United States Department of the Interior, J. A. Krug, Secretary
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THE DECLINE AND REHABILITATION OF THE SOUTHEASTERN ALASKA HERRING FISHERY

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INTRODUCTION

It is now generally accepted by those who have followed the course of the fishery to the present time that the decline of the southeastern Alaska herring fishery in the late 1930's was due to reduced abundance of fish. During the period of decreasing yields following 1935 there was, however, no consensus of opinion either as to the seriousness of the decline nor as to the reason for this trend. From the experience of preceding years a majority of the operators and fishermen believed that the supply of herrings was virtually unlimited and that fluctuations in the annual yields were due to variations in the behavior of the fish. It was not surprising, therefore, that warnings issued by the Bureau of Fisheries against overfishing were received with some skepticism and that the regulations imposed to reduce the fishing intensity were considered by some as unnecessary. The evidence from biological investigation indicated, however, that the declining yields were a result of lowered abundance of at least one important population of herring brought about by a combination of overfishing and poor recruitment to the stocks.

In an effort to check this decline the Bureau of Fisheries restricted fishing on the Cape Ommaney grounds in 1939, and permitted only experimental operations in each of the seasons of 1940 and 1941. Because these experiments demonstrated that the abundance was very low the entire district was closed during 1942 to allow the stocks a chance to rebuild.

In 1943 the Fish and Wildlife Service cautiously reopened the district under the new regulation setting a quota for each season's catch. Under this system the amount which can be taken each year is established through the measurement of abundance and by the determination of the amount that can be safely removed without endangering the future supply. The fair fishing of 1943 and the good fishing of 1944 and 1945, indicated that the abundance had markedly increased. From the excellent fishing of 1946 and from the studies of abundance that have been made it can now be safely asserted that the restoration of the stocks in this area has been achieved. This is a welcome change of circumstances for those

companies which survived the economic dislocations caused by the period of low abundance and to the fishermen and shoreworkers who depend for a livelihood on the capture and processing of this resource.

Scientific studies of the southeastern Alaska herring have been in progress since 1925 and it is the purpose of this article to account for the decline and restoration of abundance in the light of the biological data that have been accumulated over these years; to review the method used in predicting abundance upon which the catch quota of each year is based; and to comment on the probable future of the fishery in this district.

RECORD OF THE FISHERY 1927 to 1946

The most significant feature of this period was the decline of the fishery between 1927 and 1939. While a part of this decline may be attributed to economic conditions (especially the depression of 1930, which was first reflected in the fishery in 1931), the major contributing factor was a general decline in abundance over this period. This will be demonstrated in a later section of this article. As the supply decreased more effort was required to obtain the large quantities of fish necessary for the successful operation of reduction plants with the result that the overhead costs to the operators increased. Under these conditions only the most efficient plants were able to survive, accounting for their reduction in number from eighteen in 1927 to only four in 1939.

In the most recent years (1940 to 1946) this fishery has been carefully regulated by the Fish and Wildlife Service in an effort to maintain the abundance at profitable levels. The relatively small annual catch quotas have deterred expansion so that only a few companies have operated during these years. This period is not, therefore, directly comparable to the eleven years preceding when the primary limitations on the magnitude of operations were the available supplies of fish and prevailing market conditions. Statistics of the fishery are shown in table 1.

Table 1.--The total catch, the number and combined reduction capacity of plants operated, and the number and combined tonnage of fishing vessels engaged in the southeastern Alaska herring reduction fishery for the years 1927 through 1946.

Year	Catch in barrels	Number of Plants	Combined 1/ reduction capacity	Number of 2/ vessels engaged	Combined net tonnage of vessels
1927	414,000	18	3/ 146.5	70	2,146
1928	487,000	16	3/ 127.0	65	2,167
1929	630,000	12	96.5	56	1,888
1930	567,000	13	129.0	63	2,311
1931	359,000	5	47.5	25	908
1932	398,000	5	50.5	23	885
1933	493,000	6	62.5	27	994
1934	535,000	7	67.5	34	1,272
1935	465,000	8	78.5	41	1,552
1936	294,000	5	48.5	23	876
1937	403,000	8	78.5	41	1,692
1938	179,000	5	48.5	26	1,056
1939	160,000	4	39.5	23	853
1940	none	1	12.5	5	162
1941	15,000	1	10.0	3	127
1942 4/	none	-	----	-	---
1943 5/	50,000	1	10.0	4	185
1944 6/	134,000	2	20.0	8	347
1945 7/	196,000	3	32.5	12	564
1946 8/	301,000	3	32.5	12	659

1/ In tons of raw fish per hour
2/ Excludes vessels which fished only a small part of the season
3/ Excluding barge "Peralta" (capacity unknown)
4/ District closed in this year
5/ Catch quota of 100,000 barrels
6/ " " " 200,000 "
7/ " " " 250,000 "
8/ " " " 350,000 "

ESTABLISHED BIOLOGICAL FACTS

The scientific studies that have been made on the herring populations in this district since 1925 have established certain fundamental facts pertaining to abundance. This information which has been obtained through the collection and interpretation of data over a long period of years now makes it possible to furnish a rational explanation for the fluctuations that have occurred, but even of more importance it permits an evaluation of abundance in advance of the fishing season which is so essential to the proper management of the fishery. The more important of these findings are briefly outlined in the following paragraphs.

Delineation of the Herring Populations

Early in the investigation it was deemed necessary to ascertain whether this area was inhabited by a single population or by a series of distinct populations with separate spawning and feeding areas. The problems of conservation presented by the two situations are quite different since in the former protection afforded to any area would in some measure protect the whole population, whereas in the latter case protection in one area would have no effect on the populations of adjacent areas.

Studies (principally tagging) have shown that there are four major herring populations in southeastern Alaska which are most easily identified through the locality at which they spawn. In order of importance these are the Sitka, Craig, Juneau and Kootznahoo Inlet stocks. Each of these contribute to one or more of the summer feeding areas and there is much evidence to prove that each follows a rather well defined route before returning to its original spawning grounds in the following year.

The most important feeding area is in the vicinity of Cape Ommaney. Statistics show that 70 percent of the total catch of this fishery has been taken there in the period from 1929 through 1946. What then are the stocks that supply this area? Tagging indicates that the Cape Ommaney fishery is supplied almost entirely by the Sitka spawners who congregate in this vicinity during the summer period for feeding purposes. Since this population also contributes in part to the Kuiu Island and Warren Island grounds, its role in maintaining the fishery assumes even greater significance. In fact the fishery has become so dependent on this population that its abundance level is the measure of success or failure in the fishery as a whole. For the above reason the discussion of abundance in a later part of this article deals exclusively with the Sitka stock.

Abundance

Abundance may be defined as the total number of fish in the stock. In herring, as in any population of living creatures, the abundance level is governed by the ratios of births to deaths. The addition of new individuals to the stocks is being constantly opposed by removal through death, (including man's take) so that only when the gain of young to the population exceeds the loss by mortality will bhe abundance rise. When the reverse is true the abundance will fall.

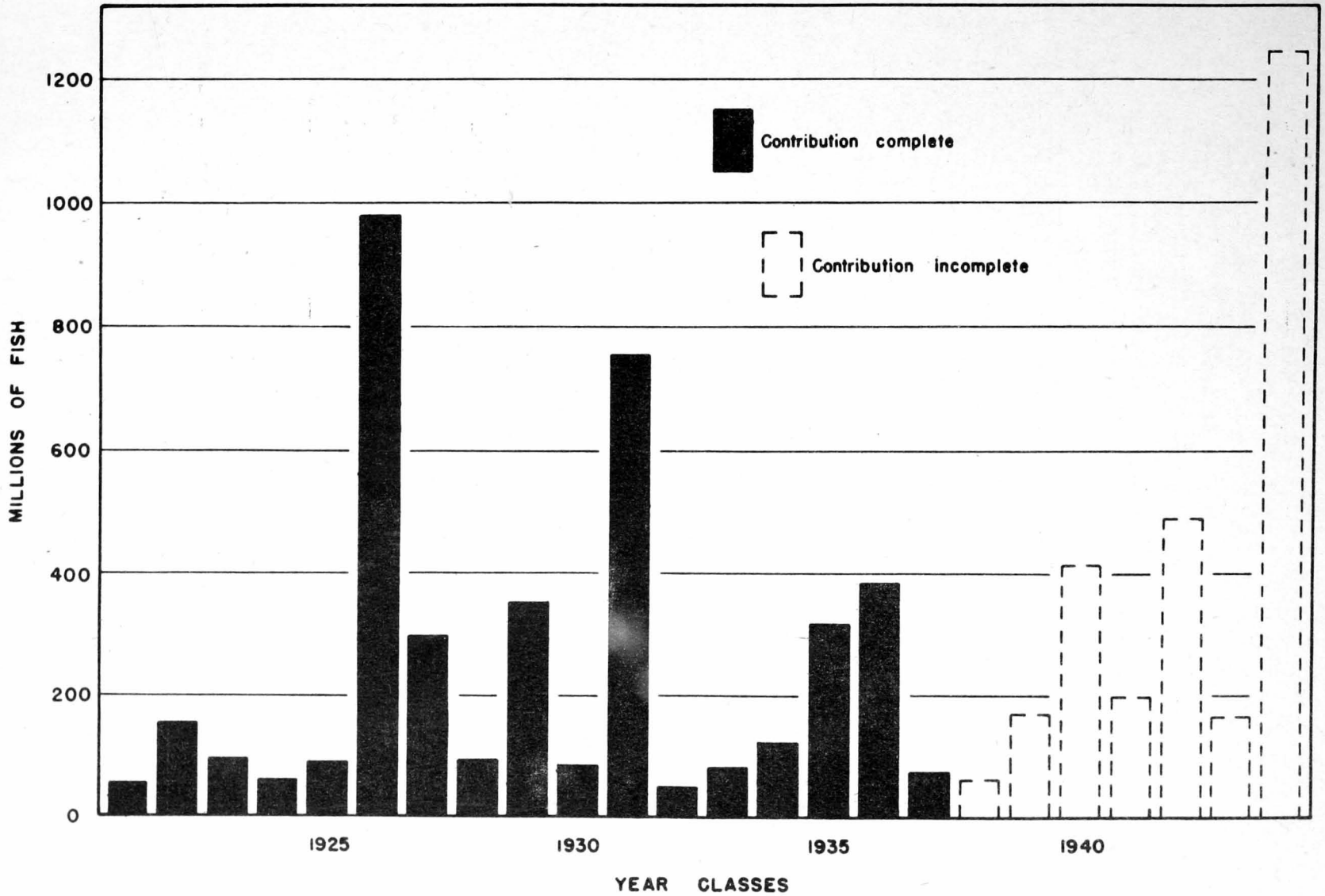

Figure 1.--The estimated contribution (in millions of individuals of each year class that has completed its existence within the fishery and the anticipated yield of those that have made only a partial contribution to date. The year classes shown are those that have contributed to the fishery during the period of 1929 to 1946.

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Factors influencing abundance. Great fluctuations in abundance independent of those caused by the fishery are characteristic of the Alaska herring These fluctuations result from the varying degrees of success which attend the spawning from year to year, so that the recruits added to the adult stocks may be in some years exceptionally numerous, and in others exceedingly scarce. This is explained by a difference in survival during the early stages of existence; either in the developing eggs, among the newly-hatched fry, or in the young immature fish.

This variability in survival has a tremendous effect upon the abundance of the stocks, since a poor, fair, or abundant brood may result from the spawning of any particular year. Whenever progeny from an exceptionally successful spawning reach an age sufficient to enter the fishery, there is a marked rise in the abundance level. Conversely, the failure of one or more spawnings leads to a decline in the abundance level. The fluctuations in the size of the year classes which have contributed to the fishery in the period of 1929 through 1946 are shown in Figure 1. Those year classes which have completed their contribution (i.e. have passed their 10th year) are shown in black, while those which have made only a partial contribution and whose total potential yield has been evaluated from their contributions to date, are shown in dotted outline. The relationship of these year classes to the decline and the rehabilitation of the fishery is discussed in a later section of this article.

Continuous observation of the age composition of the catch has shown that certain relationships occur with regularity and that their effect upon abundance has been consistent. Over a period of years the number of herring in the catch at any age is, within limits, in a fixed ratio to the number of that same yearclass that was in the catch in the preceding year. These relationships which are termed ratios of increment and decrement (since between certain ages there is an increase and between others a decrease) were obtained by comparing the contribution of the offspring of a given spawning in one season (as reflected by its percentage in the catch) with the contribution of that same year class similarly determined for the season following, after adjusting each percentage to account for changes in abundance from to year. This method provides a measure of the rate at which the members of a given year class increase or decline in available numbers between the two seasons, i. e., with an increase in age. By repeating this procedure so as to include comparisons between all near ages during the life span of a year class in the fishery, and by combining and averaging the ratios between ages for all of the year classes represented in the fishery, the average rate at which increment occurs during the first years in the life of a brood and the average rate at which decrement occurs in that brood during its later years were obtained.

Under the fishing intensity of the past these ratios show that there are 4.4 times as many individuals of a year class caught as 4-year fish as were caught the preceding year as 3-year fish. Compared with preceding years, there are only 0.7 as many 5-year fish, 0.6 as many 6-year fish, 0.5 as many 7-year and 8-year fish; and that for each age over eight the number will diminish by approximately three quarters in each succeeding year. In explanation of these variations between ratios at different ages, it is apparent that only a small part of the total numbers of a year class enter the stock from which the fishery makes its withdrawals in the third year, while the other members of that brood remain separated and unavailable, as they were in their first and second years. The remaining individuals do become available to the fishery in their fourth year so that recruitment exceeds the losses by mortality and there is a marked increase in numbers available to the fishery between the third and fourth years. The recruitment between the fourth and fifth year does not equal the numbers removed by mortality, so that during this period there is a slight loss in the number available. Mortality exceeds recruitment from this age on with the result that the year class is virtually decimated by the end of its eighth year.

Measurement of abundance. The determination of the size of population by actual count, is in the case of fish, obviously impossible. It has been necessary, therefore, for fishery biologists to apply certain indirect methods in order to determine the relative change in size of population from year to year. The two measures commonly used are the total catch and the catch per unit of fishing effort. While the total catch may depict the trend of abundance over a long period of time its obvious fault is that its magnitude in any one year will depend largely on the amount of fishing effort. The catch in the southeastern Alaska herring fishery which has fluctuated widely (see table 1) is not a satisfactory gauge of the abundance of the stocks. However, when weighted by the amount of fishing effort expended each year, the catch has provided a fairly accurate measure of changes in abundance from year to year.

The unit of fishing effort employed is the average catch per vessel in each ten-day fishing period. This catch is compared with the average size of catch made by the average vessel during comparable periods of time in former years. This index, which is in terms of number of barrels, is then weighted by the average number of fish per barrel in order to reduce the index to the relative number of individuals taken per unit of effort. To make these indices directly comparable between years each is compared to a base year of 100. The indices which have been obtained by this procedure are shown in table 2.

Table 2.--Abundance indices of the Sitka herring population as calculated from the return per unit of fishing effort for the years 1929 through 1946

Year	Abundance index in terms of the relative number of individuals	Index converted to the base year of 1932 in which the abundance equals 100
1929	84.4	72.3
1930	76.0	58.6
1931	98.0	71.3
1932	138.9	100.0
1933	104.1	70.4
1934	89.1	72.1
1935	75.4	55.6
1936	76.3	55.3
1937	75.8	69.1
1938	48.3	41.8
1939	---- Not available 1/	----
1940	---- " " 2/	----
1941	---- " " 3/	----
1942	---- " " 4/	----
1943	118.1	101.8
1944	121.4	105.4
1945	129.9	103.9
1946	137.7	116.0

1/ Cape Ommaney area closed
2/ Experimental operation; no catch made
3/ Experimental operation with restrictions on Cape Ommaney area
4/ District closed

A disadvantage of the indices just described is that they do not wholly reflect the total number of fish in the stocks but rather the degree of their availability in each particular year. It is recognized that the quantity of fish taken in any one year may be easily influenced by weather conditions governing the activity of the fishing fleet, or by other factors affecting the behavior pattern of the fish. Therefore, a rise or fall of the index in a single year over that of the preceding season is not positive evidence of a comparable change in abundance. This factor of availability however, tends to be compensatory since for each season in which adverse conditions have resulted in poor catches, there has been a season in which favorable conditions have led to good yields. For this reason no continuing decline in abundance such as occurred in the fishery between 1932 and 1939 could be attributed to lack of availability alone.

Another factor influencing the reliability of the indices of abundance is the continuous improvement in fishing gear, the increased skill of the fishermen in its use, and their increased familiarity with the fishing grounds. Unlike the hydrographic factors already mentioned which influence availability, these are not compensatory. Their effect is, on the other hand, cumulative over a period of time. No satisfactory method of weighting for these factors has yet been found and in any comparison of the indices of recent years (1943-1946) with those of the earlier years (1929-1938) this should be taken into account. If it were possible to place these indices on a common base in terms of equal fishing efficiency it is apparent that those of recent years would be relatively too high.

A more nearly accurate picture of the fluctuations in abundance that have occurred and in which the effect of the variation in availability between seasons has been largely eliminated, is shown in figure 2. Each point in this graph represents the theoretical number of individuals which would have been available to the fishery under the terms of equal fishing intensity and equal availability in each year. Basically it has been obtained by apportioning the total yield of each year class according to the average percentage contribution at each age, as calculated from the ratios of increment and decrement. A full explanation of the procedures applied to obtain these values is too involved to be properly included in this article.

Armed with these concepts of abundance the causes for the decline of the fishery in the decade of 1930-1940 do not appear so mysterious or remote. The fluctuations that occurred resulted from the progression of year classes of various magnitude through the fishery. Their influence upon abundance is graphically shown in figure 2. Except for the highly successful year classes of 1926 and 1931, and the moderately successful year classes of 1935 and 1936, the recruitment for the period was insufficient to sustain the abundance level. A contributing factor was the excessive fishing during the early years, especially between 1929 and 1935, when the average catch approximated 500,000 barrels each year. Under these conditions of low recruitment and excessive fishing the few successful year classes were rapidly exhausted so that no reserve of older individuals was accumulated to sustain the fishery in the years of low recruitment that followed.

EXPLANATION OF THE RISE OF THE FISHERY BETWEEN 1942 AND 1946

The remarkable restoration of abundance in this fishery during recent years must be attributed to the occurrence of a series of exceptionally successful spawnings together with the reduction of fishing intensity. The first successful spawning after closure of the fishery occurred in 1940, the second in 1942, and the third in 1944. In addition, the spawnings of 1941 and 1943 were above average value. The effect of these year classes upon abundance is shown in the graph of figure 2. Another factor which materially assisted in the rebuilding of the stocks was the curtailment of fishing in the years following 1938 which had the desired effect of increasing the birth rate and decreasing the death rate, thus raising the population level.

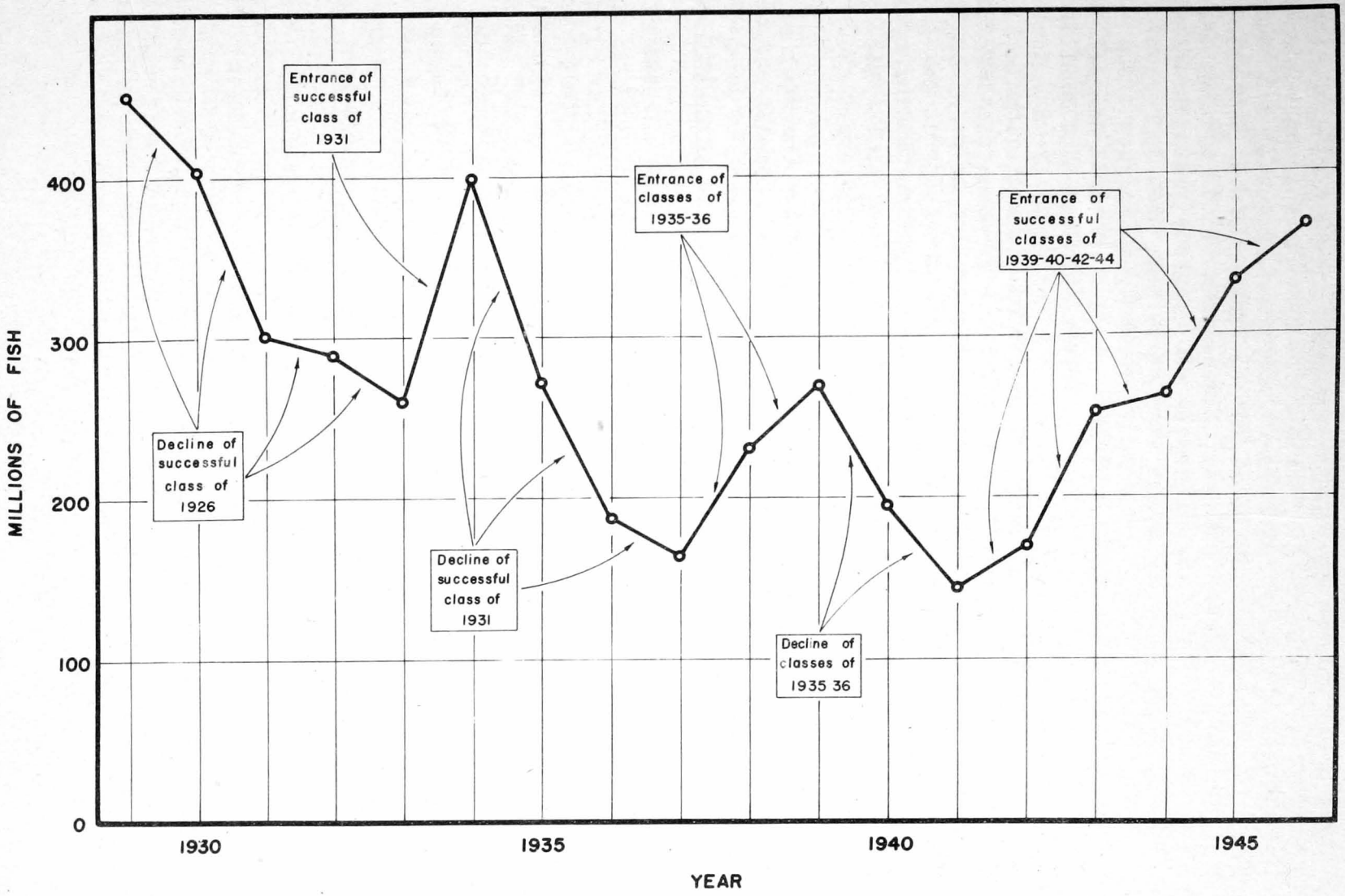

Figure 2.--Theoretical abundance of the Sitka herring population of southeastern Alaska for the period of 1929 through 1946. 23461

METHOD OF MANAGEMENT

The knowledge accumulated in the study of this fishery has provided a system of management which should greatly aid in stabilizing the annual yields. This system requires that the changes in abundance be foretold so that the fishing intensity can be adjusted to the anticipated level of abundance. By this procedure it is possible to prevent excessive expansion in periods of high abundance and so avoid the economic dislocation associated with periods of low abundance. This is accomplished by establishing catch quotas for each season. The quotas are so set as to assure that at least 5 percent of each year class will survive to its eighth year and thus provide an adult population adequate in numbers to sustain the fishery over the not infrequent periods of poor survival. This system of management should aid in stabilizing the annual yields.

Predictions of abundance are based on the observation that over a period of years the number of herring in the catch at any age is, within limits, in fixed ratio to the numbers of that same year class which will enter the fishery in the following season. As based on the ratios of increment and decrement the manner in which a typical year class will distribute its members during its span in the fishery is shown in table 3.

Table 3.--Average rates at which a year class will contribute its numbers to the fishery, based on the average rate of increment and decrement.

Age	Percentage contributed at each age	Cumulated percentage contributed at each age
3rd year	8.7	8.7
4th "	38.5	47.2
5th "	26.2	73.4
6th "	14.9	88.3
7th "	7.3	95.6
8th "	3.4	99.0
9th "	.8	99.8
10th " and older	.2	100.0

PREDICTION FOR SEASON OF 1947

Because the offspring of any given spawning make their contribution to the fishery over a period of years, it becomes possible, once a year class has entered the fishery, to estimate in advance not only its probable contribution for the following year, but also its probable yield during its entire span in the fishery. For example the total contribution of the 1944 year class can be estimated from its contribution as 3-year fish in 1946, while the total yield of the 1943 year class can be estimated from its contribution as 3-year fish in 1945 and as 4-year fish in 1946. In like manner, the potential contribution of each of the year classes expected in the fishery in the coming season can be evaluated except that for the 1945 year class which will enter the catch for the first time in 1947. Its probable contribution must be necessarily based on the average of the contributions of 3-year fish in the past, and considerable deviation from this average may be expected in any one year. The total potential yield of each year class now in the fishery, and its expected contribution in the season of 1947, as calculated in this manner are shown in table 4.

Table 4.--Year classes in the Southeastern Alaska herring fishery, their total potential contribution, and their anticipated contribution in 1947. In millions of individuals.

Age	Year class	Potential total contribution	Contribution expected in 1947	Percentage contribution
3-year fish	1945	unknown	59.5	8.7 1/
4-year fish	1944	1244.5	479.3	69.9
5-year fish	1943	167.4	43.8	6.4
6-year fish	1942	492.2	73.4	10.7
7-year fish	1941	198.1	14.4	2.1
8-year fish	1940	415.0	14.0	2.0
9-year fish	1939	171.3	1.5	.2
10-year fish and older	1938	62.4	.1	---

1/ Average percentage contribution made by the year classes which have entered the fishery in the past

The conclusion obtained from these estimates of the most probable contribution of the year classes within the fishery is that the abundance will be high in the season of 1947. The most likely source of deviation from the predicted contributions will be in the year classes of 1944 and 1945. The estimation of the strength of the 1944 year class has been obtained from its single contribution as 3-year fish in the season of 1946. As evaluated from its yield in that season this class appears to be of outstanding strength and its presence as 4-year fish should substantially raise the level of abundance over that of 1946. The 1945 year class will enter the fishery for the first time in 1947 and its estimated contribution is based only on the average contribution of entering year classes in former years which has approximated 9 percent. It can be stated with assurance that the fishing in 1947 will be exceptionally good.

FACTORS LIMITING A FURTHER EXPANSION OF THE FISHERY

The number of reduction plants that can be supported by the herring populations of this district is of vital importance to those engaged in the fishery. Past records show that there has been great expansion of reduction capacity during periods of high abundance with many failures in the subsequent periods of low abundance that have followed. The peak year of expansion was in 1927 when there were eighteen plants. Only four of these remained in 1939.

A fair approximation of the capacity of these populations as related to the size of the operation which they may be expected to support can be obtained by examining the total yields of the year classes which have contributed to the fishery in the past. These yields as measured from the catches made on the Cape Ommaney fishing grounds range from a low of 50 million to a high of 982 million individuals. The average yield of all year classes combined is approximately 230 million fish. Converted to barrels on the basis of the average weight at each age and the percent of the total yield contributed at each age this is the equivalent of 230,000 barrels of 250 pounds each. Since, on the average, only 70 percent of the district catch is composed of Cape Ommaney area catches, 30 percent may be added to this figure to account for the contributions from the other stocks (principally those of the Craig and Juneau spawning grounds). This means, then, that unless there is some unforeseen change in the basic hydrographic conditions which govern the productive capacity of these waters, or unless new populations not yet under exploitation are discovered, the average annual production will be in the neighborhood of 300,000 barrels per year. The catch quota of any year may exceed, or be less than this amount, but over a period of years this will be the expected average yield.

The present high abundance will serve to attract additional investment capital to this fishery. Those contemplating such a move are cautioned that the catch quota of each year is based solely on the rate of recruitment and has no relation to the number of plants or the minimum catch that each will require for a profitable operation. The number of plants that can be sustained on an average annual yield of approximately 300,000 barrels will depend, of course, on the economic factors involved. At present it is commonly stated that a season's operation will not pay out on a catch of less than 50,000 barrels so that unless there be a change in circumstance which would reduce this minimum, the plants now established appear to approach the maximum for this district. It cannot reasonably be contended that more facilities are needed for a full utilization of the resource since the seasonal reduction capacity of each of these plants is at least twice the 50,000 barrel minimum required. Expansion beyond the present level will mean failure of the less efficient plants at some future date when recruitment to the stocks is low.

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