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FISHERY OCEANOGRAPHY OF THE WESTERN PACIFIC: APPLICATION OF OCEANOGRAPHIC INFORMATION TO FORECAST NATURAL FLUCTUATION IN THE ABUNDANCE OF CERTAIN COMMERCIALLY IMPORTANT PELAGIC FISH STOCKS

by

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ABSTRACT

Fishery oceanography can contribute toward the optimal utilisation of the marine resources by developing fishery forecasting systems. This paper reviews briefly the current knowledge of several species of commercial importance in the Western Pacific Ocean and discusses the effects that environmental changes and fishing intensity have on the stocks. Additionally, man-induced pollution is noted to contribute toward the wide fluctuations observed in the landings of some of these resources. On the basis of some general relationships noted between the resources and the environment, long-term predictions are provided for several species. Species discussed in this short report include herring, sardine, anchovy, saury, Pacific mackerel and horse mackerel, tunas, squid, and yellowtail.

1. INTRODUCTION

The rapidly expanding human population and the impact of industrialisation have made it necessary that we utilise fully the marine food resources of the world's oceans and seas by exploiting new fishing grounds and harvesting unutilised fish stocks. Additional production can also be obtained through coastal aquaculture and mariculture. Since 1952 Japanese fishermen have contributed greatly toward increasing the harvest of pelagic resources through the application of fishery oceanography, e.g., oceanic fronts, upwelling, ridging and doming of thermocline, optimum temperature spectra, echo trace, deep scattering layer, and luring fish-lamps. The landings of some of the important fisheries, however, have undergone considerable fluctuations. These fluctuations have been attributed to changes in the natural environment, fishing activities including overfishing, and in recent years to marine pollution.

Currently fishery oceanography is expected to contribute significantly towards the understanding of these problems and to develop adequate forecasting systems which should lead to the best management of these resources.

This paper reviews briefly the results of some studies involving fishery oceanography, especially as it relates to the effects of environmental changes on the abundance of certain commercially important pelagic fish stocks in the Pacific Ocean and the adjacent waters. Further details on the subject are provided in earlier publications (Uda 1960, 1970)

2. FLUCTUATIONS OF HERRING (*Clupea palasii*), SARDINE (*Sardinops melanosticta*), AND ANCHOVY (*Engraulis japonicus*) LANDINGS

2.1 Herring fishery

The decline of the oriental spring herring fishery apparently reached its lowest level during the 1955-1963 period (Fig. 1A). Since 1964 there has been a slight increase in landings; the increase has coincided with a cool period of the Tsushima Current. Since the oriental spring herring, mainly the resources off Hokkaido and Sakhalin, fluctuates in response to solar activity denoted by secular sun-spot maxima and minima, the size of the resource is expected to continue its gradual upward trend and reach a peak period sometime within the next 40 years. The increase in the resource is in response to the weakening of the Tsushima Current or the Kuroshio Current system (Uda 1962, Birman 1971). The projection, however, is made only under the assumption that water pollution does not occur.

2.2 Sardine fishery

The sharp decline of the oriental sardine population since 1941 (Fig. 1A) has been attributed to changes in the environmental conditions (Nakai 1960, Uda 1960, Hayashi 1960). During the winter of 1963, an abnormally cold spell around Japan which was caused by a severe monsoon resulted in a mass mortality of fish, especially along the coastal sectors of the Tsuchima Current, the Kuroshio Current, as well as in the Inland Sea and the bays of Japan (Nakai, *et al.* 1967). The sardine population was especially hard hit, since the cold water hit the major spawning grounds, which were located in the sea region around the Boso Peninsula (Chiba Prefecture). The low water temperatures caused a considerable delay in the spawning activity of the oriental sardine and also resulted in a southward shift of the centre of distribution of the sardine (Fig. 2). This southward shift of sardine spawners resulted in the establishment of a Kyushu-Shikoku subpopulation, thus increasing the sardine reproduction potential along the southern sectors of the Pacific Coast of Japan.

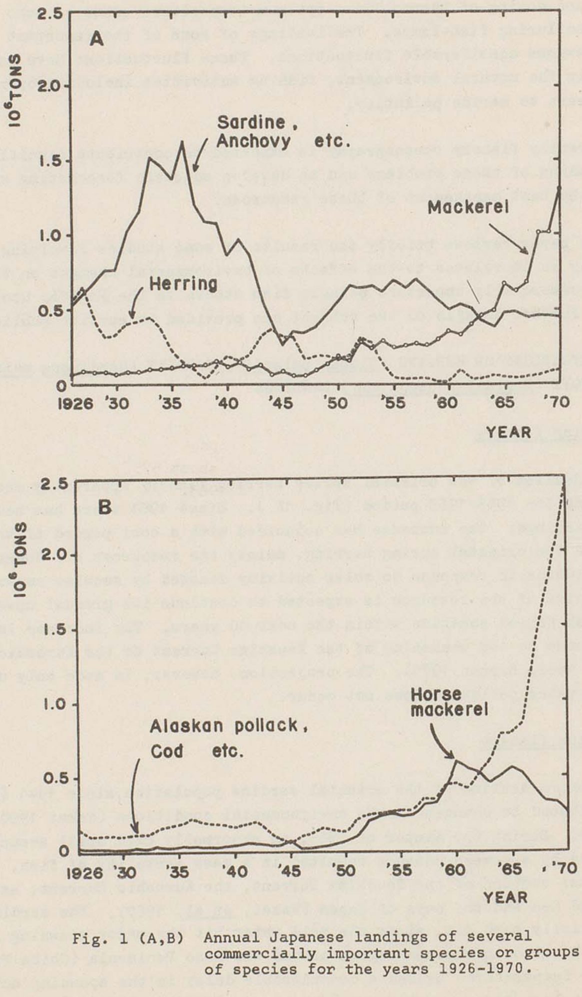

Fig. 1 (A,B) Annual Japanese landings of several commercially important species or groups of species for the years 1926-1970.

We can anticipate a return of a prosperous fishing period within the next 20 years; this increase will be in response to the cooling period of the Kuroshio waters. This projection is made on the assumption that marine pollution does not affect the spawning and nursery grounds.

2.3 Anchovy fishery

Unlike the sharp decline of the sardine population, the anchovy population has increased rapidly since 1951, especially along the Pacific coast of central Japan. This reciprocal phenomenon - decline in sardine abundance and an increase in anchovy abundance - is similar to that noted for the sardine and anchovy populations occurring off California (Ahlstrom 1960, Marr 1960, Murphy 1960). In the case of the sardine-anchovy situation in Japanese waters, environmental change rather than food competition was considered to be responsible for the shift in species dominance.

The peak in the anchovy catch occurred in 1957 when 430,000 metric tons were landed; thereafter, the annual catches have remained nearly stable at about 300,000 to 400,000 metric tons. Since the anchovy inhabits estuarine and coastal waters (Hayashi 1967), the populations may be seriously affected by increased marine pollution.

We can expect a decline in the anchovy fishery relative to the projected growth of the sardine fishery.

3. FLUCTUATION OF THE PACIFIC SAURY (Cololabis saira) FISHERY

The saury fishery of the northwestern Pacific Ocean has expanded considerably since the adoption in the 1950's of the stickheld dipnet and electric fish-lamp in the fishing operation. The saury catch reached a high of about 575,000 metric tons landed in 1958 and remained above 400,000 metric tons until 1963. After the abnormally cold year of 1963, the saury catches dropped off sharply to 200,000 metric tons or less after 1964. The low point in catch occurred in 1969 when 50,000 metric tons were landed. Coincident with the declining catches, the main fishing grounds have shifted to offshore waters; as far out as long. 160°E.

Since 1967 new fishing grounds for saury have been located in the mid-Pacific waters (long. 160°E - 170°E), at the head of the East Kamchatka Cold Current Extension (Uda 1971) and along the coasts of North America.

The distant location of the saury fishing grounds in the western Pacific may continue for the foreseeable future. There are, however, cyclical rich years which occur at several or about 15-year intervals and these coincide with the northward strength of the Kuroshio Current. The reproduction potential and the dominant size of the fish also varies accordingly (Fukushima 1969, Odate 1970). Contrasted to the rich years when the large-size fish occur, the poor years are accompanied by small-size fish which make up a noticeable proportion of the total catch.

For the future, the saury resources of the entire Pacific Ocean may become known through basic fisheries studies.

4. FLUCTUATIONS OF THE PACIFIC COMMON MACKEREL (Scomber japonicus) AND HORSE MACKEREL (Trachurus japonicus) FISHERIES

4.1 Japanese Pacific common mackerel fishery

In recent years the Pacific mackerel has migrated in large numbers into the coastal waters of Japan. Like the sardine and squid, the Pacific mackerel is an inhabitant of the cool northern waters; this contrasts with the spotted mackerel and the horse mackerel which prefer the warmer southern waters.

The abnormal cold spell in 1963 decreased the reproductive capacity of the Honshu Pacific Group of common mackerel and increased the recruitment of the Kyushu Pacific Group. The latter resulted from the southerly shift of the spawning grounds, which thus increased the abundance of eggs and larvae carried by the Kuroshio Current into the downstream coastal waters.

On the Pacific side of Japan, the quantity of mackerel eggs spawned in the area extending from the Izu Islands to the Boso Peninsula increased in quantity from 1958 and reached a peak in 1964 (Kawasaki 1971, Usami 1969, 1970).

The total Japanese catch of mackerels amounted to 1.3 million tons in 1970 (Fig. 1A). Presently, the main mackerel fishing grounds for the summer and autumn periods are located in the Northeastern Sea region of Japan, i.e. south of Kusiro (Hokkaido) and east of Hatinoe (Aomori Prefecture). During the winter-spring period, the main fishing grounds are located in the waters extending from the Izu Islands to the Boso area.

In predicting future events, we can anticipate an abundant southern spawning population of mackerel to occur with the growing intrusion of cold water; the areas of abundance to occur south to Kyushu and Shikoku and also in the East China Sea.

4.2 Horse mackerel fishery

The horse mackerel (also called jack mackerel) is a warm-water fish. The southern water population of horse mackerel, which migrates to the Japanese coasts, has been found to have the major home grounds in the East China Sea. Spawning occurs in the winter months in the middle and southern sectors of the East China Sea, and in the spring months in the northern waters of Kyushu.

During the 1951-1960 period, successful annual recruitment of horse mackerel in the East China Sea resulted in abundant 0-age groups. The successful recruitment has been attributed to the occurrence of 15^{o} - $17^{o}C$ temperatures during the spawning period from February to April. The fishery for horse mackerel flourished and reached a peak in 1960 when 550,000 metric tons were landed (Fig. 1B). Since 1960, the catches have followed a decreasing trend.

The abnormal cold period in 1963 caused the horse mackerel to undergo a southerly shift of the spawning grounds, and accordingly, a southerly shift of the centre of distribution of the horse mackerel. The catch of immature horse mackerel from the fishing grounds of the Japan Sea declined. On the other hand, there was a rapid increase in the catch along the Pacific coast of Japan. The decline in the Japan Sea has been attributed to a reduced water transport of Tsushima Warm Current waters into the Japan Sea.

5. FLUCTUATIONS OF SKIPJACK (Katsuwonus pelamis) AND OTHER TUNA FISHERIES

5.1 Skipjack fishery

Skipjack tuna are known to represent a tremendous resource in the tropical and subtropical waters of the world's oceans. This resource has not been fully exploited to date (Table I). The failure to fully develop the high seas fisheries for skipjack tuna has been due to the lack of adequate supplies of live-bait fish which are necessary for the pole-and-line fishing method, and to operational difficulties

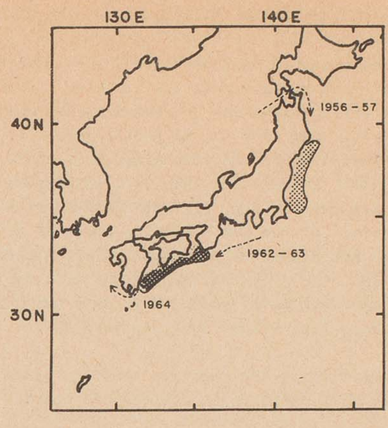

Fig. 2 Location of major concentrations of Japanese sardine during the 1950s and 1960s.

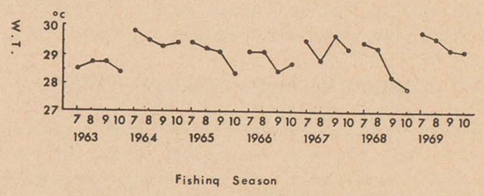

Fig. 3 Annual variation in average monthly surface temperatures in the Ogasawara-Mariana region.

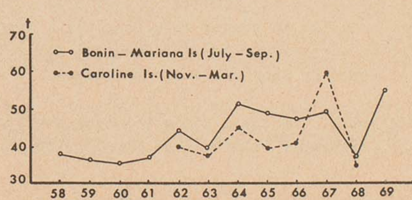

Fig. 4 Annual variation of average catch of skipjack tuna per boat in the southern waters of Japan (based on data obtained at Yaizu and Shimizu Fish Markets).

———— Ogasawara-Mariana region

------- Caroline region

associated with the purse seine method of fishing.

During the period of low temperatures from 1941-1949, the skipjack fishery in the Pacific waters adjacent to Japan yielded very low catches. After the abnormally cold year in 1963, the sea surface temperatures began to rise (Fig. 3). This rise in temperature and the possible increase in the fertilisation in the southern waters due to the cold water intrusion, led to a gradual expansion of the southern skipjack tuna fishing grounds. Increase in the yield of skipjack tuna were noted for the Ogasawara-Mariana Sea region (Fig. 4), the Marshall-Caroline Sea region (Fig. 4), and even in the waters of the South Pacific north of New Guinea and around Bismark and the Solomon Islands (Kasahara and Tanaka 1968, Iwasaki 1970). During the cold years, e.g. 1963 and 1968, the southern skipjack fishery was judged very poor; on the other hand, the warm water years, e.g. 1964 and 1967, corresponded with good fishing for skipjack tuna (Inoue 1969, Iwasaki 1970).

In general the skipjack tuna fishery has improved steadily since 1964. It is anticipated that this trend will continue in the western Pacific Ocean for the next twenty years.

5.2 <u>Tuna fisheries</u>

In the past decade (1960-1970), the yields of bluefin, albacore, bigeye, and yellowfin tunas have shown a general decline. This decline may be related to the increased fishing effort; however, we need to separate the natural fluctuations before attributing the decline to fishing. Marine pollution, e.g. oil pollution, may also be a negative factor affecting the abundance of pelagic fish.

6. FLUCTUATIONS OF THE SQUID (*Ommastrephes sloani pacificus*) FISHERY

Since 1948 the squid catches from Japanese waters have shown a general increase. Peak catches were noted in 1952, 1963, and 1968, with annual catches of 656,000, 591,000, and 668,000 metric tons, respectively. These peak years for squid catches correspond with periods of very cold temperatures. The abundance of the squid population, which is dominated by the 0-age group, is heavily dependent upon favourable environmental conditions during the spawning period. Additionally, coastal upwelling and associated oceanic fronts contribute toward establishing favourable fishing grounds.

In recent years good catches of squid have been made near Yamato Bank located in the Central Japan Sea. In 1970 140,000 metric tons were caught from this area. This high abundance of squid may have been due to strong upwelling and a strong development of the Polar Front; both conditions contribute to enrichment of the waters and a subsequent development of a high standing crop of forage organisms.

In consideration of the decline of the squid fishery around Hokkaido (northern Japan), a southerly shift of the favourable fishing zone may develop for the common squid in future years.

7. FLUCTUATIONS OF YELLOWTAIL (*Seriola quinqueradiata*) FISHERY

The rich years of the yellowtail fishery have corresponded with the intrusion of the offshore warm water "Kyucho" into the inner part of bays, e.g. 1924, 1938, 1952, 1958, and 1971. These intrusions are mostly associated with the S-type meandering of the Kuroshio Current in near-shore waters. The recruits of the yellowtail stock come from the main spawning grounds located in the East China Sea. The abundance of yellowtail appears to be cyclical, with peaks occurring at intervals of ten to twenty years.

Despite the disturbance of "hamachi" (young yellowtail) culture by marine pollution in coastal waters of Japan, the set-net fishery for yellowtail is favoured by being currently in the upper portion of a natural cycle and in a slightly recovering stage.

8. FLUCTUATIONS OF THE SUBARCTIC FISHERIES

The fluctuations of the salmon fisheries may be associated with the sun-spot cycle (Birman 1971, Uda 1963). The rate of natural mortality of juveniles in the estuary or brackish water area should be studied intensively.

The subarctic demersal fish, e.g. Alaskan Pollack, cod, red fish, and flat fish, are affected by unfavourable environmental conditions which occur in deep waters. Presumably there is some critical stage during their early life history that affects the population size.

9. CONCLUDING REMARKS

In the preceding sections, the effect of environmental changes on the distribution, recruitment, location of spawning grounds, and abundance of some of the important pelagic fisheries were discussed. In particular, the remarkable fluctuations in the abundance of some fish stocks and the catches as they relate to the abnormal cold spells in winter were mentioned. The future prospect of fisheries in response to oceanic climate was pointed out. Our concern today is that the natural fluctuations of the oceanic conditions and the fisheries are modified by the recent growing thrust of marine pollution. Such deterioration of the natural environment must be stopped completely in order to assure the continued supply of food from the sea.

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TABLE I. Landings at the Yaizu and Shimizu fish markets of skipjack caught from waters of Ogasawara, Mariana, and Caroline Islands (after Y. Iwasaki 1970).

Fishing year	August-March 1/	August-November
1962	10,859	9,973
1963	9,378	6,724
1964	20,683	13,502
1965	23,208	11,109
1966	29,480	15,672
1967	28,877	12,562
1968	21,054	9,841
1969	-	12,601

1/ The period covers the months from August of one year to March of the next year.