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Comparative Study of the Population Size of Japanese and California Sardines*

BY

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Abstract

The patterns of the annual landing of both California and Japanese sardines are similar in several points, the sudden rise in 1930s and drop in 40s, and the temporary recovery in 50s. The year class strengths were estimated by several methods. After 1950 they do not always pararel in their patterns.

Total, natural, and fishing mortality rates were also estimated by several methods. Total mortality rates increased after 1940 in both conntries especially in Japan. And this increase seems to be caused by natural causes rather than heavy fishing. And at the same time, the drop of the availability was seen.

The spacial density of larvae in their distribution seems to some extent capable to forecast the strength of the coming year class in some districts

The alternation of subgroups might be one of the reasons of the decline.

1. Preface

Among the species of Sardinops, biological studies have been made most intensively for both California sardine (*S. Caerulea*) and the Japanese sardine (*S. Melanosticta*). And moreover both of them have been most important commercial fishes at the both sides of the Pacific Ocean.

Not only both species have many similarities in their biological characteristics such as the spawning habits, growth rates, and others, but also they have a similar trend in the landing pattern in this century.

Both of them attained their peaks in the thirties after a rapid development since 1910s, followed by a drastic decline in the forties. In discussing the cause of the decline, this similarity sometimes has been refered as a main standpoint to assert that the cause of the decline is not due to the heavy fishing, but it is the world-wide one caused by the natural factors.

The auther's study aims to discuss not only the general pattern of the annual catch trend, but also the details of the population dynamics of the both species in order to compare the feature of the fluctuation of the population and catch.

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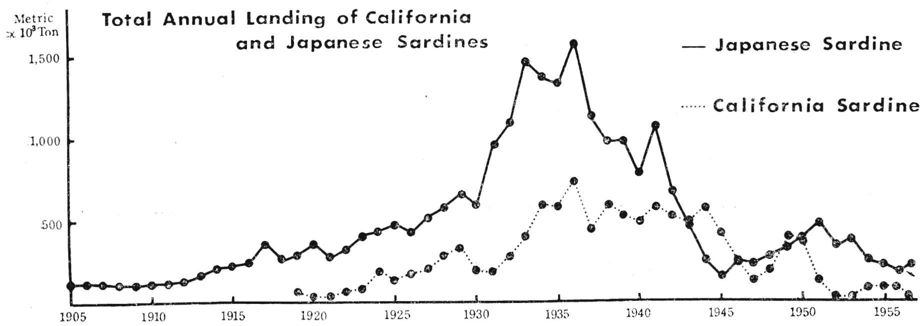
* Contribution from the World Scientific Meeting on the Biology of Sardines, Rome, Italy, Sept. 1959.

FIG. 1

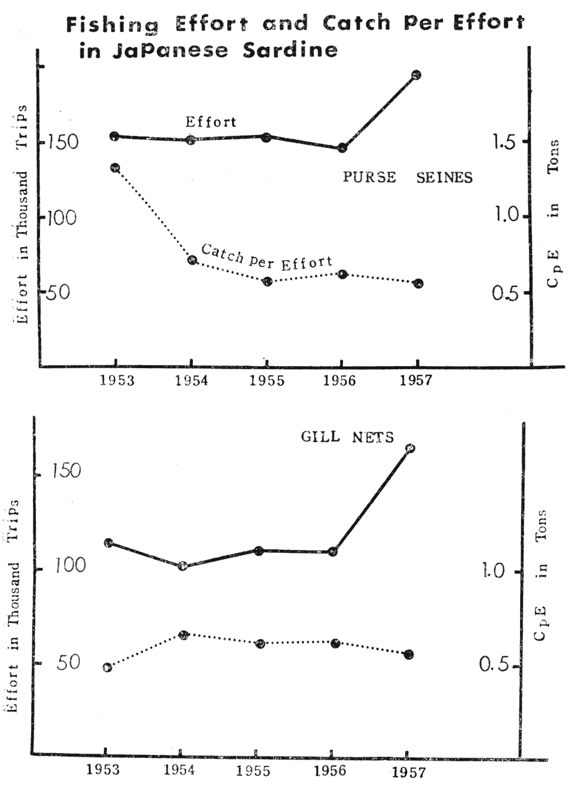


Thus we shall discuss whether the similarity of the landing pattern is the real one or only an apparent one.

2. The trend of the landing. (Fig. 1)

Although the fluctuations of the landing of the both species have a parellel trend at a glance, in detail, they have many differences. For example, the decline in Japan began in 1937 and continued until 1946, while in case of the California sardine, the drop of the yield did not take place until 1946. Of course it might be due to the difference of the economical conditions of both countries. After that even a reciprocal relationship is shown between the trend of the two countries.

FIG. 2



3. The pattern of fishing effort and catch per effort. (Fig. 2)

In Japan, reliable statistics of effort are not available throughout the country before 1940. And we can trace back only several years about the catch-effort data. And moreover, the standardization of effort by linking the data which has been employed in California sardine has not been employed in Japan. Therefore the Japanese data are not so adequate in considering the long trend of data.

Furthermore, the fishing ground extends much wider in Japan, and many types of gear are employed in the fisheries, while only purse seine is done in the Californian fisheries, such situations make Japanese fisheries much more complicated in comparing the data of both countries.

The catch of sardine per effort in Japanese purse seine has been decreasing since 1953, and this tendency is also seen in gill net fisheries which catch large fish exclusively.

4. The similarity and difference of the pattern of landing.

As have been mentioned in the previous paragraphs, there are similarities and as well, differences between the patterns of the landing of California and Japanese sardines.

4. 1. *The pattern in the developing years.*

The comparison of the rises and the drops of the landings in the two countries in 1930s and 40s shows that the drop followed immediately after the peak of 1937. There was a ceiling before the drop began after the peak.

In comparing the number of fish caught instead of the weight of the yield, the difference becomes clearer. In California, the peak in the number of fish caught does not coincident with that of the weight. The former took place in

FIG. 3

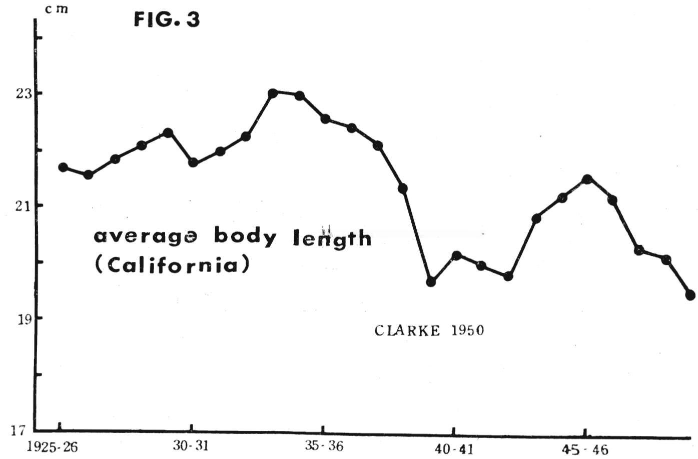
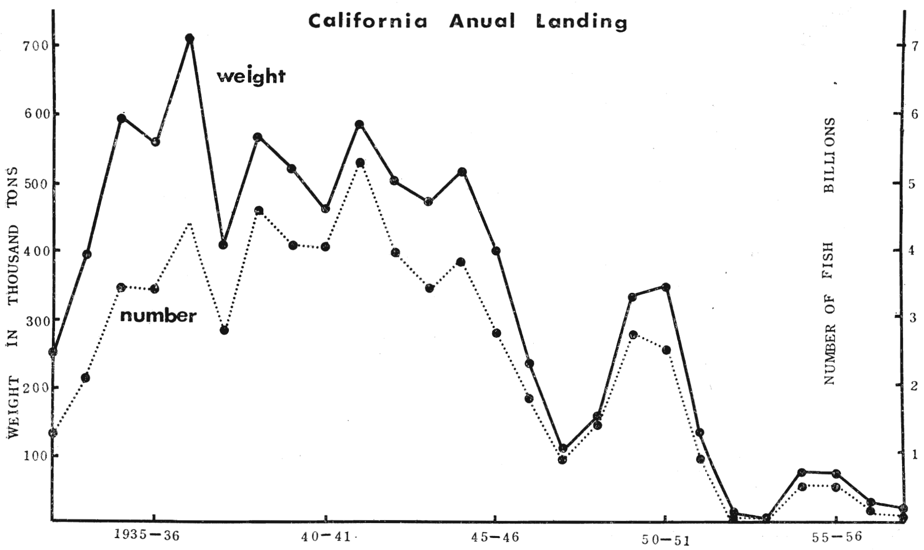


FIG. 3A



1941 against 1937 of the latter. It is caused by the decreasing of the size of fish. And in fact, the average body length of the California sardine lessened from 230 mm. of 1932, to 220 mm. in 1936, when the maximum of the yield took place, then it dropped as small as 200 mm. in 1941. (Fig. 3)

In Japan, no such data sufficient enough to show the change of the fish size in this period are available. However, it is shown that the landing by the gill nets in the Japan Sea area, which catch old fish exclusively did not change so rapidly. The increase in the 1930s took place in Hokkaido at first, then at the north-eastern coast of Honshu, in 1936. This rapid development caused the major peak in the whole Japan. Seeing that the major type of the gear in this region at those days was the set nets, it can be supposed that the increase was caused mainly by that of the small and middle sized fish, but not by the large ones.*

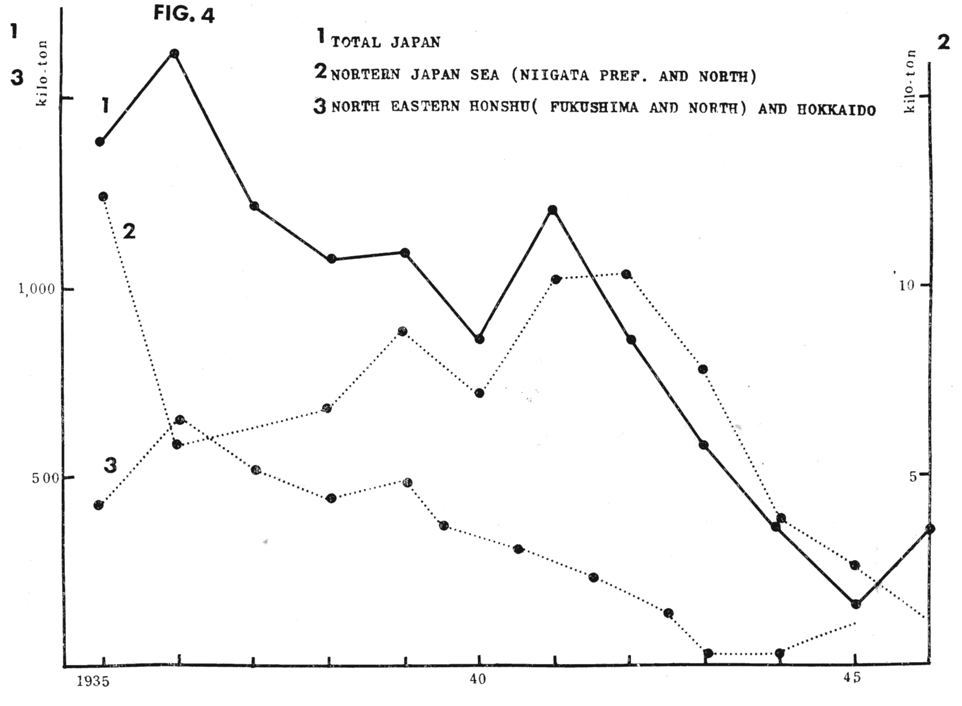
In Japan it is likely that the peak in number of fish proceeded that of weight. In other words, the outbreak of new year classes in California continued after the peak of the weight of landing, but the decrease of old fish caused the drop of the weight of the landing in spite of the increasing of the number.

On the contrary, the peak of the weight of the landing in Japan seems to have been caused by the growth of the new year classes.

4. 2. *The pattern in the declining years.*

The drop of the landing took place rapidly since 1940 in California. It occured at first in the Pacific Northwest, where the old fish disappeared, and then the landing droped comtemporary with the increase of the average age. In the coast of Central California, (San Francisco and the vicintity) the drop also

FIG. 4



* This Hypothesis is supported by the data.

happened 1946 as the last thriving year. While, the landing in the coast at the Southern California was still increasing. Namely, the severe drop after 1946 was mainly caused in the Northern fishing ground.

In Japan, on the contrary, in spite of the severe drop of landing in the north-eastern coast of Honshu and Hokkaido which occured immediately after the peak and became serious since 1940, the drop was not so severe in some places in the coast of the Japan Sea where the major part of the catch was the old fish. And there was still some tendency of increasing even in the early forties. (Fig. 4)

Thus it is noteworthy that the fluctuation of the total landing of Japanese Sardine, most of which is composed of young fish does not always coincide with that of the old ones.

5. Fluctuation of California sardine from the viewpoint of age composition. (Fig. 5)

5. 1. *Increasing years.*

Before 1932, no data were published, but it is said that the 1929 year class continued to appear as the dominant one since 1931 to 1933-34 seasons.

The increase of the average body length during the seasons 1929 through 33 shows this fact. And the dominant class was supposed to be the 1927 year class.

The general tendency in this period is that the recruitments of new year classes were increasing, and the amount of recruitments were particularly high in the middle and southern California.

On the other hand, the immigration of the young 1928 through 33 year classes to British Columbia, then the 30 through 32 year classes to U. S. were thriving until 1936-37 season, especially in the northern districts for the wintry fisheries. After that they dropped suddenly and were replaced by the young fish in the autumnal fisheries. Thus the increasing of the landing reached its peak in the 1936-37 season in San Francisco area where old fish were caught. While the number of fish increase in the Southern district where the recruitment of young fish are thriving.

5. 2. *Decreasing years.*

As MARR* pointed out the decline shows the following pattern.

5. 2. 1. *At British Columbia*; The number and the weight of the catch reached their peaks in 1941 and 1943 respectively, and after that the decreasing happened year after year, until the fish practically disappeared. The entering year class decreased since 1939 and then disappeared as the 1943 year class as the last. The age composition at this district truncated at the 1943 year class after the season of 1945-46. And then it shifted toward the older side by one year.

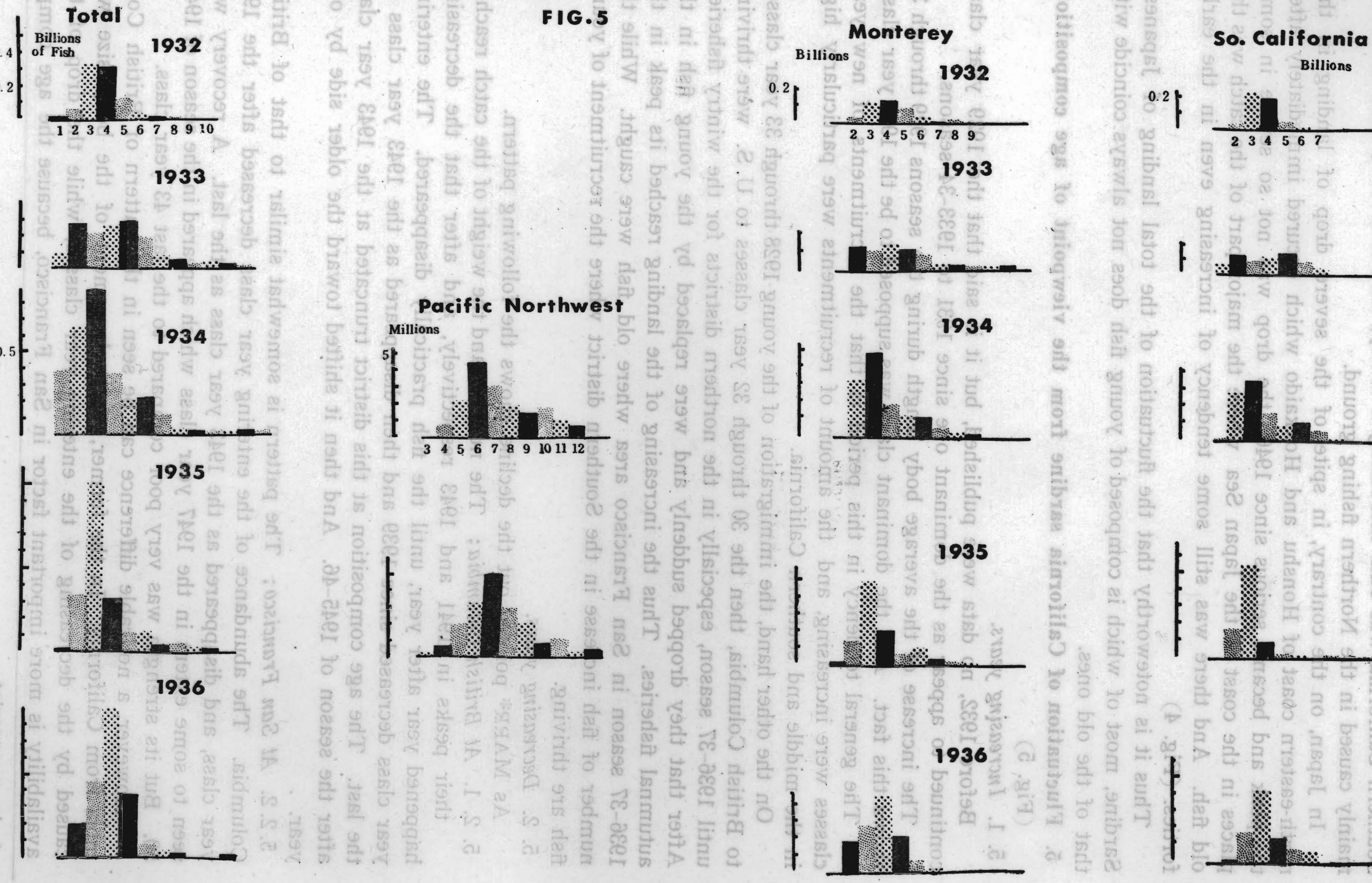
5. 2. 2. *At San Francisco*; The pattern is somewhat similar to that of British Columbia. The abundance of the entering year class decreased after the 1939 year class, and disappeared as the 1943 year class as the last. A recovery was seen to some extent in the 1947 year class which appeared in the season of 1949-50. But its strength was very poor compared to the last 43 year class.

However, a noticable difference can be seen in the pattern of British Columbia from California. In the former, the enlargement of the body size was caused by the decreasing of the entering year classes, while the drop of the availability is more important factor in San Francisco, because the age compo-

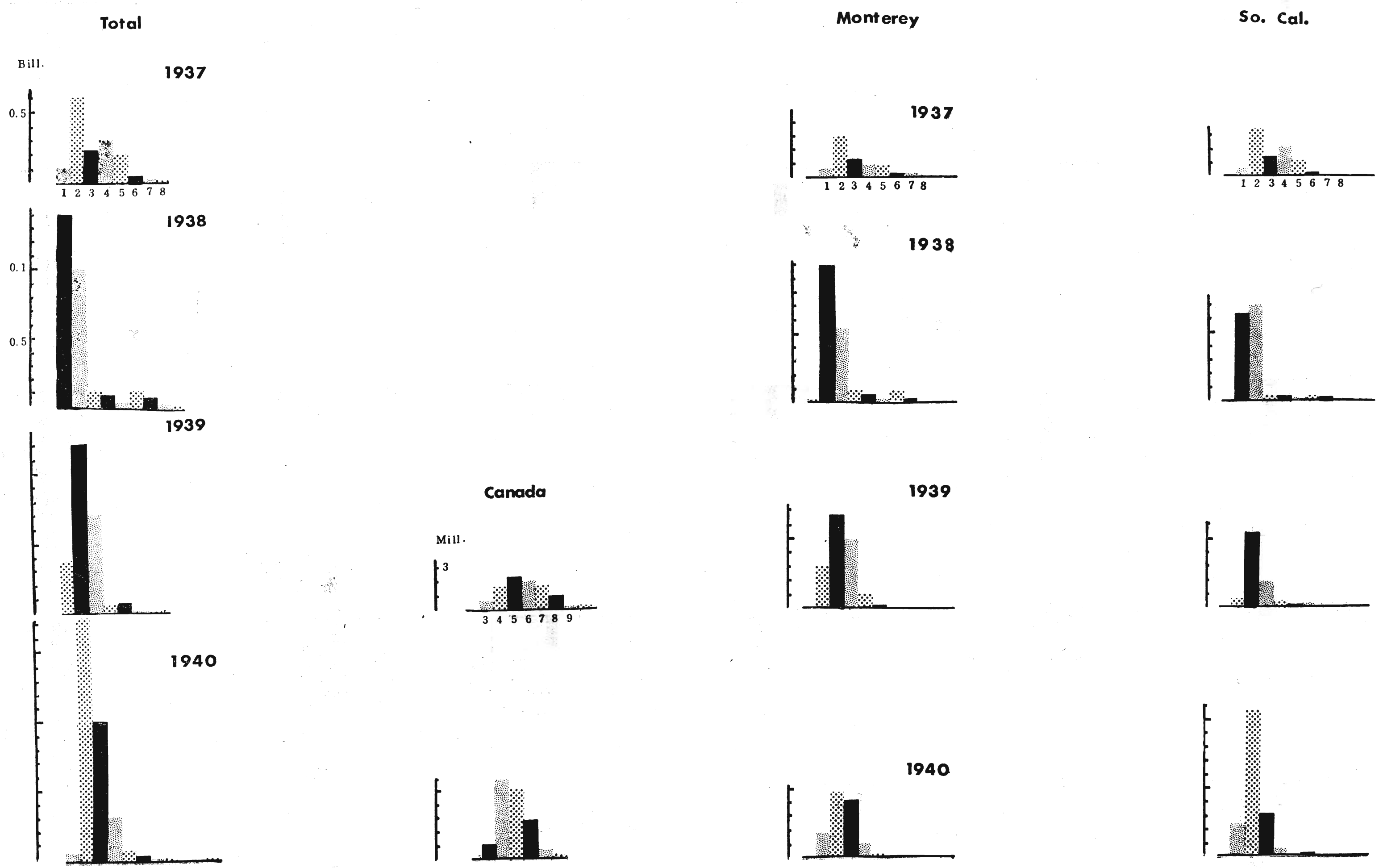
* in manascript

AGE COMPOSITION OF CALIFORNIA SARDINE

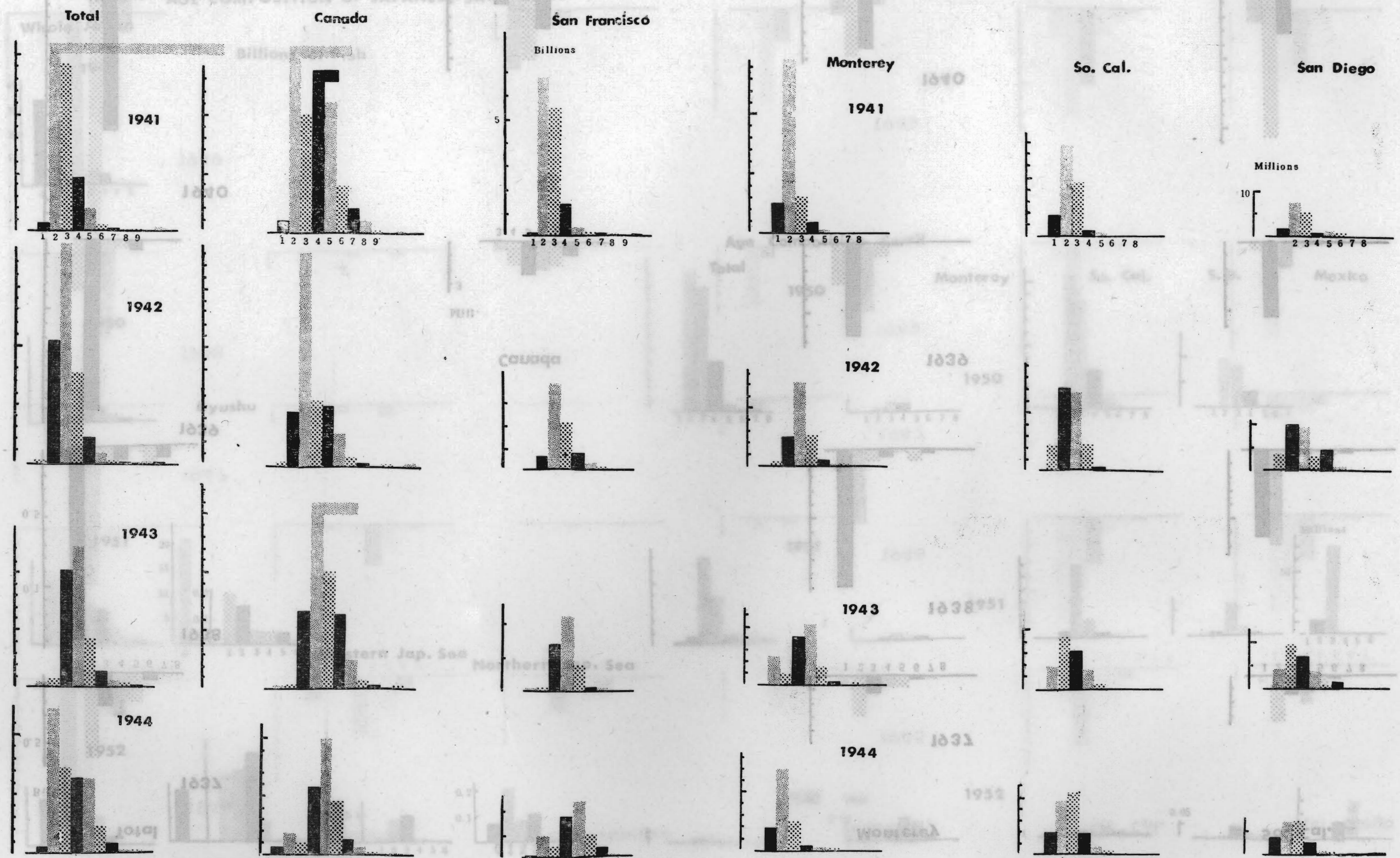
FIG. 5



Age Composition, Contd



Age Composition, Contd



Age Composition, Cont'd

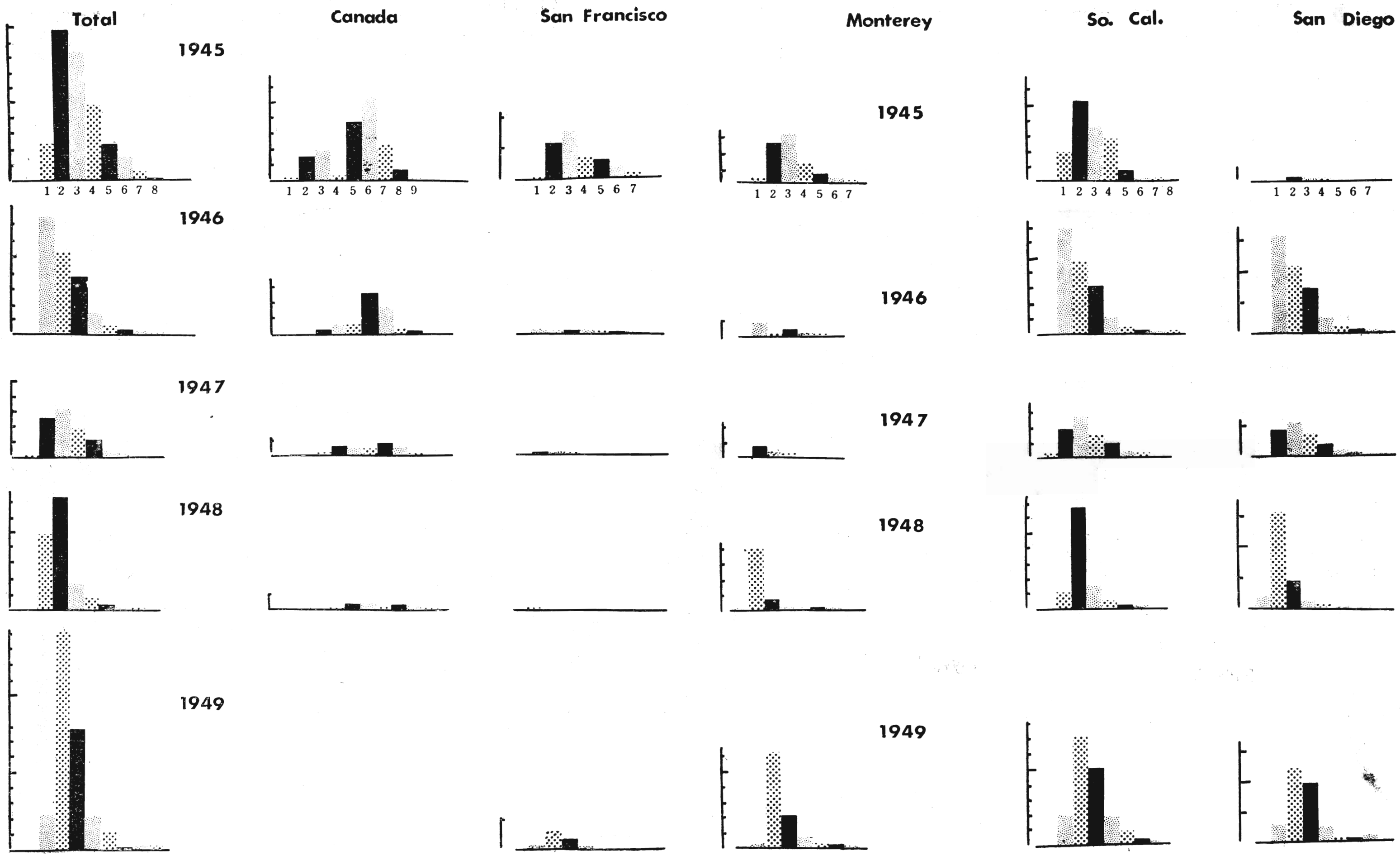
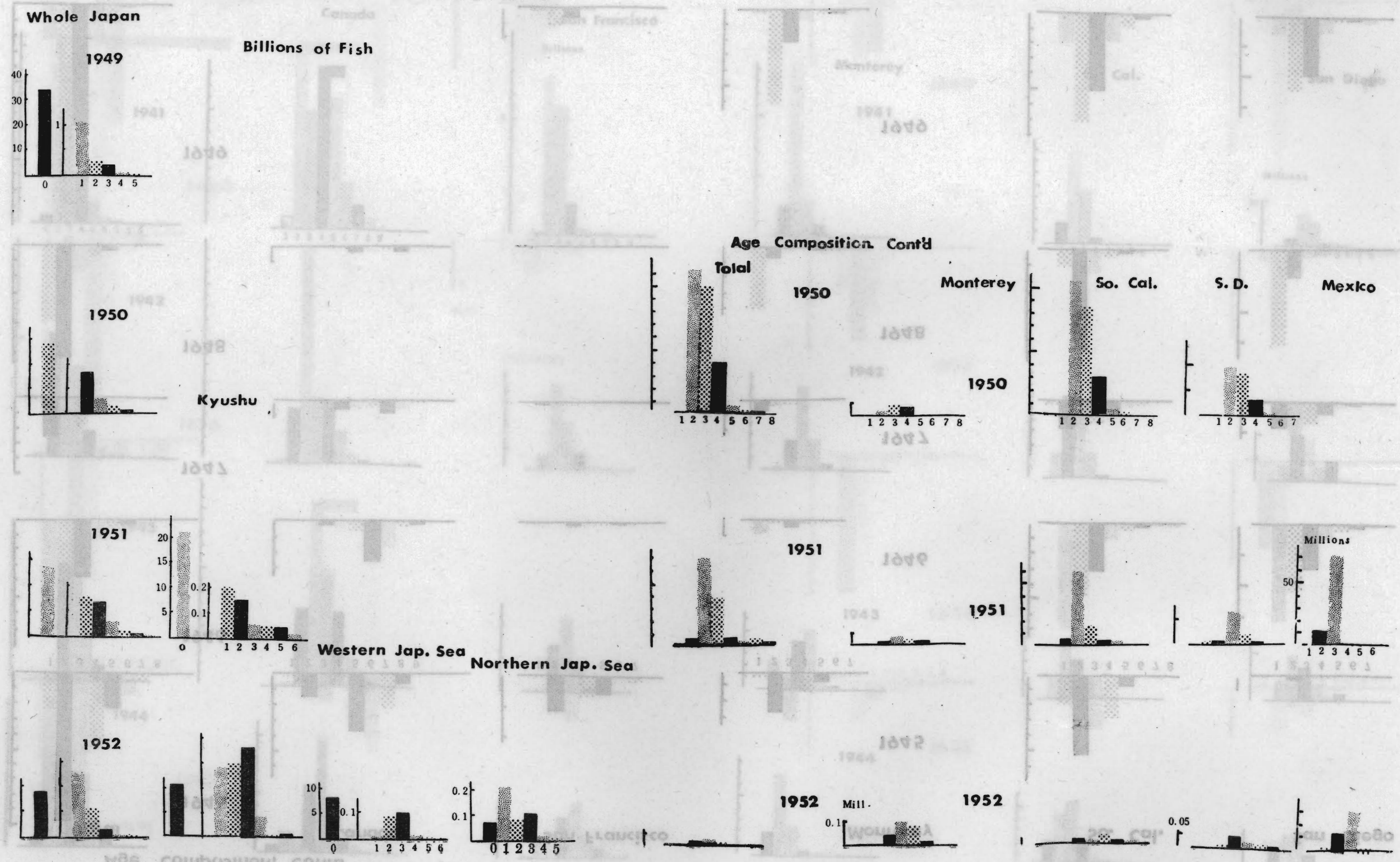
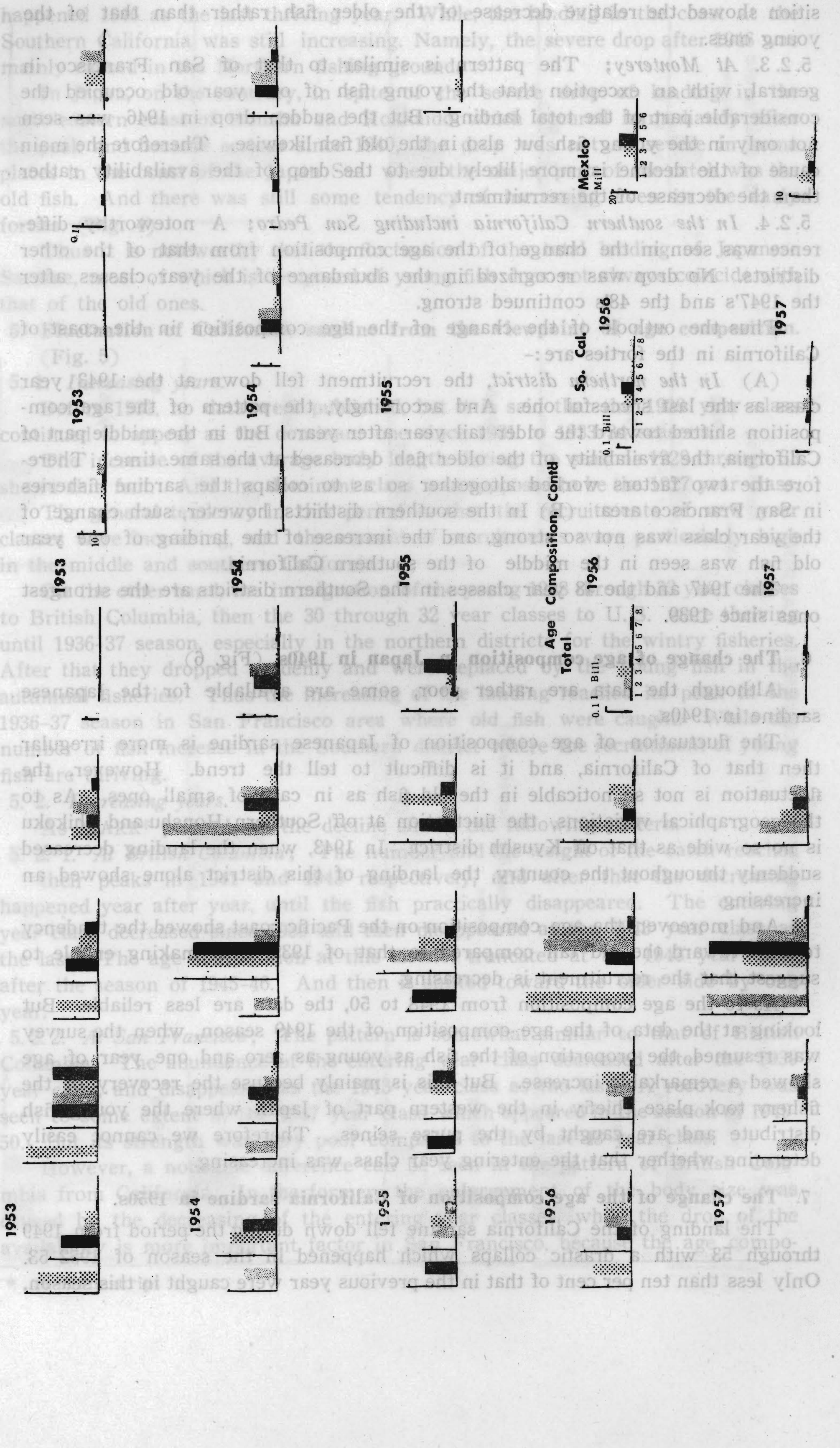


FIG. 6 AGE COMPOSITION OF JAPANESE SARDINE




Age Composition, Contd
Total
So. Cal.
Mexico
1953
1954
1955
1956
1957
Bill
Mill
0.1
10
20
1 2 3 4 5 6 7 8
1 2 3 4 5 6

sition showed the relative decrease of the older fish rather than that of the young ones.

5.2.3. *At Monterey*; The pattern is similar to that of San Francisco in general, with an exception that the young fish of one year old occupied the considerable part of the total landing. But the sudden drop in 1946 was seen not only in the young fish but also in the old fish likewise. Therefore the main cause of the decline is more likely due to the drop of the availability rather than the decrease of the recruitment.

5.2.4. *In the southern California including San Pedro*; A noteworthy difference was seen in the change of the age composition from that of the other districts. No drop was recogrized in the abundance of the year classes after the 1947's and the 48's continued strong.

Thus the outlook of the change of the age composition in the coast of California in the forties are:-

(A) *In the northern district*, the recruitment fell down at the 1943 year class as the last snccesful one. And accordingly, the pattern of the age composition shifted toward the older tail year after year. But in the middle part of California, the availability of the older fish decreased at the same. time. Therefore the two factors worked altogether so as to collaps the sardine fisheries in San Francisco area. (B) In the southern disthicts, however, such change of the year class was not so strong, and the increase of the landing of one year old fish was seen in the middle of the southern California.

The 1947 and the 48 year classes in the Southern districts are the strongest ones since 1939.

6. The change of age composition in Japan in 1940s. (Fig. 6)

Although the data are rather poor, some are available for the Japanese sardine in 1940s.

The fluctuation of age composition of Japanese sardine is more irregular then that of California, and it is difficult to tell the trend. However, the fluctuation is not so noticable in the old fish as in case of small ones. As to the geographical variations, the fluctuation at off Southern Honshu and Shikoku is no so wide as that off Kyushh district. In 1943, when the landing decreased suddenly thuoughout the country, the landing of this district alone showed an increasing.

And moreover, the age composition on the Pacific coast showed the tendency to shift toward the old tail compared to that of 1939, thus making enable to suggest that the recruitment is decreasing.

As to the age composition from 1948 to 50, the data are less reliable. But looking at the data of the age composition of the 1949 season, when the survey was resumed, the proportion of the fish as young as zero and one year of age showed a remarkable increase. But this is mainly because the recovery of the fishery took place chiefly in the western part of Japan where the young fish distribute and are caught by the purse seines. Therefore we cannot easily determine whether that the entering year class was increasing.

7. The change of the age composition of California sardine in 1950s.

The landing of the California sardine fell down during the period from 1949 through 53 with a drastic collaps which happened in the season of 1952-53. Only less than ten per cent of that in the previous year were caught in this season.

In this period only the southern part of California coast was left as the fishing ground. And the fall of the small fish was the main factor of the decline of 1951. In this year the strength of the 1949 year class which entered the commercial stock was only one twentieth of that of the 48 year class. The old fish also dropped. But the decreasing of them is not so severe as that of the new year classes. On the other hand, the main factor of the severe drop in the season 1952 was likely due to the drop of the availability of the older fish rather than the decline of the rectuitment. Namely, the decline of the two successive seasons took place in two steps; at first the decline of the recruitment and then the drop of the availability of the older fish.

A temporary recover was seen in the season 1954, though it did not reach the level of 51. The increase was partly caused by the recruitment of young 51 and 52 year classes, apparently by the rise of the availability of the old fish. The strength of the 51 year class could not be foreseen in the previous season.

It is noteworthy that the decline in the 1950-51 and 51-52 seasons were not so serious in the Mexican waters as in the central Californian waters. This fact shows that the change of the availabilty was due to the southward movement of the fishing ground.

After 1956, the landing dropped suddenly again. But the drop was also caused by the labor trouble of the price dispute. The two year classes in 1951 and 52 appeared considerably strong for those in recent years. Therefore, in Mexico where no such trouble took place, the decline was not seen. But the drop of the landing occured here in 1956, when the landing in U. S. was considerablly high.

8. The change of the age composition of Japanese sardine in 1950s

Generally speaking, the landing of Japanese sardine has ben decreasing since 1949, particularly the drop of the number of young fish below one year of age is noticable year after year since 1952. On the other hand, however, the fish of two years and older particularly the two years old fish have a tendency of increasing from the gross viewpoint of whole Japan. Though the fluctuation of year classes are not so remarkable as in the case of California, the 1949 year class was strong for threc years from 1952 through 54. The 53 year class was also as strong as it.

From the local viewpoint, however, an increase was seen in the Japan Sea, particularly in the western part of it, in spite of that of the whole Japan.

This is because of the development of the purse seine fisheries in the Japan Sea which were introduced from the western part of Japan. But the increase in this reglion was not big enough to conpensate the decine in the other parts of Japan.

In the Japan Sea, the strength of the year class has been increasing in the western part since 1951. While in the northern part, the strength of the 1953's is considerably big, and the recruitment is decreasing hereafter. In the Japan Sea, the availability has a wide fluctuation particularly in the northern part of the Japan Sea.

9. The change of the year class strength

Several methods can be adopted to estimate the strength of a year class, In Japan, the adult fish of two years and older have different fishing eeason from that of the young ones; and the fishing methods employed are very complicated.

Therefore, the relationship between the population size and the landing is also complicated. So the latter in not adequate as the index of the year class strength. Moreover it is also difficult to obtain the relationships between the effort and catch because of the variety of the types of the gears. On the other hand, the recruitment does not complete at the second year of their life. The difficulty is also seen at the two year old fish, which make the earliest adults entering the fishing ground, because two types of gear are employed, namely purse seines and gill nets, thus making unable to consider them synthetically. In case of California sardine, it is rather simple in this point. But sometimes the recruitment completes at the 3-year-old both in Japan and in California.

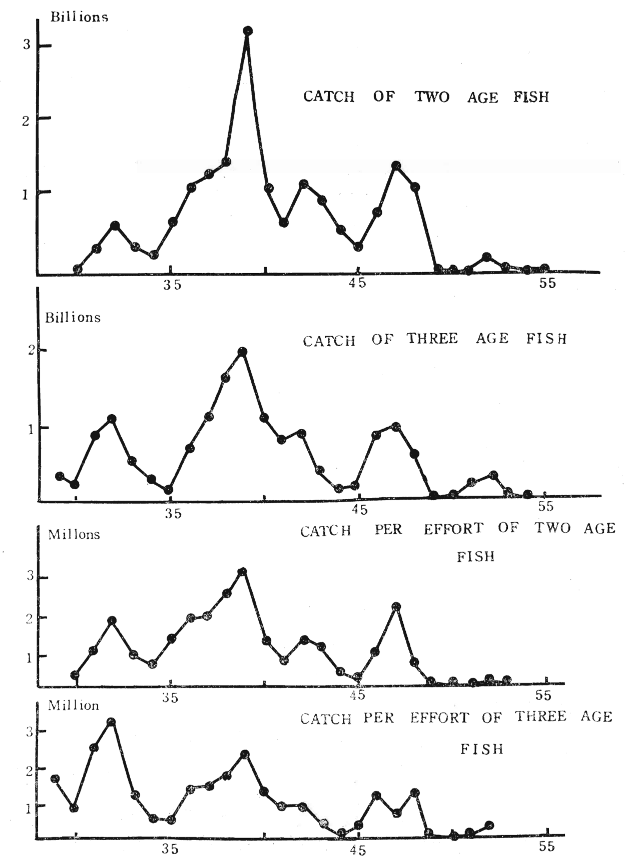
Considering these points, the following methods were adopted as the indics of year class strength.

(a) Catch of two-year old fish.
(b) Catch of three-year-old fish.
(c) Catch per effort of two-year-old-fish.
(d) Catch per effort of three-year-old fish.
(e) Virtual population size of two-year and older fish.
(f) Virtual population size per effort on two-year-old fish.
(g) Virtual population size at zero year and older.

The strength of each year class was computed by these methods. But in this case, gill net was adopted in Japan as the standard. (Fig. 7)

In considering briefly the meaning of these methods, it is rather doubtful whether the catch per effort which represents fhe spacial density of fish is adequate as the index of a population size in case of the migratory fish of which availability may change in wide amplitude and which move from one place to the other. Even if the areas of the fishing grounds are taken into consideration to adjust it, it is still unsuitable as the index of the population index. On the other hand, if we consider that some of the fish which do not migrate to the fishing ground at once, but appear there later in some time of their lives

FIG. 7. Year Class Strength (California)



and then are exploited, the virtual population size of the year class which is computed by accumulating the number caught from the same year class, or the accumulated value of landing per effort is likely more suitable for the purpose than the simple catch per effort.

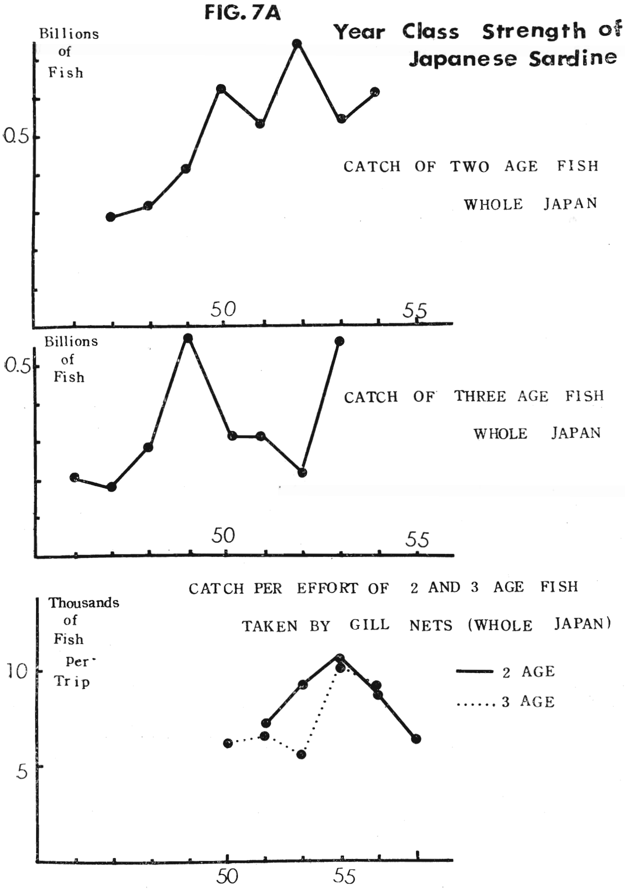
The estimated value by these methods have of course some differences each other. But the general trend of the fluctuation of the year class strength shows, (a) the rise until 1932, (b) poor recruitment in the following two years, (c) the rapid rise producing the dominant year class of 1939. But after that, a sudden drop happened and only one nineth of the strength of 1939 year class appeared in 1945. A slight recovery one third as strong as that of the 1939s took place in 1947. But this was only a temporaly phenomenon. In 1949, another decline happened and the year class strength was only one fiftieth of that of the 1939. After that, small fluctuations followed, but the strergth of year classes never reached even to the level of 1934, far from the 1939's.

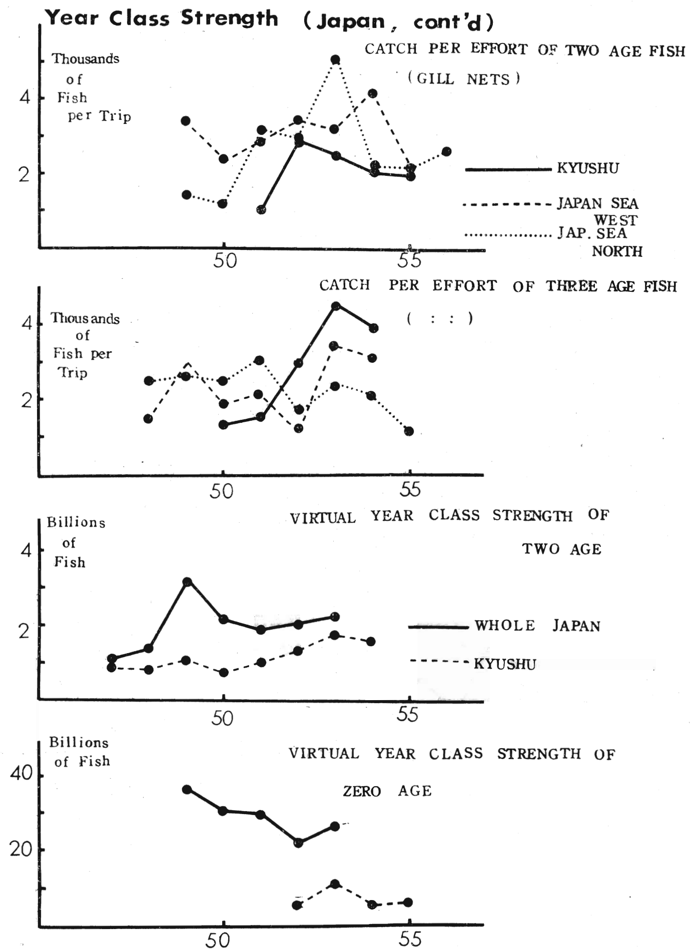
However, the decline in the northern part has a different pattern from the southern district. In the northern district, two steps of the noticable decline were seen. The first of them is that of the 1941 year class which dropped to one tenth of the 1939 year class in only two years; and the second is the severe fall at the 1943 year class as the last and dropped also to the one tenth of the previous season. On the other hand, the drop of the 1934 year class was severe in the southern part, and the drop from the 48's to 49's was also drastic. Moreover the dominancy of the 1939 year class which was the strongest one in the recent years throughout California was not so remarkable in the southern part of California.

Japanese data show only the last tail of the long trend. No wide fluctuation of the year class strength was seen as in the case of California sardine. The only exception was the 1949's which could be seen from the data of old fish. To be interesting enough, the strength of year classes seem reciprocal against those in California year to year. Namely the 1949's was the poorest on in recent years in California. Another

FIG. 7A

Year Class Strength of Japanese Sardine





example of this reciprocal relationship is the year classes of 1938 through 1941, which were supposed as poor ones in Japan.

10. Some suggestions on the factors of the year class fluctuations

As to the reason of the decline of the coming year class strength in the northern California, MARR pointed out that the drop of the water temperature off southern California took place in the middle forites. It is true that the drop of the water temperature measured at Scripps pier in the spawning season (Feburuary through April) in the 1944 through 46 season coincides the fall of the year class strength in this period. And the disappearance at the 47 year class as the last may be enough to support the hypothesis. But in 1930's, this hypothesis cannot be supported from the fact because of the strong year classes in spite of the low water temperature. (Fig. 8)

By judging the available Japanese Data, KURITA pointed out that the year classes from 1938 to 1939 seem to be caused also by the change of the enviromental factors.

Anyhow the data are too poor to explain the long term fluctuation.

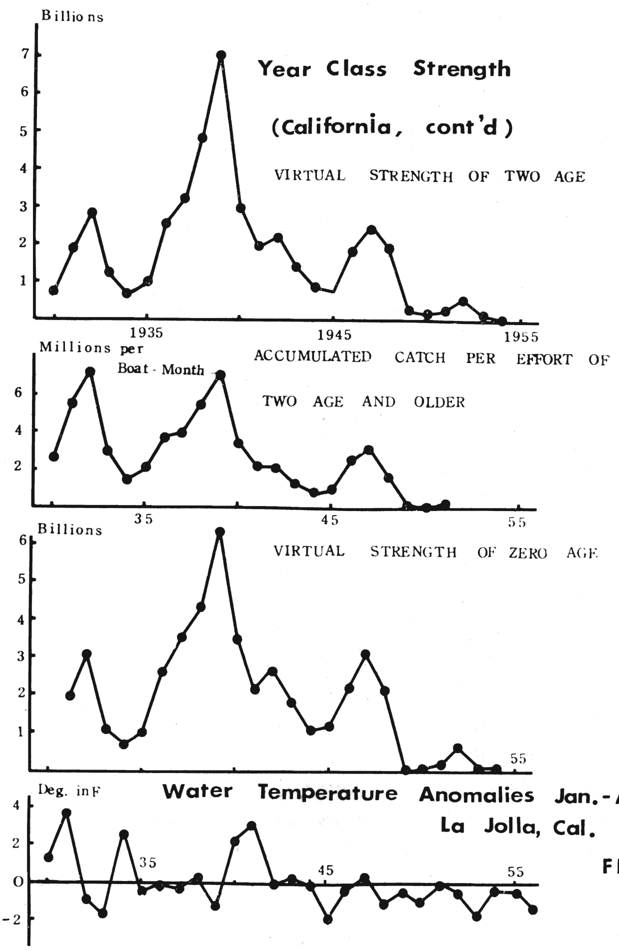


FIG.8

11. The comparison of vital statistics of Japanese and California sardine.

11. 1. *survival rate*; The longitudal survival rate of old fish of three years and older is shown as follows.

(i) *California* By catch per effort data of the whole seasons from 1932 through 1953. (the data of the season 1953-54 was not adopted, because they look like too extraordinary)

$$Z^{*}=1.019$$

By catch per effort data, broken at 1945 when a sudden drop happened,

$i_A=0.9135$ (1932 through 45)

$i_B=1.0718$ (after 1945)

Assuming the total survival rate has a normal pattern in its distribution, the difference of the total mortality rate between the two periods is not significant; but it is also noticed that the variance of them have been increasing.

In those years when the fisheries was developing, in California, the amount of effort had a fairy good relationship proportional with the total mortality rate. And moreover, a tendency was seen that the mortality rate decreases apparently

* Symbols by HOLT et. al. (1959)

in the seaeons when a strong year class entered the stock, and then it is increased gradually with a slope which became steeper by and by.

(ii) *Japan* By TAUTI (1943) the age composition of the season 1943 was estimated. By his data, the longitudal survival rate s was estimated as 0. 65 for the two-years and older fish, and 0. 63 for the three-year and older fish. The value of the total mortality rate Z $(=-log_n S)$ correspond 0. 43 and 0. 47 respectively.

In the Japan Sea, the value of s and Z for the three years and older fish are 0.69 and 0. 41 respectively.

As to Japanese sardine after 1945, the values of total mortality have been estimated as the following data.

Two-years and older;

	s	Z
Western Japan Sea	0. 21-0. 86 (mean 0. 51)	0. 67
Northern Japan Sea	0. 63-0. 52 (mean 0. 58)	0. 54

Three years and older;

	s	Z
Western Japan Sea	0. 36	1. 02
Northern Japan Sea	0. 33	1. 01

On granting the poor reliability, of the Japanese data before 1945 showed the higher survival rate compared to both of them of California at the correspon-ding years, and to those of the postwar Japan. And in addition, it is shown that the total mortality rate of Japanese sardine after 1945 is a approximately equal to that of California.

A great difference is shown, however, in the chance of appearence of the old fish. In Japan the old ones ovor six years of age appear quite seldomely, while in U. S. and Canada, it sometimes happens that the fish as old as twelve or thirteen years appear in bulk.

11. 2. *Natural mortality*

It is one of the most difficult problems in the study of population problems to estimate he natural mortality, and no effective method have been deviced. Especially in the oase of Japan before the war, where data of neither effort nor age composition are available, the value of the natural mortality can practically not be obtained.

The only data which show the value of the natural mortality in this period is obtained by the result of tagging.

By this method the value was estimatedas $M=0.3$.

Several values of the estimated natural mortality rate are show in the follo-wing table.

(i) *California*

befors the decline;

by catcy per effort data;

SILLIMAN (1943)	$M=0.3$
WIDRIG-YAMANAKA* (1954)	0. 10 (fully available)
YAMANAKA (1958)	0. 35 (partially available)

by virtual population;

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* This symbol means that the value was originally calculated by WIDRIG and was recalculated by YAMANAKA

YAMANAKA (1958) 0.34
by maximum life span; 0.14
after the decline;
by catch per effort;
WIDRIG-YAMANAKA 0.52 (fully available)
YAMANAKA 0.75 (partially available)
by virtual population;
YAMANAKA 0.4
by maximum life span YAMANAKA 0.3

(ii) *Japan*
before the decline;
by tagging;
TAUTI 0.3
after the decline;
by effort and catch;
YAMANAKA 0.5 (two year and older)
by maximum life span;
YAMANAKA 0.32

Here, a care must be taken that the apparent natural mortality of Japanese sardine has high values, one reason of which is thefluctuation of the availability of the old fish by means of the selectivity of gill nets.

It is also noteworthy that the natural mortality has a higher value after the decline compared to that before it

11.3. *Fishing mortality*

The value of the fishing mortality is obtainable by substracting the natural mortality rate from the total mortality rate.

The average value of the fishing mortality rate are shown in the following.

(i) *California*
before the decline;
YAMANAKA (1958) $F=0.81$ (fully available)
// 1.93 (partially available)
after the decline;
YAMANAKA (1958) 0.53 (fully available)
// 1.00 (partially available)

(ii) *Japan*
after the decline;
YAMANAKA (1957) 0.50–0.70 (fully available)

These figures do not show any remarkable difference between the variances of Californian and Japanese sardines.

It is an important fact that the increasing of the total mortality rate was maily caused by the natural mortality in both Japan and in California.

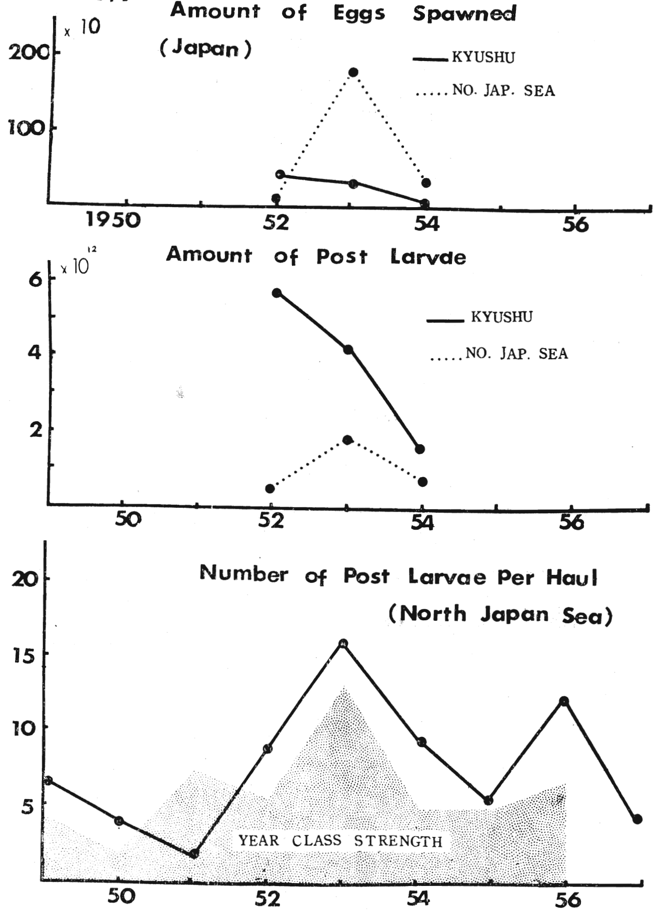
12. The pattern of the eggs abundance spawned.(Fig.9)

By the spawning survey, the amount of eggs spawned has been decreasing in the western part of Japan since 1951, and increasing in the Japan Sea, thus showing the tendency of a northward movement of the spawning ground. At the same time the total egg abundance is decreasing. On the other hand, the larval survival rate is comparatively high in Kyushu district and very low in the Japan Sea. Therefore, the number of the post larvae survived is larger in the waters off Kyushu than in the Japan Sea in spite of the less eggs. It is regretful. however, that no accumulation of data is avaliable which enable to estimate the amount of eggs spawned in whole Japanese waters since 1955.

As to the example which shows the relationship between the spawning and the year class resulted from this spawning, we have one of 1953, when an extraordinary abundant eggs and larvae were found, and the strength of the year class of the same year seems bigger in the recent years.

In comparing the abundance of the post-larvae in the waters off Noto against the strength of the year class from them, the amount of the catch of the O-age-fish in the northern Japan Sea, and the amount of two-year-old fish caught by the gill nets in the same region, we obtained the relationship seen in the Fig. 9.

FIG. 9



It seems possible to some extent to forecast the strength of the entering year class of the large sardines.

In California, the one-year-old fish are very lowly exploited. After RADOVICH (1952) the amount of the young sardines shows no clear relationship against the year class strength. (Fig. 10)

Moreover, by the amount of the larvae obtained by the spawning survey from 1951 through 54, it is hardly possible te find a clear relationship between them and the year class strength resulted. Namely, it is not easy to forecast the year class strength of the two-year-old fish.

13. Some interpretation of the fluctuation of the population size from the viewpoint of subgroup.

By MARR's hypothesis, two major groups are supporsed in California sardine, mamely, the northern and the southern. The northern group disappeared at the 1943 year class as the last. As to the evidences of this hypothesis, he pointed out the increase of the length of the formation of the first ring of scales, l_1 and the change of the age composition. Whill, in Japan, there is no such biological fact which shows the change of the growth rate at the first age of life. But

FIG. 10

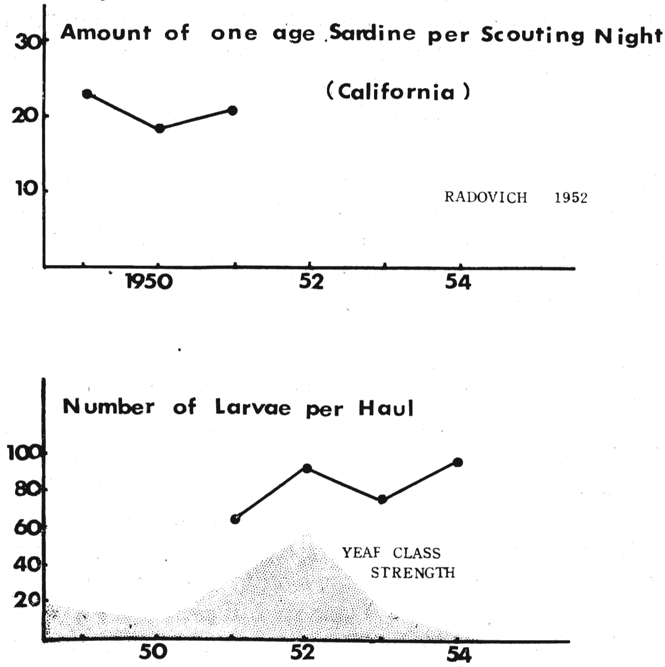
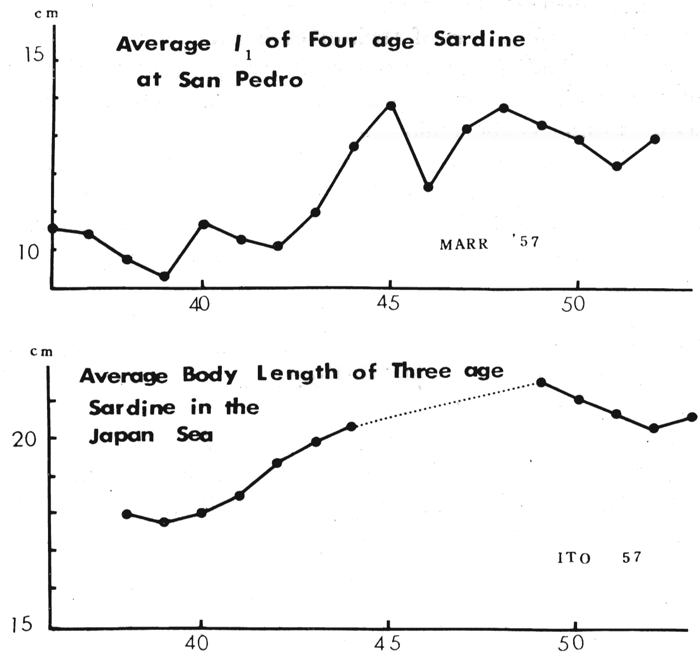


FIG. 11



one example which resembles this fact is the increase of the two years old fish at the western part of the Japan Sea in the 1940's compared to that of the 1930's. The amount of increasing reached three centimeters; and the time of the increase corresponds to that of the decreasing of the population. size. Usually this increase of the body length is considered to be due to the amount of food supply per individual fish. But it might be possible to consider it as the alternations of two groups each of which has the specific growth rate. (Fig. 11)

The number of vertebrae in Japan has been reported to have decreased compared to that of the 1930's. And the vertebrae number in the Kyushu district and in the Pacific coast were lower than that in the Japan Sea area in the same days.

In Japanese sardine, two major and two minor subgroups are suggested. The major ones are located in Kyushu waters and in the Japan Sea resdectively; and the minor ones are, in the Pacific and off Shikoku. They are mainly identified by the difference of the spawning grounds.

By ITO (1957) a hypothesis which is comparable to that of MARR was presented.

Although no evidence by means of tagging is available as in the case of he California sardine, the Kyushu group is supposed to distribute in thetwestern part of the Japan Sea as well as in the Kyushu waters, while the Japan Sea group does in the middle and southern part of the Japan Sea.

By some unknown case, the infant mortality rate increased in the late 1930's, thus caused the decline of the Japan Sea group with high vertebrae number, and then lowered the average number of vertebrae iu Japan as a whole.

The second step of the decline happened in the Kyushu group. The reason of the decline is still ambigous. But one of the considerable reasons, and which is often claimed is that the decline of the Kyushu in the recent years is caused by the heavy fishing which is due to the development of purse seine in this area. However, as the present author has already mentioned, the value of natural mortality rate in the first year of their lives is high enough to make the effect of fishing unclear. And moreover the relationship between the population size and that of the resulting year class is not clear. Therefore we cannot determine that the heavy fishing is the major cause of the decline.

As for the view on the major cause of the heavy decline which took place in late 1930's in Japan, and then in the middle 1940's in California, it is agreed that the drop of the recruitment occured. And then that the second stage of the decline took place in 1950's, of which reason seems the drop of the availability.

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摘　　要

日本産マイワシと米国カリホルニヤ産サージンの資源量変動の比較

山　中　一　郎

日本産マイワシとカリホルニヤ産サージンの漁獲量の変動は1930年代に急増，40年代に急落し，また50年代に一時的回復を示すなど類似点が多い．種々の方法で各魚種の年級量を年別に推定したが，50年代以後では必ずしも両魚種の傾向は一致していない．

また種々の方法により全減少率，自然死亡率および漁獲死亡率を推定した．1940年以後両魚種とも全減少率は増加し，ことに日本産のものにそれが見られる．またこの増大は漁獲よりは自然要因によるものと見られ，同時に利用度の低下も見られている．

稚仔の空間分布密度は所により添加年級量を予測せしめることが出来る．

資源減少の一因として Subgroup の交代が考えられる．

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