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III. THE ACCOMPLISHMENT OF FISHERIES OCEANOGRAPHY IN JAPAN AND ITS FUTURE PROSPECT

by MICHITAKA UDA

The Development of Fisheries Oceanography in Japan

The organization of fisheries oceanography in Japan was founded by Tasaku Kitahara and others in 1909. Since 1913 Prefectural Fisheries Experimental Stations established in Japan started to conduct regular monthly or seasonal surveys on some fixed lines. The results and data were published in the Semi-annual Oceanographic Investigations ("Kaiyotyosa Yoho") Vol. 1–75., succeeding the Rept. of Basic Fisheries Investigation ("Gyogyô Kihon-tyosa Hôkoku" 7 Vol. 1–3. Most of data were from the Imperial and Prefectural Fishery research vessels including "Misago Maru" (154 tons) belonging to Tyosen (afterward Korea) Governmental Fisheries Experimental Station, Taiwan (Formosa) Governmental Fisheries Experimental Station— "Syonan Maru" (417 tons) and Hokkaido Fisheries Experimental Station— "Tankai Maru" (85 tons), and others. The Imperial Fisheries Experimental Station have had the "Sôyô Maru" (202 tons)

During the period 1930–1941 simultaneous multiple ship surveys were conducted repeatedly and successfully, using Nansen bottles with the reversing thermometers and chlorine titration method in the Japan Sea and Pacific Approaches.

The potential characteristic of Japanese Fisheries Oceanography using so many number of surveying boats was necessiated to elucidate the complex and variable oceanographic conditions of waters adjacent to Japanese Islands.

Before 1948 the effort of fisheries oceanographic investigations has been concentrated into the biological surveys of important food fishes and their environmental conditions (oceanographic structures and their changes). The ultimate aim of those investigations was to obtain the means of fisheries prediction.

Since 1949 the established 8 Regional Fisheries Research Laboratories with the research vessels "Soyo Maru", "Tenyo Maru", etc. have been carried out surveys for the conservation and exploitation of fisheries resources. Fisheries Agency with research boats "Toko Maru" (1000 tons) and "Syoyo Maru" (700 tons) etc. has conducted surveys for the exploitation of new fishing grounds in the Atlantic, Indian Ocean and South Pacific Ocean with its adjacent waters.

The Imperial Fisheries Institute, which later became the Tokyo University of Fisheries, built a training and research ship, the "Kaiyo Maru" (140 tons) in 1900. This was followed by "Unyo Maru" (442 tons) in 1909, the "Hakuyo Maru" (1327 tons) in 1929, and finally at present the "Umitaka Maru" (1453 gross tons), with the "Shinyo Maru" (382 tons) and "Seiyo Maru" (217 tons). The ships associated to the fisheries department of several other universities are:

Hokkaido University............ "Oshoro Maru" (1181 tons), "Hokusei Maru"
Kagoshima University........ "Kagoshima Maru" (1038 tons), "Keiten Maru"
Shimonoseki Fisheries University..................... "Koyo Maru" (1215 tons)
Nagasaki University.............................. "Nagasaki Maru" (600 tons)

Oceanography on availability

Many exploratory cruises by experimental fishing boats, using modern scientific methods and equipments on the basis of long years maritime experiences, aided materially to discover new fishing grounds, and consequently contributed to the expansion of Japanese fisheries with tremendous increase of yields.

The localization of fish concentration is associated with the pattern of a narrow zone of the optimum water (a complex of optimum temperature, salinity, turbidity, currents, bottom configuration, depth and character (including sediment) of bottom, food plankton, benthos etc.) or optimum oceanographic structure for each fishery.

As a compiled result of studies for the existing fishing grounds during the first half of the 20th century, Uda (1940, 1957) prepared a diagram of optimum temperature spectra of some important commercial fishes of Japan which indicates the basic pattern of fish shoaling curve in response to normal environmental conditions.

Annual observation of temperature trend can provide us the prediction formula of the occurrence and disappearance of fishes (sardine etc.).

In 1918 T. Kitahara proposed "Kitahara's Law", fish assemblage near a line of convergence— "Siome", which was further developed by M. Uda (1936, 1958), stating that the oceanic front reveals the area where marine life is concentrated and where fishing is favourable usually presenting a "Siome" (streak of a line of convergence) on the ocean surface as an indicator. In particular, zone fringing to the area of upwelling (divergence), ridging or doming of deeper cold water, and eddies or in other word, peculiar three-dimensional oceanographic structure corresponds to good fishing grounds.

Enrichment pattern due to topographically developed back-eddy systems (near a strait, channel, penninsula, cape, island, reef, estuary mouth etc.) corresponds to rich feeding areas, and consequently good fishing grounds for mackerel, squids, anchovy, sardine and yellow-tail etc. Dynamically produced eddies along oceanic fronts are rich feeding areas supplied with an abundance of planktonic food and small fishes. In the northern hemisphere, cyclonic (counterclockwise) eddies constitute good fishing area in the marginal zone in association with the belt of favourable water temperature e.g. pacific saury, whales etc. in the Polar Frontal zone; albacore at the Kuroshio Front. In the southern hemisphere, clockwise eddies develope along the Antarctic Convergence or Divergence as favourable whaling grounds, just north to the pack-ice zone.

The meteorologically abnormal onshore-current, "Kyutyo" (Rapid current or stormy current) produces a heavy catches of yellow-tail, sardine, tunas etc. into the coastal set-net fishery by the approach of the intruding abnormally warm and saline (unfavourable) watermasses (T. Miura, 1926, M. Uda, 1927, 1953, K. Kimura, 1940).

An useful estimation of fish abundance and concentration is introduced by echo-trace or by DSL in considering the amount of grazing food plankton. Many fishing grounds had been newly exploited by means of echo-sounder, fish-lamp, dredge, core-sampler e.g. Yamato-Bank in the mid-Japan Sea, that in the Okhotsk Sea, and many volacanic guyot as fish-bank for tunas, because geomorphological irregularities on the sea bottom such as reef, bank, seamount, canyon, sea-valley, ridge, etc. bring about localization or concentration of fishes, affecting their migration routes.

We, Japanese fisheries oceanographers found anomalous Kuroshio associated the occurrence of cold water mass and great influence of fisheries conditions. Moreover, we were able to forecast the cool summer associated with the abnormally cold (stronger) Oyashio Ourrent in conjunction to the profound change of fisheries conditions and crop harvest of rice and bean, etc. in northern Japan.

After the World War II, the estimation of fisheries yield or the absolute population size on vital statistics, using the powerful tool of population dynamics has made some progress. However, they are convinced soon that the reproduction potentials or recruitments of important commercial fishes are too much changing in response to the change of natural environments. On the contrary to the decline of the western spawning population the sudden growth of the eastern spawning population was found in the case of herring fishery and sardine fishery in the waters neighbouring to Japan within recent fifteen years. Tremendous yields of pelagic saury and squids show quite strange fluctuation to the eyes ignorant for oceanography. The uprise of blufin-tuna and skipjack fishery, the occurrence and disappearance of shrimp fishery in the Yellow Sea, the outburst and still continuing fishery of horse mackerel in recent years are only credible through fisheries oceanographic interpretation.

Since 1952, Japanese high sea salmon fisheries and tuna longline fisheries started to extend their operations. Tuna fishermen conducted subsurface observation of water temperature down to the 200m. depth and currents by drift of gears. Salmon gill-netter observed color of the sea, transparency, water temperature to the 50m. depth, and currents by the drift of nets.

Since 1947 the Antarctic whaling has begun again. Whalers conducted observations of water temperature down to 50 m. depth, currents, transparency, salinity, eye-observation of the patch of food plankton, pack-ice or iceberg, etc. Set-net fishermen are carrying out observation twice a day of water temperature at 0, 50, 100 m. depths, transparency, currents, weather, etc.

Trawlers conduct observation from surface to bottom (water temperature, etc.) and sampling of sediments and benthic fauna. This, nowadays practices of Japanese fishermen of oceanographic aids to their daily fishing operation are very popular.

On the other hand, since 1955 NORPAC Project almost continued oceanwide surveys were undertaken internationally. Tuna fishermen, whalers, and trawlers are now accustomed to the world-wide fishing cruise in Japan. Accordingly, Japanese fisheries oceanography are turning to world-wide or global scale.

In recent years Tuna Fishermen Association has started their own research and published journal "Maguro Gyogyo" (Tuna Fisheries) at Misaki (Kanagawa Pref. Fish. Expt. St.). Tokai University is publishing regular (10 days) oceanographic charts for tuna fishermen's use and developed the method of facsimile broadcast for far-ranging tuna-boats. Meteorological Agency are publishing regular oceanographic charts (water temperature, salinity, currents and anomalies) every decades with the weekly radio broadcast. Marine Observatory at Nagasaki publishes another oceanographic map every ten days in the East China Sea for trawlers, purse-seiners and anglers, etc.

Marine meteorological aids

Japanese fisheries oceanographers made some success in the past in studying problems associated with the safe and efficient conduct of fishing operations in cooperation to Japanese fishermen e.g. methods of locating fish schools of aggregations of commercially valuable fishes, or of discovering unutilized fish-populations by using fish-finder, aerial scouting (fish-finding flight), fish-lamp, electric pulse-shock, and the observation of correlated oceanographic structure, etc. in addition to the classical methods.

Concerning the operation of fishing gear and boats in order to prevent or at least effectively reduce the damage due to storms, high winds, abnormal currents, advanced knowledge of sea-conditions were obtained. For example, studies of set-net fishery affected by currents using the method of model experiment (H. Miyamoto, 1952), studies of the whaling in the north Pacific subarctic waters taking account of sea fog and state of sea, set-net damage investigation due to storm wave, etc. could be quoted. Yellow-tail catch at the set-net fishing grounds has shown a close relation with the occurrence of cyclones and atmospheric fronts in winter and spring, showing peak of catch on a few days before and after the passage of a cyclone. This fact enables fishermen to predict the catch by the weather map. Subarctic salmon fishing fleet and antarctic whaling fleet are getting great benefit from the special weather prediction on board every year. Also tuna fishermen are seeking economical fishing navigation all over the world oceans. Trawlers also are following the same.

Oceanography on the Estimation of Population Size of Fishes

In recent years (1952–1966) the traditional Japanese fishermen displayed a remarkable activity to exploit unexplored fishing areas in the world oceans in advantage of oceanographic knowledge above mentioned. However, our most important task to estimate relative population size basing on the knowledge of oceanic changes is still not fulfilled.

Longterm cyclic fluctuation in commercial fisheries as the result of changes in the reproduction, development, distribution or availabillity of fish-stocks caused by the cyclic environmental changes depend on the degree to which the conditions depart from these laid down as the optimum conditions. Thus, concerning fluctuations of tunas, sardine, herring, salmon fisheries, etc, studies based on the oceanographic and climatological changes were undertaken by M. Uda (1958, 1961, 1962).

Fluctuation of Hokkaido herring fishery was keenly studied in long past years by Hokkaido Fisheries Experimental Station and Hokkaido Regional Fisheries Research Laboratory (Kurakami *et al*. 1952. Kawana 1948, 1949, Hirano, 1953, 1957, Konda, 1953, Motoda, 1965). Herring decline in recent years is mostly attributed to the oceanic warming from south. However, the mechanism in detail is still unknown.

Fluctuation of sardine fishery alike to California sardine occurred in Japan or in oriental waters was studied intensively by Z. Nakai and others (1962) in Tokai and other Regional Fisheries Research Lab. The cause of recent decline (since 1941) was seeked in the anomalous conditions of the meandering Kuroshio and the cooled down of the northern Japan Sea waters (Nakai, 1956 and Uda, 1958).

Now in Japan the regional fisheries laboratories are studying the critical environmental conditions controling the rate of mortality or survival in the early stage of fishes (herring, sardine, mackerel, horse mackerel, squids, yellowtail, saury etc.) such as the characteristic water masses, transport and dispersal by wind and currents, in particular in the Kuroshio Current Systems. In the abnormal cold winter of 1963 a mass mortality of fishes occurred along the coast of Japanese waters in the southern and western part. After then red tide prevailed in spring and summer. Alternate change is remarked in some fish stocks. Fertilization due to the change of natural environment seems to provide important key to solve this problem.

Fluctuation of skipjack, bluefin-tuna and albacore fisheries are also remarkable in Japan, presumably due to the change of environmental conditions in response to the growth and decay of the Kuroshio and Oyashio Currents, coastal and equatorial upwelling and effect of cold water intrusions (Uda, 1961, H. Yamanaka, 1962).

The effects of overfishing and water pollution upon the fish-stocks for coastal fisheries are another important problems being attacked by fisheries scientists including the fields of population dynamics and coastal oceanography. After the World War II new fields called nearshore oceanography or estuarine oceanography for the use of many fishermen engaging pearl-oyster culture, oyster culture, laver (sea weed) culture, fishes (younger yellowtail, puffer, sea-bream, etc.) and shrimp, octopus cultures, etc. are rapidly developing in Japan. A new science called fisheries engineering treating problems of artificial construction of fishing grounds (construction of dam, wave protecting fence, channel digging, pumping circulation, etc.) with the combination of oceanographic and marine engineering methods is growing.

Development of Fisheries-Oceanographic Survey aud Dissemination Since the start of coastal daily regular observation, offshore monthly regular survey (sectional and synoptic) in combination with field survey of fishing grounds during past half century, we have published normal or averaged oceanographic charts (water temperature, salinity, transparency, currents, etc.) in the waters around Japan. Also, general distribution of plankton, benthic animals and commercial fishes with its time variation pattern was described in maps.

Concerning interrelationship of the aggregation, movement of fishes and environmental conditions, as well as the relation between the meteorological disturbances and fisheries, studies are made with the result of some useful prediction indices. Thus, by the request of fishermen, fisheries forcast (by means of radio broadcast, telephone, newspaper, etc.) started thirty years ago in national, regional or local scale for some important fisheries (skipjack, pacific saury, sardine, mackerel, yellowtail, herring, squids etc. and continued to the outbreak of World War II (Pacific).

Reopening of the Japanese Fisheries-Oceanographic Broadcast by the Fisheries Agency was on July 1, 1965, using radio and facscimile, etc.

Japanese Hydrographic Office serves seasonal current maps (GEK measured current and geostrophic current) with wireless current communication. Tohoku Regional Fisheries Research Laboratory publishes oceanographic chart every 5 days for the skipjack, saury and tuna, mackerel fishermen's use. Tokai and Nihonkai, Nankai Fisheries Research Laboratories do the similar service with predictions. Local (prefectural) Fisheries Experimental Stations (several tenth in number) are all carrying out similar services in more detail of fisheries, with adequate guidance for fishermen on the sea. The international and national cooperated communication and oceanographic maps for fishermen's use should be considered in future.

Future Prospect

Future lines of fisheries oceanographic reserach should be layed out to elucidate the actual state of environmental effects and to clear up the mechanism and the factors underlying in oceanic climate and fisheries conditions, and ultimately to be able to predict fisheries fluctuation. Fisheries oceanography should aim to challenge the changing seas and oceans and biological changes at various trophic levels, especially environmental requirement critical for survival of fish larvae, etc. We should bring together fishery biology, especially population dynamics which tells us how a fish population reacts to fishing in a steady environment, and fisheries oceanography which can afford the relative population strength or the prospect of their trends in a changing environment. How the environmental factors affect on the marine life to be studied physiologically or ecologically might be an important aspect.

Longterm fluctuation of oceanic climate and fish populations with the interrelated mechanisms could be solved by the well-coordinated surveys cooperated of all interested countries and organizations.

Oceanographic instrumentation and related engineering techniques, and experimental studies on the sea and in the laboratories as well as theoretical studies should be promoted. Not only ship observation in the sea but also oceanographic observation using aircraft and satellite (color TV camera, infra-red film), manned and unmanned bouys installed by automatic instruments, underwater research submarine may be useful.

Fisheries Oceanographic Center, national and international, might be needed to promote the said activity in cooperation.

Particularly cooperated program of fishery biological and oceanographical studies, to estimate and evaluate the population size and to conserve it within maximum sustainable yield is noted

Within the safe limit of conservation of fish-stock we can use oceanographic aids to increase the marine production most effectively.

All international efforts to contribute to increase the valuable fish population and to prevent the actions to decrease them should be encouraged.

IV. PRESENT PROBLEMS OF SOME COMMERCIAL FISHERIES IN JAPAN

A. Focal Problems of Tuna Fisheries Oceanography

Skipjack. Migration theory was proposed by Rotschild (1965) in the eastern and mid-pacific basing on the data of tagging expt. and biological studies. Migration theory proposed by some Japanese scientists in the western pacific is not still settled. Recently skipjack fishery is again growing up in the waters around Japan and especially in the tropical pacific centered Mariana Sea wherein a great sea disater of fishing fleet (7 boats lost) hitted by Typhoon 29 occurred on Oct. 7, 1965 near Agrigan Is.

1) Cyclic changes recognized in the production (yield or catch), migration and size (body length and weight, fat coefficient W/L^3) of skipjack, albacore and bluefin tuna, in response to the changes of oceanic conditions.
2) Evidences were obtained by marking experiments showing East-West trans pacific migration, as well as N-S migration.
3) Findings of longterm correlative fluctuation of Equatorial Current-systems and water masses in relation to the meteorological conditions (pressure systems and wind-systems, monsoon and trade winds) were increased.

4) Reciprocal correlated variations of skipjack and tunas fishing conditions in the western (Japan) and eastern (American) sides in response to the conjugate changes of oceanographic conditions were established.
5) Upwelling in the Equatorial Counter Current Regions and in the subsurface Equatorial Region, especially in the layer of 100-200 m. depths corresponding to the swimming layer of tunas for longline fishing a remarkable upwelling of Subarctic Intermediate Water resulting to the fertilization and its changes in the upper layer and consequently to the fluctuation of reproduction potential of tunas or population size of tunas was found in world oceans.
6) Tropical skipjack fishery having tremenedous potential resources in the world oceans which are not exploited owing to the lack of live-bait available for pole and rod fishing or to the economical and operational difficulties for pursesein-ing seems to be hopeful in future by overcoming them scientifically.
7) Major seasonally changing currents including monsoon currents may contribute to the seasonal feeding and spawning migration of skipjack-tuna. Migration routes of skipjack can be correlated to the trains of islands and banks on the sea-ridges. Tagging experiments should be encouraged more.
8) Localized concentration of fishes could be correlated to the whirl currents and eddies along the oceanic fronts, meandering between current-systems, which correspond to the singular features of thermocline topography (doming, ridging, troughing).
9) Assesment of spawning grounds, nursing grounds and the abundance of unex-ploited fish-stocks is urgent problem to study. Biological studies of fishes (gonads etc.) and sampling of fish-eggs and larvae with the enviromental conditions should be promoted. Age composition and racial study (including serological study of blood-type etc.) are notably important. What kind of food organisms on food chain or food web is existing and changing temporally in quantity or in proportion is also the problem.

Tunas Longline Fishery

1) Exploitation of the remaining unexploited fishing areas by the utilization of fisheries oceanographical methods.
2) Cooperative survey to assure the conservation of tuna stocks and permissible maximum utilization (M.S.Y.)
3) The effects of fishing operations on virgin tuna resources.
4) Finding out distribution, concentration and dispersal of tunas;
5) Estimating population size, and evaluating the fishing areas;
6) Developing prediction technique in the everchaning seas and oceans, using oceanographic and other scientific data;
7) Developing exploitation techniquses for new fishing grounds.
8) Developing rapid communication techniques for fishery, oceanographic and meteorological informations for more effective fishing operations and the safety of fishing vessels.
9) Determination of optimum environmental conditions for spawning and nursing grounds of tunas, especially for tuna larvas and juveniles.
10) Distribution of fishing efforts most efficiently for the fishing areas, fishing season and the tuna species while keeping maximum sustainable yields on the basis of scientific knowledge.