# FISHERIES OCEANOGRAPHY IN JAPAN, ESPECIALLY ON THE PRINCIPLES OF FISH DISTRIBUTION, CONCENTRATION, DISPERSAL AND FLUCTUATION

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## INTRODUCTION

Oceanographic studies of existing fishing grounds and exploratory expeditions into new areas to discover new fishing grounds have aided very materially in increasing the efficiency of fishing, and have contributed greatly to the tremendous yield of the Japanese fisheries in recent years. After the first investigation of oceanic currents around the Japanese Islands by drift bottle experiments started by Yuji Wada in 1893, Tasaku Kitahara founded a fisheries oceanographical organization in Japan in 1909 and proposed (1918) the principle of fish assemblage near a line of convergence ("Siome"). This principle was further developed by M. Uda (1927-58), K. Kimura (1940-58), and others.

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, such as salmon, herring, sardine, and tuna, 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 enough research be available and that equipment be highly efficient in tracking down and capturing the school of fish. The fishing operations, both in amount of area covered and actual fishing done, are restricted by weather and ocean conditions. There are a number of problems associated with the safe and efficient conduct of fishing operations such as methods of locating schools—fish finders, aerial scouting, observation of the oceanographic structure of water, etc.; maritime meterological knowledge and information to prevent or at least effectively reduce the damage due to storms, abnormal currents, etc.; processing and transport to market of the fish caught; the management of the fishery to assure continued maximum sustained yield; and safe navigation.

Fisheries science, from the view point 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 includes 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 and the extent of the catches, in both good and poor years. With reference to the progress acquired by fisheries during the first half of this century, the following principles of fish distribution, concentration, dispersal, and fluctuation proposed by the writer, based on his research (1927-1958), are illustrated.

## PROPOSED PRINCIPLES

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

(2) 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 (1952) found marine fishes to be sensitive to temperature changes of 0.03° in his experiments.

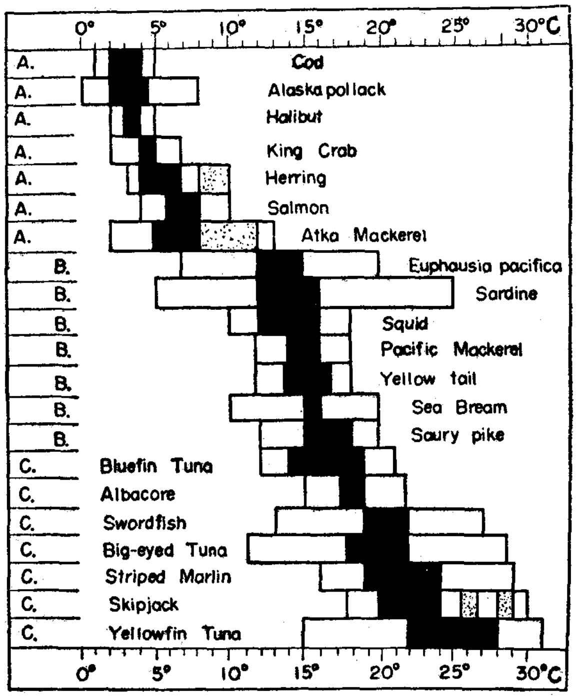

FIGURE 1. Optimum water temperature spectra of important fishes in Japan (Uda 1957).

Uda (1940, 1957) prepared a diagram (Fig. 1) of optimum temperature spectra for some of the important commercial fishes of Japan, in which the optimum temperatures (range about 4°–5° C) are shown as each characteristic "proper value" ($\theta_o$) in the following equation.

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

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

A similar probability curve for salinity can be prepared.

(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 up-welling (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, 1936, 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, 1906, and extended by others), states that highly productive and consequently good fishing grounds are found in areas of up-welling. The Scripps Institution of Oceanography has conducted some basic work on the mechanics of productive up-welling in the California Current System.

(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, squid, yellowtail, etc. (Uda, 1958).

(d) Thermoanticlines or ridgings occur in some sub-surface fishing grounds (e.g., tuna fishing areas in the Equatorial Pacific) as pointed out by T. Cromwell, 1958. This is due to a variety of underwater up-welling 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 (counterclockwise) eddies representing cold eddies, constitute good fishing areas in the marginal zones of up-welling (e.g., saury, whales, squids, etc., in the Polar Frontal Zone; albacore in the Kuroshio Front) and are associated with favourable water temepartures.

In the southern hemisphere clockwise eddies develop along the Antarctic Convergance as favourable whale grounds just north of the pack ice zone (M. Uda, 1954, K. Nasu, 1959) (Fig. 2).

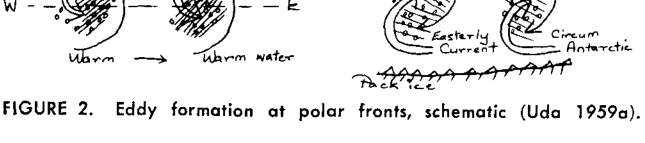

FIGURE 2. Eddy formation at polar fronts, schematic (Uda 1959a).

(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 artifically by certain physical and chemical processes become potential areas for fishing or for acquiculture by having available ample supplies of the primary nutrient substances.

Physical factors important in developing productive areas include:

(a) Turbulent mixing, 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, 1958). 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. Morita 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 (1957) 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 ($\nabla S$) 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 par-

ticular 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 or 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 Kyusyu—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" formations 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.

A useful indirect estimation of fish abundance and concentration may be made by considering the amount (or concentration) of food plankton or fishes as shown by echo traces or DSL (Uda 1956).

(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 in salmon tanks are planned (J. Brett 1958, and others).

(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 in 1927, and more recently at Lowestoft Fisheries Laboratory, England, 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 (sardines, etc.) by attracting them to the anode pole has been under experimentation at the California Academy of Sciences and elsewhere. It shows promise of being of use in future fishing (e.g. success in the U.S.S.R. in freshwater fishing) and also may have some application in studying 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 a gradient of electromagnetic potential is associated with current, 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, J. 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. J. Hjort (1926) first remarked upon the importance of wind and current at such periods and J. N. Carruthers *et al.* (1951) 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 are 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. isobaths 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, or 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, 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 earthquake, heavy storms, volcanic eruptions, "tunami", etc., the fishing areas and fishing conditions may become quite disorganized and altered.

(20) "Red Tides" and other abnormal "bloomings" of plankton (e.g., *Phaeocystis* in the North Sea herring areas) drive away fish schools and disrupt fishing. Near the margin of such discoloured areas we sometimes find good catches.

(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 enviromental 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 Fig. 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).

## FLUCTUATIONS IN FISHERIES: LONG TERM TRENDS AND PREDICTION

### A. *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 irreg-

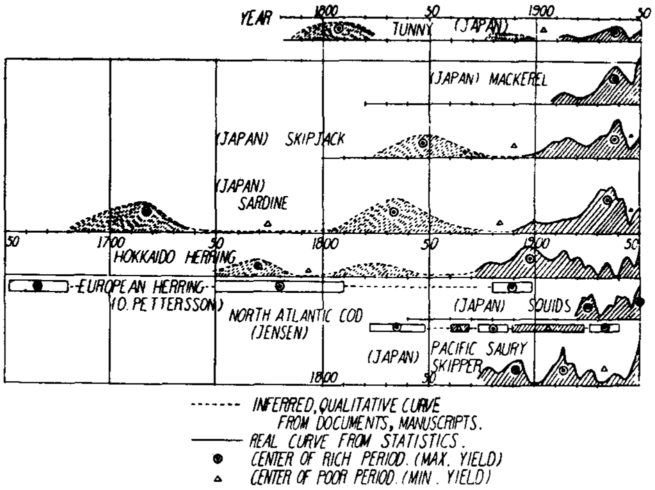

FIGURE 3. Long period variations of the catches of important fishes (Uda 1952).

TABLE 1

RECENT FLUCTUATIONS OF THE FISHERIES IN THE JAPAN SEA

(b-bad; bb-very bad; g-good; gg-very good)

| | Period (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 |
| 4 | 1917-1921 | g | -- | b | (1913-20) |
| 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 |

ular way) with intervals of nearly a century, or 20-30 years, or 50-60 years (See Fig. 3 and Table 1.)

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

$$N = N_o e^{-rt} \sum \cos (wt - \mu) \quad . \quad . \quad . \quad . \quad (1)$$

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):

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

(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:

$$N = \Phi\ (x - c_1t,\ y - c_2t) \text{------------} (3)$$

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 (euphausiids, 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).

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°(–13°C, young) |
| B | Squid | 1941–43 | 1951 ('52) | 12°–16°C(10°–18°) |
| B | Sardine | 1933–39 | 1947–50 | 12°–16°C |
| B | Yellowtail | 1942–43 | 1951–52 | 14°–16°C |
| B | Mackerel | 1939 | 1954 ('51–'52 Japan Sea) | 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 | -- | 1955–58 | 17°–19°–(21°C) |

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).

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 *et al.* (1951). 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 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 of law of alternate predominance in the seas, or correlational balance sheet between pisci-predator, 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 Fig. 3, 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).

### B. *Examples of fluctuation*

(a)

| *Cold years* | *Warm years* |
|---|---|
| 1900-1910-1915 | 1926-40 |
| 1941-49 | (peak: 1932-37) |
| (1940—Baltic heavy ice,<br>1942-44—Arctic heavy ice) | (Kuroshio northerly extended,<br>Atlantic current strong) |
| | 1951-55; Japan |
| | (1954-58; Pacific N. America) |

(b) In 1958 the Japanese high sea salmon fishing grounds in the Bering Sea and Aleutian waters changed remarkably, compared with those in 1957, due to the change of meteorological and oceanographic conditions (Uda, 1959a).

(c) 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. Because of 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.

## CONCLUDING REMARKS

The effect of environmental conditions on the early stages of life cycles of fishes is a very important factor in the study of fisheries and should be studied intensively in the future. Within recent years such studies concerning mackerel, sardine, herring and tuna, etc. have been started. Fluctuations in fisheries for important pelagic fishes seem to occur on a world-wide scale. There is a need for international co-operation in the study of environmental variations.

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