed with shell and gravel or flat rocky reefs or banks, 30-100 m in depth.

(ii) Near the shelf edge or sea valley edge or near the coastal steep edge.

(iii) During the daytime, sink to the bottom, and at night ascend to near-surface strata, similar to the Deep Scattering Layer.

(iv) Cloudy, calm and warm declining weather. Rainy or windy weather and strong tidal current flows result in the squid sinking to lower strata.

(v) The deeper cold water, through upwelling, has an influence on the upper warmer zones in which the squid are swimming.

(vi) If the vertical temperature gradient is great, e.g. 10° or more, the catch is not good; if medium, e.g. 5° or thereabouts, the catch is good; if small, it is again poor.

(vii) If the daily water temperatures at the 20-40 m level varies fairly rapidly the catch is good; if it is slower, the catch is poor.

(viii) Eddies, with upwelling (coastal upwelling, near banks and islands).

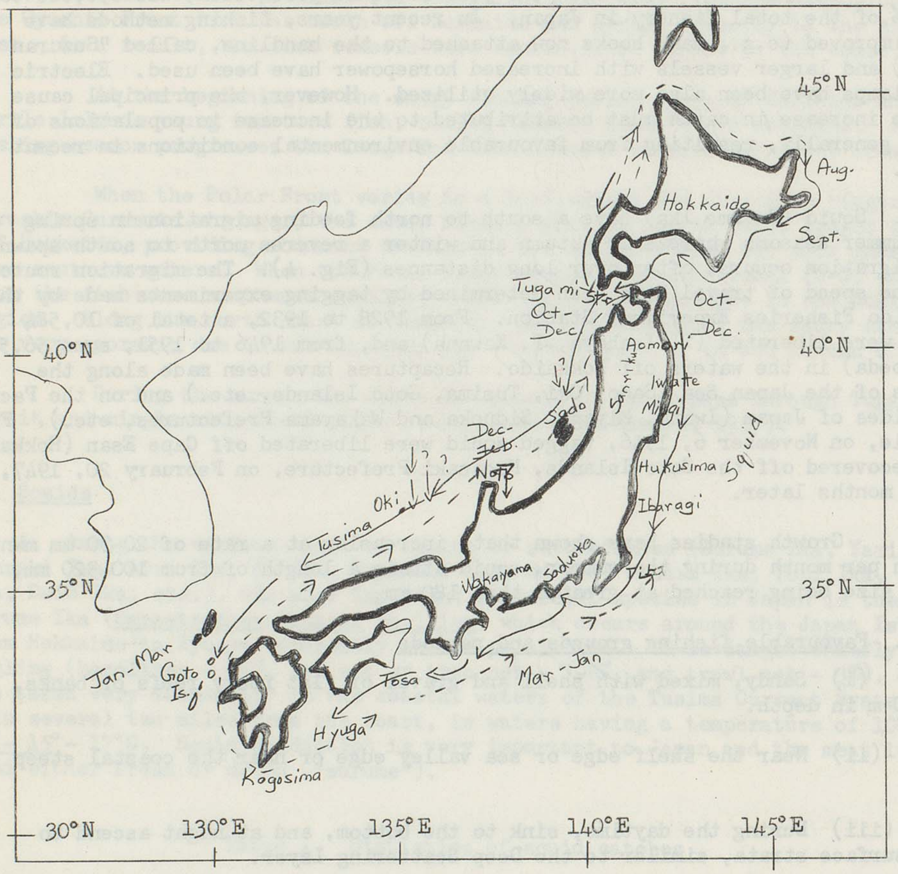


Fig. 4. Squid migration.

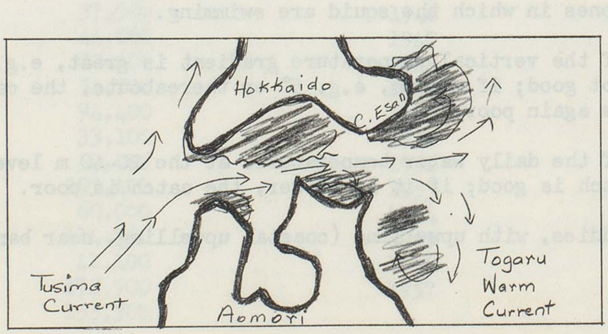


Fig. 5. Squid fishing grounds in relation to coastal eddies and fronts.

D. Fishing season

Northward: Northwest of Kyusyu in February and March;
Oki in April;
Noto and Sado in May;
South Hokkaido in mid-June;
Wakkanai-Sado, Cape Erimo to Kinkazan in July;
South Sakhalin-Akita, S.E. Hokkaido-Sanriku in August;
Mamiya Strait-Tugaru Strait, S. Kurile, Etorof-Tugaru Strait in September;
S. Sakhalin-Tugaru Strait, Nemuro Strait-Tugaru Strait in October;

Southward from Hokkaido: Soya Strait-Noto, S. Hokkaido-Tiba Prefecture in December.

Since the squid are mostly one-year-olds (2-year-olds being rare) and normally spawn and die at the end of the first year, the spring-summer northward migration consists of smaller-sized individuals. The waters off Hokkaido appear to be the northern limit of squid distribution and migration, and here, where they remain longest, nearly half the year, the best fishing grounds are found. Here the best catches are made. Especially around Tugaru Strait is centred the main squid fishing ground where in summer, squid of relatively smaller size are taken and, in the autumn larger individuals.

The spawning grounds of the squid have not yet been clearly defined. However, K. Yamamoto, 1953, and T. Kawana (1953, 1957) have suggested the Tusima Strait area as the main spawning region based on collections of larvae above the deeper rocky reefs and banks. Water temperatures in this area in winter are greater than 16°C. Off Noto, Oki, etc., where winter water temperatures greater than 10°C occur, spawning may also occur. It is also suggested that from these areas the squid larvae are carried by the Tusima Current and the West Kyusyu Coastal Current to the Pacific side of Japan.

E. Favourable fishing conditions and fluctuations therein

(i) Since squid swim up and down in the 20-50 m stratum of water, the cooling off and sinking of the warmer upper layers of water by the upwelling of lower cold water or by the intrusion horizontally of colder water leads to a concentration of the squid and consequently creates a very favourable fishing area. BT observations of the thermal structure of waters is very helpful in locating squid fishing grounds.

(ii) Dusk and dawn are the best times for fishing squid. At these times of the day the squid swim up near the surface and are actively feeding. Accordingly, they are then at maximum availability. The fish-finder is very useful in finding squid, also in finding the location of the food animals by echo trace of the DSL.

(iii) The full moon period is in general a time of poor fishing, in comparison with new moon or half moon phases, mainly by reducing the effect of the fish lamps.

(iv) Good fishing occurs at tidal-change periods, such as from high water to low water and conversely.

(v) At the most successful squid fishing season in Hokkaido waters, i.e. November to early December, sudden storms frequently strike the small squid boats and cause disaster. Just before the storms arrive, however, the fishing is usually exceedingly good, though it is also dangerous.

(vi) A good catch by one boat per night is 1000 Kan (nearly 4 tons) and by one person - 100 Kan. A record catch off Cape Esanmisaki by 20 fishermen with hand-lines in 4 hours amounted to 1300 Kan (260 squid/man/hour or 4.3 squid/min.).

(vii) During the winter the fishing conditions for squid and yellow-tails are similar with respect to ocean and weather conditions.

(viii) Rich and poor years of herring and squid fishing appear to occur in Hokkaido waters alternately.

(ix) In the autumn of 1956 the abnormal development of a cold front off Cape Erimo caused the migration path of the squid to swing to Sanriku (Pacific side) and resulted in a very poor fishery in the Hakodate (Tugaru Strait) area. The location of the Polar Front during the autumn months is a most important factor in setting up the migratory path of the squid and thus, in large measure, controls the success or failure of the Hokkaido squid fisheries.

(x) In the Japan Sea area the squid catches appear to have a long-period variation, as follows (M. Uda, 1958):

Warmer period		Cooler period	
1917-1921 1932-1940 1954-1955	sardine catch, good squid catch, poor	1913-1916 1922-1926 1941-1952 1957-1958	sardine catch, poor squid catch, very good

In the Japan Sea periods of very good squid fishing correspond with periods of cooler water (especially near the end of such periods) and of stronger cold currents.

(xi) In years when the squid populations and the fisheries are good, the squid are present over wider areas and migrate further than in poor years. This is presumed to be due to a change in survival rate because in poor years the southerly spawning migration is adversely affected by the stronger warm current in winter.

Seminar 5. The tuna and Skipjack fisheries

1. General. The early bluefin tuna fishery took place in coastal waters. In Japan, in recent years, longlining for tuna has developed rapidly and at present is being carried out in the Pacific, Indian and Atlantic Oceans. The Japanese annual catch of tunas for the period 1953-1957 is shown in Table 1 (statistics were provided by the Japanese Fisheries Agency, 1958).

Table 1. Japanese annual catch (metric tons) of tunas, 1953-1957

Fishery	1953	1954	1955	1956	1957	Ratio 1957/1953
Mothership longline	8,030	14,119	14,064	11,183	14,104	1.74
Longline (based in Samoa, Santos Is. in Pacific)			7,241	7,091	8,817	-
Longline (landed in Atlantic) Bases: Italy, Brazil, Cuba, Morocco					16,885	-
Longline (landed in Japan)	128,625	151,040	177,380	214,229	238,043	1.86
Species						
Skipjack (Katsuwo)	72,698	99,821	99,670	97,988	117,904	1.62
Bluefin (Kuromaguro)	17,580	19,750	23,086	36,923	34,200	1.95
Albacore (Binnaga)	51,964	55,898	48,390	65,778	77,723	1.50
Big-eyed (Mebati)	29,156	25,661	41,971	48,961	60,304	2.07
Yellowfin (Kiwada)	35,890	52,916	67,711	80,864	99,524	2.77
Striped marlin (Makaziki)	3,915	10,230	7,211	9,055	8,730	2.23
Broadbill Swordfish(Makaziki)	5,306	10,091	12,416	13,304	11,153	1.23
Black marlin (Kurokawa)	15,961	18,431	11,351	25,210	29,783	1.87

In 1957 the catch of tunas by longlines amounted to 238.7×10^3 tons, an increase of 86% since 1953 and 12% since 1956. It is reported for 1958 that the catches of skipjack, bluefin, big-eyed and yellowfin tunas had increased further but those for albacore were poor. Poor catches of albacore were also reported for the U.S. fishery.

The number and size of tuna boats increased progressively (1939 - 1107 boats, 53,561 gross tons; 1954 - 1622 boats, 124,132 gross tons). The boats became equipped with modern navigational instruments and fishing aids.

The main fishing gears for tuna include floating longlines, pole and lines (for albacore and skipjack), set nets, troll and purse seines.

The general tuna fishing grounds have been described by H. Nakamura *et al*. (1957, 1958) (Fig. 1).

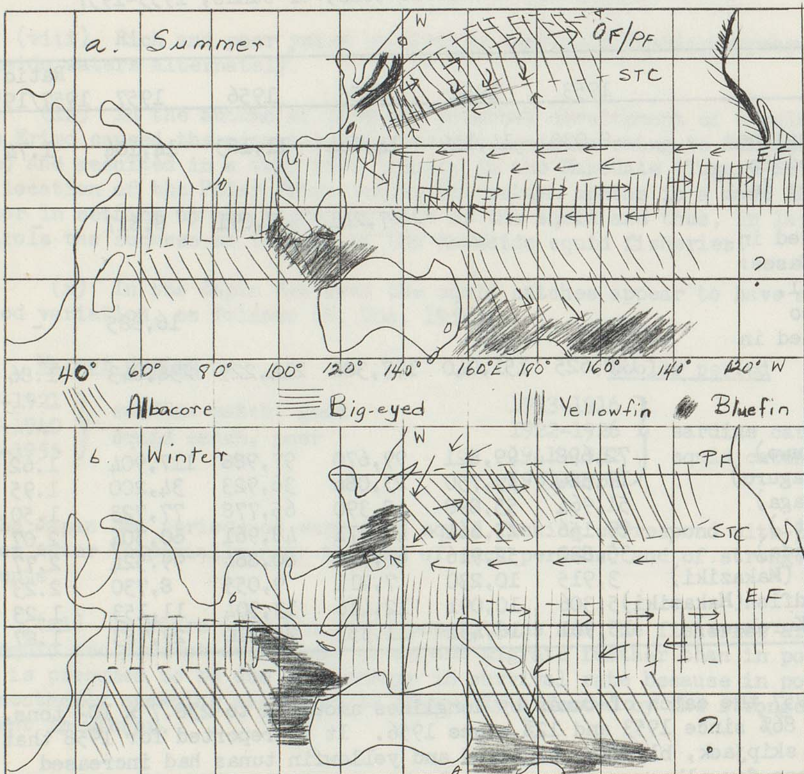


Fig. 1. Tuna long-line fishing area (H. Nakamura, 1958, Uda, modified, 1958)

(i) The tunas are found in environments characteristic of each species. The environments are identified with current systems and have water mass boundaries as barriers.

(ii) Equatorial tuna fishing grounds extend latitudinally and are confined by equatorial current systems.

(iii) Within a current system local concentrations of tuna may occur and these may be related to some topographical condition.

(iv) Tunas appear to remain and migrate within a current system generally; however, during seasonal changes (March, September) individuals may migrate from one current system to another. (It has been suggested that some albacore in the North Pacific migrate to the South Pacific to spawn.)

2. Yellowfin tuna (Neothunnus macropterus) "Kiwada-maguro"

A. Fishing for tuna in the Pacific Equatorial region first began in 1939 near the Caroline Islands. The catch was mainly yellowfin and marlin. Particularly good fishing areas were found in the Equatorial Counter Current. Yellowfin were abundant between 0°-10°N (H. Kawamura, 1938, 1939; Y. Inami, 1940). Upwelling of deep fertile water and high plankton production were noted in this region (Marukawa, 1940). Large concentrations of big-eyed tuna, marlin and skipjack were found between 10°-20°N in the North Equatorial Current.

Uda (1952) computed convergence $K = -(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y})$ (see Oceanographic Seminar No. 2), using G. Schott's current maps. He pointed out that eddies in the frontal zone of K - maximum and regions of favourable tuna catches, estimated from hooked rates (fish per 100 hooks), coincided. Such areas were located off Mindanao at about 130°E (remarks by S. Aoyama, 1940) and at about 140°-160°E, 0°-5°N.

B. Investigations of tuna in the Equatorial mid-Pacific are being carried out by POFI. Since 1950 the research vessel Hugh M. Smith, while fishing with longlines, has found rich yellowfin areas (maximum hooked rate = 12.9 fish) between 1°-6°N near Christmas Island (G. Murphy, R.S. Shomura, 1952). The oceanographic mechanism operating in this area is described by T. Cromwell (1953). O.E. Sette has attempted to consider these findings together (1953, 1955).

C. In the eastern Equatorial Pacific yellowfin and skipjack grounds, and schooling of these species, have been investigated by the Inter-American Tropical Tuna Commission. Results of population dynamics (1954-1958) (Schaefer, Shimalda, Orange et al.) and oceanographic studies in this area since 1952 (W. Wooster and T. Cromwell, 1958) have been published. The suggestion of high productivity on the thermoanticline or ridging in this area and in the Cromwell current (T. Cromwell, 1957) poses an interesting problem for future study.

D. During 1930-34 the tuna grounds in the eastern Indian Ocean, Bay of Bengal (near Andaman, Nicobar Islands) and in the vicinity of Sunda Islands were successfully exploited by the vessels Hakuyo Maru (Imp. Fish. Instit.). Haruna Maru, Syonan Maru (Formosa Gov't. Fish. Expt. St.). Before World War II Japanese tuna boats, led by research vessels from the Fisheries Experimental Station, fished yellowfin in the South China Sea (Paracel Reef, Dangerous Reef, west of Luzon, Parawan and Borneo, Scarborough Reef, etc.) in the Australasiatic Mediterranean Sea (including Sulu Sea, Celebes Sea, Flores Sea, Lombock Strait, Sunda Strait, Mollucca Sea and Timor Sea).

3. Tuna fisheries in the Indian Ocean

A. Tuna fishing in the Indian Ocean developed rapidly since the autumn of 1952. Fishing started south of the Sundas Islands and expanded westwards mainly along the Equatorial zone (55°-13°S) to areas south of India and Ceylon, Maldive and Laccadive Islands, Arabian Sea, the vicinity of Madagascar, and south to 25°S.

The tunas in the Indian Ocean characteristically are distributed according to current systems (see Table 2) (H. Nakamura et al., 1952, 1955, 1958).

Table 2. Percentage composition of tuna catches of the research vessel Tone Maru by species

		Fishing areas	Yellowfin	Big-eyed	Albacore	Marlin
Equatorial	A	66°-69°E 4°-6°S	95.3%	2%	1.0%	1.6%
Counter Current	B	57°-61°E 3°-6°S	93.5	2	0.3	4.2
Current indistinct	C	57°-60°E 8°-12°S	85.6	0	9.0	5.4
South Equatorial Current	D	51°-64°E 15°-25°S	45.3	0.6	34.6	19.0

Peak catches of Southern bluefin (*Thunnus thynnus macovii*) were made in waters 8°S-15°S, east of 110°E during September-October; 8°-20°S, east of 100°E during November-December, and off the west coast of Australia in April. The dominant size group ranged between 140-170 cm (fork length). The mode was 155 cm (K. Mimura, 1958). Catches of Indo-maguro south of Sunda and off the north and south coasts of Australia were maximal during September-February and minimal during June-July. The period of low abundance occurred when upwelled cool waters were adjacent to coastal waters.

Albacore in the south Indian Ocean occur mainly around 10°S and along the Equator (May and June) east to about 90°E.

Big-eyed tuna are widely distributed in the Indian Ocean but are most abundant in the eastern region (June-September).

Yellowfin are widely distributed between 15°N and 25°S during October-January, but are most abundant at about 5°S. Maps showing the relative abundance in each month were published by the Nankai Regional Fisheries Research Laboratory (Koti).

T. Yoshiwara (1951, 1952, 1954) and H. Maeda (1955) studied the distribution of longline-caught tuna and inferred their shoaling statistically. Damage to hooked tuna by sharks and killer whales is being reduced by shooting, thus driving them off.

B. Following 1952 and 1953, the years of maximum yield, the hooked rate declined, becoming lowest in 1958. The reduction of the virgin population in size is an immediate and inevitable effect of the fishery. POFI has shown this for the mid-Pacific region. Intense fishing activity also may have caused the fish to disperse, thus resulting in smaller catches.

K. Kimura (1958) studied the variations in the annual hooked rates. The extent to which fishing, environmental factors or local variations in migrations have influenced the decline remains to be studied. Maximum sustainable yield of skipjack has apparently never been approached, even during periods of greatest exploitation.

4. Tuna fisheries in the Atlantic Ocean

Many biologists (M. Sella, 1931, 1932; F.S. Russel, 1934; H. Thiel, 1938, H.C. Godsil, 1949; F.G.W. Smith, 1957) have studied the tunny (bluefin) in the western Atlantic and the Mediterranean Sea. Long-range migrations from lower to higher latitudes in the warmer season and reverse direction in the cooler season has been determined from the detection of fish hooks, etc.

Following exploratory fishing by the vessels Sagami Maru (Kanagawa Pref. Fish. Expt. St.) and Toko Maru (Japanese Fisheries Agency) in 1957, 16 larger Japanese clippers (600-1000 ton class) longlined in the Equatorial Atlantic Ocean. Yellowfin were abundant northeast of Guinea and albacore southwest of the Ivory Coast, Africa.

5. Tuna fisheries in the south Pacific Ocean

Albacore occur in the south Pacific Ocean between 10°-38°S (as far north as 2-3°S during June-July) and west to 155°W. Distribution east of 155°W at present is not known. Spawning occurs from the lower latitudes to near the Coral Sea, New Caledonia and Solomon waters.

Yellowfin occur south to 35°S in the winter and 25°S in the summer (Homma, Kamimura, 1957).

Bluefin tuna grounds discovered during surveys by the Syonan Maru (1957), were found to extend from east of New Zealand to the Tasman Sea.

Striped marlin are abundant in the region 17°-30°S, 150°E-165°W (M. Homma and T. Kamimura, 1958). Currents and other oceanographic features in this area were reported by H. Yamanaka (1957).

6. Albacore (*Germo germo*, Lacepede) "Binnaga".

A. Albacore or long-fin tuna are pelagic and inhabit saline waters. M. Uda and E. Tokunaga (1937) reported that albacore in the North Pacific are found in 17°-21°C water but are most abundant in 18°-20°C. The Polar Front constitutes the northern limit of these waters; the Sub-Tropical Convergence the southern limit. Migration of the fish is cyclonic in pattern. Movement is northward in the spring of the year and southward in the fall. A similar migration is noted for albacore off the North American west coast, between California and British Columbia.

B. Taggings in recent years have shown that some albacore migrate from waters off California to Ogasawara, south of Japan, along the region of Sub-Tropical Convergence.

C. Good albacore fishing occurs in back eddies of ridges, oceanic islands or banks and in cyclonically upwelled cooler water masses along the frontal zone of the Kuroshio.

D. In the spring (March, April) albacore appear off Japan in the Kuroshio Counter Current between 27°-34°N and migrate in a northeast direction. This is a feeding migration.

E. Dense schools of albacore, feeding upon small fishes and zooplankton, appear in the early summer (June, July) in upwelled cold water in marginal Kuroshio area; for example, off Kumano Nada or within 300 sea-miles southeast of Cape Nozimazaki.

F. A good pole and line fishery for small (>10 kg) or medium (10-20 kg) sized albacore takes place in the summer (June, July) east of Kinkazan, about 150-350 sea-miles offshore (145°-149°E), especially along the Oyashio front in warmer waters (18°-21°C).

In the fall and winter, albacore migrate southwards to offshore waters near the Sub-Tropical Convergence. Searching for favourable temperate zones is carried out by longline vessels 1000-2000 miles to the eastward of Japan.

M. Inoue (1958) showed that albacore are segregated by size during their northward spring-summer and southward fall-winter migrations. Small-sized fish are found in cooler, northern waters; large-sized fish in warmer, southern waters.

G. Exploratory fishing by the Japanese Fisheries Agency during May to October, 1938 and 1939, in the area 10°-35°N and 170°E-160°W showed that albacore were present in sack-like, warm eddies formed by concentrations of isotherms.

7. <u>Fluctuations in the albacore fishery</u>

A. Cyclic variations in body weights of big-eyed tuna and albacore in alternate years were noted by biologists of the Nankai Regional Fisheries Research Laboratory (H. Nakamura, 1958).

B. Large fluctuations in the abundance of albacore have been observed during the last 30 years. The fluctuations appear to be due to large-scale changes in oceanic conditions. Periods of good catches were 1930-40 (best years: 1936-38) and 1950-57 (best years: 1951, 1952, 1957). This suggests cyclic changes of about 10 years' duration

C. From 1931 to 1937 the albacore fishing grounds have expanded eastwards offshore and southwards (Table 3).

Periods of good catches by pole and line in the summer and by longline in the winter alternated. Pole and line catches were dominant during 1927-31, 1938-40 and 1951-57. Longline catches were dominant during 1932-35 and 1941-50. (Albacore appeared in schools off British Columbia during 1939, 1940 and 1948). The pole and line catches from 1931 to 1937 declined annually.

Table 3. Boundaries of albacore fishing grounds, 1931-38

Year	Boundaries	Area of concentration	
1931	30°-39°N, 145°-150°E	36°-38°N, 146°-148°E	Uda
1932	30°-39°N, 145°-157°E	34°-39°N, 148°-153°E	Uda
1933	31°-39°N, 150°-164°E	31°-39°N, 151°-157°E 31°-39°N, 161°-169°E	Uda
1934	28°-39°N, 155°-170°E	32°-37°N, 163°-169°E	Uda
1935	29°-39°N, 158°-175°E	31°-38°N, 165°-175°E	Uda
1936	26°-38°N, 158°-178°E	27°-35°N, 161°-175°E	Uda
1937	25°-40°N, 160°-180°E	27°-39°N, 163°-176°E	Aikawa
1938	26°-41°N, 158°-179°E	27°-38°N, 162°-176°E	Aikawa

8. Bluefin tuna (Thunnus orientalis) "Kuro-maguro"

Tunny (bluefin or black tuna) migrate northwards along the Japanese coast during the spring and summer in the cooler waters of the coastal front.

A. Fluctuations in the tunny and sardine fisheries are similar. During 1933-40 each species was abundant between Kyusyu and Sakhalin on the west coast of Japan and between Taiwan and the Kuriles on the east coast. Since 1941 in the Northern Japan Sea the tunny disappeared and the sardine catches declined. About 1949 tunny re-appeared but fish were small in size. By 1953 medium-sized fish were caught. As the tunny increased in size and number their distribution northward was noted. During the summer and fall, 1956, in waters near Aomori Pref. (41°-42°N), tunny weighing about 100 kg supported an active purse-seine fishery. Bluefin tuna have also returned to waters south of Formosa. There is a suggestion that the waters become more fertile during the southward intrusion of cold water, which in turn might have an effect upon the strengths of year-classes. This phenomenon has been observed for sardines and mackerel west of Kyusyu.

The progressive northward distribution of tunny will continue for several years together with the shifting of a favourable environment. Changes will occur with fluctuations of the Tusima Current.

B. S. Iehisa (1939) reported that the occurrence of bluefin south of Kyusyu during January-March of 1939 was closely associated with water mass boundaries. T. Kawana (1934) and T. Kida (1936) discussed the bluefin tuna fishery south of Hokkaido in relation to the vertical temperature gradient. M. Uda (1952) pointed out that:

(i) the best fishing areas were found in temperatures of 18°-20°C where the Kuroshio and cold coastal water met. These areas were located south to Kyusyu in the winter and along the marginal area of the Kuroshio south or east to Japan in the spring and summer.

(ii) big concentrations of tunny occur in areas A and B shown in Figure 2. These fish are feeding upon smaller fishes (sardine, saury, flying fish, mackerel). The areas are located where convergence in the frontal zone is maximal.

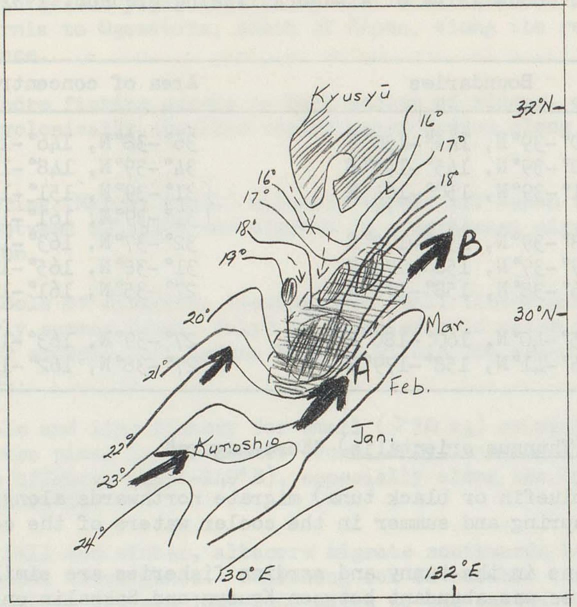


Fig. 2. Bluefin tuna fishing grounds, January, February, March (1935-1941).

(iii) unusually large catches of bluefin tuna were made along the west coast of Kyusyu during the winter of 1938. The Tusima Current was stronger than normal. Shortly after the storm of February 5-6, 1939, water temperatures dropped sharply and catches in area A and B of Figure 2 declined. The tunny migrated rapidly northward along the west coast of Kyusyu (during the winter) resulting in unexpectedly large catches by coastal set nets. In April tunny had migrated into the Japan Sea along the coast and large catches were made from south to north. During this time water temperatures along the southern coast of Kyusyu were low. During 1936-40 there was evidence of a westerly deviation of the Tusima Current from the normal axis, and upwelling of cold water off Kumano Nada.

(iv) exceptionally large catches of tunny occurred in 1891 (1123 tons in Nagasaki Pref.) and again in 1939 and 1940. The periodicity of these large catches and the occurrence of extremely large numbers of sun spots is similar. The catches are possibly related to the fluctuation of the Kuroshio.

In 1950 and 1951 young tunny were again abundant in the Japan Sea. Their abundance coincided with a rise in water temperatures.

Long-term fluctuations of 110 years have been noted by M. Sella (1929) for the tunny fisheries of the Mediterranean Sea.

9. Skipjack (Katsuwonus pelamis) "Katsuwo"

Pole and line fishing, using sardines or anchovy as live bait, in the spring and summer is carried out mainly off Sanriku (northeastern Japan). Water temperatures range from 20°-24°C but fishing is best in 22°-23°C water (M. Uda, 1934, 1939, 1940, 1941). In general, best fishing occurs where tongues of warm (20°-22°C) and cold (15°-16°C) water meet along the Oyashio Front (Polar Front). The 22°C isotherm is recognized as an indicator (Uda, 1936). Vertical sections of these areas show a marked thermocline (0 m = 20°-22°C; >100 m = 6°-10°C).

The migration route of skipjack is associated with the warm Kuroshio Current. Fish are found in waters having salinity values between 33.0-35.0‰ (with peak occurrence in 34.6-34.8‰), water transparency of 20 m, and water colour corresponding to I-III in the Forel Scale.

Indicators of fish schools are:

(i) Siome (Uda, 1933);

(ii) drift wood, which represents pure Kuroshio area;

(iii) flocks of birds, whales, which represent warm, saline Kuroshio water (or nearly sub-tropical water);

(iv) sharks which represent northern transitional water mass between the Oyashio and Kuroshio (K. Kimura, 1957, 1958).

The concentration or density of skipjack tuna is represented by

$$K = \frac{m + 0.1n}{m + n}$$

where m, n are the numbers of times dense and thin schools, respectively, have been observed. The frequency of biting, q, is next calculated

$$q = \frac{3p_2 + 2p_1 + p_0 + 0.5p_{-1} + 0.1p_{-2}}{p_2 + p_1 + p_0 + p_{-1} + p_{-2}}$$

where p_2, p_1, p_0, p_{-1}, p_{-2} are the numbers of very good, good, medium, poor and very poor biting, respectively.

Schooling index is then calculated

$$\frac{N'}{\ell t} = akq$$

where N' is the total number of fish angled,
ℓ is the number of rods used, and
t is the duration of angling.

Accordingly, the number of skipjacks per rod per hour is proportional to the concentration of fish and degree of biting.

During their northward migration, skipjack are fished in many localities. Using early season catch data or those for southern localities, the total annual catch or that for the northern area only can be predicted.

Catches in different localities are affected by the intensity of the cold and warm currents. For the years when the Kuroshio was strong (1933, 1937, 1939, 1942, 1950) catches in the north were relatively greater than those in the south. For years when the Oyashio was strong (1934, 1941, 1944, 1945) southern catches were relatively greater than those in the north.

Skipjack catches changed during the day. Catches were best just after sunrise and in the early morning (5-9 o'clock) but thereafter declined.

Skipjack fishing is good prior to strong monsoons or storms.

Off Kyusyu, Okinawa and Bonin Island fishing grounds are associated with banks or reefs (M. Tominaga, 1957) with peculiar eddies or vertical flow.

Small boats fish skipjack along the coastal front where there is an intrusion of offshore warm water.

Tagging experiments have shown that the migration route corresponds to the changing positions of the fishing grounds.

Seminar 6. The mackerel, yellowtail and related fisheries

I 1. Review of mackerel (refer to H. Kasahara and H. Ito, 1953)

Scombroidae:

Scomber japonicus - common mackerel - Masaba, Honsaba, Hirasaba. Distributed in Japanese waters from Hokkaido to Kyusyu and off the Korean and Sakhalin coasts. On the Pacific side of Japan, extends north to 30°N. Occurs in transitional water of medium salinity and in water temperatures of 14°-16°C.

Scomber tapeinocephalus - southern or spotted mackerel - Gomasaba, Marusaba. Distributed in waters south of Tusima Strait and Cape Inubōzaki to Kyusyu and close to Formosa. Occurs in sub-tropical warm, saline water.

Trachurus japonicus - horse mackerel - Maazi, Hiraazi. Found in all coastal waters close to the bottom.

2. Concerning common mackerel

A. I. Takayama, M. Uda, J. Tukusi (1936) record that:

(i) When a favourable temperature zone of 14°-16°C coincides with the fishing depth (hook depth of handline or longline, gill net depth, etd.) good catches result.

(ii) The catch per unit of fishing effort shows a positive relation to the temperature differences (degree, extent, width of thermocline) between the upper and lower strata of intermediate optimum temperature zone. The greater the temperature difference, the greater the catch (Fig. 1 b).

Fig. 1 a

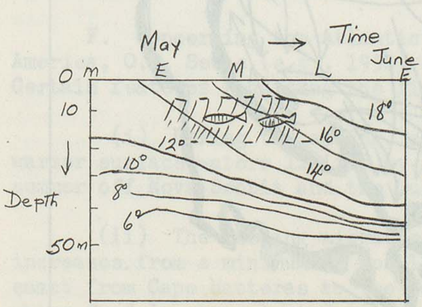
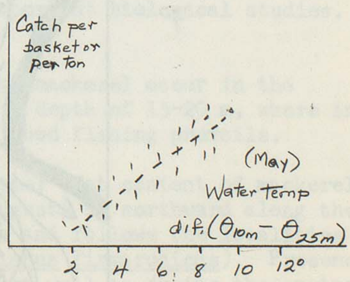


Fig. 1 b



(iii) In warmer years, e.g. 1930, the fishing period occurs earlier; in colder years, e.g. 1931, it is later.

(iv) There is a relation of size (age) of fish to the optimum water temperature, the larger fish appearing on the fishing grounds earlier and the smaller ones later. In mixed populations of various sized fish, the curves are superimposed but the modes of each size are distinct, due to the different migration patterns.

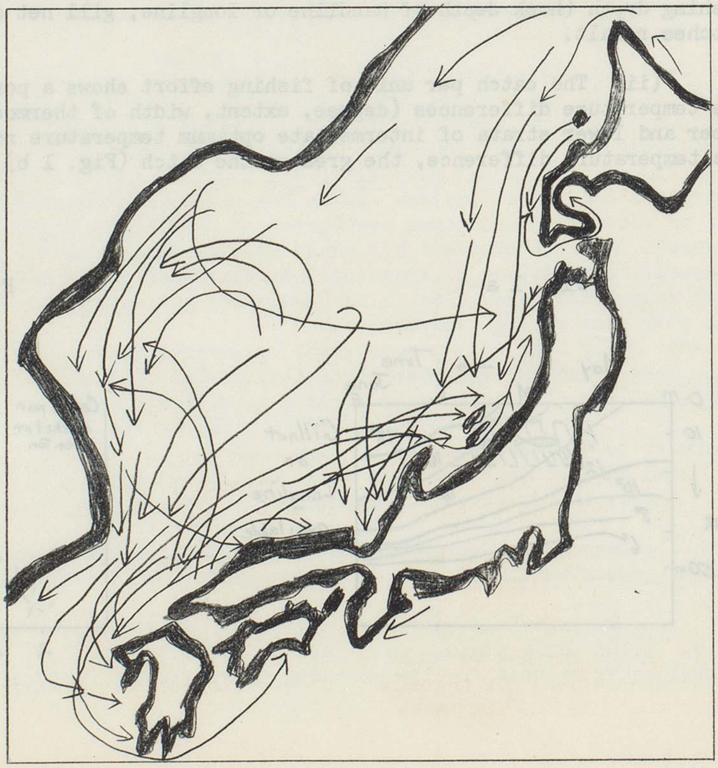
B. There appears to be very little difference between the periods of good fishing and suitable temperatures on the Pacific side of Japan and the Japan Sea side.

The principal mackerel spawning grounds on the Pacific side are believed to be in the coastal waters from Tiba Prefecture (Kamogawa Bay, Tateyama Bay), Wakayama Prefecture to Kagosima Prefecture. Spawning occurs in the spring - April, May and June.

During the autumn and winter, mackerel are fat and delicious; however, in June and July they become thin and are not as tasty. In general, large-sized mackerel (30-45 cm in length, 0.5-1.0 kg in weight, 3-4 years in age) are found only on the Japan Sea side, while smaller sizes (15-30 cm, 0.05-0.3 kg, 1-2 years) occur on the Pacific side (H. Aikawa, 1936).

C. The migration of mackerel has been studied by means of tagging experiments, conducted by H. Marukawa and S. Kamiya (1930), generally similar to the experiments on yellowtail (Fig. 2).

Fig. 2. Migration of tagged common mackerel.



The mackerel in the Japan Sea are considered to be all one population and the intermingling of the populations on the Korean and Japan coasts has been shown to occur (e.g., in winter in the Tusima Strait, in summer near Hokkaido). The mackerels of the Pacific and Japan Sea coasts of Japan come together and mingle during the winter in the waters south of Kyusyu. The rate of fishing, as computed by M. Tauti (1942), of around 0.006, when compared with a rate of survival of 0.21 suggests that there is no danger of reduction of the mackerel stocks because of overfishing.

D. For the Japan Sea area, i.e., along the Korean coast and in Tusima Strait and in the East China Sea, S. Saito _et al_. (1934) report that:

(i) Large schools of mackerel moving in autumn down along the east coast of Korea were caught by purse seines and gill nets. Those fish, not so caught, entered Tusima Strait and were taken during the winter by angling with fish lamps. In the Tusima Strait they join with the schools coming down along the Japan coast.

(ii) The catch of mackerel is related to lunar calendar days, larger catches being made on dark days.

(iii) The fishing rate for mackerel is directly related to the transparency of the sea water, particularly in the Yellow and East China Seas.

(iv) Young fish, larvae and eggs are taken in the waters near the Tusima Strait from April to July which suggests that this is the location of the main spawning ground of the Common Mackerel.

(v) The spotted mackerel is caught along the southwestern Korean coast in summer and autumn, July to November, by purse seine and set net.

E. Mackerel in Tusima Strait are caught in the back eddies of Tusima Island (off the east coast) principally in winter and spring and again in autumn. Indicators of good fishing areas are (aside from echo traces by fish finders):

(i) "Siome" or "sio zakai" (boundary of water masses)
(ii) White-tinted turbidity, of biological origin
(iii) Flocks of sea gulls
(iv) Patches of "Ami" (zooplankton, such as _Euphausia pacifica_), which are of a light pink colour and usually about 10 m in diameter (Nagasaki Pref. Fish. Expt. Sta., Nagasaki Univ., 1952, and Saikai Regional Fish. Res. Lab.).

F. Concerning the Atlantic Mackerel (_Scomber scombrus_ Linnaeus) of North America, O.E. Sette (e.g., 1950) carried out many important biological studies. Certain features regarding the fishery may be given:

(i) During the spring, summer and autumn the mackerel occur in the warmer surface waters limited by the thermocline to a depth of 15-20 m, where in summer off Nova Scotia and the Gulf of St. Lawrence good fishing prevails.

(ii) The feeding migration in spring and summer (fat content of mackerel increases from a minimum in April to a maximum in August) is northward along the coast from Cape Hatteras to the Gulf of St. Lawrence and follows the localities where food is concentrated (copepods, especially _Calanus finmarchicus_). Presence of schools during the autumnal southward migration, as well as during the spring northward movement, is revealed by the biological luminescence and phosphorescence in the sea, called "the water fires".

(iii) The lower limit of water temperature of the Atlantic mackerel wintering areas appears to approximate 7°-8°C and occurs around Cape Hatteras - Georges Bank. Spawning occurs in the Cape Hatteras - Cape Cod area in waters of 7°-8°C temperature.

(iv) Active feeding usually occurs around dusk and dawn and in calm weather.

(v) High mortality of larvae, due to shortage of food and dispersal by unfavourable winds, occurred in 1932. In spite of heavy recruitment, the lowest catch in 1937 may have resulted from an abnormal climate of high temperature. Similar conditions were observed in 1939.

The above are valuable references for mackerel fishing in Japan. The migrations of Pacific mackerel, shown, by tagging experiments, to occur from Lower California to the British Columbia coast and even into northwest Alaska (D.H. Fry, Jr. and P.M. Roedel, 1949), as well as that for Atlantic mackerel, correspond closely to the results obtained in Oriental waters.

P.G. Corbin (1947) reported temperature limits of 10°-16°C and salinity limits of 35.0-35.5‰ in the mackerel spawning grounds of the Celtic Sea. Most spawnings occurred in March, April and May, with some in June but rarely in July. The Progress Report of the Calif. Co-oper. Ocean. Fish. Invest. in 1956 reports many new findings concerning the Pacific mackerel as well as the jack-mackerel and anchovy by E.H. Ahlstrom, J.E. Fitch <u>et al</u>.

The Pacific mackerel spawns off southern California and northern Baja California (including the Gulf of California) during March-July at temperatures of 12°-18° (estimated from Figs. 6-8, J.L. Reid, Jr., 1958) or 13°-23° (Fry, 1936, Roede, 1949).

3. In the Japan Sea, the conditions for mackerel fishing in relation to sea conditions were studied by M. Ishino (1958), from which the following observations are taken:

(i) Except for the period 1944-1949, the yield of mackerel has shown a gradually increasing trend, with marked increases in 1931, 1932, 1950 and 1951.

Years	Yield of mackerel	
1918	59,000 tons	
1927	90,000 "	Pre-war maxima
1939	153,600 "	
1952	286,700 "	Post-war
1954	293,700 "	

(ii) Poor years in the mackerel fishing occurred in 1913-1919 and 1930-1935.

(iii) The total catch of mackerel west to Wakasa Bay is proportional to the total trend in the yield of mackerel in the Japan Sea. This assists in forecasting the likely total yield from the catch in the earlier fishing period.

(iv) The catches of mackerel in the years 1917, 1934 and 1951 were low since they were the initial years of warmer periods, 1917-1921, 1932-1940, 1950-1955.

(v) Mackerel were caught by purse seine, lift net, set net, angling, long line, beach seine and gill net. Since fishing around Noto Peninsula in March occurred 2 months earlier than the fishing further south in the vicinity of Wakasa Bay in May it suggests a difference between the northern large-sized mackerel (N. Hanamura, 1958) and the southern migrating groups.

(vi) In the spring the northern migration coincides with a rise in water temperature while in the autumn the southern movement occurs during a period of falling water temperatures.

4. A. Uda (1958) has noted the movement of the main mackerel fishing grounds in the Japan Sea to coincide with the northerly seasonal shift of the highest saline water mass of the Tusima Current as with the most favourable temperature zone of 12°-18°C (around 14°-16°C).

B. The catches of common mackerel and horse mackerel, which have increased in recent years, particularly in the Tusima Current area of the East China and Japan Seas, may be due to the general increase in reproductive potential caused by natural environmental factors, except for the increases due to the introduction of new and improvement of old fishing methods and the greater exploitation of new fishing areas, e.g. in the East China Sea where a 30,000-60,000 ton increase has taken place.

C. The mackerel fishing areas in the Japan Sea are closely related to the topographical upwelling caused by a deep cold water intrusion as well as by coastal frontal eddies (refer to Oceanographic Seminar notes on the Japan Sea).

D. In the southern Japan Sea (along the Yamaguti - Tottori Prefectures) mackerel fishing was excellent in 1953 and 1954 and then declined, whereas in the northern Japan Sea (Niigata, Yamagata, Akita Prefectures) mackerel fishing increased remarkably in 1955 and 1956.

E. In Isikari Bay, on the Japan Sea, schools of large mackerel (spawners in 13°-20°C) brought about heavy catches in 1949-1951 and then a rapid decline occurred (N. Hanamura, 1958).

F. In the East China Sea and Yellow Sea (Fig. 3) the Common Mackerel is distributed along the inner coastal front whereas the Spotted (southern) Mackerel is found along the outer front of the Tusima Current, near the Continental Shelf edge (M. Uda, 1958).

Particularly in the area of 27°-30°N, 123°-126°E where, by pole and line as well as stick-held dipnet and purse seine, fishing has been conducted, a new fishing area for spotted mackerel and horse mackerel has been developed in recent years with annual yields of more than 80,000 tons of fish, landed by hundreds of boats. Near to the inner water zone of the common mackerel and white marlin (which preys on the red-back or scad mackerel) fishing grounds, new areas for fishing spotted mackerel and black marlin (which preys on jack mackerel) have been exploited. Waters favourable for spotted mackerel (temperature, 20°-26°C; salinity 34.3-34.6‰) and for black marlin (temperatures, 23°-28°C) occur from December to April, respectively (T. Morita, 1958).

The mackerel fishing area extends from 30°N to the vicinity of Formosa and fishing operations are carried on chiefly in the period of the prevailing

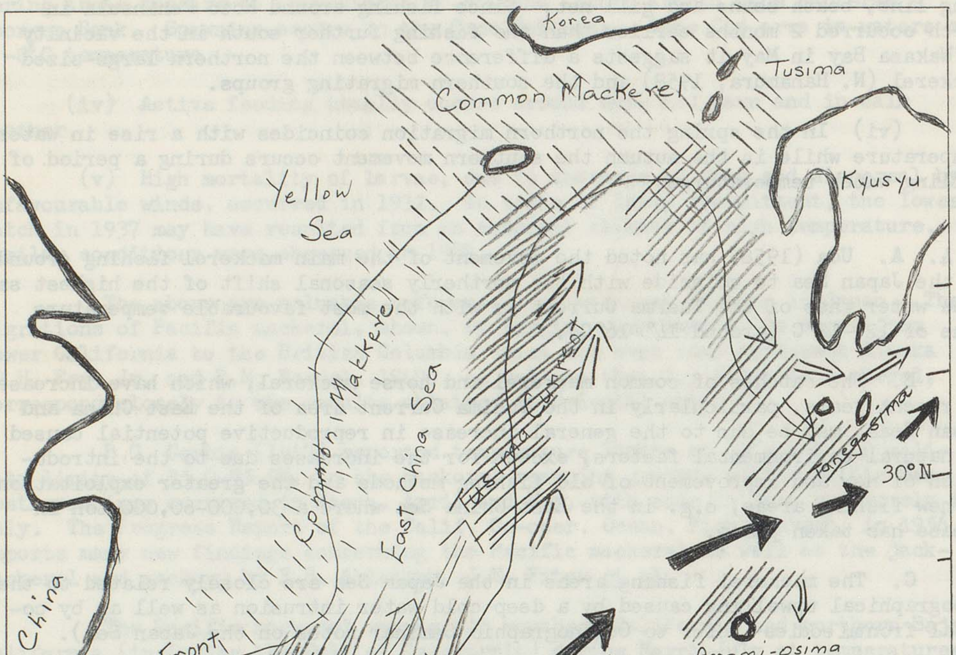


Fig. 3.

northeast monsoon, when in the northern area (27°-29°N, 124°-125°E) from October to June medium-sized mackerel of 1-2 years of age are captured and in the southern area (Uwoturi Zima - Taiwan, Sowo), November to March when large-sized fish are found.

Transported and dispersed by the currents, the young mackerel are found in the nursery areas south and southwest of Kyusyu in March to August, swimming in waters of 18°-23°C in temperature and 34.2-34.7‰ in salinity around the reefs or fish banks, near the contact zone of warm (subtropical) water and coastal water (T. Morita, 1958).

G. Since about 1951 successful broods of horse mackerel have brought about surprisingly abundant catches of small-sized young fish in set-nets and trap-nets around the coasts of the Japan Islands on both the Pacific and Japan Sea sides south of Hokkaido.

Horse mackerel spawning takes place in February to April (15°-17°C) in the East China Sea and supplies continuously successful recruits under favourable environmental conditions (M. Uda, 1958).

H. Pacific coast fishing grounds. Banks near the Idu Islands (Omurodasi, Takase, Hyotanse, etc.) and near Tiba Prefecture are very productive fishing areas of the mackerel. The composition (proportions of common and spotted mackerel), total catch and catch per area fluctuate from year to year alternately as shown by the records from 1933-1958 (Reports of Tiba and Tokyo Pref. Fish. Expt. St.).

II <u>Yellowtail</u> (<u>Sardinops quiqueradiata</u> T & M), "Buri" in Japan. (Refer to "Review of Yellowtail and Fishing" by T. Matsushita, 1953, H. Miyamoto, 1952).

1. <u>General</u>. Yellowtail are caught in almost all coastal waters of Japan, from Sakhalin, Hokkaido, North Korea to south of Kyusyu. The catch has varied from 25,000 tons to 60,000 tons during the period 1930-1952. Some size to age data are as follows:

Age	Body weight	Japanese name
0	-	Mozyako (baby fish attached to seaweed)
1	0-0.7 kg	Wakana (-go)
2	0.7-1.9 kg	Inada
3	1.9-3.5 kg	Warasa (15°-18°C)
4 & 5	Over 3.5 kg (in Sagami Bay) (14°-17°C)	Buri (small and large)

Yellowtail mature at the end of 3 years, and spawn in April, May and June. The spawning grounds are mainly south of Japan, and heavy spawnings occur in the vicinity of the Danzyo Gunto Islands southwest of Kyusyu in temperatures of 19° to 20°C (K. Uchida <u>et al</u>., 1958). The larvae, after hatching, are transported by the current to the north and in the cooler, northern waters the growth rate is slower (K. Kimura, 1949). Yellowtail feed on sardine, anchovy, squid, horse mackerel, mackerel, saury, etc. Yellowtail are caught by set net or trap net, angling, longline, purse seine, gill net, etc.

2. <u>Yellowtail fishery in relation to the environment</u>

A. M. Uda (1927) studied the yellowtail catches at the Goto set net fishing ground (Nagasaki Prefecture) and found a close relation with the occurrence of cyclones and atmospheric fronts in winter and spring. Maximum catches occurred 2-1 days before and 1-2 days after the passage of a cyclone, as a result of the turbulence in the sea due to the storm. In the Segami Bay set net fishery (M. Uda, 1937) this pehnomenon was confirmed by similar statistical methods, though in this case the maximum catch occurred from one-half a day before to 2 days after the cyclone (Fig. 4). Looking for the appearance and movement of cyclones and fronts on weather maps west of Japan, forecasts can now be made of yellowtail catches. Many similar studies have been made in other fishing areas in Japan (especially notable, K. Takasiba, 1954-58). Usually the day when a good catch of yellowtail is made is clear, windy (northwesterly monsoon prevailing), after the passage of a cyclone moving to the east Pacific.

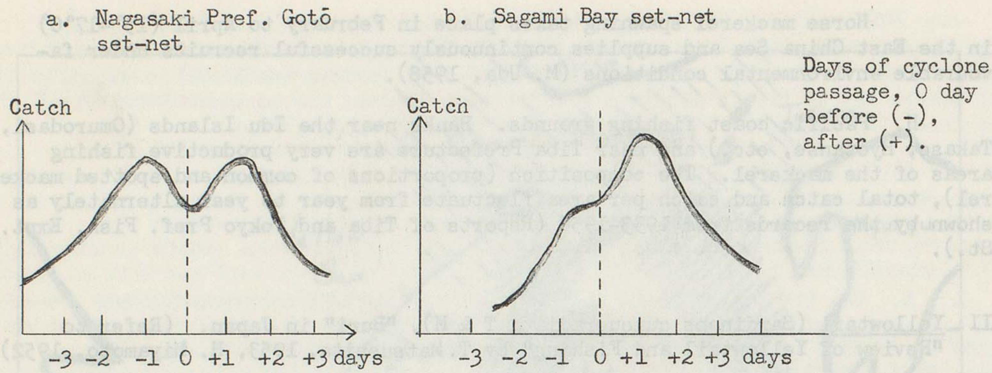


Fig. 4. Yellowtail catch.

B. Accordingly, the advance indications of a large catch would be:

(i) Snow in winter, rain in warmer weather, accompanied by the cyclone passage.
(ii) Southerly winds the day before the arrival of the cyclone, in warm sector.
(iii) Rapid, strong coastal current - hinders fishing operations.
(iv) Turbid water, stirred up by swell or waves, and of low salinity due to heavy precipitation.

C. (a) Poor years for yellowtail fishing are indicated by:

(i) Weak circulation in the bay (Sagani Bay, Toyama Bay, Wakasa Bay).
(ii) Mild, warm winter (weak monsoon).

(b) Good years, conversely, are marked by a warm water intrusion which depresses the coastal water, and by an active circulation in the bays.

D. The best fishing period in Sagami Bay corresponds to the time when the water temperatures are at or close to the minimum and the salinity and transparency of the sea water are at or close to the maximum. Temperatures of 14°-16°C represent good fishing conditions; at temperatures above 18°C or below 13° catches are poor or non-existent (Uda, 1956).

E. Most favourable fishing areas:

(i) Located in the northwest parts of a bay, protected from severe winter monsoons and high waves.
(ii) Where nutrients (phosphates) are rich, dissolved O_2 high and plankton is abundant.
(iii) Where no large rivers bringing in turbid water occur.
(iv) Where natural food (sardines, etc.) is abundant.
(v) Where eddies occur.

(vi) Where a deep notch in the continental shelf front occurs and there is a steep mountain behind, i.e., near the 200 m isobath., with the net at 40-100 m depth.

(vii) Near cape, bottom (fs. sh. Ms. pb. R).

F. Recently F. Mitani (1957) discussed the correlation between local catches of yellowtail and its secular variation.

3. Rich year cycle of yellowtail. M. Uda and K. Honda (1934) have reported that:

(i) The size of the yearly catch of "Buri" on the Goto set-net grounds is correlated significantly with the number of catches of 1000 individuals (correlation coefficient, $r = +0.82$).

(ii) The size of the yearly catch is chiefly determined by the size of the dominant year class which, in turn, is dependent on the conditions prevailing during the early life of the fish, when conditions for survival are critical. These usually occur 4 to 6 years prior to appearance in the fishery. (Good fishing seasons appear to occur when the sun spot number is intermediate between maximum and minimum).

(iii) The duration of the yellowtail fishing period is longer than normal when the average temperature in March is lower than in January ($r = +0.65$) and when the rise in temperature is slower.

(iv) The catch days of yellowtail (N') and other fish (N") during a season of "T" days, coincided exactly on "P" days

$$\text{Let } \frac{P}{T} \Big/ \frac{N'}{T} \times \frac{N''}{T} = Q$$

When $Q > 1$, correlation is positive
When $Q = 1$, correlation is neutral
When $Q < 1$, correlation is negative

It was found that the following correlations occurred:

Sardine to yellowtail - $Q = 1.0 - 1.3$
Tuna to yellowtail - $Q = 0.6 - 1.3$
Mackerel to yellowtail - $Q = 0.5 - 1.0$

Therefore, the yellowtail catch is positively associated with the sardine catch but negatively with the mackerel catch. Presumably the yellowtail prefers white, turbid water while the mackerel does not.

(v) When the weather is stormy, monsoons are strong and warm water intrusions are frequent, big catches occur.

(vi) The Kuroshio Current forms a wall or barricade of warm water at Cape Sionomesaki, etc., cutting off migration, but when Kuroshio retreats offshore again the fish proceed southwestward.

Seminar 7. The whale fishery

References: 1) Omura, H. et al., 1952. Whale science and whaling.
2) Omura, H. 1950. S.C. Rep. Whale Res. Inst.
3) Japan Whaling Assoc. 1954. Japanese Whaling Industry.
4) Maeda, K. and Y. Teraoka. 1952. Whaling.
5) Kasahara, H. 1950. Whaling and whale stocks in the adjacent waters of Japan.

1. General

Whaling is an important industry in Japan. In 1957 the annual catch contributed 0.58 million metric tons of raw material. Whales are taken in the Antarctic, the northern Pacific and in the waters around Japan. Chief products of the industry are oil, and meat for human consumption. Japanese consume 65,000 tons of frozen or salted meat annually.

Table 1. Whale catch in Japan

	Species	1953	1954	1955	1956	1957
Larger species	Total	5,392	8,788	10,997	1,294	16,016
	Blue	651	361	690	460*	686
	Fin	2,687	4,785	5,934	6,286	7,513
	Humpback	64	294	305	291	76
	Sei	684	776	509	837	2,252
	Sperm	1,306	572	3,559	5,031	5,420
Smaller species	Total	1,239	803	871	1,210	not
	Minke	406	365	427	532	yet
	Baird-beaked	270	230	258	297	noted
	Pilot	460	75	61	297	
	Killer	66	100	86	38	
	Others	37	33	40	46	

* Right whale included

Table 2. Whale catch in the 1957 season

Whales	Antarctic	Northern Pacific	Coastal larger whale	Coastal smaller whale	Antarctic one season (1957-'58)
Total	8,092	4,816	3,109	not	11,763
Blue	611	70	5	yet	656
Fin	5,848	1,405	260	noted	7,295
Humpback	71	0	0		223
Sei	133	1,641	178		1,466
Sperm	1,429	1,700	2,361		2,123
Reduced to Blue (except Sp.)	3,585.5	-	-		4,637.0

Whaling in the sub-Arctic waters of the North Pacific was started by American whalers in the middle of the 19th century, when the right whale was the main object of pursuit. Japanese began whaling from coastal bases along the Kurile Islands, Hokkaido and Sanriku near the end of the century. A Japanese expedition showed the high potential for commercial whaling by factory ship in the North Pacific in 1937. In 1940, 681 whales were taken in 80 days and in 1941, 590 were captured in 70 days. These were caught mostly along the coast of Kamchatka and in the Arctic Ocean, and consisted mostly of fin whales. One or two Japanese factory ships have operated successfully in the North Pacific and Bering Sea, north and south of the Aleutian Islands, each year since 1952.

Japanese coastal whaling as an organized industry dates back to the 17th century. The modern era began in 1899 with the advent of the steam whale catcher and modern harpoon gun. An annual average of 1,661 whales were taken from 1911 to 1945.

Pelagic whaling near the Bonin Islands was carried on from 1923 to 1953. Whaling in the East China Sea was resumed on a small scale in 1955.

2. Migration of whales

Whale marking experiments in the North Pacific from 1949 to 1958 have provided some useful information on the migration of whales in this region (Kawakami, T., 1958). Marked whales and recoveries from 1949 to 1957 are as follows:

	Species					
	Sperm	Sei	Fin	Blue	Hump	Total
Marked	1915	189	444	32	248	2828
Per cent recovery	3.0	9.5	8.1	12.5	0	4.1

Location of marking is as follows:

Ogasawara	216 whales
Sanriku-Hokkaido	1623 whales
North Pacific	981 whales

On the northward migration, fin whales enter the Bering Sea from both the American and Asian sides of the North Pacific. Some go beyond the Bering Sea to the Arctic Ocean for the summer months. American and Asian stocks visit the same feeding grounds, but the extent of intermingling of the two is not yet known.

The extent of the migration of baleen whales is shown by the recovery of 3 marks from humpback whales captured off Okinawa in 1958. These had been marked 2 to 3 years earlier near Unalaska. The migrations of baleen whales in the southern hemisphere are better understood from marking data. Generally the southern baleen whales are segregated into several communities which migrate from the polar ice northwards, towards or even as far as the Equator, to breeding grounds along the east and west coasts of each great southern continent (Norwegian Whaling Gazette No. 11, 1957).

3. Whaling grounds

Figures 1 and 2 show the supposed migration routes and whaling grounds in the North Pacific.

Fig. 1. Migration of whales and whaling grounds (Uda, 1959).

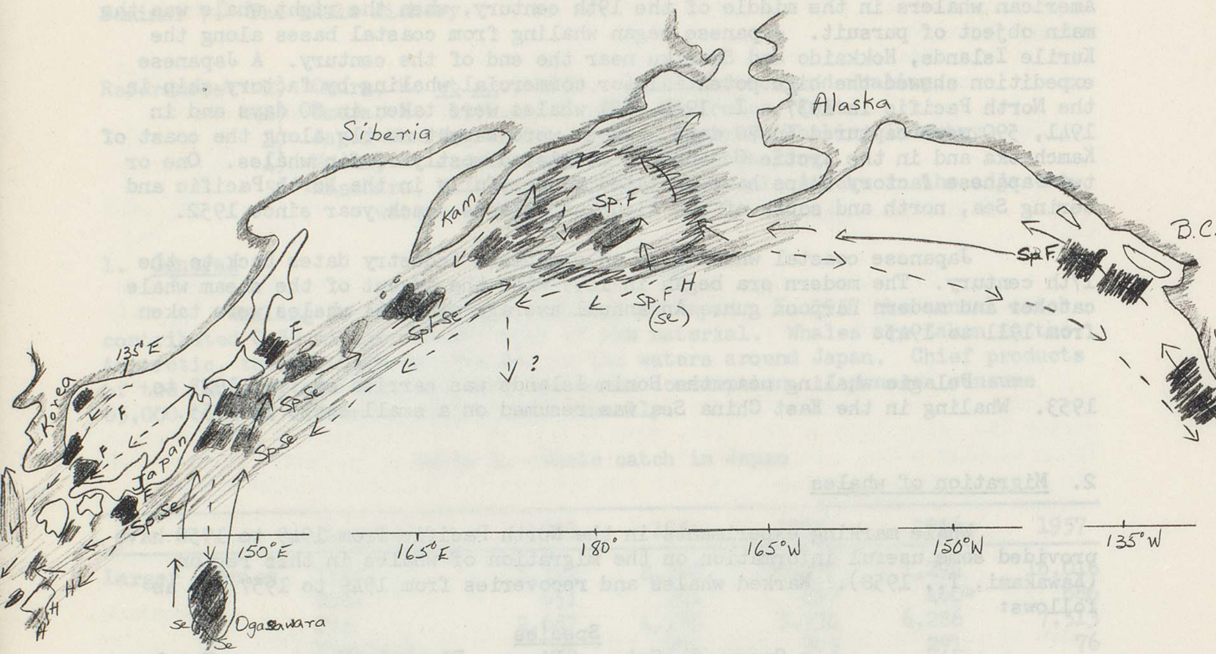
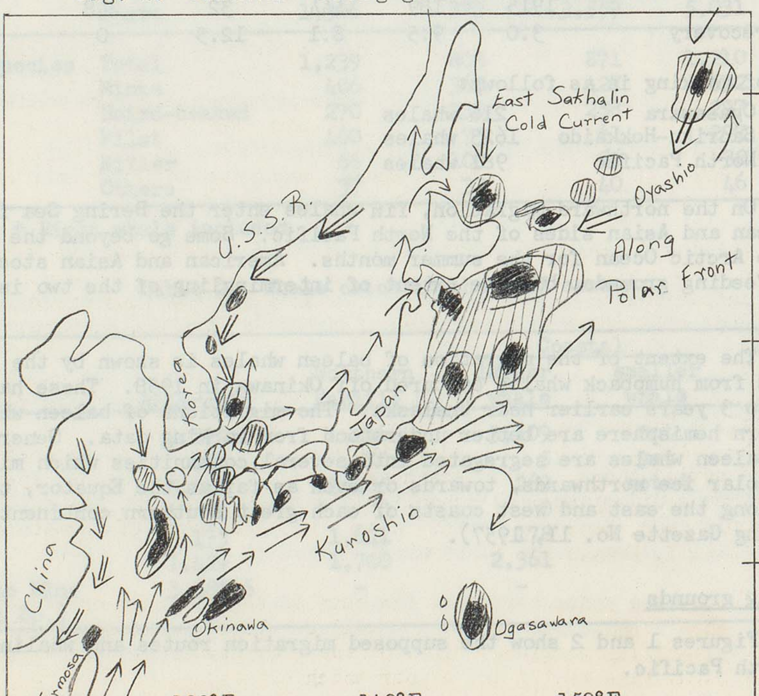


Fig. 2. Oriental whaling grounds and currents.



Whales were formerly distributed densely off the southern coasts of Japan. Within the last century the abundance of fin and blue whales in these waters has declined.

Whaling in recent years shows a northerly displacement off Japan. Within the last 10 years the centre of abundance has shifted from waters off Sanriku to waters off Hokkaido, in a northeasterly direction (M. Uda et al., 1958). The composition of the whale catch has also changed. With the decrease in right whales, blue whales, humpback whales and fin whales, in that order, sperm and sei whales have become the dominant species.

Fluctuations in the whaling grounds correspond to fluctuations in ocean currents. In the interests of whale conservation there should be more attention paid to biological and oceanographical studies as they relate to the whale fishery.

4. Whale fishery in relation to oceanography

The British Discovery Committee has, during the last 40 years, made great contributions to knowledge of the Antarctic whaling grounds. A. Hardy and R. Gunther (Discovery Repts., 1935) related the occurrence of whales to the distribution of krill (Euphausia superba) and to the abundance of phosphate and phytoplankton in Antarctic waters. Poor phytoplankton was related to an abundance of krill and whales.

The condition of the ice in summer relates closely to whale distribution. Years of heavy ice usually are associated with good whaling. The whaling grounds shift to lower latitudes and the end of the summer feeding period is delayed.

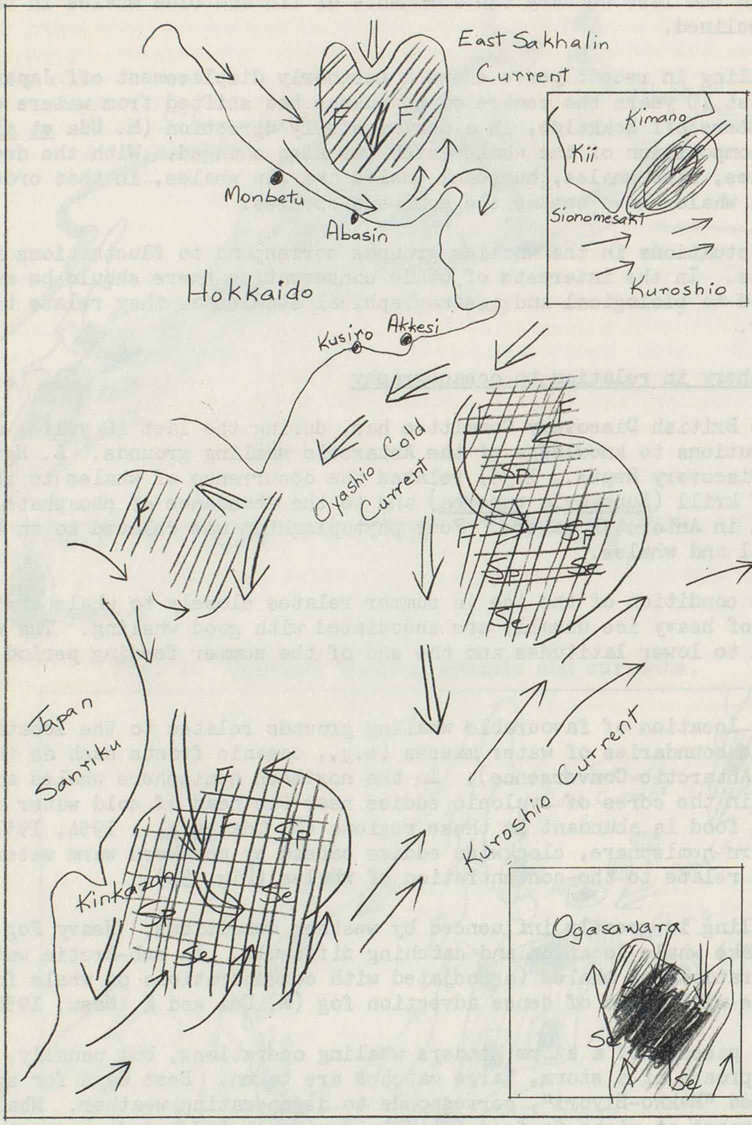
The location of favourable whaling grounds relates to the location and pattern of the boundaries of water masses (e.g., oceanic fronts such as the Polar Front or the Antarctic Convergence). In the northern hemisphere whales are most concentrated in the cores of cyclonic eddies near the head of cold water intrusions. Whale food is abundant in these regions (M. Uda et al., 1954, 1957, 1958). In the southern hemisphere, clockwise eddies caused by northern warm water intrusion seems to relate to the concentration of whales (Fig. 3b).

Whaling is greatly influenced by weather conditions. Heavy fog and stormy seas make whale location and catching difficult. In sub-Arctic waters, dense concentrations of whales (associated with concentrations of whale food) often coincide with areas of dense advection fog (M. Uda and K. Nasu, 1956).

The passage of a storm hinders whaling operations, but usually, just before the approach of a storm, large catches are taken. Best days for sperm whaling, called "Makko-Biyori", corresponds to degenerating weather. Whales approach the coast at night to feed actively during periods of degenerating weather and spring tides. In waters near to the Aleutian Islands, sperm whales feed mainly on squid mixed with schooling fish such as saury, and sei whales feed on zooplankton, saury, clupeids, Alaska pollack, etc. (T. Nemoto and K. Nasu, 1958; Z. Nakai, Y. Honzyo and M. Anraku).

Whales are concentrated by the development of lines of convergence ("siome"). When oceanic fronts are not well developed, whales are well dispersed and catch availability declines. In 1957 the poor development of "siomes" resulted in poor food, thin whales and a poor catch off Japan.

Fig. 3 a


East Sakhalin
Current
F
F
Kimano
Kii
Monbetu
Abasin
Sionomesaki
Hokkaido
Kuroshio
Kusiro
Akkesi
Oyashio Cold
Current
Sp
F
Sp
Se
Sp
Se
Japan
Sanriku
Kuroshio Current
F
F
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Kinkazan
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Ogasawara
Se
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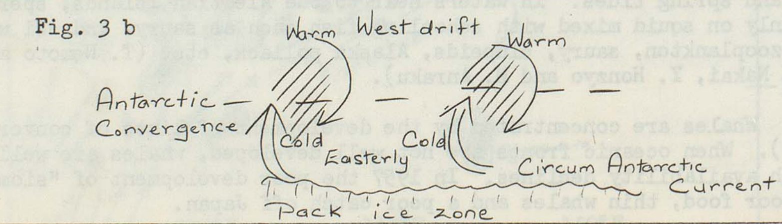
Fig. 3 b


Warm
West drift
Warm
Antarctic
Convergence
Cold
Cold
Easterly
Circum Antarctic
Current
Pack ice zone

An unusually large catch of fin whales was taken off the coast of British Columbia during the summer of 1958. This is attributed to the abnormal intrusion of warm water, the top of which was located approximately off Cape Cook. The high water temperatures apparently caused a shortage of plankton food, and the incidence of empty stomachs in the 1958 catch was higher than in any other year since this station began to operate in 1948. Fin whales were also thinner than in previous years. Sperm whales apparently retreated to cooler northern waters during the summer of 1958. They were unusually scarce off Vancouver Island but were frequently observed in the Gulf of Alaska.

Whales appear to concentrate more in the early morning and in the late evening, probably as a result of the vertical migration of whale food plankton.

Whales tend to concentrate in waters where bluefin tuna and skipjack or saury concentrate in August to October off Sanriku.

The optimum water temperatures of the whaling grounds are comparatively eurythermal. However, each whale species seems to favour certain temperatures. Sei whales are most frequently found in warm waters of 14°-24°C; sperm whales are frequently found in intermediate temperatures of 12°-24°C; fin whales are frequently found in cooler water (10°-22°C).

Favourable temperatures for whale hunting along oceanic fronts in the Northeastern Sea off Japan are: in winter (January-March) 8°-16°C, in spring (April-June) 8°-20°C, in summer (July-September) 14°-25°C, and in autumn (October-December) 10°-20°C.

Whaling grounds seem to have moved farther offshore in the last ten years. In 1957, whales ranged to 200-250 miles offshore. This is due presumably to the progressive movement of the Kuroshio Current offshore.

Whaling grounds used to be located in eddies along the frontal zone, indicating the location of particular types of food plankton.

Seminar 8. The principles of fish distribution, concentration and dispersal

1. <u>General</u>

Information on where, when and how fishing grounds are found, how the fishery conditions on them vary, what factors produce good and poor years, and to what extent fishing can be improved, is of urgent concern to all fishermen. They attempt to get some understanding through collection of all available data and from long years of experience under varying ocean and climate conditions.

A fishing ground may be defined as a locality or area where a fishery is economically conducted on large forms such as whales or on populations of fish generally, such as salmon, herring, etc. Fisheries Science, in dealing with fish shoals (or fish schools) on the fishing grounds must determine the reasons for their general distribution, their concentrations in certain areas and their general dispersal. It is important, of course, that there be available enough vessels of suffient capacity to get to and exploit the fishing areas and the vessels and equipment must be highly efficient in tracking down and capturing the schools of fish. The fishing operations, both in amount of area covered and actual fishing done, are restricted by weather and ocean conditions. Moreover, the economic value of the fish depends on the biochemical processing, the preservation technology, the market and the taste and preferences of the people.

However, the chief basic requirements for a successful fishery are an understanding of the quantities of fish likely to be available, and where, when and how much they concentrate and can produce an optimum catch or maximum sustained catch to the fishermen, in relation to the fishing effort used. It is essential, also, to promote proper conservation by guarding against overfishing on the one hand, and, on the other, to prohibit water pollution, both to be assured by well-ordered regulation and management.

Two avenues of approach to acquire the necessary information required for proper development of fisheries have been (1) by fisheries oceanographical (hydrobiological) researches of the ocean and the oceanic fisheries and (2) by biological, mathematical and physical researches on the fish stocks.

With reference to the first, we may cite the works of T. Kitahara (1918), M. Uda (1927-1958), K. Kimura (1935-1958) and others in Japan. Otto Pettersson (1921) studied the fluctuations over many years of the Scandinavian herring fishery in relation to the intrusion of Atlantic ocean water as an internal wave. J.B. Tait (1952) brought together and summarized many important studies in his book "Hydrography in relation to Fisheries" and valuable individual contributions to knowledge have been made by J.N. Carruthers (1951), O.E. Sette (1955), H.B. Hachey (1955) and G. Dietrich <u>et al</u>. (1957), H.U. Sverdrup (1955) and others.

In the field of marine biological population dynamics, first undertaken by F.V. Baranov (1918) and J. Hjort (1928), many contributions have been made. Some of these are: F.S. Russell (1931), M. Graham (1935, 1956), W.E. Ricker (1944, 1958), M.B. Schaefer (1954), M. Tauti (1944, 1956), J.C. Marr (1951), F.N. Clarke and J.C. Marr (1956), I. Kubo and T. Yoshiwara (1958), H. Aikawa (1949, 1958), Z. Nakai (1955), H. Miyamoto (1952), and S. Ekman (1953).

Fisheries Science, from the viewpoint of fisheries oceanography, seeks to find the principles controlling the abundance of fish in the four-dimensional (x, y, z, t) field of fisheries and embraces the theory of fishing conditions, fishing areas or grounds, fishing periods or seasons in any time section, as well as the variations in fishing conditions in any spatial section. As a practical extension, it seeks to develop fisheries forecasts or predictions, not only of the fishing grounds and fishing seasons, but also of the distribution of the fish and the extent of the catches, in both good and poor years.

2. Proposed principles

(a) Marine organisms are distributed according to the variable environmental (hydrobiological) conditions which they require for successful development.

(b) The basic pattern of the fish shoaling curve in response to normal environmental conditions is shown by the probability curve which is modified by special sea conditions, such as a cold front, etc., or by the composition (size, etc.) of the fish schools.

H. O. Bull (1928) found marine fishes to be sensitive to a temperature change of 0.03°-0.01°C in his experiment.

Uda (1940) prepared a diagram (Fig. 1) of optimum temperature spectra for some of the important commercial fishes of Japan, in which the favourable temperatures and optimum temperatures (range about 4°-5°C) are shown as each characteristic "proper value" (σ) in the following equation:

$$N = N_o e^{-\frac{(\theta-\theta_o)^2}{2\sigma^2}}$$

where σ is the standard deviation, a measure of the range, θ is the water temperature and θ_o is its mode, N is the number or catch of fish, with N_o representing its peak. When σ is large it is called eurytherm, when small, stenotherm and in the range ($\theta_o \pm 2\sigma$), 98% of N are included.

A similar probability curve for salinity can also be prepared.

Uda (1940) measured the body temperature of skipjack, which was higher than the surrounding water by 1°-2°C.

Off the northeast coast of Japan, due to the existence of a cold wall of water, the northward migration of skipjack was halted.

Since $$\int_{\theta_1}^{\theta_2} N_o e^{-k(\theta-\theta_o)^2} d\theta = \int_{\theta_1}^{\theta_2} f(\theta) d\theta,$$

put $$f(\theta) = N_o e^{-k(\theta-\theta_o)^2} \lambda\,\theta$$

$\lambda\,\theta > 1$ for θ (18°-21°C) steep slope

< 1 for θ (21°-23°C) gentle slope

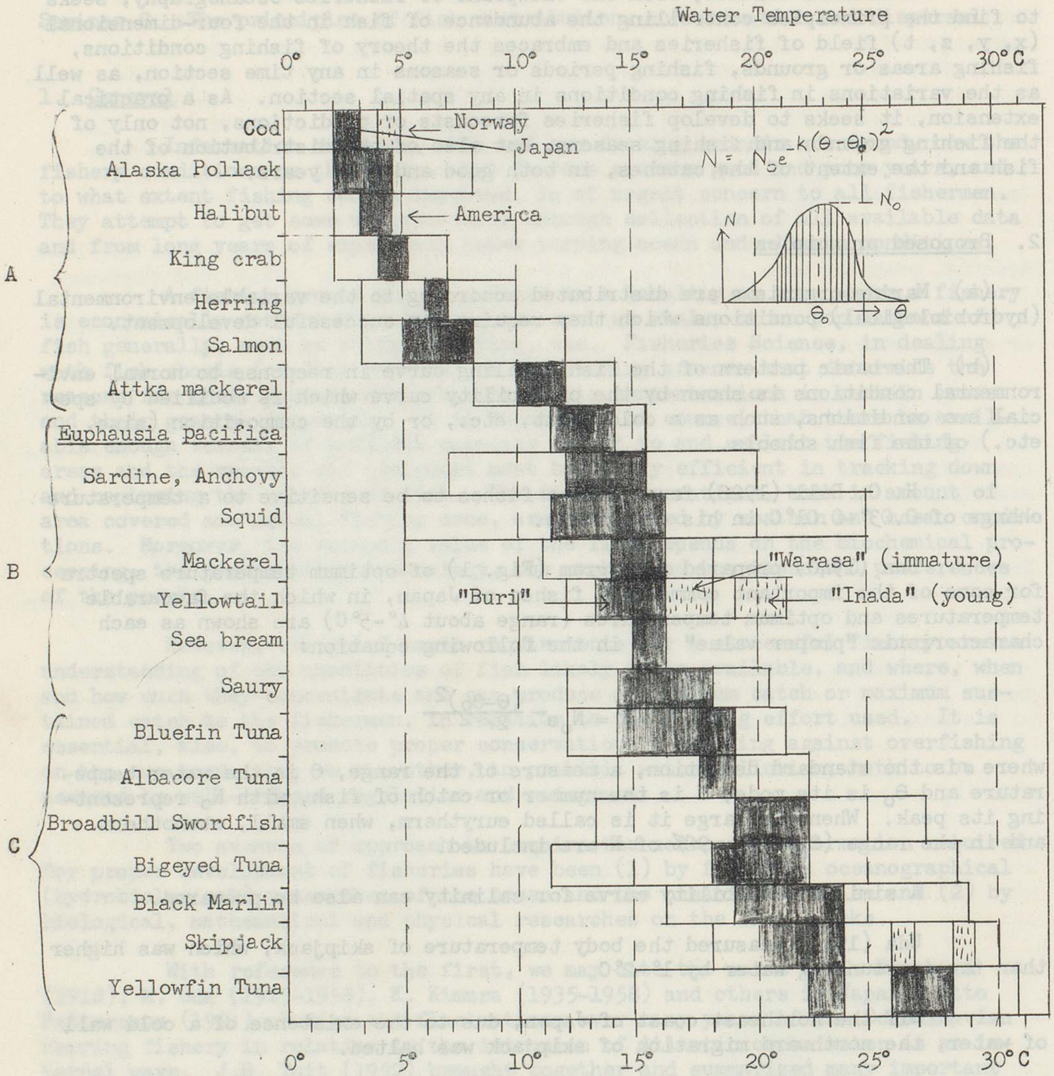


Fig. 1. Optimum temperature spectra of important commercial fishes in Japan

Fishermen locate schools of fish by observing bubbles on the sea, flocks of birds, discoloured water, luminescence (or "water fires") at night, presence of fish skipping or jumping at the surface, or by use of a feeling wire, etc. If we assume the total amount as (M), area of distribution as S, the concentration of fish as $\int o$, and the unit school of fish as N, then the area of distribution, S, in three-dimensional form, can be measured by the echotrace of a supersonic fish-finder or ascertained from the oceanographic structure (M. Uda, 1930-1958; G. Dietrich, D. Sahalage, K. Schubert, 1957). With a combination of $\int o$ found by trial fishing using gill net, trawl, line angling, long lines, purse seine, etc., then ($M = \sum N = \int\int o dS$) will give the quantity M. A useful indirect estimation of fish abundance and concentration may be made by considering the amount or concentration of the food plankton or fishes as shown by echotraces of the DSL (Uda et al., 1957). Another indirect method utilizes the survival rate as estimated from the year-class composition, while aerial scouting also provides useful information.

Marking or tagging methods also give rough estimates.

$$M = \frac{m}{f} = \frac{m}{r} = \frac{m}{\frac{x}{X}} = \frac{mX}{x}$$

when M = amount of catch
f = fishery rate
r = rate of recapture
X = number of fish liberated
x = number of fish recaptured

Consideration has to be given to the possibility of selectivity of the fishing gear, i.e., the likelihood of the mesh size used to capture fish of only certain sizes or to take only certain species. In this regard, obtaining samples by use of explosives might be more desirable, but due to the danger involved, this is not a popular procedure.

3. The localization of fish concentrations is determined by the narrowness of the optimum water zone and each special three-dimensional oceanographic structure. Especially good fishing grounds correspond to the zone of the oceanic fronts (boundaries) of water masses, including "siome" or lines of convergence, and to the zone of upwelling (area of divergence) and other factors, as stated below such as ridging, entrainment, eddies, turbulent mixing, etc.

(a) Kitahara's law (first postulated by T. Kitahara, 1918, and extended by M. Uda, 1938, 1958) states that the "oceanic front" corresponds to the area where marine life is concentrated and where fishing is good, having a "siome" (line of convergence) on the ocean surface as an indicator.

(b) Nathansohn's law (first laid down by A. Nathansohn in 1908 and later extended by others), states that highly productive and consequently good fishing grounds are found in areas of upwelling. Scripps Institution of Oceanography (R. Revelle, J. Reid Jr., K. Yoshida and others) has conducted some basic work on the mechanics of productive upwelling in the California Current System (1954-1958).

(c) Topographically-developed back eddy systems (near a strait, channel, peninsula, cape, island, estuary mouth, etc.) are rich feeding areas, and are good fishing grounds for mackerel, yellowtail, etc. (Uda, 1958).

(d) Thermoanticline or ridgings occur in some sub-surface fishing grounds (e.g., tuna fishing areas in the Equatorial Pacific) as pointed out by T. Cromwell in 1957. This is due to a variety of underwater upwelling or some type of entrainment.

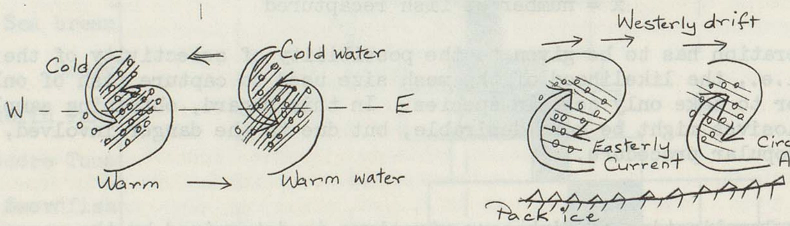
(e) Entrainment (J.P. Tully, 1952, 1956) in estuaries, on the continental shelf edge, insular shelf edges, or near fishing banks, produces a highly fertilized zone and produces good areas for fishing or other aquiculture.

(f) Dynamically-produced eddies along oceanic fronts are rich feeding areas, supplied with an abundance of planktonic food and small fish. These attract the fish which tend to remain there and consequently develop into suitable fishing regions.

(g) In the northern hemisphere, cyclonic (counter-clockwise) eddies, representing cold eddies, constitute good fishing areas in the marginal zones of upwelling (e.g., saury, whales, squids, etc. in the Polar Frontal Zone, albacore in the Kuroshio Front) and are associated with favourable water temperatures.

In the southern hemisphere clockwise eddies develop along the Antarctic Convergence as favourable whale grounds just north of the pack ice zone (M. Uda, 1954, K. Nasu, 1958) (see Fig. 2).

Fig. 2. Polar Front (N. Lat.) (S. Lat.)



4. Warm and cold water intrusions into well-developed suitable water temperature zones bring about concentrations of fish and produce good fishing areas. By the intrusion of unfavourable water masses (e.g., abnormally warm, saline, or cold, fresh water) the fish also become concentrated. For example, the meteorologically abnormal onshore current "Kyutyo" (rapid current or storm current) produces a heavy catch of yellowtail, sardine, tuna, etc., to the coastal set-net fishery.

5. According to K. Brandt's theory (1899) of the development of the organic life cycle of the food chain, productive zones which are fertilized either naturally or artificially by certain physical and chemical processes become potential areas for fishing or for aquiculture by having available ample supplies of the primary nutrient substances.

Physical factors important in developing productive areas include:

(a) <u>turbulent mixing</u>, due to waves and currents, which has been observed in coastal areas or around oceanic banks and islands (e.g., the shrimp grounds, etc., along the S.W. coast of India in the summer monsoon period, as pointed out by N.K. Panikkar (1955)). Productivity of the fishing grounds of herring, cod, etc., in the coastal straits of British Columbia may be attributed to the mixing effect of the strong tidal currents, similar to the straits in the Inland Seas of Japan.

(b) internal waves (of the tidal period) as studied by C. Cox, K. Yoshida and T. Marita in 1958 in the southern Sea of Japan. The fertilization of the tuna grounds on the deep oceanic banks or sea mounts may be due to internal waves. L.N. Cooper (1952) has suggested that internal waves on the continental shelf edge may contribute to the fertilization of the mackerel fishing grounds in the Celtic Sea and A.R. Miller (1950) has studied the mixing processes over the shelf edge.

(c) mixing by convection due to winter cooling, which is important in the seas of higher latitudes. The productivity of the Okhotsk Sea, Bering Sea, Japan Sea, Yellow Sea and China Sea depends largely on the winter monsoon.

6. Schooling of fishes (N) is a function of a special group of hydrobiological conditions (S), the spatial gradient (∇S) and the rate of time variation ($\dot{S}$). Thus, $N = f_n(S, \nabla S, \dot{S})$. Where continuously stable or uniform ocean conditions prevail, the concentration of fish and consequently the development of good fishing areas cannot be expected. A marked spatial gradient in water temperature, etc., or a sudden change in these features is a promising indication of a good fishing area or of a good catch.

7. During the feeding migration, schools of fish seek out areas where the food organisms are abundant and arrive normally at the time when the food is abundant. The food forms vary according to the particular likes and dislikes of the species and according to their size. The feeding migration appears to follow along a definite route in which the areas or zones of abundant food organisms are connected by a series of eddy systems, lines (areas) of convergence ("siome") or areas of upwelling related to the prevalent offshore winds (e.g., yellowfin, sardine, squid fishing grounds).

Topographical peculiarities along the coasts, such as capes, long headlands, inlets, islands, etc., affect the current and wind-flow patterns and produce back-eddies which become, at appropriate times of the season, good fishing grounds. Oceanic islands and banks located along volcanic chains (such as Kyusyo - Formosa, Idu Islands - Ogasawara - Mariana, etc.) constitute the migration routes of tuna and skipjack.

Cold streams in which there is an abundance of food organisms make up portions of the migration routes of some species of fish, such as the saury, squid, chum salmon, etc., and the "loop-sack" formed portions at the end of cold and warm currents along the frontal zone represent very excellent feeding and fishing areas for saury, whales, albacore, skipjack, etc.

8. The spawning migration, stimulated by the sexual hormones as the gonads mature, and occurring as the temperature changes reach a maximum, appears to follow an instinctively determined route corresponding to the same environmental pattern, though in reverse. The biological features bringing about the schooling

of the fish and their return to the natal spawning ground, as influenced or directed by environmental and physiological factors are of great interest. Physiological and ecological experiments by Brett (1958) and others in salmon tanks are planned.

9. Fishing by means of fish lamps depends on the phototaxis of the fish, related to the prey-predator sequence in the food chain, each having a specific and favourable range of luminosity (saury, sardine, mackerel, horse mackerel, squid, etc.). The attraction of fish schools by light sources in a limited confined space has been studied by M. Tauti and H. Hayasi, 1927, and more recently at Lowestoft Fisheries Laboratory, using supersonic fish-finders.

Bright moonlight seems to disperse fish over a wider area and commonly fish lamps are much less effective in attracting fish during the period of full moon.

10. The electrotaxis of fish (sardine, etc.) by attracting them to the anode pole has been under experimentation at Hopkins Marine Biological Station and elsewhere. It shows promise of being of use in future fishing (e.g., success in the USSR in freshwater fishing) and also may have some application in migration of fishes. Electric screens have already been successfully used in rivers (in Japan, M. Okada first made experiments in 1929). Fishing by using an electric pulse was investigated by T. Kuroki (1956). Since in the ocean, currents are associated with a gradient of electromagnetic potential, as indicated by G.E.K. based on the Faraday effect, the electromagnetic patterns in fish migration in the ocean present a very fascinating problem for the future.

11. During the spawning migration, fishes are confined to comparatively narrow zones of favourable temperature (stenotherms) and become more densely schooled the closer they approach their spawning areas. After spawning, they tend to disperse again. Some die, while others migrate to new feeding grounds. The eggs and larvae are transported by the currents and gradually are scattered widely, some of them, in due course, finding favourable nursery areas. In 1909, Johannes Schmidt reported that Icelandic cod larvae, spawned on the south coast of Iceland, were carried by currents to the northern nursery grounds. Subsequently, in 1922, he reported on his famous studies of the migration of eel larvae from the Sargasso Sea to the European and American coasts by means of the Gulf Stream.

In Japan, within the last ten years, much information has been obtained concerning the transport and dispersal of larval fishes from the spawning ground to nursery areas for squid, mackerel, horse mackerel, sardine, anchovy, yellowtail, saury, etc. From early spring to early summer great numbers of floating larval fishes are carried by the Kuroshio and Tusima Currents and their branches.

It is most important to study the natural mortality or rate of survival, as well as the growth rate in these early, critical periods of sea life, particularly in relation to the environmental conditions. Johann Hjort (1926) first remarked upon the importance of wind and current at such periods and J.N. Carruthers <u>et al</u>. (1951, 1955) postulated the effect of prevailing wind conditions in the North Sea on the brood strength of bottom fishes. H.B. Hachey (1955) also studied the effect of wind and current on the brood strength of cod and haddock on the Newfoundland Grand Banks. Therefore, studies of currents and wind conditions, etc., on the spawning and nursery grounds can indicate (foretell) the subsequent fate of new broods and consequently the probable yield of commercial species and can provide useful information on the routes of adult migration and on the availability of the fish, as related to environmental conditions.

In connection with spawning migrations, the occurrence of unfavourable counter currents may delay the arrival of the maturing fish at the normal spawning season or may shift the spawning area to a less favourable region or may shorten the normal and favourable spawning period for the area, all of which is likely to lead to a reduction in the reproductive potential. A succession of such situations over a number of years results in a decline in the fishery (sardine, herring, etc.). Conversely, continued favourable currents during the period in question increases spawning success (longer, favourable spawnings) in well-fertilized productive areas. Thus good fishing years result.

12. Submarine topography and bottom characteristics, including the bottom sediments, may affect the migrations of fish. For example, the yellowtail follows along the 50-100 m isobars of the Continental Shelf; the sea bream prefers a fine sand and shell bottom near a bank or reef. Some fish tend to assemble on banks or reefs, on the margin of sea-valleys or canyons, on sea mountains, close to the Continental Shelf edge or near the coast (ground fishes and pelagic fishes).

Such topographical or geological irregularities bring about the localization or concentration of fish, as contrasted to the smooth, unbroken, flat sea bottom. Therefore, the exploration of the sea bottom by means of echo sounders, dredges, core samplers, etc. is important in fisheries.

13. Fish which migrate in mid-water areas, i.e., in the optimum temperature zone, are concentrated there by the vertically confining influences of the upper and lower unfavourable temperature strata and also horizontally by flows of less favourable waters (e.g., squids, mackerel, tuna).

14. Fish tend to move upward into relatively shallower strata for feeding and collect in those areas where the prey-food forms are concentrated. Feeding in these areas usually extends from twilight or dusk ("Yu Mazume") to dawn ("Asa Mazume") or sunrise and during the late evening, night, and early morning is the best period for fishing (angling, netting, lining). The time of the turn of the tide (ebb to flood, flood to ebb) is another very good fishing period, especially for angling.

These above-mentioned periods correspond to the time when the fish are actively feeding, as indicated by echotraces and catch samples (e.g. Uda et al., 1957).

15. Generally speaking, coincident with the approach of meteorological disturbances such as typhoons, cyclones and fronts, the fish present in coastal waters swim up closer to the surface and feed very actively. Consequently, both before and after such atmospheric disturbances good fishing occurs. On the high seas, however, the fish tend to scatter widely at such times and seek out new feeding

areas. To follow such fish or locate them again is a difficult problem.

16. In accordance with the state of development of the convergence and the temperatures prevailing (i.e., whether favourable or not) the productiveness of the fishing grounds and the development of the fish thereon will differ for each species present.

17. During the season of the spring tide (full moon, dark) the fish schools tend to approach closer to the coast (whales, tuna, etc.).

18. Stormy gales or severe monsoons cause fish to collect to the leeward of islands and headlands, etc. to avoid the rough seas (yellowtail, saury, flying fish, etc.).

19. After severe earthquakes, heavy storms, volcanic eruptions, "Tunami", etc., the fishing areas and fishing conditions may become quite disorganized and altered.

20. "Red Tide" and other abnormal "bloomings" of plankton (e.g. phaeocystis in the North Sea herring areas) drive away fish schools and disrupt fishing.

21. Long-term cyclic fluctuations in commercial fisheries are the result of changes in the reproduction, development, distribution or availability of fish stocks as caused by cyclic environmental changes. The effect of such changes depends on the degree to which the conditions depart from those laid down by Uda (1958) as the optimum conditions and defined by the temperature spectra of Figure 1. Fluctuations occur in all fishes whether they be associated with cold currents (Group A in Fig. 1), intermediate cold-warm currents (Group B), warm currents (Group C) or coastal water areas (Group D, not shown in Fig. 1).

Seminar 9. Environmental conditions controlling the efficiency of fishing operations

1. General

There are a number of problems associated with the safe and efficient conduct of fishing operations. Some of these are:

(a) Methods of locating schools or aggregations of commercially valuable fish or of discovering unutilized populations. In addition to the classical methods of observation by eye, e.g., presence of birds, "siome", patches of bubbles or oil excretions, skipping or jumping of fish, "water fires", or areas of lumenescence, coloured areas or special features on the sea surface produced by fish, there are now used the modern techniques involving fish-finders, aerial scouting, observation of the oceanographical structure of the water, etc.

(b) The operation of fishing vessels and gear. In order to prevent or at least effectively reduce the damage due to storms, high winds, abnormal currents, advance knowledge of weather and sea conditions is required. Prior information on weather conditions can also be of advantage in more effectively carrying out fishing operations.

(c) Processing and transport to market of the fish caught. Chemical and mechanical technology for the preservation and utilization of commercial fish is required, as well as economic studies of marketing distribution and consumption.

(d) Management of the fishery. Not only must there be continuous studies in modifying present gear or in discovering new techniques to capture fish, but also investigations into the protection and regulation of stocks to assure continued maximum sustained yield.

(e) Safe navigation. Studies of fishing craft must be made to assure that the proper types of vessels are used in proceeding from the base harbours to the fishing grounds and return and that appropriate navigational aids and life-saving equipment are provided.

We propose to confine discussion to (b) above, the operation of fishing vessels and gear.

2. Fishing methods and fishing gear. Well reviewed by H. Miyamoto (1958).

Each type of fishing is adapted for specific kinds of fishing grounds and for most effective operation. For example, trawling operations are conducted on areas of flat bottom. Rocky, irregular ground is usually avoided. However, close to banks and reefs there are often good populations of bottom fish and very expert trawling operations are required to prevent damage to the gear. Pole and line and hand-line fishermen prefer fishing banks and reefs. For such fisheries bathymetric charts and the use of echo sounders are very helpful in avoiding damage to gear and in assuring productive catches.

Time of day (twilight to dawn in some instances, day-time in others) and weather conditions (winds, fogs, air temperatures, precipitation, humidity, etc.) have an influence on fishing operations both in higher and lower latitudes.

3. Environmental conditions as related to the various fisheries

A. Pole and line fishing for mackerel in winter is disrupted by the severe northerly winter monsoons and early spring extratropical and tropical cyclones of "Taiwen Bozu", meaning Formosa-generated cyclones. For albacore in early summer and skipjack in spring, summer and autumn, operations are conducted in warm, calm weather, but may be interrupted by typhoons. There are many sad remembrances of the loss of skipjack vessels and coral-dredging boats prior to 1910 but today, with the use of steel, motor-driven craft and the storm warnings provided by wireless and radio, such disasters rarely occur. The loss of expensive live bait in excessively hot summers in tropical waters remains an important problem.

B. Hand-line angling (for squid, etc.) is greatly influenced by currents. The strength and direction of a current is indicated by the inclination of the line when suspended from an anchored boat in the water with a weight or lead at the bottom end. J.N. Carruthers' and T. Kawakami's current meters are designed on the same principle.

In the case of strong tidal currents, such as on the spring tides, angling cannot be carried on. Neap-tides or near to slack water are more suitable. In a stratified current from the sea surface to the bottom, the line may have an irregular or "S"-shaped pattern with varying inclinations from top to bottom. On a drifting boat the line or wire may sometimes drop vertically due to the balance of current and counterwind force.

Sea bream fishing occurs in the straits and channels, but ceases during the stronger tidal current periods.

C. Set-net fishing is conducted along the Japan coast in areas where the currents are not too strong and an onshore flow of oceanic water occurs. Some trapnetting and gillnetting is carried on in the active tidal areas of the West Korean Sea, Ariakekai, Tokyo Bay, Funday Bay, etc., catching migrating fish which are brought in by the tidal current.

H. Miyamoto (1952) reported on studies of the set-net fishery and described how in model experiments, the form of the net changed with the current pattern.

M. Uda (1927) reported that notwithstanding the fact that fishing during the passage of a cyclone has to be curtailed, the fish brought into the set-net fishing areas produce large catches. However, too strong a current ("Kyutyo" or storm current) may sweep away large set-nets and cause great damage and possibly injury or loss of life to fishermen (Uda, 1953). In somewhat less pronounced currents, even 60 to 100 fishermen may not be able to lift the nets and fishing has to be terminated (Miyamoto, 1952).

D. Purse seine fishing is most productively carried on near the coasts of Tohoku (northeast of Japan) for bluefin tuna, mackerel, sardine, etc. in summer and autumn in the northwest part of the Japan Sea, off Korea in autumn, and off the west and north coasts of Kyusyu for sardine and mackerel in early spring and summer. These fishing areas have the common characteristics of calm waters and seasons when the dense schools of fish are confined to the shallow, warmer waters by a well-developed thermocline, similar to the California sardine areas.

However, in late May 1957, off the south coast of Tohoku, six sets of purse seines were broken and taken away by the fast Kuroshio current. In the mid-summer of 1948, a strong stratified current occurred in the seas of Amakusa Nada and Goto Nada, to the west of Kyusyu near Nakasaki, and carried away ten purse seines set out for small-sized sardine (Uda, 1949, T. Tsujita, 1949, 1952). Sometimes in the East China Sea similar losses due to a stratified current (fresh rapid current in the surface layers and counter saline currents in deep strata) occur. These happen frequently off the mouth of the Yangtze River.

The coupled effect of wind and current is particularly serious in the operation of purse seines.

E. Longline tuna fishing can be carried on in quite rough seas, since the gear is near the lower boundary of the convection layer (wind-stirred layer), which is limited sharply by the thermocline in the equatorial region. Being quite different to the tunas swimming in the warmer surface waters and caught by pole and line or trolling, the tunas caught by longline are of much larger size and frequent deeper strata. Since the war, larger tuna vessels have been built, some of the super-clipper type more than 500 tonnage. Vessels of 1,000 tons appeared in 1956 and 1957. They operate chiefly in the Indian and Atlantic Oceans.

However, at the present time high-speed mid-type tuna boats (250-350 tons) with large fish holds and making up to 7 cruises per year are more economically operated. Tuna boats of 100-200 tons operate in the North Pacific and the Equatorial Pacific and eastern Indian Ocean. Vessels of 200-300 ton capacity are used in the South Pacific and West Indian Oceans. Trips may be for as long as 1-4 months.

In the North Pacific off the east coast of Japan in winter, albacore longlining is carried on, under very adverse conditions experienced during the severe winter monsoons (prevailing westerlies). Good catches are made and the high quality fish bring a high market price. However to avoid the strong counter-winds, the fishermen prefer to make the return cruise to the home harbour close to the 30°N line in the comparatively calm southern sea.

In the Equatorial Pacific, Indian Ocean and Atlantic, in the 10°N-10°S zone, good yellowfin tuna fishing takes place. Here the weather is relatively calm but rainy throughout the year and the fish feed readily. In the 12°-20°N and S zones, midget hurricanes or typhoons occasionally occur and tropical cyclones may be encountered. A warning system must be available regarding hurricanes, typhoons and tropical cyclones in the 10°-40°N and S areas, especially in the warmer seasons (summer and autumn). In the North Indian Ocean, Bengal Sea and Arabian Sea, rough seas during the summer season, due to the strong prevailing monsoon and moist, hot weather, make fishing difficult.

Far-ranging vessels, equipped with refrigerating equipment, are capable of conducting far distant fishing operations, but nevertheless, for a steady, reliable and economic fishery, operations conducted from land-based stations are preferable.

Tuna schools are found abundantly near oceanic fronts which usually consist of lines of convergence with complex currents and eddies. Careful fishing carried on in fronts indicated by "Siome" result in large catches, but there is grave danger of losing gear or getting it all tangled up and thus making no catches.

Sharks and killer whales give trouble to tuna fishermen in the Indian and Pacific Oceans. They tend to drive away the tuna schools and may take tuna right off the longline, leaving only the heads of the fish on the hooks.

F. Whaling. M. Uda and K. Nasu (1956) reported and computed:

$$F = K.V.S.O.$$

where F = amount of the whale catch
V = the rate of discovery by ordinary look-out procedures
S = schooling propensity of whales
O = rate of whaling operation
K = proportional constant, dependent on the characteristics of the plankton, topography and other elements of the whaling grounds.

Due to the influence of an approaching cyclone, the sea condition becomes unfavourable, whereupon (S) increases with the approach of the cyclone and causes (F) to increase. When a cyclone approaches a whaling ground, the southerly wind sets up a dense sea-fog (advective fog) in the cold water areas off northern Japan, and as a result (V) decreases. Since naturally (F) will be proportional to (V) and (O), including the rate of gun-hit as its main factor (which is inversely proportional to the sea conditions or wind (W), i.e., $O \propto \frac{1}{W}$),

we have $F = K'\frac{VS}{W}$ or $S = \frac{FW}{K'V}$

In the summer of 1956 and 1957 in the Okhotsk Sea, due to the low-water temperatures resulting from much sea ice during the winter and spring, dense fog made the spotting of whales exceedingly difficult and this was one reason for the poor whale catch.

Whaling grounds in the Antarctic are located along the pack ice zone and close to icebergs. Ice conditions and storms greatly restrict the whale catch.

G. In salmon fishing, conducted in the waters off the Aleutian Islands and in the Bering Sea one strange phenonemon frequently encountered is "Bō-ami" or "Bō-maki Ami", and refers to the rolling up of the gillnets by the complex currents of the upper and lower layers of the stratified currents produced by internal waves or lines of convergence ("Siome"). In stormy weather it occurs quite frequently and also in the complex currents off the Aleutian Islands. Many nets are lost in this way every year.

Heavy, stormy weather often causes fishing to be stopped and gives the salmon boats a holiday. In 1957, the weather was relatively very calm, cyclones were few and the salmon fleet enjoyed its highest efficiency. However, in 1958 frequent cyclonic storms occurred with the result that only 64% of normal fishing could be done. In May the fishing amounted to only 58%, June - 70%, July - 65%, August - 56%, i.e. at the beginning and end of the fishing season operations had to be severely curtailed.

From April to early June during the salmon season in northern waters, extratropical cyclones occur with gusty, stormy weather from the west, frequently causing boats to be lost and fishermen drowned. A suitable warning system is urgently needed, since Arctic air masses intrude very rapidly. Toward the end of the season, July and August, tropical cyclones may also occur, but fortunately there have not yet been any disasters from them.

H. The <u>King crab fishery</u> operates along the west Kamchatka coast north to 56°N in April. Drift ice and pack ice are close to the fishing areas. In 1956 the drift ice in the Okhotsk Sea disappeared in the middle of May.

I. <u>Miscellaneous fisheries</u>. Those fisheries which are carried on underwater by divers, etc., are very dependent on water temperature and transparency. The activity of sonar fish-finders and hydrophones is restricted by the distribution or stratified pattern of the water masses. Abnormal populations of jelly fish, porcupine puffers, etc., occasionally interrupt fishery operations over wide areas. All varieties of fishes caught should be utilized fully.

4. <u>Environmental conditions affecting aquiculture in shallow areas</u>

Typhoons in Japan (summer and autumn) occasionally cause great damage. Typhoon "Kitty" in 1948 destroyed the abalone grounds along the shores of Sagami Bay and Sanriki when the mountainous surf dislodged, overturned and piled up the inter-tidal and shore masses of rocks, stones, etc. It also ruined the clam beds on Tokyo Bay when the flooded rivers brought down and deposited thick masses of sediment. The high waves in the river estuary caused great damage also in those areas where sea weeds were being cultured on bamboo poles or on nets. Great damage was also done to oyster rafts.

In 1955 typhoon "Ruth" struck South Kyusyu. The huge surf stranded the rafts on which black pearl oysters were being cultured and killed many of the oysters.

At times during strong winter monsoons, the wind-driven waves stir up the areas where laver is being cultured and cause considerable damage and loss of leaves (e.g., in the Ise Bay and Tokyo Bay, etc.).

The freshwater discharge from flooding rivers frequently results in heavy mortality in seaweeds and oysters. This "midusio" or "nigasio" (meaning bitter water mass) produces "Isoyake" or coastal areas which have the appearance of burnt-over fields.

After floods during the warmer season of the year "red tides" or "red water" may occur. This causes great mortality among oysters and cultured pearl oysters. Furthermore, suspended material transported from the land by the heavy rains becomes attached to seaweed and covers up clam-rearing grounds, causing much damage to the physiological processes.

Hot and dry weather increases the salinity and raises the temperature of the water in which oysters are being cultured and has a deleterious effect.

After the passage of an extratropical cyclone during the winter of 1956, a violent gale occurred along the Sanriki coast and swept away many rafts on which laver was being cultured. Similar losses of rafts may occur when storm tides occur or during Tunami, i.e. seismic floods.

5. In general, it may be said that in the waters adjacent to Japan, fishing operations are greatly hampered by and severe losses result from the occurrence of (a) typhoons in summer and winter, (b) high winds during the passage of extra-tropical cyclones in winter and spring, (c) strong winter monsoons and (d) dense summer sea fogs. Prompt weather forecasting, indicating the approach of high winds, etc., is very essential in guarding against loss of life and loss or damage to vessels, boats and gear.

Seminar 10. Fluctuations in fisheries; long-term trends and prediction

1. General

Fish populations (P) in nature repeatedly increase and decrease (accompanied by extension and contraction of their ranges) under some unknown and complex natural environmental conditions. The fishing conditions and the resulting amount of catch (N) for each fish species (sardine, herring, tuna, etc.) fluctuate from year to year (in a periodic or some irregular way) with intervals of nearly a century, or 20-30 years, or 50-60 years. (See Fig. 1 and Table 1) (M. Uda, 1952, 1957).

Table 1. Recent fluctuations of the fisheries in the Japan Sea
(b = bad; bb = very bad; g = good, gg = very good)

Periods	(interval of years)	Sardine	Tuna	Squid	Herring
1	1868-1905	b	g	–	g
2	1906-1912	gg	b	–	b
3	(1913-1917)	gg	–	g	gg (1913-20)
4	1917-1921	g	–	b	
5	1923-1931	b	–	g	–
6	1932-1940	gg	gg	–	b
7	1941-1948	b	bb	gg	g
8	1949-1955	gg	gg	gg	b
9	1956-1957	–	gg	b	b

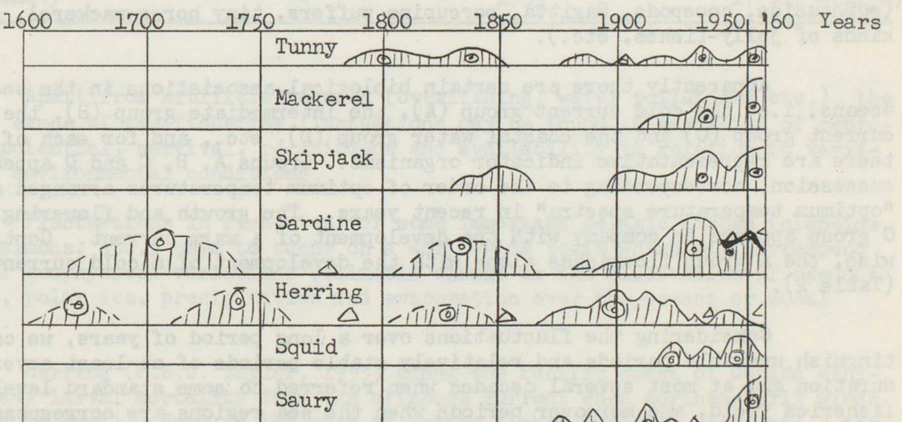


Fig. 1. Fluctuation of Japanese important fisheries (yield)

In general, the periodic decay (or growth) of yield can be expressed as:

$$N = N_0 e^{-rt} \sum \cos (wt - \mu) \text{ --------------- (1)}$$

The actual fluctuations of a fish population (or catch) is the result of its natural fluctuation modified by some artificial factors (e.g. fishing or some bad effects of industrial wastes) (M. Uda, 1957).

Following M.B. Schaefer (1954):

$$\frac{dP}{dt} = f(P) - KPF \text{ --------------- (2)}$$

where K, F, P, are all functions of environmental factors.

In company with the movement of predominant warm currents and cold currents, the zones of favourable and unfavourable catch shift and undulate from north to south or south to north meridionally (y - direction) along the coast, and from offshore to nearshore, or nearshore to offshore laterally (x - direction). As the function of the movements in each direction, x, y, with velocities c_1, c_2 respectively, we have:

$$N = \Phi (x - c_1 t, y - c_2 t) \text{ --------------- (3)}$$

The migration route of fish shoals approaches the coast in rich years and moves further away from the coast in poor years (e.g. sardine, yellowtail, etc.).

The fishing gears suited to each fishing locality change from set-net near the coast to purse seine in the intermediate waters to drift gillnet and longlines offshore.

We can find groups of important fish species which show positive and negative variations, respectively, and also indicator species for each group (euphausids, copepods, Sagitta, porcupine puffers, tiny horse mackerel, some kinds of jelly-fishes, etc.).

Apparently there are certain biological associations in the seas and oceans, i.e. the cold current group (A), the intermediate group (B), the warm current group (C) and the coastal water group (D), etc., and for each of them there are representative indicator organisms. Groups A, B, C and D appear in succession, corresponding to the order of optimum temperatures arranged as "optimum temperature spectra" in recent years. The growth and flowering of the C group appears in company with the development of a warm current. Contrariwise, the A group flourishes along with the development of a cold current (Table 2).

Considering the fluctuations over a long period of years, we can distinguish unstable periods and relatively stable periods of at least several years' duration and at most several decades when referred to some standard level of fisheries yield, and moreover periods when the sea regions are correspondingly unstable and relatively stable.

The conditions in the regions of the sea on the route of feeding migrations, especially near the oceanic fronts, fluctuate greatly and show unstable (rich or poor) catches. Regions of the sea near the spawning grounds and along spawning migration routes show comparatively stable catches.

The spawning grounds and nursery grounds move not only from south to north or from north to south, but may vary in the relative percentage abundance of fish present on the grounds as we see in the cases of sardine, herring, etc. The sudden change in the long-term variation is brought about by the sudden growth or decay of warm and cold currents (e.g. in the years of 1923, 1941 and 1951).

Table 2. Phase lag of the mode (maximum) of catch curves and their optimum temperature.

	Fish species	Period I (years)	Period II (years)	Optimum water temperature
A	Herring	1944-45	-	3°-8°C
A	Atka mackerel	1944-48	(1951-53)	2°-6°C (-13°C youngs)
B	Squid	1941-43	1951('52)	12°-16°C(10°-18°C)
B	Sardine	1933-39	1947-50	12°-16°C
B	Yellowtail	1942-43	1951-52	14°-16°C
B	Mackerel	1939	1954('51-'52 Japanese)	13°-18°C
B	Saury	1932-40	1955	15°-18°C
B	Horse mackerel	1940-41	1954-57	15°-18°C
C	Bluefin tuna	1936-41	1956-57	(12°)-14°-19°-(21°C)
C	Albacore	1935-40	1954-57	18°-21°C
C	Skipjack	1936-38	1955-57	20°-24°C
D	Anchovy	-	1955	17°-19°-(21°C)

Apart from artificial causes (overfishing, water pollution, etc.), the ultimate cause of the fisheries fluctuations may be found in variation of reproduction potential, survival, recruitment and availability in relation to variations in environmental conditions.

Fluctuations in fisheries for some important pelagic fishes (clupeids, tunas, salmons, etc.) seem to occur on a world-wide scale which may correspond to global geophysical variations (climatic change or the fluctuation of oceanic currents, polar ice, precipitation and evaporation over the oceans or zonal regions).

Herring (F.H.C. Taylor, 1955) along the Pacific coast of Canada exhibited heavy larval mortality from the offshore current when northeasterly winds prevailed in April. Even in the case of bottom fishes (haddock, cod, etc.) the effects of environment, especially the wind conditions at the larval stage, are very serious, as shown by H.B. Hachey (1955) and J.N. Carruthers <u>et al</u>. (1957). Dominant year-classes of important fish populations (e.g. sardine, herring, bluefin tuna, etc.) and favourable environmental conditions may occur over several (10 to about 20) years, and the appearance of large-sized (old fish) populations without the succeeding year-classes (small-sized fish) give us warning of the approaching end of good fisheries. Conversely, the increase of young and adults year by year may foretell a growing fishery.

The inverse relation between sardine and anchovy or others may suggest some law of balance or law of alternate predominance in the seas. T. Hayasi (1957) drew up a balance sheet between piscipredator, plankton feeder and benthos feeder. Concerning sardine, mackerel, herring, Pacific saury or other fish populations, we can recognize the fluctuation of the spawning grounds in the course of spawning migration routes, and the corresponding environmental fluctuation may be the fundamental cause of this fluctuation. A special phase for each prosperity of fish populations can be pointed out as we see in Figure 1, Tables 1 and 2. In conclusion, we should define the abundance and maximum sustainable catch as a function of environmental factors (W.E. Ricker, 1958).

2. <u>Cyclic changes in fisheries environments</u>

A. Geophysical cycles or periods in the sea and atmosphere (K. Takahasi, 1958)

(i) Weather cycle
- Several minutes (gravitational waves
- Half a day (free oscillation in the atmosphere, pressure)
- 1 day (solar radiation, diurnal change)
- About 4 days (cyclone passage, unstable waves, weather in spring and autumn 3-4 days)
- 7 days (high depression growth and decay, 3 colder and 4 warmer days)
- 13.5 days (about half of tidal 29 days, and half of solar sun spot 27 days)

Atmospheric Circulation
- 24 days (weickman)
- 36 days, 72 days, 3 months, 5 months, 9.6 months

Planetary wave (prevailing westerlies)
- 25-36 days (around the earth)

Solar activity
- 1 year (radiation); 4 years (calamity due to storm)
- 7 years (6.58 years, rain); 9 years (winter air temperature)
- 11.2 years (sun spot); 35 years (Brückner)
- 60 years, 80 years (solar activity)

Climatic cycle
- Low latitude 3 years, Europe 7.2 years, summer, winter temperature 16 years
- 700 years (Nisioka)
- Sun spot number varies parallel to the numbers of typhoon and storm, inversely to the frequency of heavy snow
- 81 year cycle (S. Fujiwhara, rice famine year due to cool summer)
- 80, 90 years (typhoon, heavy snow)
- 60, 80, years (flood)
- 50, 100 years (dry spell)
- 9 years (North Pacific high meridional shift)

(ii) Oceanic cycle

2.5 months (velocity of Kuroshio - J. Masuzawa, T. Ichiye)
Half a year, summer, winter maximum, spring, autumn minimum
(Gulf Stream - Iselin, Fuglister; Kuroshio - Uda, Fukuoka)

Lunar tidal period:
- Gulf Stream (shingle) - W.S. Von Arx <u>et al</u>.
- Kuroshio temperature - Uda
- Internal wave (salinity - Arthur); (temperature - C. Cox, O. Pettersson)
- (14 days) - current, sea level (Kuroshio) - D. Shoji

10-12 years, 30-35 years - Kuroshio - Uda (Fisheries)
10 several, several 10 years, 60-80 years, 100 years - Uda (Fisheries)
7-10 years - Tusima Current - Uda
7 years - Tusima Current (East China Sea, Japan Sea) - Hidaka and Suzuki
15 years - Kuroshio (cold water mass) - Nan'niti
10 several years - Gulf Stream - Iselin
11.6 years, 18.6 years - sea level (Japan) - H. Miyazaki
4.5 years - Polar Front - M. Hatanaka, Kawai
About 4, 5, years (3.5-6) North Pacific circulation - Uda
7-8 years - Kusunoki - Tusima Current
11 years - Japan coastal temperature - Uda, Fukuoka
1800 years, 80-90 years, 18 years, 9 years - O. Pettersson

B.

<u>Cold years</u>	<u>Warm years</u>
1900-1910-1915 1941-49 (1940 - Baltic heavy ice, 1942-44 - Arctic heavy ice)	1926-40 (peak: 1932-37) Kuroshio northerly extended, Atlantic current strong 1951-55 - Japan (1954-58 - Canada, B.C., U.S., Pacific side)

3. <u>Salmon grounds</u>

A. In the northern waters, salmon fishing grounds change remarkably from year to year. For example:

1957 (spring and summer)	1958 (spring and summer)
Arctic high, strong	Arctic high, weak
Easterly wind prevailed	Strong northwesterly wind prevailed (8-9 m/s)
North Pacific high, weak, stormless, calm	North Pacific high, weak, easterly shifted; stormy cyclones frequent
Warm in the north Bering Sea	Cold in the northwest Bering Sea
Kurile, W. Kam, and Okhotsk Sea cold	
Cold core retreated to west	Cold core (dichothermal) persisted
Oyashio prevalent and S. Aleutian current strong (warmer)	S. Aleutian currents weak
Fronts developed	Fronts undeveloped
Favourable temperature zone shifted to north	Favourable temperature zone shifted to south

1957 (spring and summer)	1958 (spring and summer)
Salmon migration and distribution changed and temporary dense concentration stayed	Salmon not concentrated
Poor catch in south, rich catch in north	Poor catch (165°-170° C, around 50° N)

B. The decline of Asiatic and Alaskan salmon and herring fisheries in the past 50 years suggests to us the effect of Arctic and sub-Arctic warming on land and in the sea.

The historically big catch of sockeye salmon and herring in British Columbia (Fraser River) in 1958 suggests local variation of environmental conditions. Under the pressures of fisheries and man-made civilization (water pollution, deforestation, traffic and construction, disturbances, etc.) the complex fluctuation of fisheries in relation to environments (natural and artificial) should be studied.

4. Prediction of Fisheries

A. Distribution or concentration:

Where - fishing locality
When - fishing period
How much - fishing yield or amount of catch } Studies on marine zoogeography, fisheries ecology and fisheries oceanography are concerned

General trends:

Rich year or bad year
Declining
Growing } Population dynamics and fisheries oceanography are mainly involved

Why - study of mechanisms (to find useful prediction indices of importance)

Comparative study:

In developed area - natural fluctuation and artificial fluctuation
In undeveloped area - natural fluctuation only

B. Co-operative studies of fisheries scientists, oceanographers and fishermen are necessary.

C. Organization:

a) Systematic surveys and collection of data (including information)

(i) environmental conditions
- meteorological data, etc.
- oceanographical data - regular observations
- fisheries data and information, fishermen collected data and others

(ii) catch statistics, etc. concerning fisheries

b) centre and branches

(i) data, sample processing, information selection, compilation and broadcast from Information Service Centre (speedy)

(ii) basic study to promote prediction in order to find useful prediction indices

(iii) forecasting (prediction) activity

c) Committee for surveys and technological improvements (instrumentation, etc., such as the electric analogue computor (Japan, N. Doi)), conferences, training and education of scientists.

References

Aikawa, H. and Y, Konishi, 1940. The scientific investigation of the Sardine Fishery. On the racial problem of the Japanese Sardine (Sardinia melanosticta T & S). J. Imp. Fish. Exp. Sta., 10: 355-416.

Amemiya, I. and T. Abe, 1933. Suisan Gakkai Ho. (Bull. Sci. Fish. Ass.) 5(4). (In Japanese)

Amemiya, I. and O. Tamura, 1941. Ibid. 8(3, 4).

Baranov, F.V., 1918. [On the question of the biological basis of fisheries.] Nauchnyi issledovatelskii ikhtiologicheskii Institut, Izvestiia, 1(1): 81-128.

Beklemishev, C.W. and V.A. Burkov, 1958. The relationship between the plankton and the water masses in the frontal region in the N.W. Pacific. Trans. Oceanol. Acad. Sci. U.S.S.R., 27.

Birman, I.V., 1958. [On the distribution and migration of Kamchatka salmon in the Northwest Pacific.] Materialy po biologii morskovo perioda zhizni dalnevostochnykh lososei : 31-51. Published by VNIRO, Moscow.

H.O. Bull (1928).

Brett, J.R., 1952. Temperature tolerance in young Pacific salmon, etc. J. Fish. Res. Bd. Can. 9(6): 265-323.

1957. Salmon research and hydro-electric power development. Bull. Fish. Res. Bd. Can. 114, 26 pp.

1958. We must learn more about salmon. Western Fisheries 56(1).

Carruthers, J.N. 1951. An attitude on "fisheries hydrography". J. Mar. Res. 10(1): 101-118.

Clark, F.N. and J.C. Marr, 1956. Population dynamics of the Pacific sardine. Progress Repts., Calif. Co-op. Oceanic Fish. Invest., 1 July 1953 to 31 March 1955 : 11-48.

Cooper, L.H.N., 1952. Water movements over the continental slope in relation to Fisheries Hydrography. Rapp. et Proc - Verb. 131.

Cromwell, T., 1953. Circulation in a meridional plane in the Central Equatorial Pacific. Jour. Mar. Res. 12(2): 196-213.

Dietrich, G., Sahrhage, D. and K. Schubert, 1957. The localization of fish concentrations by thermometric methods. Intern. Fishing Gear Congress, 1957, Paper No. 34.

Ekman, S., 1953. Zoogeography of the Sea. Sidgwick and Jackson, London. 417 pp.

Foerster, R.E., 1941. The mortality of young pilchards, 1941. Prog. Rep., Pac. Biol. St. and Pac. Fish. Exp. St., Fish. Res. Bd. Canada, No. 48: 3-8.

1955. The Pacific salmon of the Canadian Pacific Coast. International North Pacific Fish. Comm., Bull. 1: 5-55.

Graham M., 1935. Modern theory of exploiting a fishery, and application to North Sea trawling. J. Conseil Expl. Mer, 10: 264-274.

1956. Sea Fisheries: their investigation in the United Kingdom. Edward Arnold (London), 487 pp.

Hachey, H.B., 1955(a). A review of Canadian oceanography. Assoc. Intern. d'ocean. Phys. Procès-Verbeaux, No. 6: 204.

1955(b). Storm surges and internal adjustments in the water mass. Ibid. No. 6: 121-122.

1955(c). Water replacements and their significance to a fishery. Bigelow vol., Deep Sea Res., Supp. to vol. 3, pt. II: 68-73.

1955(d). The hydrography of Hudson Bay. Trans. Roy. Soc. Can. Ser. III, Vol. 48: 19-23.

Hirano, Y., 1943. On the food of salmon. Hokkaido Fish. Scient. Invest., News, 583.

1953. A review on results of tagging experiments on the salmon Oncorhynchus. Hokkaido Fish. Sci. Inst.

Hodgson, W.C., 1957. The herring and its fishery. Routledge and Kegen Paul.

1958. On the interpretation of the East Anglia Herring, 1923-1955. Jour. du Conseil pour l'explor. de la mer, 23(3).

Ikeda, N., 1933. A study of the "Samma" (Cololabis saira) fishing in 1930. J. Imp. Fish. Exp. Sta., Vol. 3: 341.

Inoue, M., 1958. Studies on movements of albacore fishing grounds in the northwest Pacific Ocean. Adaptability of water temperatures for albacore in the winter season from observations of records on catches and optimum water temperatures by fishing boats. Bull. Jap. Soc. Sc. Fish. 23(11).

International North Pacific Fisheries Commission, 1955. On the salmon in waters adjacent to Japan. Bull. I: 57-92.

1957. Annual Report. C. Research by United States : 54-86. Vancouver, Canada.

Ishida, A., 1952. A review of the herring fishery and biological studies in Japan. Fish. Sci. Ser., No. 4, Japanese Fisheries Agency.

Japanese Whaling Association, 1955. Biological investigation of the northern Pacific whales in 1954.

Kaganovsky, A.G., 1949. Certain problems relating to the biology and population trends in pink salmon. Izv. TINRO, XXXI.

Kasahara, H. and Ito, H., 1953. The ecology of the Pacific Mackerel. Fish. Sci. Ser. No. 7, Research Div. Fisheries Agency Japan. 131 pp.

Kasahara, H, and N. Otsuru, 1952. A review of researches on Pacific Saury. Fish. Sci. Ser. No. 3, Japanese Fish. Agency.

Kasawara, K., 1950. Whaling and its resource in the adjacent waters of Japan. Rept. of Nippon Suisan Co. Res. Inst.

Kawamoto, N.Y., 1956. Experiments with the Fish Gathering Lamp. Proc. 6th IPFC Session, Tokyo, 1955 : 278-279.

Kawana, T., 1948. Studies on the stock of Hokkaido herring. I. Yearly catch per trap-net from 1870-1946. Bull. Jap. Soc. Sc. Fish. 14(2).

1949. Ibid. II. Solar-index and amount of brood. Bull. Jap. Soc. Sc. Fish. 14(4).

Kawata, S., 1956. Current Status of Fish Finders in Japan. Proc. 6th IPFC Session, Tokyo, 1955 : 265-266.

1957. "Fish Finders" (Tyojunta Tiki), Tokyo.

Kimura, K., 1943. On the coastal stormy current "Dai Kyutyo". Rept. Central Meteor. Office, 19(1).

Kimura, K. and S. Fukusima, 1956. Researches on Pacific Saury Fisheries. Repts. Tohoku Reg. Fish. Res. Lab.

1958. Ibid.

Krogius, F.V. and Krokhin, E.M., 1953. [A means of restoring and increasing the runs of Kamchatka salmon.] Trans.Conf. on Problems of Salmon Management in the Far East. Ikhtiologicheskaya Komissaya, Tr. Sovesh' 4: 10-21.

1956. Results of a study of the biology of the Sockeye salmon, condition of the stocks and fluctuations in numbers in Kamchatka waters. Voprosy ikhtiologii, 7: 3-20.

Kubo, I. and T. Yoshihara, 1957. [Study of fisheries resources.] Kyoritsu Publishing Co., Tokyo, 345 pp. (In Japanese)

Kuragami, M. and T. Kawana, 1934. An abnormal concentration of Sardine off Hidaka Coast. (In Japanese). Rep. Hokkaido Fish. Exp. St., No. 223.

Kurita, Susumu, 1957. Causes affecting the size of sardine stock in the waters off Japan and adjacent regions - with particular reference to the catch declining since 1941. Bull. Tokai Reg. Fish. Res. Lab. No. 18: 1-14.

Maeda, H., 1956. Shoaling tendency in Tuna observed in the Great Sunda Archipelago. Proc. 6th IPFC Session, Tokyo (1955): 239-246.

Manzer, J.I., 1958. Salmon distribution and abundance in the northeast Pacific Ocean. MS Rept. Biol. No. 656, Fish. Res. Bd. Can., 38 pp.

Marr, J.C., 1951. On the use of the terms abundance, availability and apparent abundance in fisheries biology. Copeia: 163-169.

Matsue, Y. and Y. Komaki, 1958. Researches on Euphausids. Rept. Tusima Current Res. Proj., Vol. 2, Jap. Fish. Agency.

Miller, A.R., 1950. A study of mixing processes over the edge of the continental shelf. J. Mar. Res., 9(2).

Mimura, K., 1958(a). Fishing conditions of the so-called Indo Maguro (Thinnus maccayi?) in the eastern seas of the Indian Ocean. Rept. Nankai Reg. Fish. Res. Lab., No. 7.

1958(b). Study of the fishing condition of the yellowfin in the Indian Ocean, esepcially on the annual differences in the hooked rate and size composition. Rept. Nankai Reg. Fish. Res. Lab., No. 7.

Mitani, F., 1957. Correlation between catches on fishing grounds and secular variation in catch of the yellow-tail along the coast of Japan. Bull. Jap. Soc. Sci. Fish., Vol. 22, No. 10.

Miyamoto, H., 1956. Synthetic fibre for fishing nets and ropes in Japan. Proc. 6th IPFC Session, Tokyo, 1955: 267-270.

Moiseev, P.A., 1955. Geographic distributions of the fishes and certain commercial mammals of the Okhotsk and Bering Seas. Trans. Inst. Oceanol. Acad. Sci., U.S.S.R., Vol. 14, 120 pp.

1958. [The ocean fishery for salmon and certain problems for study.] Materialy po biologii morskovo perioda zhnizi dalnevostochnykh lososei: 3-7. Published by VNIRO, Moscow.

Murphy, Garth and Richard S. Shomura, 1952. New Tuna Source. Pan-American Fisherman, May.

Nakai, Z., 1939. Some information helpful for predicting sardine fisheries in Korea with special reference on relationships between the mortality and seismological, meteorological and oceanographical conditions in 1932. (In Japanese). Suisan Kenkyushi, 34(4).

1943. A summary of Sardine Resource Investigation and causes of the Fishing adversity. (In Japanese). Minutes of 3rd. Subcomm., 7th. Commit. Scien. Tech. Council.

1949. Why cannot the sardine be caught? (In Japanese). Suisan Kikan, No. 2, Fish. Assoc. of Great Japan.

1956. Do fishing lights affect the fish population? Proc. 6th. IPFC Session, Tokyo, 1955: 273-274.

Nakai, Z. and K. Honjo, 1954. A preliminary report on surveys of plankton and salmon stomach contents from the North Pacific. Fish. Agency Japan. Tokai Reg. Fish. Res. Lab., Spec. Publ. No. 3: 6-12.

Nakai, Zinziro, Usami Shuzo, Hattori Shigemasa, Honjo Koji and Shigeichi Hayashi, 1955. Prog. Rept. Co-op. Iwashi Resources Invest. April 1949 - December 1951. Tokai Reg. Fish. Res. Lab., Tokyo, Sept., 116 pp.

Nakamura, H., 1958. The present status and the future of Tuna fisheries researches. Rept. Nankai Reg. Fish. Res. Inst.

Nakamura, H. and Y. Hiyama, 1958. Recent studies on Tunas and Marlins in Japan. Proc. 8th. Pac. Sci. Cong., 1953, Vol. III: 165-182.

Nakamura, H., Y. Yabuta and K. Mimura, 1956. Longline Tuna fishing grounds in the Indian Ocean. Proc. 6th IPFC Session (Tokyo, 1955): 220-249.

Neave, F., 1953(a). "Even-year" and "off-year" pink salmon populations. Trans. Roy. Soc. Can., 46, Sect V: 55-70.

1953(b). Principles affecting the size of pink and chum salmon populations in British Columbia, J. Fish. Res. Bd. Can., 9(9): 450-491.

1958. Stream ecology and production of anadromous fish. The Investigation of Fish-Power Problems, H.R. MacMillan Lectures in Fisheries, Univ. of B.C.: 43-48.

Neave, Ferris and R.E. Foerster, 1955. Problems of Pacific Salmon Management. Trans. 20th N.A. Wildlife Conf.: 426-440.

Neave, F. and W.P. Wickett, 1953. Factors affecting the freshwater development of Pacific salmon in British Columbia. Trans. 7th Pac. Sci. Congress, 1949, 4: 548-556.

Oka, N., 1956. Some basic problems in the development of Fisheries Statistics in Japan. Proc. 6th IPFC Session, Tokyo :317-320.

Omura, H., 1950. Rept. of the Whale Res. Inst., No. 4.

Omura, H. et al., 1952. Sei-whales in the adjacent waters of Japan.

Pacific Fisherman, 1957. Yearbook Number. 227 pp., Seattle, Wash.

Pettersson, Otto, 1926. Hydrography, Climate and Fisheries in the Transition Area. Journ. Conseil, Vol. I, No. 4: 305-322.

Ricker, W.E., 1944. Further notes on fishing mortality and effort. Copeia, 1944 (1): 23-44.

1950. Cycle dominance among the Fraser sockeye. Ecology, 31(1): 6-26.

1958(a) Production, reproduction and yield. Veh. Int. Verein, Limnol. 13: 84-100.

1958(b) Maximum sustained yields from fluctuating environments and mixed stocks. J. Fish. Res. Bd. Can., 15(5): 991-1006.

1958(c) Handbook of Computations for Biological Statistics of fish populations. Fish. Res. Bd. Can., Bull. 119, 300 pp.

Russell,F.S., 1931. Some theoretical considerations on the "overfishing" problem. J. Conseil Expl. Mer, 6: 3-27.

Sano, S., 1952. A preliminary note on the natural propagation of dog salmon Oncorhynchus keta. Rept. Hokkaido Fish Hatchery, 7(1,2): 61-68.

Sato, R., 1937. On new migration paths of salmon, revealed by experiments in 1936. Bull. Jap. Soc. Sci. Fish. 6(4): 171-174.

Schaefer, M.B., 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Bull. Inter-American Tropical Tuna Comm. 1(2): 27-56.

Semko, R.S., 1954. Stocks of West Kamchatka salmon and their commercial utilization. Izv. TINRO, XLI, 119 pp.

1958. [Some data on the exploitation, distribution and migration of Far-Eastern salmon in the open ocean.] Materialy po biologii morskovo perioda zhizni dalnevostochnykh lososei, : 8-30. Published by VNIRO, Moscow.

Sette, O.E., 1955. Consideration of mid-ocean fish production as related to oceanic circulation systems. J. Mar. Res. 14(4): 398-414.

1958. Nourishment of Central Pacific Stocks of Tuna by the Equatorial Circulation System. Proc. 8th Pac. Sci. Congress (1953) : 131-148.

Stevenson, J.C., 1955. The movement of herring in British Columbia waters as determined by tagging with a description of tagging and tag recovery methods. Conseil Permanent International pour l'Exploration de la Mer, Rapports et Procès-Verbaux, 140 (II): 33-34.

Taguchi, Kisabura, 1957. Salmon fisheries and its resource in the North Pacific. 166 pp. Tokyo.

Tait, J., 1952. Hydrography in relation to fisheries. Edward Arnold & Co., London, 106 pp.

Takayama, S., 1956. Fishing with Light in Japan. Proc. 6th. IPFC Session, Tokyo, 1955: 276-277.

Tamura, T. and S. Kawai, 1953. A study of the natural food of the salmon in the offshore waters of Hokkaido. J. Res., Faculty of Fish., Hokkaido Univ.

Tauti, M., 1942. Bull. Japan Soc. Sci. Fish., 10(5).

Taylor, F.H.C., 1955. The Pacific herring (Clupea pallasi) along the Pacific coast of Canada. Intern. North Pac. Fish. Comm. Bull. 1: 105-128.

Tully, J.P., 1952. Notes on the behaviour of fresh water entering the sea. Proc. 7th Pac. Sci. Congress, 3: 267-288.

Tully, J.P. and A.J. Dodimead., 1956. Pacific salmon water? Fish. Res. Bd. Can., Pac. Prog. Rept. 107: 28-32.

Uda, M., 1927. Relation between the daily catch of fish and the meteorological elements.- Part I. Statistical studies in the influence of the motion of cyclone upon the fishing. Jour. Imp. Fish. Inst. 23 (3): 80-88.

1930. On the movement of Pacific saury fishing ground north to Chiba Pref. (In Japanese) Suisan Butun Danwa Kaiho, 18.

1933. The shoals of "Katsuwo" and their angling. Bull. Jap. Soc. Sc. Fish., 2(3).

1934. The results of simultaneous oceanographical investigations in the Japan Sea and its adjacent waters in May and June, 1932. J. Imp. Fish. Exp. Sta. Vol. 5: 186-235.

1936. Results of simultaneous oceanographic investigations in the Japan Sea and its adjacent waters during October and November, 1933. J. Imp. Fish. Exp. Sta., Vol. 7: 150-178.

1936. Fishing centre of "Sanma" (Cololabis saira) correlated with the head of Oyasiwo Cold Current.

1937. Results of hydrographical investigations in the Sagami Bay in connection with the "Buri" (Seriola quinqueradiata T & S) fishing. Jour. Imp. Fish. Exp. Sta. 8: 1-50.

1938. Hydrographical fluctuation in the northeast sea-region adjacent to Japan of North Pacific ocean. A result of simultaneous oceanographical investigation in 1934-37. J. Imp. Fish. Exp. St., 9: 1-66.

1940. On the recent anomalous hydrographical conditions of the Kuroshio in the south waters off Japan proper in relation to fisheries. J. Imp. Fish. Exp. St. 10.

1941. The results of the hydrographic surveys in the China Sea in the summer of 1939. J. Imp. Fish. Exp. Sta. (11).

1949. On the correlated fluctuation of the Kuroshio Current and the cold water mass. Oceanog. Mag. 1(1) CMO.

1952. On the relation between the variation of the important fisheries conditions and the oceanographical conditions in the adjacent waters of Japan. 1. Jour. Tokyo Univ. Fish., 38(3): 363-389.

1953. The Kuroshio and its branch currents in the seas adjacent to Hachyo Island in relation to fisheries (I). Record of Oceanog. Works in Japan. 1(1).

1954. Studies of the relation between the whaling grounds and the hydrographical condition (1). Sci. Rep. of the Whales Res. Inst. No. 9: 179-187.

1956. Correlation of hydrographic and meteorological features with the fluctuation in certain fisheries in the waters off Japan. Proc. 6th IPFC Session, Tokyo, 1955: 258-259.

1958. On the abyssal circulation in the northeast Pacific area. Geophys. Mag. 28(3).

1958. On the problems of oceanic fronts in relation to sea disasters. J. Naut. Soc. Japan.

1958. General consideration on the fluctuation of the Tusima Current system and its related fisheries conditions. Rept. Tusima Current Res. Proj. Vol. 1, Jap. Fish. Agency.

Uda, M. and A. Dairokuno, 1957. Studies of the relation between the whaling grounds and the hydrographic conditions. II. A study of the relation between the whaling grounds off Kinkazan and the boundary of water masses. Sci. Repts. Whales Res. Inst. No. 12: 209-224.

Uda, M. and K. Nasu, 1956. Studies of the whaling grounds in the northern sea-region of the Pacific Ocean in relation to the meteorological and oceanographic conditions (1). Sci. Repts. Whales Res. Inst. No. 11: 163-179.

Uda, M. and G. Okamoto, 1936. Effect of oceanographic conditions on "Iwasi" (sardine) fishing in the Japan Sea. J. Imp. Fish. Exp. Sta. 7: 19-49.

Uda, M. and N. Suzuki, 1958. Studies of the relation between the whaling grounds and the hydrographic conditions. (III). The averaged conditions of the whaling grounds and their trends of variation during 1946-55. Sci. Repts. Whales Res. Inst. No. 13: 215-229.

Uda, M. and E. Tokunaga, 1937. Fishing of Germo germo (Lacépède) in Relation to the hydrography in the North Pacific waters. I. Bull. Jap. Soc. Sc. Fish. 5(5): 295-300.

Walford, L.A., 1954. Fluctuating Fishing Stocks: What we know about this world-wide riddle. Proc. Fish. Products Conf., 47th Annual Convention, National Canners Assoc., : 3-9.

Wooster, N.S. and T. Cromwell, 1958. An oceanographic description of the Eastern Tropical Pacific. Univ. Calif. Scripps Inst. Oceanogr. Bull. 7(3): 169-282.

Yamahira, K., 1954. Salmon Investigations in 1953. Research Division, Fishery Agency of Japan.

Yamamoto, T., 1956. Progress of Fisheries Statistics in Japan. Proc. 6th IPFC Session, Tokyo, 1955 : 313-316.

Yamanaka, H., 1957. On the currents in the Solomon Seas from the drift of the Tuna long-lines between June and August. Repts. Nankai Reg. Fish. Res. Lab., No. 5.

Yamanaka, H., 1958. Variability of the Hooked Rates for Broadbill Swordfish in the North Pacific. Rept. Nankai Reg. Fish. Res. Lab., No. 7.