REPORT OF THE
INTERNATIONAL PACIFIC HALIBUT COMMISSION

APPOINTED UNDER THE CONVENTION BETWEEN CANADA AND THE UNITED STATES OF AMERICA FOR THE PRESERVATION OF THE NORTHERN PACIFIC HALIBUT FISHERY

NUMBER 28

UTILIZATION OF PACIFIC HALIBUT STOCKS: YIELD PER RECRUITMENT

BY

THE STAFF,
INTERNATIONAL PACIFIC HALIBUT COMMISSION

SEATTLE, WASHINGTON
1960

FOREWORD

The 1953 Convention between the United States and Canada for the Preservation of the Halibut Fishery of the Northern Pacific Ocean and Bering Sea continues the purposes of prior conventions, specifically stating that the objectives of the Convention are to develop the stocks of halibut to levels which will permit maximum sustained yield and to maintain the stocks at those levels.

This report indicates by the use of a yield-per-recruitment model the progress made toward developing the stocks to levels of maximum yield. The model indicates that recruits to the fishery are now being utilized at an optimum or near optimum rate. This and other phases of the Commission's research into the dynamics of the Pacific halibut stocks will be reported upon from time to time as further progress warrants.

The following members of the scientific staff contributed to the analyses and to the text of the report, namely, William H. Hardman, Richard J. Myhre, Alonzo T. Pruter, G. Morris Southward, Richard A. Kautz, and the Director Henry A. Dunlop and Assistant Director F. Heward Bell. Other members of the staff, Kenneth W. Exelby, Gordon J. Peltonen and William L. High aided in the compilation of the data.

UTILIZATION OF PACIFIC HALIBUT STOCKS: YIELD PER RECRUITMENT

By

THE STAFF,

INTERNATIONAL PACIFIC HALIBUT COMMISSION

CONTENTS

INTRODUCTION

By 1930 it was evident that the stocks of Pacific halibut on all but the very recently discovered banks beyond Sanak Islands were overfished. For all grounds south of Cape Spencer, Alaska the combined annual catch had declined from a level of about 55 million pounds in the 1910-1913 period to about 22 million despite a doubling of fishing effort. The annual catches on grounds west of Cape Spencer were generally maintained to 1930 but only by continually increasing the fishing effort and progressively extending the fishery to the westernmost limit of the species' range. In 1931, although fishing west of Cape Spencer was more intense than in 1926 and then encompassed all grounds in the region, the catch there was 5 million pounds less than in 1926. Removals prior to 1931 had clearly exceeded additions to the stocks both south and west of Cape Spencer.

Effective regulation of the fishery began in 1932 under powers granted by the second halibut Convention which was ratified in 1931. Objectives of regulation were to halt the decline in the fishery and rebuild the stocks to levels of greater productivity. These objectives were reached by holding annual catches slightly below additions to the weight of the stocks by growth and new recruits. Permitted annual catches were increased as the rising catch per unit of fishing effort showed that the improvement of the stocks was continuing.

In 1959 the Pacific Coast catch was 71.5 million pounds, over 27.0 million pounds greater than in 1931, the year immediately preceding regulation. The increase in catch in 1959 alone had a landed value of about $5,000,000, which is about twice the combined funds that have been appropriated for the Commission by Canada and the United States during the 36 years of its existence.

The ultimate objective of management of the Pacific halibut fishery is to determine the level at which maximum sustainable yields may be obtained from each stock and to stabilize each stock at that level by applying an appropriate amount of fishing. Attaining this objective involves solution of complex biological problems that are further complicated by the longevity of the halibut which causes a delay of many years between any change in removals or in the environment and the attainment of stability within each stock. To achieve maximum yields it is necessary to determine the present degree of utilization.

While the empirical method of control has been used in the past and needs to be continued in the future, it must be supplemented wherever possible by studies designed to measure the various individual factors that determine the size and yield potential of the various stocks.

Four primary factors determine the weight of any exploited population: recruitment, growth, deaths due to natural causes and deaths due to fishing. This report summarizes what may be inferred concerning potential yields of the Pacific halibut by making use of present knowledge regarding the above factors. Present estimates of growth, fishing mortality and natural mortality are examined in the light of the relative reliability of the data used, and the best values are used in the model.

While studies on recruitment and upon the relationship between size of spawning stock and progeny are in progress, the nature and extent of the relationship for the range of values that may be involved remain undefined. Hence the usual assumption is made that recruitment is constant over the stock levels studied in the model.

Taking into account the rate of growth at each age and the natural mortality rate, theoretical yields have been determined for a wide range of fishing mortality values and for different assumed ages of entry into the fishery. In the event that fewer young are produced at low spawning-stock densities, predicted yields for some of the higher rates of fishing mortality may be overestimated. If the production of young remains constant at all high densities of adult stock, the yields from a given recruitment will be as shown in the figures for low rates of fishing. On the other hand, if recruitment declines beyond some high level of stock density the yields per pound of recruits may be overestimated for very low fishing rates.

The theoretical model presented suggests that the present yields are within 10 to 15 percent of the theoretical maxima. According to the model the yields could be maximized only by greatly increasing the amount of fishing, one and two-thirds times south of Cape Spencer and two and one-half times west of Cape Spencer. Whether the increases in yield could be achieved cannot be answered as large increases in fishing mortality would result because of the size of the annual production and these might significantly alter the other factors affecting the yield per recruitment. Also, practical considerations would seem to preclude applying such great increases in fishing effort to attain such insubstantial and probably doubtful increases in yield. Furthermore, the history of the fishery has repeatedly shown that such high fishing levels as are envisaged in the model actually resulted in sharply reduced yields.

MORTALITY RATES

To study the yield per recruitment in the stocks of halibut it is necessary to secure estimates of total mortality and to partition such mortalities between natural causes and fishing. Age composition and tagging studies are the primary sources of information regarding total mortality and its fishing and natural components. Catch statistics can also provide estimates of fishing mortality alone. It is desirable to compute mortality rates from each source because not only are they independent, the assumptions required in each case are not the same.

Unless otherwise noted, all mortality rates mentioned in this report are instantaneous rates.

MORTALITY RATES FROM TAGGING EXPERIMENTS

The use of tagging to estimate mortality rates requires that the tagged fish be representative of the population being sampled. It also requires that the tags are permanently attached and that they are always observed and also reported upon recovery. The mortality estimates obtained are only acceptable to the extent that these conditions are met.

The recoveries from several of the larger tagging experiments in Area 2, the grounds south of Cape Spencer, and Area 3, all grounds west of Cape Spencer, were analyzed to obtain estimates of the mean annual rates of total mortality. All fish less than 80 centimeters in total length at release have been omitted from the analysis because they are not always fully available. All fish that were recovered by boats fishing primarily for other species were also omitted to make the experimental data more typical of the population fished by the halibut fleet. With present data, the mean mortality rates for Area 2 and Area 3 were almost identical with or without this exclusion.

The weighted average annual total mortality rate, $\bar{a}$, was computed from the equation

$$\bar{a} = 1 - \sqrt{\frac{\frac{R_3}{C_3} + \frac{R_4}{C_4} + \cdots + \frac{R_t}{C_t}}{\frac{R_1}{C_1} + \frac{R_2}{C_2} + \cdots + \frac{R_t}{C_t}}} \qquad \text{.......(1)}$$

where R represents the number of usable recoveries obtained each year and C is the corresponding commercial catch in pounds for the grounds in question. The equation is a modification of that of Jackson (1939), the adjustment for catch tending to minimize the effects of annual changes in availability and in fishing effort. According to Chapman and Robson (1960), a bias present in Jackson's original equation can be eliminated by including the t^{th} or last term in both the numerator and denominator of the ratio inside the radical of equation (1) provided R_t is small. Although the data were truncated to include only the recoveries from the first five usable years, the number of returns in the last year was usually less than ten. The correction for catch is usually superior to a correction for effort alone because of the inverse relationship between availability of fish and effort. However, for the experiments used in this report the two methods provide almost identical values.

Recoveries in the zero-year, that is, the year of tagging, were not used because they are not comparable to those of subsequent years.* For the same reason it was occasionally also necessary to omit first-year recoveries. The decision as to whether first-year returns were usable was made by inspection of the returns in subsequent years.

A method similar to one described by Ricker (1948) has been used for estimating the average annual rates of fishing and natural mortality for halibut. Data required for these computations are the total mortality rate, the mid-date of tagging, the number of tagged fish recovered in each year during the experimental period and the number of years in the experimental period. The computations again are complicated by the fact that zero-year and occasionally first-year recoveries cannot be used in computing the mean rates of fishing and natural mortality. Therefore, allowance must be made for fishing and natural deaths during the years omitted to arrive at an estimate of the number of tagged fish present at the start of the first usable recovery year.

The computed rates of total, fishing and natural mortality for several experiments are shown as instantaneous rates in Table 1. The data from which these estimates were obtained are given in Appendix Tables 1 and 2.

In addition to sampling error, the estimates of mortality shown in Table 1 are subject to errors that arise because the assumptions upon which they are based are not completely satisfied. Also, the residual method of partitioning total mortality results in attributing to natural mortality deaths which are in fact due to fishing. This would make natural mortality rates shown in Table 1 too large and fishing mortality rates correspondingly too low. In the present absence of information on the magnitude and consistency of these errors from time to time and from ground to ground, any comparison between experiments should be made with caution.

*Ricker (1948) called this Type C error.

Table 1. Estimated instantaneous rates of fishing, natural and total mortality from tagging.

Experiment	Fishing Mortality	Natural Mortality	Total Mortality
Area 2			
Upper Hecate Strait, 1949	0.25	0.48	0.73
Upper Hecate Strait, 1951	0.34	0.35	0.69
Upper Hecate Strait, 1952	0.30	0.44	0.74
Upper Hecate Strait, 1953	0.38	0.40	0.58
Lower Hecate Strait, 1952	0.21	0.53	0.74
Lower Hecate Strait, 1953	0.26	0.37	0.63
Goose Islands Ground, 1947*	0.33	0.55	0.88
Goose Islands Ground, 1951	0.32	0.35	0.67
Arithmetic average	0.30	0.43	0.73
Area 3			
Kodiak Island Region, 1949	0.03	0.30	0.33
Kodiak Island Region, 1950	0.04	0.59	0.63
Kodiak Island Region, 1951	0.07	0.71	0.78
Kodiak Island Region, 1952	0.06	0.41	0.48
Yakutat, 1951	0.14	0.30	0.44
Arithmetic average	0.07	0.46	0.53

*Trawl Caught.

The mortality rates determined by tagging are discussed later in this report along with those determined by other methods.

MORTALITY RATES FROM AGE COMPOSITION

Total Mortality Estimates

Several methods for estimating total mortality from age composition of exploited fish populations have been applied to the halibut data depending upon the circumstances.

Whenever a series of two or more years of data were available, total mortality estimates were derived by averaging individual estimates of the decline in numbers from one age to the next of all the fully-recruited year classes in the series of samples. Estimates were computed for age groups above the point of maximum representation of the year class but excluding the scarce older fish to assure full recruitment and adequate representation in the samples. The choice of age groups was varied from period to period and from area to area to meet the above conditions. Some variation in values would result from changing the age groups used.

Generally, estimates were made between each successive pair of years and then averaged over each period under consideration. Considerable variation occurs in the year-to-year estimates of total mortality due to short-term changes in availability.

Specifically, estimates were calculated as follows: the decline in natural logarithms, *ln*, of the abundance measure, *N*, (catch in numbers of fish per 10,000 skates) of the year classes, *x*, under consideration were taken from year *j* to year *j+1* and averaged for the number of year classes involved, *r*, as the estimate of the total instantaneous mortality coefficient, *i*, in Ricker's (1958) notation, thus:

$$i = \frac{\sum_{x=1}^{r}\left[\ln_x N_j - \ln_x N_{j+1}\right]}{r} \qquad (2)$$

where x is taken from 1 to r. The average total mortality for several years can be derived by averaging these yearly estimates for the period involved. Alternatively, the average mortality for such a period can be calculated from the decline in natural logarithms of year-class strength from year j to year $j+t$ as follows:

$$i = \frac{\sum_{x=1}^{r}\left[\frac{\ln_x N_j - \ln_x N_{j+t}}{t}\right]}{r} \qquad (3)$$

The latter method has the advantage of averaging-out short-term fluctuations in availability that influence estimates made on a year-to-year basis although it depends critically on availability in the two years, j and $j+t$. The number of fully-available age groups, r, limits the period over which estimates can be made by this method.

Whenever the age composition of the halibut has been represented by a catch curve in only a single year, estimates of total mortality were made by a modification of the method of Jackson (1939), assuming constant recruitment and stable conditions over a period at least as long as there are fully-available age groups represented in the catch curve. This method gives an estimate of the total annual percent survival, s, which is calculated as follows:

$$S = \frac{{}_2N_j + {}_3N_j + \text{-----} + {}_rN_j}{{}_1N_j + {}_2N_j + \text{---} + {}_{(r-1)}N_j} \qquad (4)$$

where ${}_1N_j$ represents the abundance of the first year class (or youngest age group) considered fully-recruited in year j, and ${}_rN_j$, that of the last year class considered fully available in the same year. The total annual mortality rate, a, was calculated from the above by $a = 1 - s$ and converted to total instantaneous rate by use of tables of Ricker (1958).

Estimates of the average instantaneous rate of total mortality derived by the above methods for sections of Areas 2 and 3 are shown in Table 2. The data from which they were obtained are given in the Appendix Tables 3 to 10. The values shown were derived from year classes which were considered most consistently available in the areas concerned as indicated in Appendix Tables 11 through 15.

For the Goose Islands population the rates given each year are the average of the total instantaneous mortalities derived, by Equation (2), from the decline of year classes in numbers from ages 9 to 10, 10 to 11, and 11 to 12 as shown in Appendix Table 11. There are indications that the age of full recruitment on these grounds has shifted in recent years and this has been considered in calculation of the estimates shown in Appendix Table 12, using Equation (3), with ages 9 to 11 in the years 1935 to 1951, and ages 10 to 12 from 1951 to 1958. When the year-to-year estimates in Appendix Table 11 were averaged by two-year periods and compared with comparable values in Appendix Table 12 by analysis of variance, they were found to be not significantly different.

Samples from Hecate Strait, where systematic sampling began in 1950, did not permit consistent choice of age groups as was possible for Goose Islands because of greater variability in the relatively short series of data. Consequently, choice of age groups used in the calculations using Equation (2) on year-class declines in this area varied from year to year, as described in Appendix Table 13.

The use of younger age groups in 1953 was necessitated by abnormally high

Table 2. Estimated instantaneous rates of total mortality from age composition.

	Area 2		Area 3			
Year	Goose Islands	Hecate Strait	Yakutat	Portlock-Albatross	Shumagin Islands	Bering Sea
Prior to 1930	—	—	—	0.73	0.67	—
1936	1.11	—	—	0.22	—	—
1937	0.31	—	—	0.54	—	—
1938	0.46	—	—	0.94	—	—
1939	0.91	—	—	0.76	—	—
1940	0.19	—	—	0.15	—	—
1941	0.82	—	—	0.27	—	—
1942	0.36	—	—	0.76	—	—
1943	0.84	—	—	0.63	—	—
1944	0.09	—	—	0.10	—	—
1945	1.42	—	—	—	—	—
1946	0.10	—	—	—	—	—
1947	0.20	—	—	—	—	—
1948	0.78	—	—	—	—	—
1949	0.20	—	—	—	—	—
1950	0.58	—	—	0.58	0.73	—
1951	0.67	0.44	0.39	1.42	—	—
1952	0.10	0.64	—	*	0.34	—
1953	0.17	0.31	—	0.82	0.51	—
1954	0.62	0.62	—	0.37	0.40	—
1955	0.76	0.21	—	0.53	0.43	—
1956	0.58	0.54	—	0.60	0.34	0.22
1957	0.78	0.84	—	0.25	0.54	—
1958	0.42	0.09	—	0.26	0.49	0.53

*Negative value.

availability of the year classes comprising the older age groups, the latter giving an appearance of no mortality from 1952 to 1953. Beginning in 1954, with the institution of two seasons of fishing in Area 2, the combined age composition was used. Because of the greatly increased availability in 1953, the estimates in 1954 may be unduly high for some year classes.

The single estimate for Yakutat in Table 2 was made by use of Equation (4) from the catch curve of a sample taken in the summer of 1951. Age groups 13 to 22 were used.

The single estimate of 0.73 for the Portlock-Albatross grounds in Area 3 prior to 1930 was derived from age groups 14 to 17 from a sample taken in 1927 in the same manner as for Yakutat. Use of all the fully-recruited age groups in the Portlock sample produced an estimate of approximately 0.62 but was considered less dependable due to indicated sampling variation in the older age groups.

There was an unavoidable interruption in sampling of Area 3 catches from 1945 through 1948, but for all other years the estimates for Portlock in Table 2 are the average of the instantaneous total mortalities, derived by Equation (2) using all year classes available at ages 13 to 20 as shown in Appendix Table 14.

As in Hecate Strait, sampling of catches from the Shumagin Islands grounds was sporadic until recently and the available data from which mortality estimates can be made are limited, necessitating use of different age groups from one year to the next in the calculations. Equation (4) was used to obtain the estimate of 0.67 for the Shumagin Islands prior to 1930 from a single sample taken in 1929, using age groups 12 to 17. Employing age groups from 12 to 20 yielded a slightly lower estimate of 0.62 which also was considered less dependable due to sampling variation in the older age groups.

The estimate for the Shumagin Islands for 1950 shown in Table 2 was obtained by the same method from the numbers in age groups 11 to 18 in a single sample taken by the Commission in July-August of that year. From 1952 to 1958, the values for the Shumagin Islands were derived by Equation (2), but as in other areas it was necessary to vary the age groups used from year to year as shown in Appendix Table 15. With no sample available for 1951, the value shown for 1952 is the yearly average decline from 1950.

The estimate of total mortality of 0.22 for the Bering Sea in 1956 was taken from the age composition of the original exploratory catch of the Commission from those grounds in the summer of that year. It is an average of several estimates ranging from 0.18 to 0.26 by applying Equation (4) to as few as five age groups (from age 15 to age 19) and to as many as 18 age groups (from age 14 to 31).

The considerably higher subsequent estimate for 1958 of 0.53 is the average yearly year-class decline from the "virgin" condition in 1956 to the intensively-fished condition in 1958 using year-classes 1944 to 1933 at ages 12 to 14 . . . to ages 23 to 25, calculated with Equation (3).

Natural Mortality Estimates

Average estimated rates of natural mortality calculated by the regression of total mortality upon the associated fishing effort—the y-intercept serving as an estimate of natural mortality—showed a consistency from area to area and were generally in agreement with the estimates from other sources listed in Table 3. However, due to the long extrapolation necessary and a lack of statistical confidence in individual estimates obtained, the regression method was not accepted.

Whenever possible, therefore, other methods including that of Silliman (1943) for separating fishing from natural mortality were used. The latter method is essentially a two-point comparison between periods in which fishing conditions have been reasonably stable at two different levels. Although these conditions are usually only partially fulfilled in the data used herein, the ratios between arbitrary periods may be compared.

Estimates of natural mortality determined by various methods are given in Table 3 showing their range. The mean value is regarded as the best estimate obtainable from the data.

For the Goose Islands population, the Silliman-method estimates of natural mortality were obtained using total mortality estimates shown in Appendix Table 12 calculated from ages 9 to 11 for the 1926 to 1940 year classes and from ages 10 to 12 for the 1941 to 1946 year classes.

Table 3. Estimated instantaneous rates of natural mortality from age composition.

Region	Method	Natural Mortality	
		Range	Mean
Goose Islands	Silliman	0.19 to 0.20	0.20
Hecate Strait	Silliman	0.07 to 0.33	0.24
Portlock-Albatross	Silliman	0.11 to 0.18	0.15
Portlock-Albatross	Virtual population	0.09 to 0.29	0.20
Shumagin Islands	Silliman	0.14 to 0.17	0.16
Bering Sea	Catch Curve	0.17 to 0.23	0.20
		Average of above values 0.19	

Note: The rejected regression method provided a mean value of 0.20.

In the absence of stable periods of differing fishing conditions on the Goose Islands grounds, the data were arbitrarily averaged by 5-year periods. Those 5-year periods between which there were moderate differences in effort and total mortality provided values of natural mortality of 0.19 (1935-39 and 1946-50) and 0.20 (1941-45 and 1951-56, excluding the 1943 year class for reasons of obviously aberrant availability).

Partitioning the data for northern Hecate Strait shown in Table 2 into two parts (1950-54 and 1955-58) and applying the associated fishing effort by the Silliman method produced an estimate of natural mortality of 0.27. Other estimates based on total mortality calculated by using various age groups ranged from 0.07 to 0.33.

Because of a lack of difference in fishing effort, the Silliman method was unworkable on data from the Portlock-Albatross region except by grouping the data in 5-year periods and comparing these with a catch-curve estimate of total mortality for a sample taken in 1927. An average estimate of natural mortality of 0.15 was obtained with a range of 0.11 to 0.18 depending on the periods compared.

Comparing the recent data from the Shumagin Islands grounds with the single sample taken prior to 1930 and using the associated average effort produced approximately the same average estimate of natural mortality, 0.16, that was obtained for the Portlock-Albatross region, with a range of 0.14 to 0.17 depending on the number of years of the recent effort data included in the comparison.

Using a method similar to the "virtual population method" of Fry (1949) and Paloheimo (1958), Chapman (Ms.) obtained estimates of fishing and natural mortality from reconstruction of the relative sizes of recent year classes. The values for fishing and natural mortality which according to this method yielded a calculated total mortality rate closest to that determined from age-composition material were taken as best. A natural mortality rate of 0.20 appeared to be the best estimate, but those ranging from 0.09 to 0.29 could not be ruled out due to an inherent lack of sensitivity in the method.

The range of estimates from age composition support acceptance of a rounded value of 0.20 as a best estimate of the instantaneous rate of natural mortality for the halibut in both Areas 2 and 3. The average of all the best estimates for both areas in Table 3 is equal to 0.19. Reasonable confidence in the estimates is gained from the limited range of magnitude of the averages from area to area and from method to method.

Further support for the use of an instantaneous rate of natural mortality of 0.20 for the halibut stocks generally is found in the fact that the instantaneous rate of total mortality as determined from age composition samples for the newly discovered stock on the Bering Sea edge in 1956, Table 2, ranged from 0.17 to 0.23 using age groups 16 to 19, and age groups 14 to 19 respectively. Since tagging experiments have indicated that there is considerable emigration of halibut out of the Bering Sea to the heavily-fished grounds elsewhere on the coast, the above natural mortality estimates would tend to be maximum.

Fishing Mortality Estimates

The foregoing estimates of total and natural mortality rates may be used to determine the fishing mortality rate, the latter being equal to total mortality less natural mortality.

For Area 2, the best estimate for the current total mortality may be taken as the average (0.50) of the rates shown in Table 2 for Goose Islands and Hecate Strait samples in the years 1953-1958. Since the *best* estimate of natural mortality was 0.20, the indicated value for fishing mortality is 0.30 (0.50 minus 0.20).

The best estimate for the current total mortality for Area 3 may be taken as 0.46, which is the average of the rates shown in Table 2 for all Portlock-Albatross and Shumagin Islands samples in the years 1953-1958. Since the best estimate of the natural mortality was 0.20, the indicated value for fishing mortality is 0.26.

The virtual population method of estimating natural mortality, which was applied to Portlock-Albatross samples, provided estimates of fishing mortality rates for that region which ranged from 0.14 to 0.31 with a median value of 0.21.

MORTALITY RATES FROM CATCH STATISTICS

The "logistic model" described by Schaefer (1957) provided estimated rates of fishing mortality of 0.90 for Area 2 and 0.60 for Area 3. These estimates were derived from statistics of the catch, catch per skate and total skates fished annually during the years 1926 to 1957. The method has the desirable feature of providing estimates that are independent of those derived from tagging and age composition. However, the method implies that the rate of increase in the population responds immediately to changes in density and that the rate of increase at a given weight of population is independent of the age composition of the population. These assumptions do not hold for the halibut which is long-lived and where there have been significant changes in age composition over the period under consideration. Also, other calculations of the above parameters show that the method is very sensitive to small changes in the basic data, and that for this reason also it may be unsatisfactory for the purpose at hand.

DISCUSSION OF MORTALITY RATES

For both Area 2 and Area 3 the best estimate of the natural mortality rate is 0.20. This is the value provided from varied analyses of age-composition materials and also corresponds to the total mortality rate indicated for the "virgin" Bering Sea population. Tagging provides much higher estimates of natural mortality as would be expected due to inherent deficiencies in the tagging method which minimize fishing mortality.

In Area 2, age-composition materials indicate a best estimate of the current fishing mortality rate of about 0.30. This estimate is confirmed by those from various tagging experiments which provided a range of value between 0.21 and 0.36. On the other hand, an analysis of catch statistics provides an estimate of 0.90. Since the latter estimate exceeds the total mortality rate computed by the other methods it must be ruled out and the 0.30 rate accepted as a best estimate for the current fishing mortality in Area 2.

For Area 3, the estimates of fishing mortality from tagging and age composition are widely divergent, ranging from a mean of 0.07 based on tagging to 0.25 based on age composition. Analyses of catch statistics provide an estimated rate of fishing mortality of 0.60.

Since the values of fishing mortality derived from tagging experiments in Area 3 west of the Yakutat region are widely at variance with those determined by other methods including age-composition studies, the value of 0.07 must be considered as unacceptable. Final judgment on this question must be reserved until investigations under way can reconcile the wide differences in values.

The value of 0.60 obtained from the analysis of catch statistics also cannot be accepted as it approximates the total mortality obtained from age composition and thus must be considered too high.

A virtual population method applied to age-composition materials provided a best estimate of fishing mortality for the Portlock region of 0.21 whereas the total mortality rate computed for all Portlock and Shumagin Islands age-composition samples less the best estimate of natural mortality suggested a fishing mortality of 0.25. Although there is considerable variation in the individual estimates from age composition, these are sampling errors and largely non-directional.

Consideration of the relative acceptability of the several foregoing values leads to the tentative acceptance of the range from 0.20 to 0.25 as the best estimate of current fishing mortality in Area 3.

GROWTH RATES

Growth rates used in this report were determined from the average lengths at each age as computed from radius measurements of the otoliths for representative periods in the history of exploitation. Lengths were converted to average weights from a length-weight table. The power-function equations determined from the age-weight data in Table 4, and shown below that table, were used to calculate the weights in Table 5.

Table 4. Average weight of halibut in pounds by age for Portlock-Albatross 1926 and 1956 and for Goose Islands 1956 as determined by back calculations.

Age	Portlock-Albatross 1926	Portlock-Albatross 1956	Goose Islands 1956
5	—	—	5
6	—	—	7
7	5	6	7
8	6	17	9
9	7	17	14
10	8	23	15
11	11	28	19
12	17	34	34
13	22	37	37
14	22	57	36*
15	26	67	32*
16	28	63*	—
17	23*	54*	—
18	26*	67*	—
19	—	81	—
20	23*	86	—

*Reduction probably due to sample size and difference in growth of successive year classes.

Equations used in extrapolation:

Portlock-Albatross grounds

1926 $\ln(\text{wt.}) = -2.03310 + 1.87095 \ln(\text{age})$

1956 $\ln(\text{wt.}) = -2.01055 + 2.19945 \ln(\text{age})$

Goose Islands grounds

1956 $\ln(\text{wt.}) = -1.76242 + 2.00489 \ln(\text{age})$

Back-calculated lengths were used for two reasons. They permitted the estimation of growth rates in years from which no samples were available and also provided estimates of average lengths at the same comparable time in each growing season.

Table 5. Weight to the nearest pound, natural logarithms of weights (ln) at age 5 to 40 and instantaneous coefficients of growth (g), for Portlock-Albatross halibut in 1914, 1926 and 1956 and for Goose Islands halibut in 1956.

Age	Portlock-Albatross									Goose Islands		
	1914			1926			1956			1956		
	Wt.	ln*	g	Wt.	ln*	g	Wt.	ln*	g	Wt.	ln*	g
5	2	0.81421		3	0.97808		5	1.52933		4	1.46433	
			0.36			0.34			0.49			0.37
6	3	1.17192		4	1.31919		7	1.93034		6	1.82986	
			0.30			0.29			0.40			0.31
7	4	1.47436		5	1.60760		10	2.26938		8	2.13892	
			0.26			0.25			0.34			0.27
8	6	1.73634		6	1.85743		13	2.56307		11	2.40663	
			0.23			0.22			0.29			0.24
9	7	1.96742		8	2.07779		17	2.82215		14	2.64276	
			0.21			0.20			0.26			0.21
10	8	2.17415		10	2.27493		21	3.05388		17	2.85402	
			0.19			0.18			0.23			0.19
11	11	2.36115		12	2.45325		26	3.26351		21	3.04511	
			0.17			0.16			0.21			0.17
12	13	2.53186		14	2.61604		32	3.45489		25	3.21955	
			0.16			0.15			0.19			0.16
13	14	2.68890		16	2.76579		38	3.63093		29	3.38002	
			0.15			0.14			0.18			0.15
14	17	2.83430		18	2.90445		44	3.79393		34	3.52860	
			0.14			0.13			0.16			0.14
15	19	2.96966		21	3.03353		52	3.94567		39	3.66692	
			0.13			0.12			0.15			0.13
16	22	3.09629		24	3.15428		60	4.08762		45	3.79632	
			0.12			0.11			0.14			0.12
17	24	3.21522		26	3.26769		68	4.22095		50	3.91785	
			0.11			0.11			0.13			0.11
18	28	3.32737		29	3.37464		77	4.34667		56	4.03245	
			0.11			0.10			0.13			0.11
19	31	3.43345		32	3.47580		87	4.46559		63	4.14086	
			0.10			0.10			0.12			0.11
20	34	3.53408		36	3.57176		98	4.57841		70	4.24369	
			0.10			0.09			0.11			0.10
21	38	3.62981		39	3.66304		108	4.68572		77	4.34151	
			0.09			0.09			0.11			0.09
22	41	3.72108		42	3.75008		120	4.78804		84	4.43478	
			0.09			0.08			0.10			0.09
23	45	3.80829		46	3.83324		132	4.88580		86	4.52389	
			0.08			0.08			0.10			0.09
24	49	3.89179		50	3.91287		145	4.97941		100	4.60922	
			0.08			0.08			0.09			0.08
25	53	3.97190		54	3.98926		159	5.06922		109	4.69208	
			0.08			0.07			0.09			0.08
26	57	4.04885		58	4.06264		174	5.15548		118	4.76971	
			0.07			0.07			0.09			0.08
27	62	4.12289		62	4.13325		188	5.23849		127	4.84538	
			0.07			0.07			0.08			0.07
28	66	4.19423		67	4.20120		204	5.31846		137	4.91827	
			0.07			0.07			0.08			0.07
29	71	4.26310		71	4.26695		221	5.39566		147	4.98865	
			0.07			0.06			0.08			0.07
30	76	4.32961		76	4.33038		237	5.47022		157	5.05661	
			0.06			0.06			0.07			0.07
31	81	4.39394		81	4.39172		255	5.54234		168	5.12235	
			0.06			0.06			0.07			0.06
32	85	4.45623		85	4.45113		274	5.61217		178	5.18601	
			0.06			0.06			0.07			0.06
33	92	4.51660		90	4.50870		293	5.67985		190	5.24770	
			0.06			0.06			0.07			0.06
34	97	4.57517		96	4.56454		313	5.74550		202	5.30754	
			0.06			0.05			0.07			0.06
35	103	4.63205		101	4.61878		333	5.80926		214	5.36567	
			0.06			0.05			0.06			0.06
36	109	4.68731		107	4.67149		354	5.87122		226	5.42214	
			0.05			0.05			0.06			0.05
37	114	4.74107		113	4.72275		376	5.93149		239	5.47708	
			0.05			0.05			0.06			0.05
38	121	4.79341		118	4.77265		400	5.99015		253	5.53053	
			0.05			0.05			0.06			0.05
39	127	4.84435		124	4.82124		423	6.04727		265	5.58261	
			0.05			0.05			0.06			0.05
40	133	4.89403		130	4.86861		445	6.10296		280	5.63380	

*The ln. weight is the result of successive solutions at different ages of the power function of the age-weight relationship.

The growth rate, g, was expressed as the instantaneous rate of change in weight and was given by the difference between the natural logarithms of weights in successive years:

$$g = \ln(WT_{t+1}) - \ln(WT_t) \quad \text{Ricker (1958)}$$

In practice these logarithmic values are the result of successive solutions at different ages of the respective power-function equations for the different samples as shown in footnote of Table 4. The growth rate was calculated through age 40 on the basis of growth from one year class to another of those contributing to the catch in a single year (Table 5).

Lee's phenomenon, the underestimation of the average length for young halibut when back-calculated from the otoliths of an older halibut, is present in the calculated lengths. However, since essentially the same age groups have been used in the back calculations, this phenomenon does not invalidate comparisons of growth over the periods covered herein.

As shown in Table 6 for Goose Islands, 1935-1956, and Hecate Strait, 1950-1958, the growth rate of Area 2 halibut has not changed greatly, at least during the past two decades. On the other hand, there has been a great increase in the growth rate of Area 3 halibut starting in the mid-1920's (Table 4).

Table 6. Average back-calculated lengths in centimeters of 10-year old halibut from Goose Islands and Upper Hecate Strait.

Year	Goose Islands	Upper Hecate Strait
1935	92	—
1936	95	—
1937	101	—
1938	95	—
1939	86	—
1940	83	—
1941	89	—
1942	83	—
1943	—	—
1944	92	—
1945	83	—
1946	85	—
1947	86	—
1948	91	—
1949	90	—
1950	90	96
1951	87	93
1952	85	85
1953	86	89
1954	85	91
1955	89	92
1956	86	88

The variation in the age-weight relationship between sections of Area 2 is shown in Table 7 for 1958. The indicated regions account for a very large proportion of the catch from Area 2 as a whole. The Goose Islands population shows the lowest age-weight relationship. Back-calculated values for Goose Islands and upper Hecate Strait support this finding.

The age-weight relationship of the Portlock-Albatross halibut is considered representative for Area 3 as a whole. Over one-half the Area 3 catch is taken from the Portlock-Albatross grounds and there is a relatively free though delayed interchange of fish within Area 3.

Table 7. Observed age-weight relationship in pounds in 1958 for sections of Area 2.

Age	Goose Islands	Lower Hecate Strait	Upper Hecate Strait	Inside S.E. Alaska
3	6	7	—	—
4	8	8	9	9
5	9	12	11	9
6	9	14	12	8
7	10	15	13	10
8	12	21	17	13
9	16	25	24	16
10	20	37	27	20
11	23	44	35	27
12	25	52	34	30
13	25	51	46	49
14	32	55	38	52
15	34	63	44	59
16	39	75	—	59
17	43	81	—	71
18	51	93	—	74
19	58	61	—	82
20	61	100	—	79
21	68	123	—	90

AGE OF ENTRY

In the computations recruitment was assumed to be constant at age 5 and at a weight of 1000 pounds for all combinations of growth and mortality rates. Growth and natural mortality rates were applied starting at age 5. It was assumed that all recruitment to the fishable stock occurs within one year. The effect of different ages of entry into the fishery was examined by applying the fishing mortality rates to the recruits at successive ages of entry in one-year intervals starting with age 5 and continuing to age 14. This means that the size of the stock entering the fishery from ages 6 through 14 would differ from 1000 pounds, depending upon the effect of the combination of growth and natural mortality rates and the number of years these rates operated without fishing mortality being added. In actuality, recruitment does not occur in this manner but instead extends over several ages. However, the age at which recruitment is 50 percent complete in the actual fishery corresponds to the age of entry in the model. For example, in Area 2 an age of entry of approximately seven years in the model corresponds to the age at which recruitment is about 50 percent complete in the present fishery. For Area 3, an age of entry of about 11 years in the model corresponds to the age at which recruitment is about 50 percent complete in the fishery.

YIELD PER GIVEN RECRUITMENT

Relative productivity of a year class for various combinations of the parameters of growth rates and natural and fishing mortality rates may be obtained from models depicting the yield from a given recruitment to the fishable stock. The utility of models for determining the potential productivity of a year class has been demonstrated by Ricker (1945 and 1958) and Beverton and Holt (1957)*.

The ultimate value of the models requires knowledge of the parameters and the interrelationships of any alteration of the parameters. Good estimates of growth rates are available for halibut over a considerable period of the history of the fishery. Constant natural mortality rates have been used throughout since there is no evidence to the contrary. However, there is little knowledge of how changes in one parameter may affect others.

* The method and notation of Ricker (1958) have been used in this report.

In the computations recruitment was assumed to be constant at age 5 and at a weight of 1000 pounds. Natural mortality rates were applied starting at age 5.

In Area 2, the yield per recruitment was calculated using growth rates observed for halibut from Goose Islands grounds in 1956 (Table 5). The growth of the halibut in this region is generally lower than in other parts of Area 2. As the growth rate has not changed greatly since at least 1935, the yield per recruitment is probably representative of the conditions since that time.

In Area 3, where marked changes in growth rate have occurred, the yield per recruitment was determined using growth rates observed for halibut from the Portlock-Albatross region in 1926 and in 1956 (Table 5). Limited observations available for 1930 suggest that the 1926 growth rate may also be adopted to represent yield conditions in 1930.

Using 1956 growth rates for Area 2 and Area 3, the yields were calculated for two different treatments with regard to types of natural mortality. Yields were calculated assuming natural mortality to be constant at all ages considered in the model with values of 0.15, 0.20 and 0.25. Yields were also calculated assuming natural mortality to be different for young and for old halibut. In the latter group, two natural mortality conditions were studied: (1) a rate of 0.10 for all ages 5 through 10 together with a rate of 0.20 for all ages older than 10, and (2) a rate of 0.30 for ages 5 through 10 together with a rate of 0.20 for ages older than 10. Yields for Area 3 using the 1926 growth rate were computed only for natural mortality rates of 0.15, 0.20 and 0.25 at all ages.

For each natural mortality rate employed, the yields were calculated for fishing mortalities of 0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.40 and 0.50. In addition, values were computed for entry ages of 5 to 14 years for every combination of rates described above.

Calculations of yields were carried out to the nearest ten thousandth of a pound (values to the nearest pound are shown in Tables 8 through 20). Yields were determined by two methods. The first method involved continuing the calculations until the value of "weight of stock" when rounded off equalled one percent of the initial weight at age 5. This procedure resulted in terminating the calculations at a much younger age for large values of p (fishing mortality) than for small values of p. At large values of p the age at which the calculations were terminated became critical because inclusion or omission of the last one or two ages changed the calculated yield at the older ages of entry (13 and 14-year olds) as much as 100 percent. With this method, for large values of p, the one percent stock level is reached at an average age only 1 or 2 years beyond the last age of entry or sometimes by the last age of entry.

The second method involved continuing the calculations of yields through age 35 for all values of p. This latter procedure was used in determining the yields included herein. It has two advantages over the first method. First, it permits the values to be duplicated. To duplicate the values obtained by the first method it would be necessary to know the exact age at which the calculations were terminated for each combination of p and q (natural mortality). The second advantage is that even for large values of p, at age 35 the yield is so small and has been carried to an age sufficiently beyond the last age of entry so as to have little effect on the final calculations.

The plotting of the yields has been done in three different ways. Figures 1 - 3 are yield-isopleth diagrams for a q of 0.20 on which lines of eumetric fishing show the ages of entry that would provide the maximum yield for each rate of fishing. In Figures 4 - 16 the yields for each fishing rate are shown for odd-numbered ages of entry 5 through 13 years. The latter series of figures can be used to determine readily the optimum fishing rate for each age of entry. Yields are plotted against ages of entry in Figures 17 - 29 for fishing mortality rates ranging from 0.05 to 0.50. The shape of the lines of yield at ages 11 and older in Figures 21 and 26 is the result of reducing the amount of natural mortality. These Figures, 17-29, show the relative increase or decrease in yield resulting from different fishing mortality rates at any age of entry. They also show the optimum age of entry for each fishing mortality rate.

In Area 2 the best estimate of natural mortality is 0.20 at all commercial ages. Assuming that the actual fishing mortality rate p in Area 2 is 0.30, the yield from the theoretical model in Figures 1, 5 and 18 can be used to determine the present degree of utilization of recruits in that area. For an age of entry of 7 years, which approximates that in the current Area 2 fishery, increasing the fishing effort one and two-thirds times would produce only about a 3 percent increase in yield. If the natural mortality rate were 0.25 an increase in yield of about 9 percent is indicated by the theoretical model. On the other hand, should the natural mortality rate be 0.15 a loss in yield of about 3 percent would result from increasing the fishing mortality from 0.30 to 0.50.

In Area 3, using 0.20 as the best estimate for natural mortality and from 0.20 to 0.25 as the best estimate for fishing mortality, Figures 2, 10 and 23 serve to show the present degree of utilization of recruits in that area. These figures indicate a maximum yield at an age of entry of about 10 years and a fishing mortality of about 0.50. This maximum indicated by the theoretical model would be about 16 percent above the yield under the 0.20 fishing rate and age of entry of 11 years. For the present fishing mortality rate of 0.20 and an age of entry of 11, approximately that currently prevailing in Area 3, the model suggests that an increase in yield of about only 4 percent would be realized from decreasing the age of entry to about 9 years.

If the natural mortality rate in Area 3 were 0.15 with an age of entry of 11 years, only a 4 percent increase in yield would result from increasing the fishing mortality from 0.20 to 0.50. For a natural mortality rate as high as 0.25 and age of entry of 11 years a 26 percent increase in yield would result from increasing the fishing mortality from 0.20 to 0.50.

For a natural mortality of 0.20 and an age of entry of 11 years, which approximates that in the present Area 3 fishery, increasing the fishing mortality from its present value of 0.20 to 0.50 would produce about 16 percent increase in yield.

Assuming that natural mortality is above the present best estimate and that increased fishing would not alter the other parameters, some of the figures suggest that substantial increases in yield could be obtained by greatly increasing the fishing effort. However, it should be noted that increasing the fishing to one and two-thirds times the present level in Area 2 and to two and one-half times in Area 3 would result in levels of fishing similar to what prevailed in the late 1920's under which the yields were lower and declining. On this account and due to the known variability of the data it is probable the suggested increases in yield would not occur.

Table 8. Yield in pounds per 1000 pounds of Area 2 halibut reaching age 5 in 1956 at ages of entry 5 to 14 with q = 0.15 at all ages (average weight of stock carried to age 35).

Age of Entry	YIELD p=0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50
5	1231	1558	1626	1612	1577	1538	1465	1409
6	1236	1604	1709	1722	1709	1686	1638	1599
7	1230	1631	1767	1805	1812	1804	1780	1757
8	1214	1639	1802	1862	1885	1892	1889	1882
9	1188	1630	1814	1894	1930	1949	1966	1972
10	1153	1606	1807	1899	1950	1979	2012	2029
11	1112	1570	1783	1886	1947	1984	2031	2057
12	1066	1523	1745	1857	1925	1970	2028	2061
13	1016	1468	1696	1814	1889	1939	2007	2046
14	963	1406	1638	1759	1839	1893	1970	2012

Table 9. Yield in pounds per 1000 pounds of Area 2 halibut reaching age 5 in 1956 at ages of entry 5 to 14 with q = 0.20 at all ages (average weight of stock carried to age 35).

Age of Entry	YIELD p=0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50
5	779	1082	1212	1261	1281	1287	1275	1260
6	763	1082	1232	1300	1336	1357	1367	1369
7	738	1064	1230	1311	1360	1393	1422	1438
8	705	1031	1207	1297	1356	1399	1442	1470
9	667	988	1168	1264	1329	1382	1433	1470
10	625	935	1109	1214	1283	1343	1398	1445
11	581	877	1047	1153	1225	1289	1346	1393
12	537	816	981	1084	1156	1226	1280	1330
13	492	754	911	1012	1083	1158	1207	1257
14	448	692	840	936	1005	1088	1128	1178

Table 10. Yield in pounds per 1000 pounds of Area 2 halibut reaching age 5 in 1956 at ages of entry 5 to 14 with q = 0.25 at all ages (average weight of stock carried to age 35).

Age of Entry	YIELD p=0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50
5	542	806	946	1025	1067	1099	1127	1139
6	515	779	930	1017	1069	1112	1158	1184
7	482	739	890	985	1042	1093	1151	1187
8	444	689	838	934	993	1049	1115	1159
9	405	634	776	871	928	988	1058	1105
10	365	576	709	800	865	914	985	1033
11	326	517	641	726	788	835	904	951
12	288	461	574	652	710	754	817	865
13	253	407	509	580	634	675	733	779
14	221	357	449	512	561	599	651	695

Table 11. Yield in pounds per 1000 pounds of Area 2 halibut reaching age 5 in 1956 at ages of entry 5 to 14 with q = 0.10 at age 5 - 10 and q = 0.20 at ages over 10 (average weight of stock carried to age 35).

Age of Entry	YIELD p=0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50
5	1267	1689	1820	1835	1806	1756	1655	1568
6	1273	1746	1929	1988	1994	1971	1909	1846
7	1262	1777	2006	2106	2149	2153	2133	2099
8	1236	1778	2046	2183	2255	2292	2317	2316
9	1194	1749	2045	2213	2312	2375	2444	2478
10	1136	1689	1999	2187	2308	2391	2497	2563
11	1062	1596	1906	2102	2232	2326	2453	2539
12	981	1484	1784	1978	2107	2203	2333	2423
13	899	1371	1657	1846	1973	2068	2200	2292
14	816	1257	1528	1709	1832	1926	2056	2147

Table 12. Yield in pounds per 1000 pounds of Area 2 halibut reaching age 5 in 1956 at ages of entry 5 to 14 with q = 0.30 at ages 5 - 10 and q = 0.20 at ages over 10 (average weight of stock carried to age 35).

Age of Entry	YIELD p=0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50
5	506	721	838	906	951	981	1020	1044
6	479	688	806	878	926	961	1008	1041
7	448	647	762	833	882	917	967	1004
8	417	603	712	780	827	861	909	945
9	386	559	661	725	769	801	845	878
10	357	518	614	674	716	745	784	813
11	331	482	575	631	672	700	738	765
12	307	448	538	593	635	663	702	730
13	283	414	500	553	594	623	662	690
14	260	380	461	511	552	580	618	647

Table 13. Yield in pounds per 1000 pounds of Area 3 halibut reaching age 5 in 1956 at ages of entry 5 to 14 with q = 0.15 at all ages (Average weight of stock carried to age 35).

Age of Entry	YIELD p=0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50
5	2029	2400	2415	2302	2176	2061	1874	1740
6	2071	2527	2614	2549	2458	2368	2216	2105
7	2095	2625	2779	2761	2705	2641	2510	2441
8	2101	2693	2908	2934	2911	2873	2795	2735
9	2088	2730	3000	3066	3074	3060	3016	2983
10	2059	2738	3057	3159	3194	3202	3191	3184
11	2016	2720	3080	3213	3273	3301	3318	3337
12	1958	2677	3073	3231	3312	3358	3400	3447
13	1890	2612	3038	3218	3316	3377	3440	3516
14	1813	2529	2978	3175	3288	3361	3441	3551

Table 14. Yield in pounds per 1000 pounds of Area 3 halibut reaching age 5 in 1956 at ages of entry 5 to 14 with q = 0.20 at all ages (average weight of stock carried to age 35).

Age of Entry	YIELD p=0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50
5	1215	1620	1753	1741	1717	1679	1601	1533
6	1218	1668	1849	1870	1877	1864	1823	1782
7	1204	1688	1909	1958	1992	2001	1995	1978
8	1176	1681	1894	2004	2061	2089	2113	2120
9	1136	1652	1883	2014	2088	2131	2181	2207
10	1086	1603	1845	1990	2078	2134	2205	2247
11	1028	1539	1785	1940	2038	2102	2189	2244
12	965	1464	1708	1867	1972	2041	2141	2205
13	898	1380	1618	1779	1886	1959	2067	2137
14	830	1291	1518	1677	1786	1858	1972	2046

Table 15. Yield in pounds per 1000 pounds of Area 3 halibut reaching age 5 in 1956 at ages of entry 5 to 14 with q = 0.25 at all ages (average weight of stock carried to age 35).

Age of Entry	YIELD p=0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50
5	804	1138	1306	1373	1400	1405	1391	1368
6	787	1139	1334	1428	1478	1504	1523	1525
7	757	1115	1329	1442	1509	1551	1598	1621
8	717	1070	1294	1419	1499	1553	1620	1660
9	669	1009	1236	1367	1455	1516	1598	1650
10	617	958	1163	1295	1386	1451	1542	1603
11	562	882	1078	1208	1299	1366	1461	1526
12	507	802	987	1112	1201	1266	1363	1429
13	453	723	894	1011	1097	1159	1254	1320
14	402	645	802	911	991	1049	1140	1204

Table 16. Yield in pounds per 1000 pounds of Area 3 halibut reaching age 5 in 1956 at ages of entry 5 to 14 with q = 0.10 at ages 5 - 10 and q = 0.20 at ages over 10 (average weight of stock carried to age 35).

Age of Entry	YIELD p=0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50
5	2023	2593	2684	2615	2496	2369	2138	1957
6	2064	2737	2921	2924	2860	2773	2596	2445
7	2081	2849	3115	3192	3186	3146	3033	2924
8	2072	2905	3255	3402	3454	3462	3423	3365
9	2035	2916	3331	3539	3645	3700	3737	3737
10	1969	2874	3334	3588	3739	3835	3942	3999
11	1872	2773	3252	3534	3712	3834	3988	4088
12	1757	2631	3112	3402	3592	3725	3901	4018
13	1636	2475	2947	3240	3436	3576	3766	3894
14	1512	2308	2766	3056	3253	3396	3593	3729

Table 17. Yield in pounds per 1000 pounds of Area 3 halibut reaching age 5 in 1956 at ages of entry 5 to 14 with q = 0.30 at ages 5 - 10 and q = 0.20 at ages over 10 (average weight of stock carried to age 35).

Age of Entry	YIELD p=0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50
5	751	1037	1156	1209	1233	1243	1246	1242
6	733	1030	1165	1233	1271	1294	1319	1333
7	706	1005	1148	1225	1272	1301	1339	1365
8	660	967	1113	1194	1244	1277	1321	1352
9	623	923	1068	1151	1202	1236	1281	1312
10	586	877	1022	1105	1156	1191	1235	1265
11	550	835	980	1064	1118	1155	1201	1231
12	515	792	937	1025	1082	1122	1175	1210
13	478	745	888	976	1035	1077	1134	1173
14	440	695	833	921	980	1023	1082	1124

Table 18. Yield in pounds per 1000 pounds of Area 3 halibut reaching age 5 in 1926 at ages of entry 5 to 14 with q = 0.15 at all ages (average weight of stock carried to age 35).

Age of Entry	YIELD p=0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50
5	1072	1383	1465	1473	1455	1430	1380	1339
6	1070	1413	1525	1556	1557	1546	1518	1493
7	1059	1425	1562	1613	1631	1634	1626	1616
8	1038	1422	1578	1647	1679	1694	1704	1706
9	1009	1404	1576	1659	1702	1728	1753	1768
10	974	1374	1558	1652	1705	1739	1777	1801
11	934	1333	1525	1627	1688	1728	1777	1809
12	890	1285	1481	1589	1656	1700	1757	1796
13	843	1230	1427	1540	1611	1659	1723	1766
14	794	1170	1367	1482	1555	1606	1674	1721

Table 19. Yield in pounds per 1000 pounds of Area 3 halibut reaching age 5 in 1926 at ages of entry 5 to 14 with q = 0.20 at all ages (average weight of stock carried to age 35).

Age of Entry	YIELD p=0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50
5	691	982	1099	1160	1192	1204	1207	1202
6	672	973	1104	1184	1226	1250	1273	1282
7	657	948	1088	1180	1232	1265	1305	1326
8	612	913	1055	1155	1215	1255	1306	1336
9	574	868	1009	1115	1179	1223	1284	1320
10	535	809	954	1062	1128	1175	1242	1282
11	493	753	891	1000	1067	1115	1186	1227
12	452	696	825	933	998	1046	1120	1160
13	412	638	757	864	927	974	1050	1087
14	373	581	688	793	854	899	978	1009

Table 20. Yield in pounds per 1000 pounds of Area 3 halibut reaching age 5 in 1926 at age of entry 5 to 14 with q = 0.25 at all ages (average weight of stock carried to age 35).

Age of Entry	YIELD p=0.05	0.10	0.15	0.20	0.25	0.30	0.40	0.50
5	488	733	873	953	1014	1035	1071	1090
6	460	700	845	933	993	1030	1081	1112
7	426	656	801	892	957	998	1059	1097
8	390	605	746	837	903	946	1012	1052
9	352	551	685	772	839	881	949	994
10	315	495	621	703	769	808	882	920
11	279	440	556	632	696	730	796	839
12	245	387	493	563	624	653	713	756
13	214	338	434	497	556	579	635	674
14	185	293	379	435	493	509	560	596

As previously noted, the line of eumetric fishing is shown in Figures 1, 2 and 3 by the dash line. P indicates the best estimate of present conditions in Areas 2 or 3 in Figures 1, 2, 5, 10, 18 and 23.

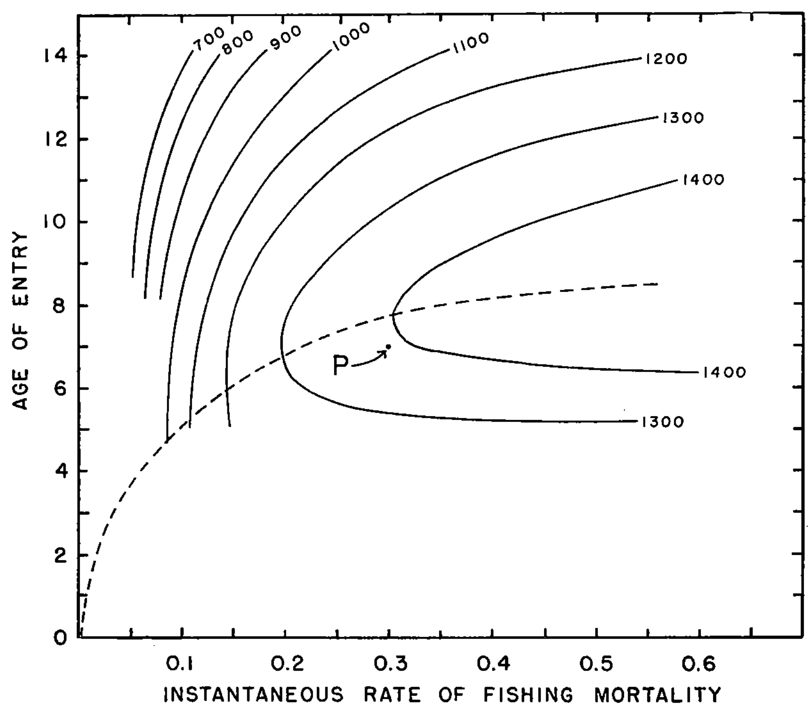

Figure 1. Yield isopleth diagram for Area 2 using 1956 Goose Islands growth rate and q = 0.20.

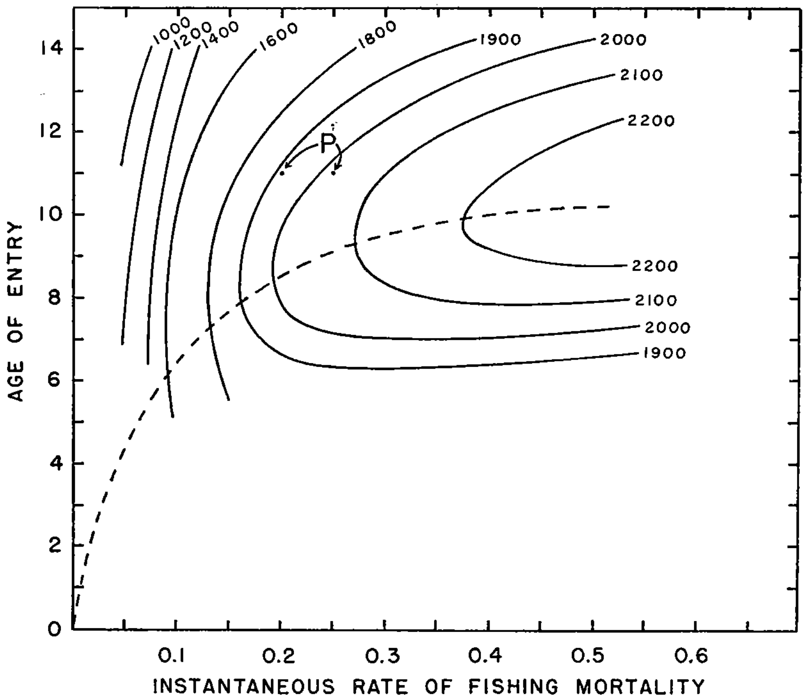

Figure 2. Yield isopleth diagram for Area 3 using 1956 Portlock-Albatross growth rate and q = 0.20.

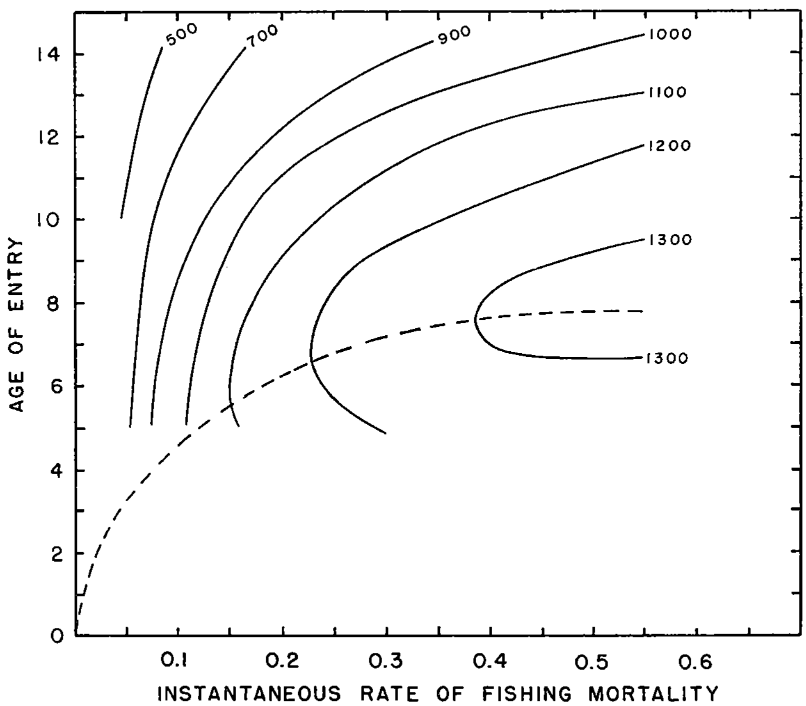

Figure 3. Yield isopleth diagram for Area 3 using 1926 Portlock-Albatross growth rate and q = 0.20.

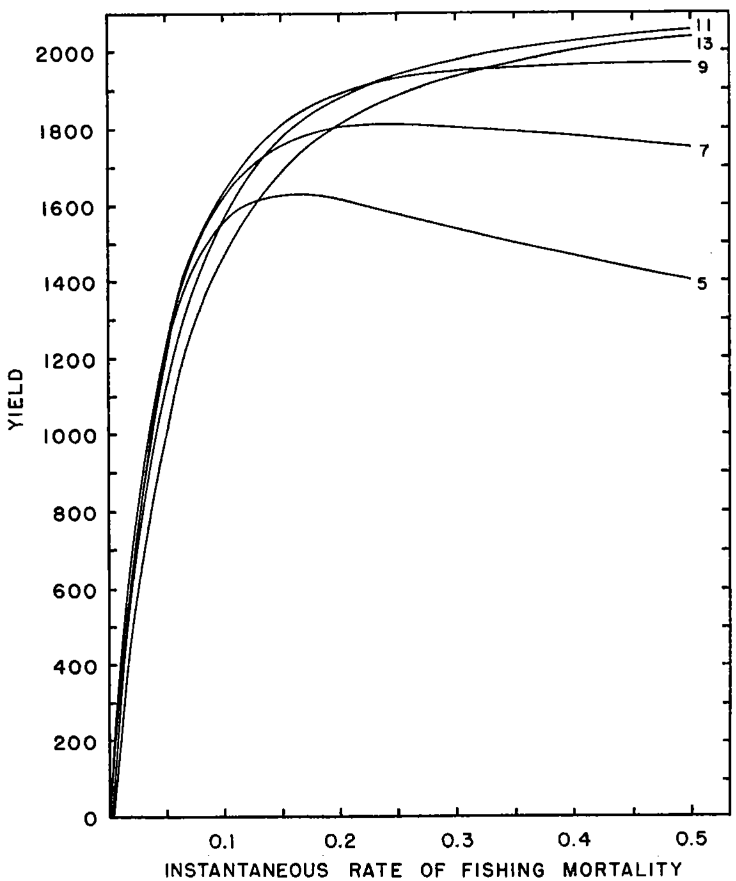

Figure 4. Yield as a function of fishing rate for various ages of entry in Area 2 using 1956 Goose Islands growth rate and q = 0.15.

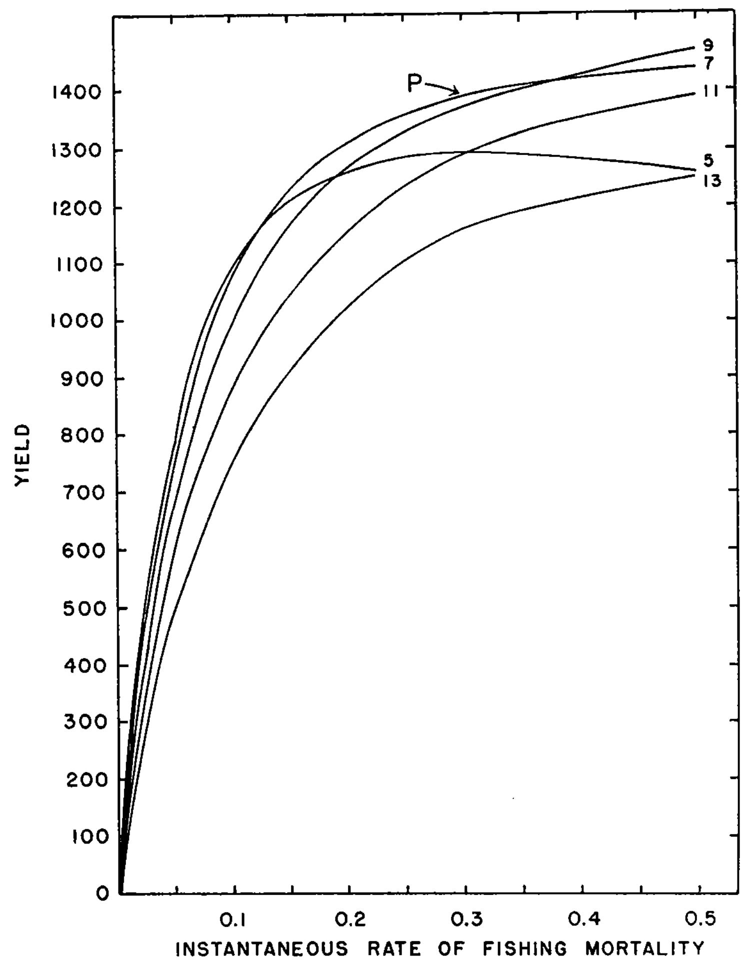

Figure 5. Yield as a function of fishing rate for various ages of entry in Area 2 using 1956 Goose Islands growth rate and q = 0.20.

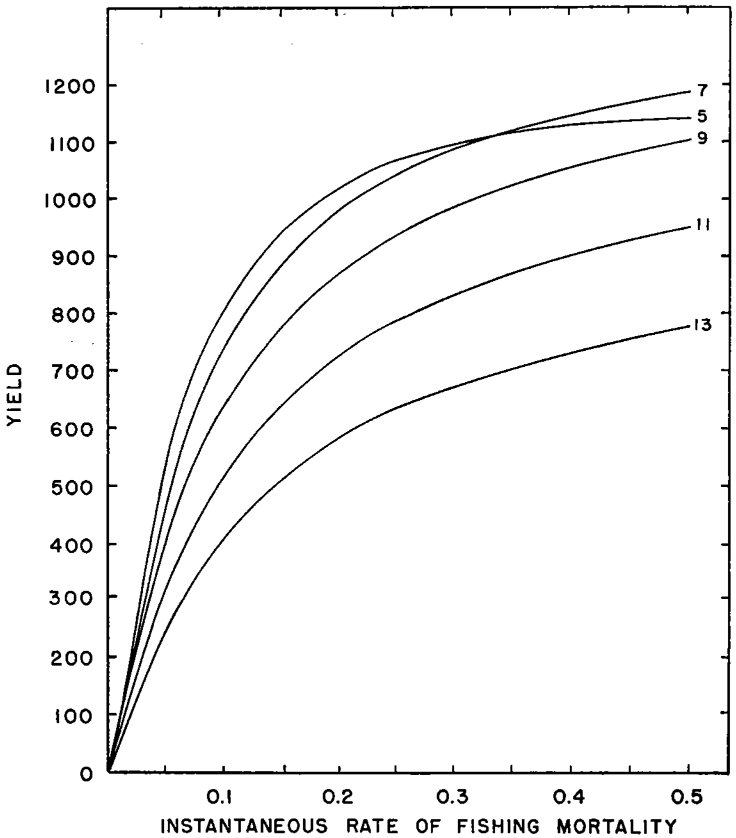

Figure 6. Yield as a function of fishing rate for various ages of entry in Area 2 using 1956 Goose Islands growth rate and q = 0.25.

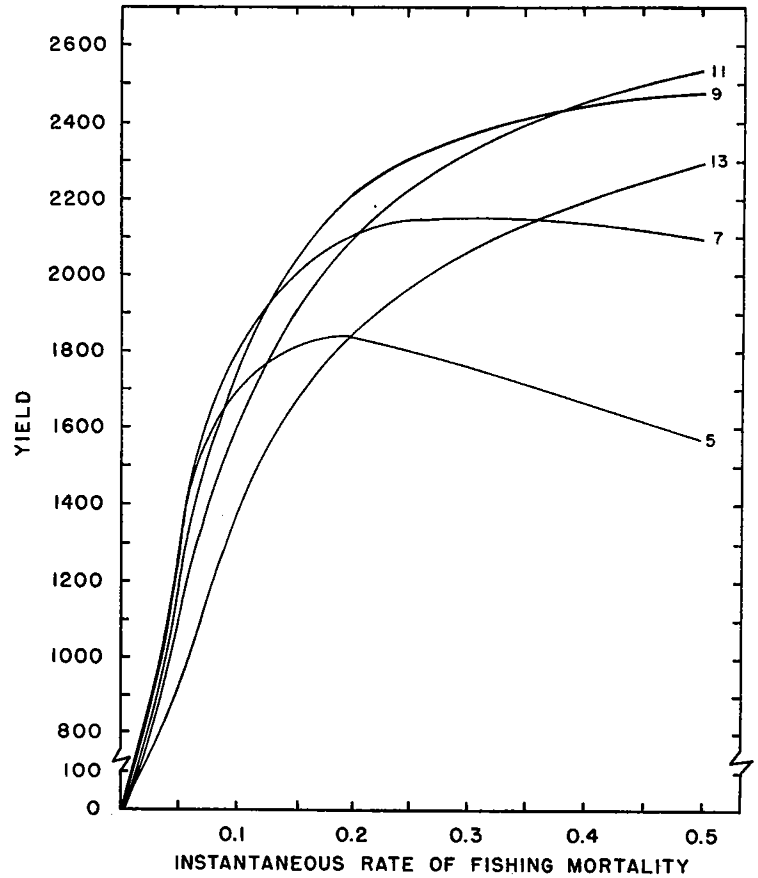

Figure 7. Yield as a function of fishing rate for various ages of entry in Area 2 using 1956 Goose Islands growth rate and q = 0.10 for ages 5-10 and q = 0.20 for ages over 10.

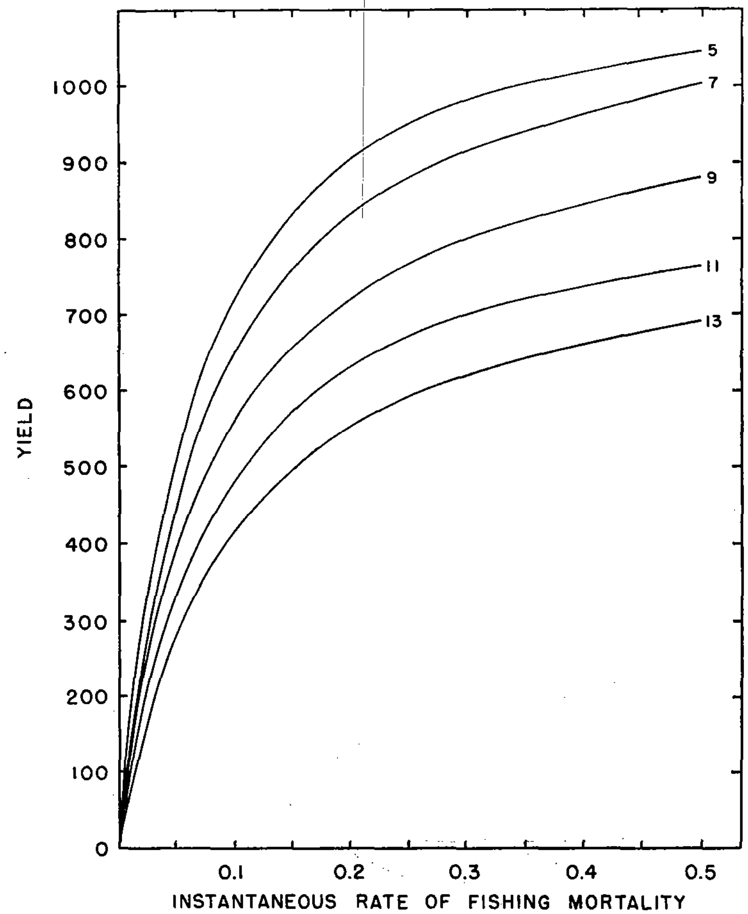

Figure 8. Yield as a function of fishing rate for various ages of entry in Area 2 using 1956 Goose Islands growth rate and q = 0.30 for ages 5-10 and q = 0.10 for ages over 10.

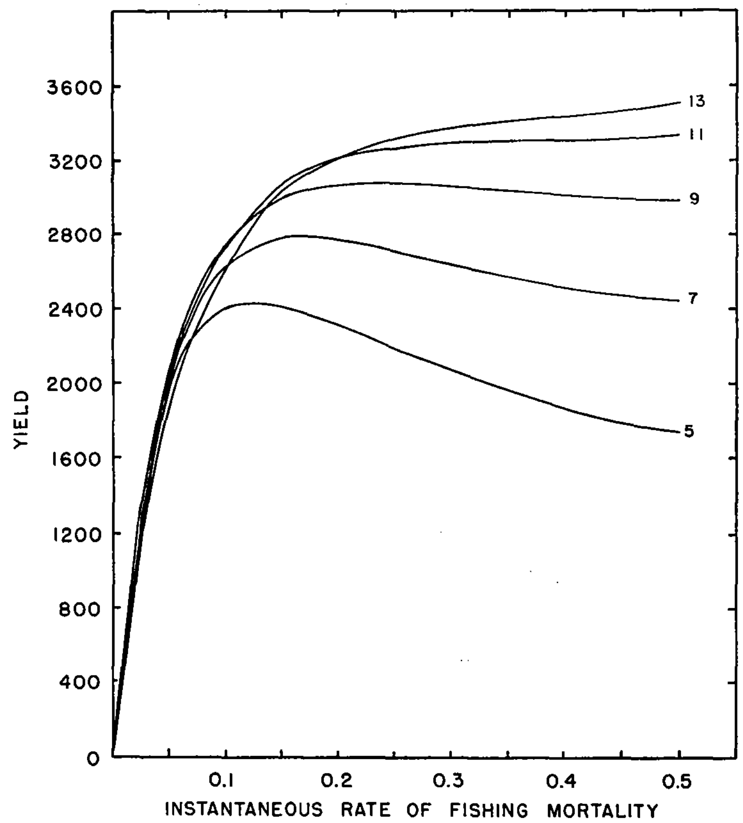

Figure 9. Yield as a function of fishing rate for various ages of entry in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.15.

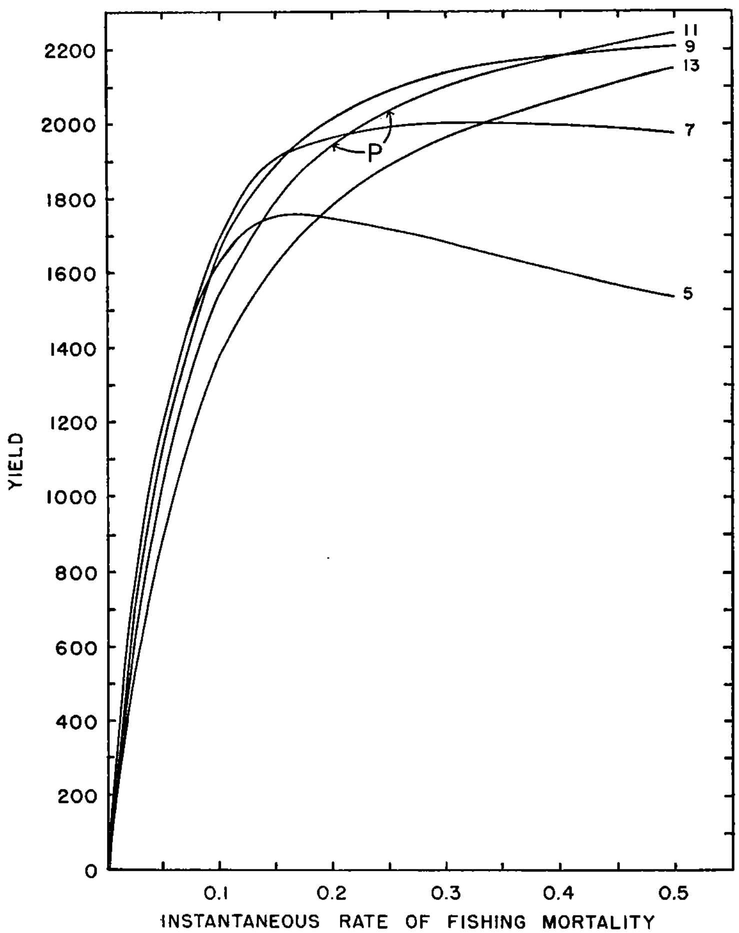

Figure 10. Yield as a function of fishing rate for various ages of entry in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.20.

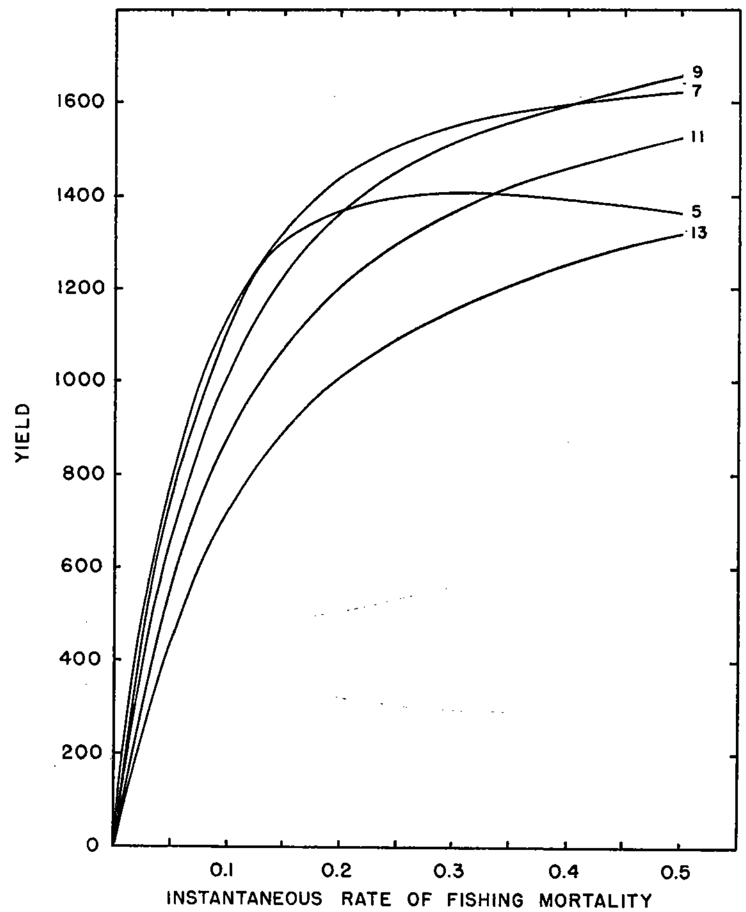

Figure 11. Yield as a function of fishing rate for various ages of entry in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.25.

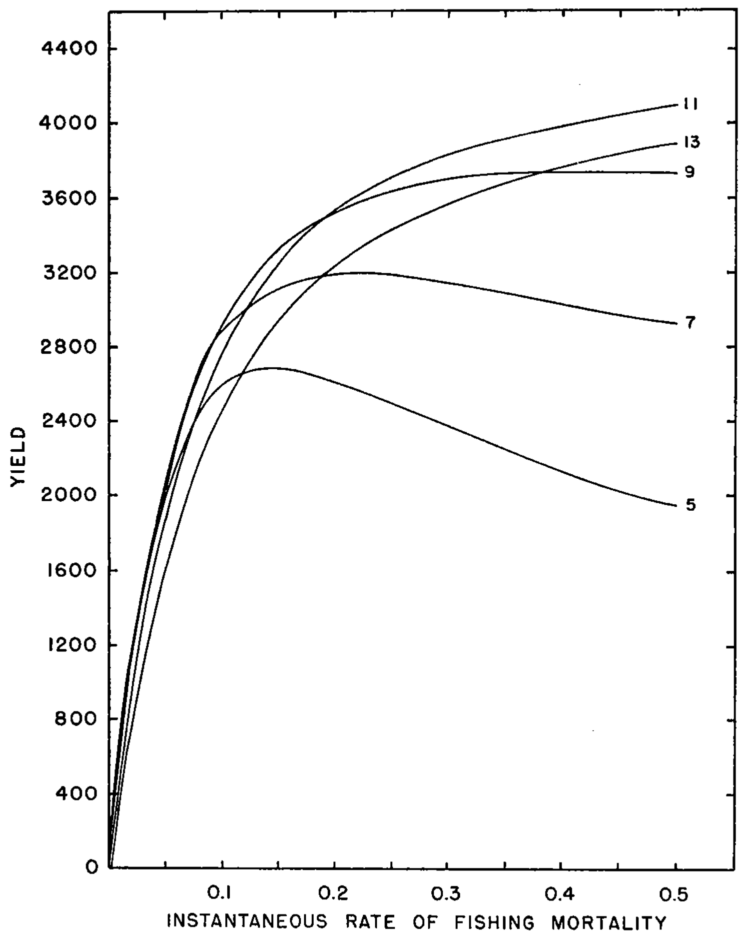

Figure 12. Yield as a function of fishing rate for various ages of entry in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.10 for ages 5-10 and q = 0.20 for ages over 10.

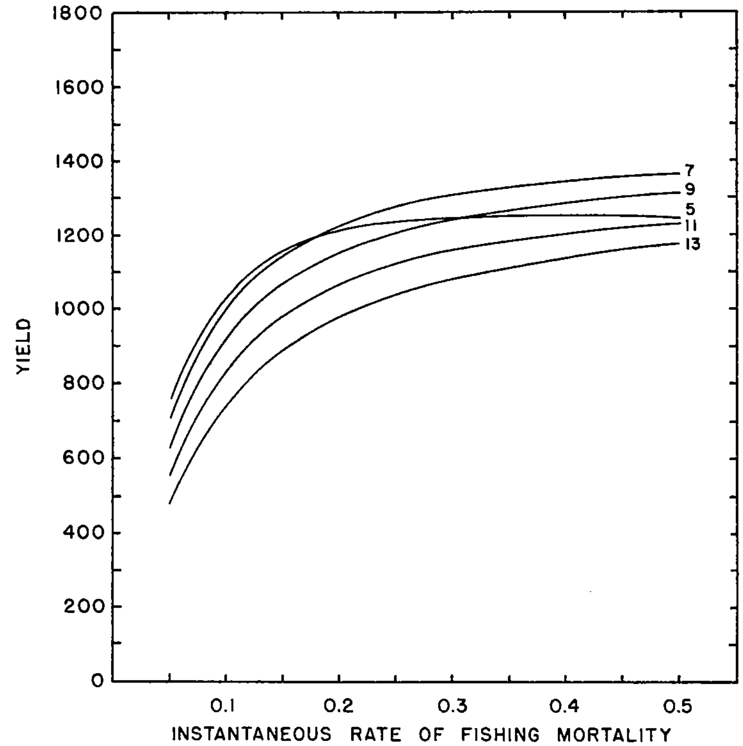

Figure 13. Yield as a function of fishing rate for various ages of entry in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.30 for ages 5-10 and q = 0.20 for ages over 10.

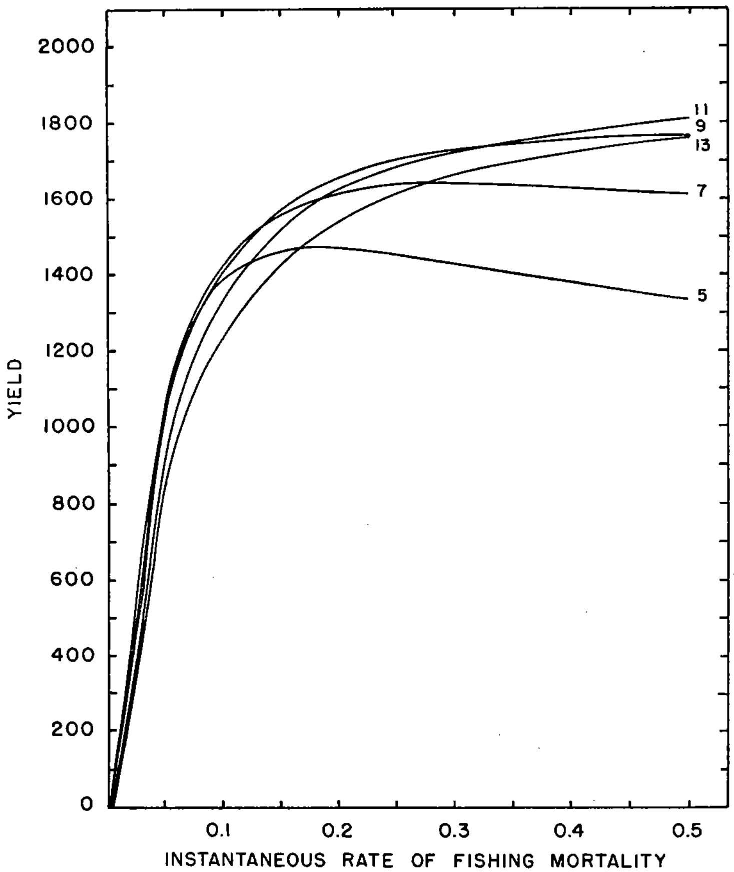

Figure 14. Yield as a function of fishing rate for various ages of entry in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.15.

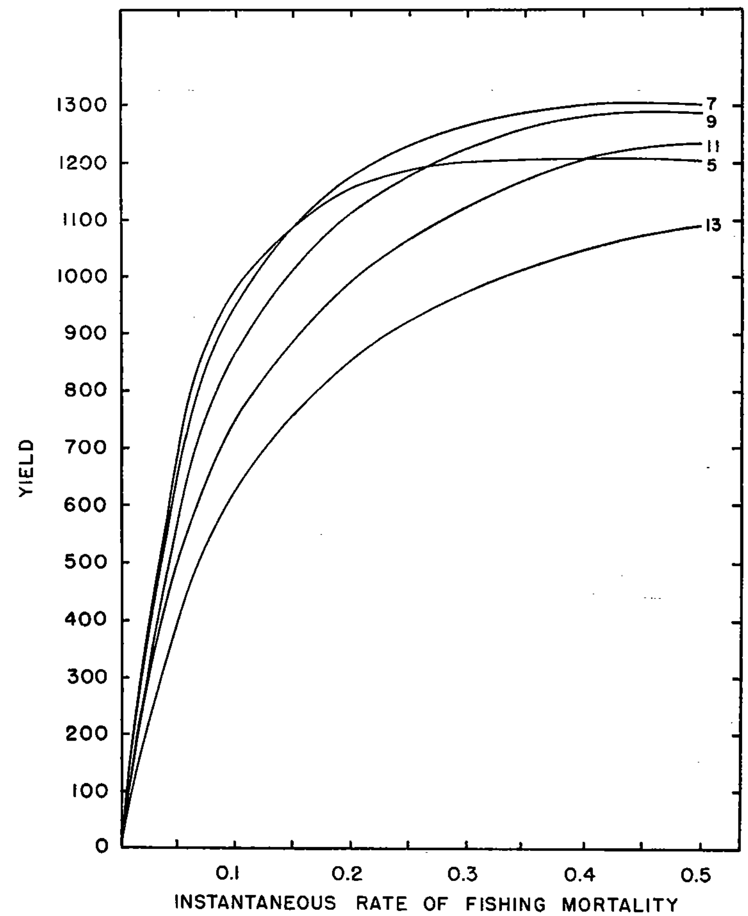

Figure 15. Yield as a function of fishing rate for various ages of entry in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.20.

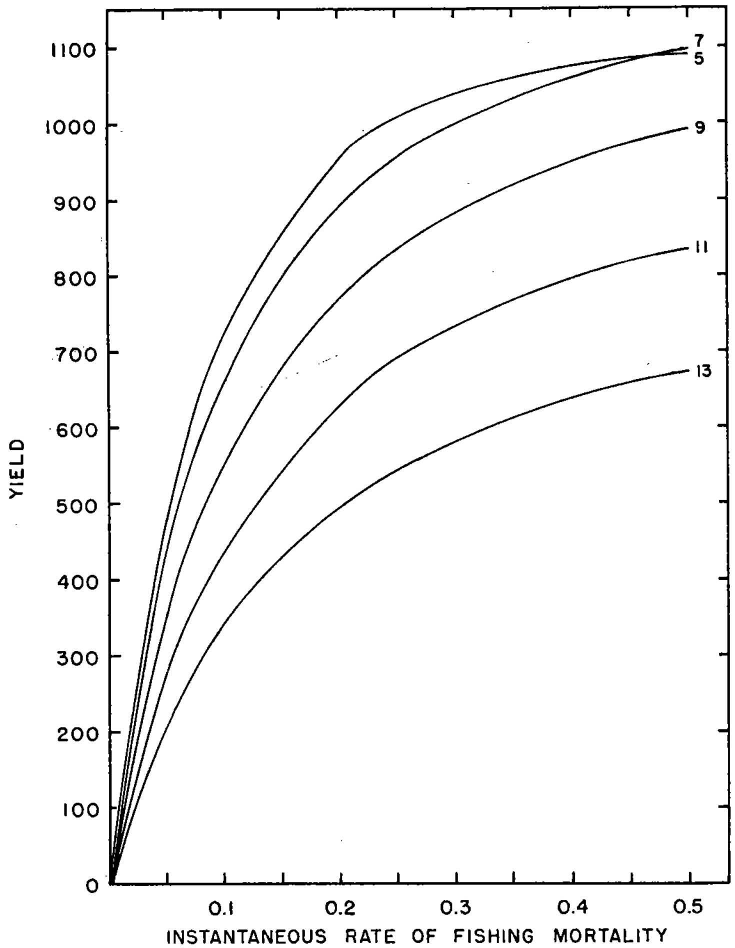

Figure 16. Yield as a function of fishing rate for various ages of entry in Area 3 using 1956 Portlock-Albatross growth rate and $q = 0.25$.

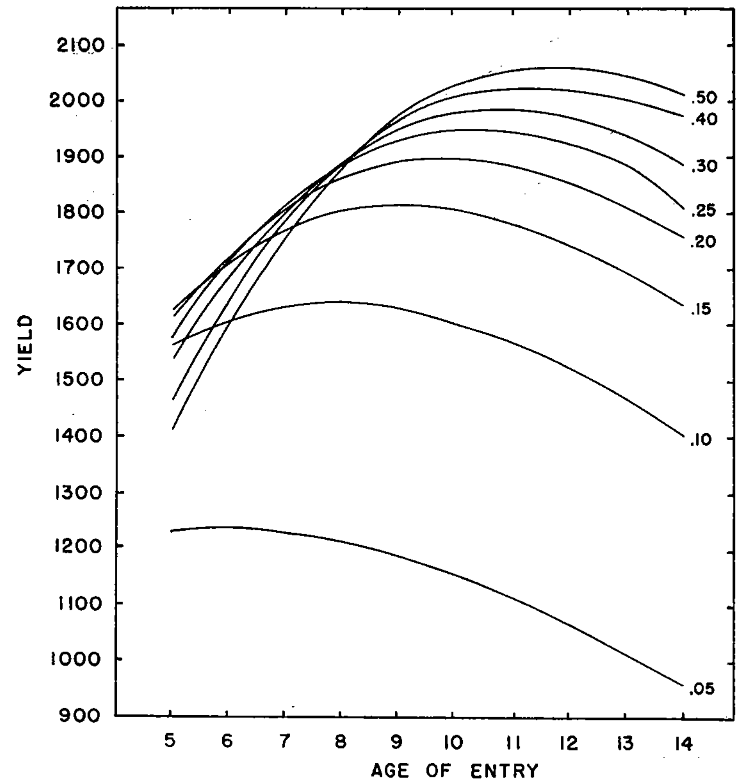

Figure 17. Yield as a function of age entry for various fishing mortality rates in Area 2 using 1956 Goose Islands growth rate and $q = 0.15$.

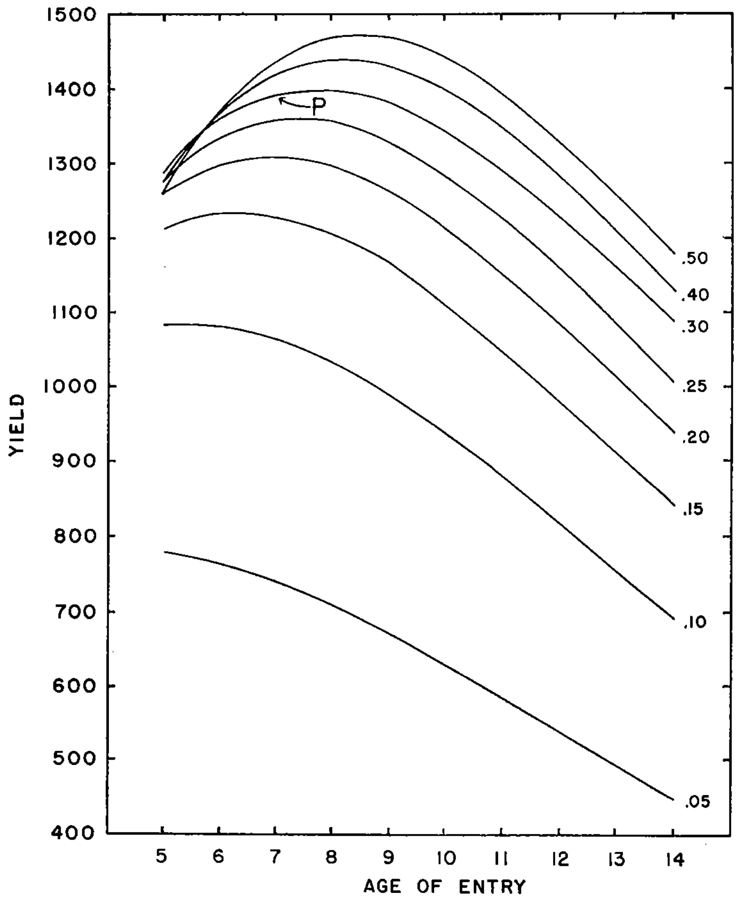

Figure 18. Yield as a function of age of entry for various fishing mortality rates in Area 2 using 1956 Goose Islands growth rate and q = 0.20.

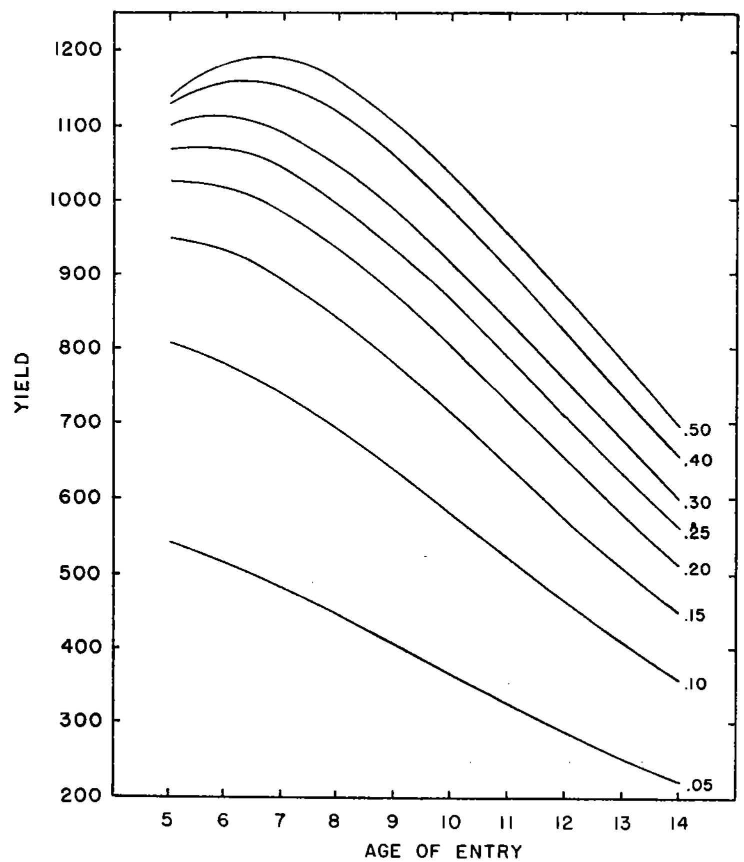

Figure 19. Yield as a function of age of entry for various fishing mortality rates in Area 2 using 1956 Goose Islands growth rate and q = 0.25.

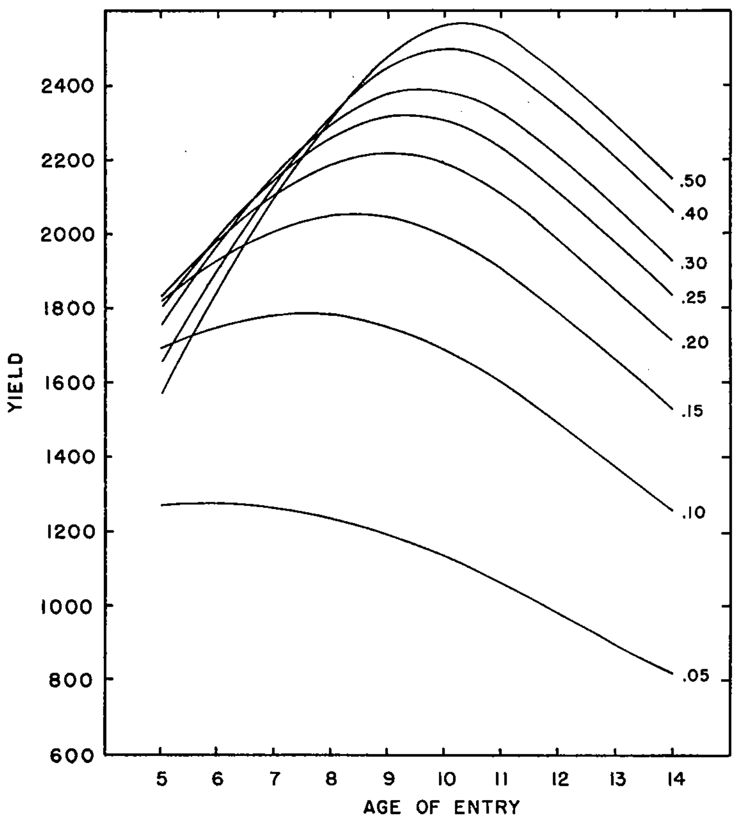

Figure 20. Yield as a function of age of entry for various fishing mortality rates in Area 2 using 1956 Goose Islands growth rate and q = 0.10 for ages 5-10 and q = 0.20 for ages over 10.

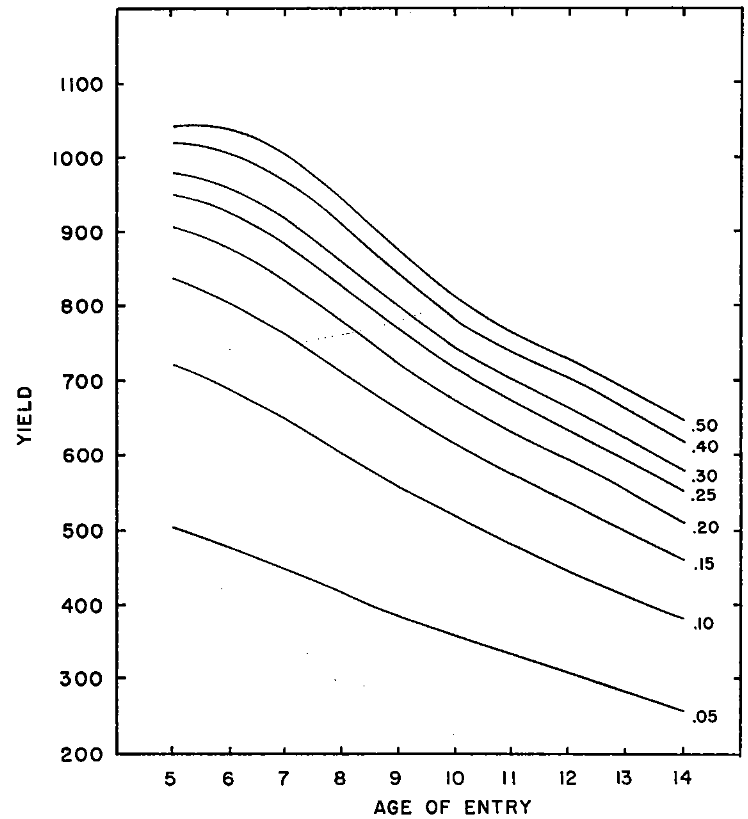

Figure 21. Yield as a function of age of entry for various fishing mortality rates in Area 2 using 1956 Goose Islands growth rate and q = 0.30 for ages 5-10 and q = 0.20 for ages over 10.

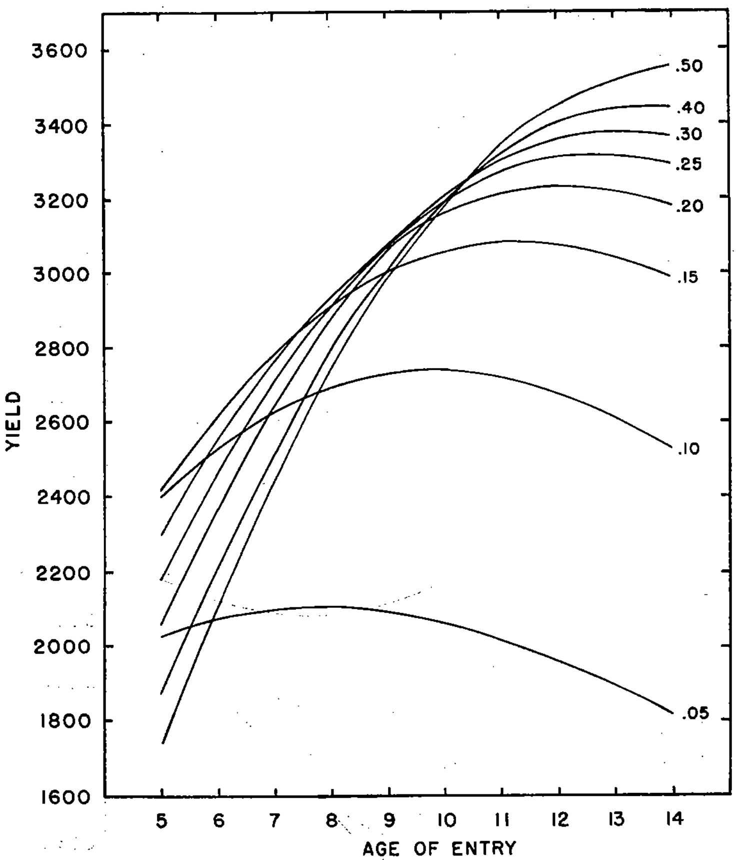

Figure 22. Yield as a function of age of entry for various fishing mortality rates in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.15.

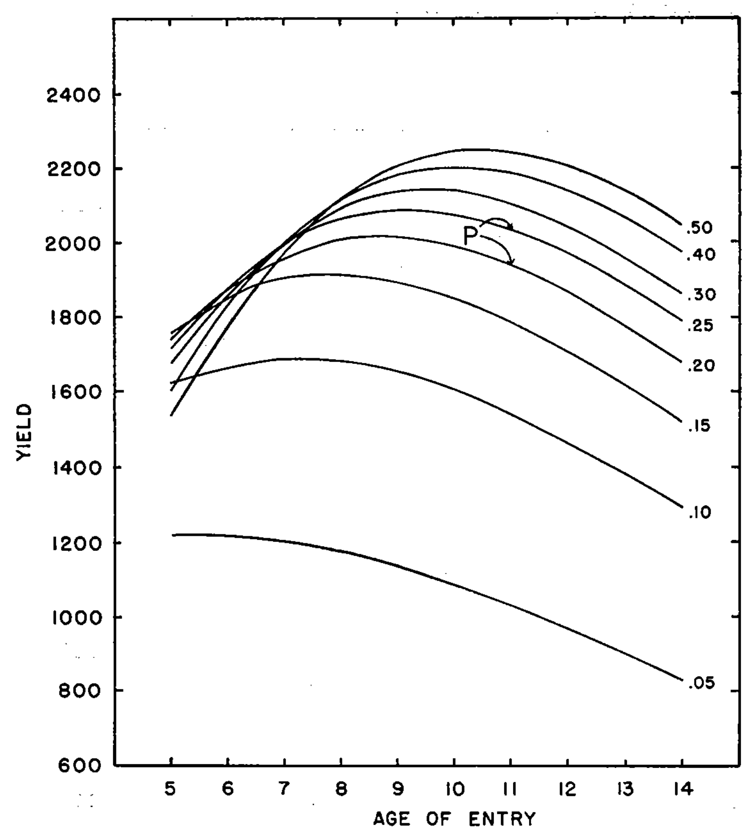

Figure 23. Yield as a function of age of entry for various fishing mortality rates in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.20.

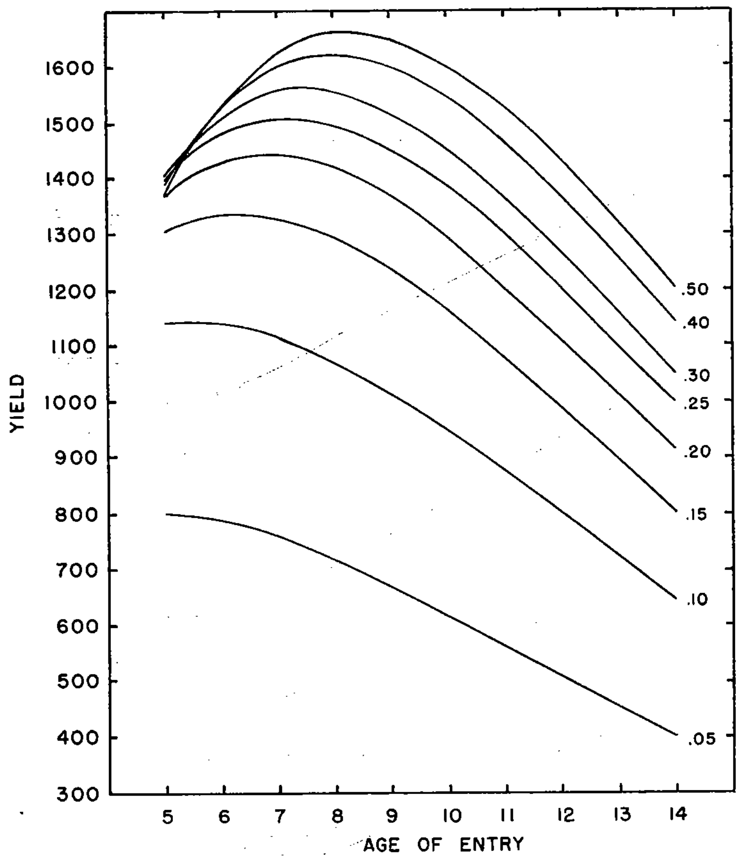

Figure 24. Yield as a function of age of entry for various fishing mortality rates in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.25.

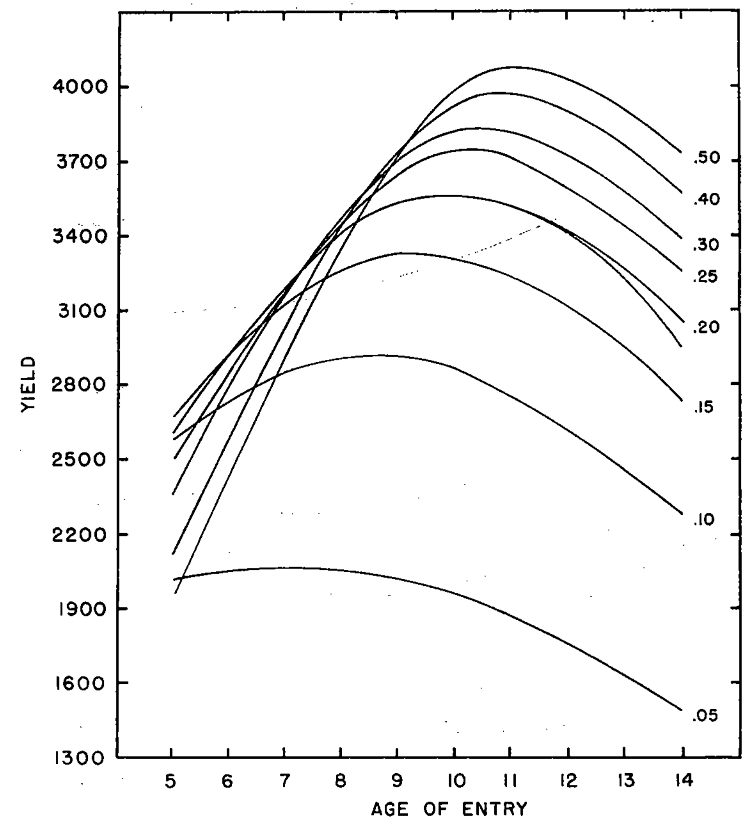

Figure 25. Yield as a function of age of entry for various fishing mortality rates in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.10 for ages 5-10 and q = 0.20 for ages over 10.

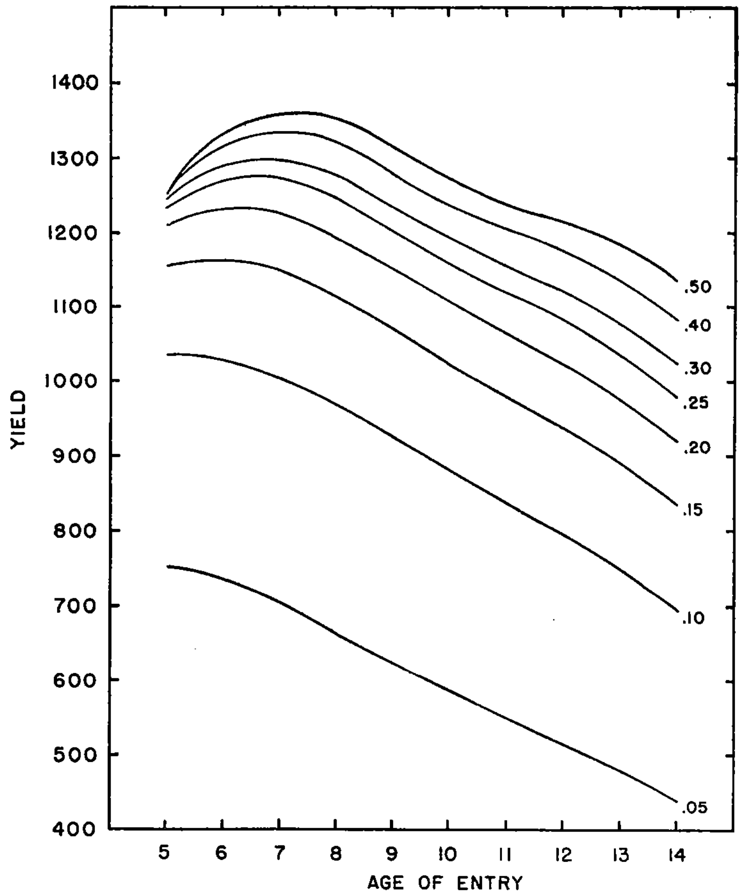

Figure 26. Yield as a funution of age of entry for various fishing mortality rates in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.30 for ages 5-10 and q = 0.20 for ages over 10.

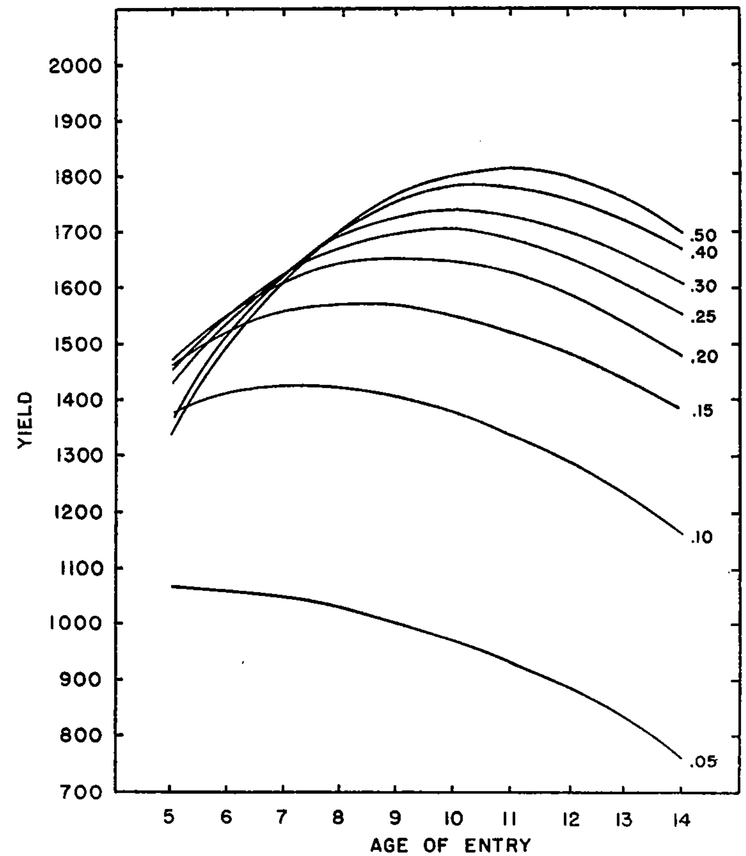

Figure 27. Yield as a function of age of entry for various fishing mortality rates in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.15.

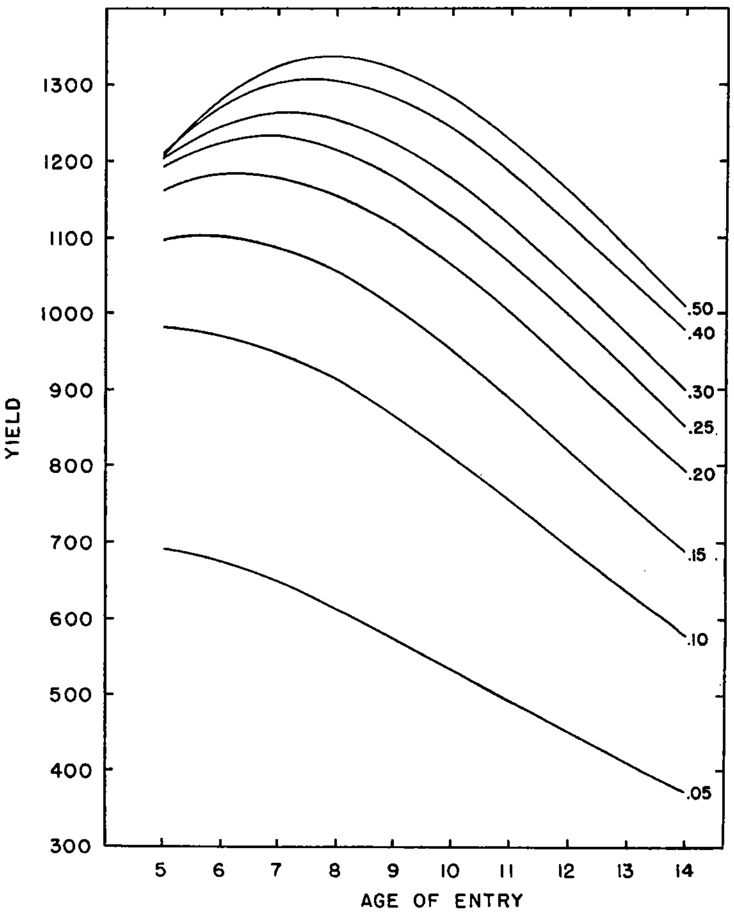

Figure 28. Yield as a funution of age of entry for various fishing mortality rates in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.20.

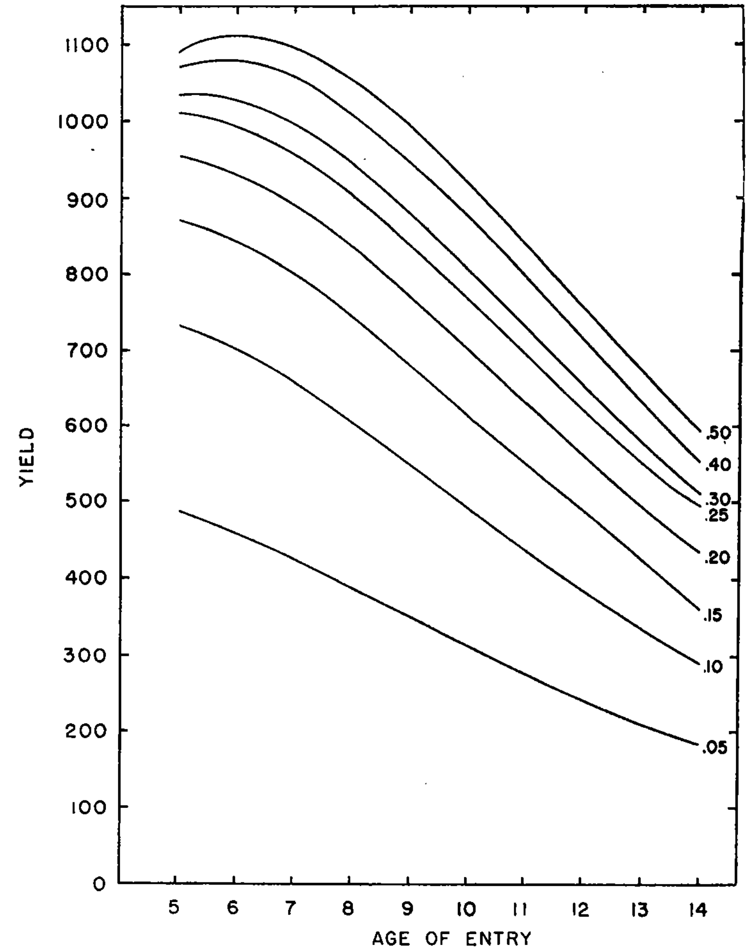

Figure 29. Yield as a function of age of entry for various fishing mortality rates in Area 3 using 1956 Portlock-Albatross growth rate and q = 0.25.

SUMMARY

Data for estimating current instantaneous rates of mortality of halibut were available from three primary sources: returns from tagging experiments, age composition data, and catch and effort statistics. A number of methods of analysis of each series of data were utilized. The estimates obtained showed considerable variability according to the source of data and the analytic method employed.

Analysis of the returns from a number of tagging experiments conducted between 1949 and 1953 provided average estimates of instantaneous fishing, natural and total mortality respectively of 0.30, 0.43 and 0.73 for Area 2, and of 0.07, 0.46 and 0.53 for Area 3. Age composition studies using a number of analytical methods provided average estimates of instantaneous fishing, natural and total mortality of 0.30, 0.20 and 0.50 respectively for Area 2 and 0.26, 0.20 and 0.46 for Area 3. Estimates of fishing mortality obtained from catch and effort statistics were rejected as unrealistic since they exceeded the estimates of total mortality from both tagging and age composition studies.

Best estimates for fishing and natural mortality were adopted taking into consideration the reliability of the estimates derived from each source of data and by each method of analysis. It was recognized that errors inherent in the tagging method of determining mortalities cause overestimation of natural mortality and underestimation of fishing mortality. Estimates based on age composition data are not as likely to be subject to such directional bias. Consequently the values of mortality rates from age composition studies were accepted as the best estimates.

Estimates of growth rates were computed from the average length at each age obtained by the back-calculation method. Observed length-weight relationships were used to convert the length at each age to weight.

Using a range as well as the best estimate of natural mortality and computed growth rates in a yield-per-recruitment model, theoretical yields were calculated for a wide range of fishing mortality rates and for observed and assumed ages of entry into the fishery. In the absence of any clear evidence to the contrary, recruitment was considered as constant for the stock levels studied.

The value of the model lies in the possibility that the changes in yield resulting from changes in level of fishing may be predicted. The limitation of the model is that it assumes constancy in the parameters under changing levels of fishing.

The yield-per-recruitment model, using the best current estimates of age of entry, growth, fishing mortality and natural mortality indicates that in Area 2 an increase in fishing would not provide a substantial increase in yield, and in Area 3 fishing would need to be doubled to provide about a ten percent increase in yield.

This theoretical approach supports the belief that the empirical method that has been used in regulating the fishery has resulted in an optimum or near optimum utilization of recruits.

ACKNOWLEDGMENTS

The authors wish to acknowledge the suggestions regarding both the analysis and text contributed by Dr. Douglas G. Chapman of the Department of Mathematics, University of Washington; Dr. Keith S. Ketchen, Fisheries Research Board of Canada; and Mr. R. A. Fredin and Mr. R. P. Silliman of United States Fish and Wildlife Service.

LITERATURE CITED

Beverton, R. J. H. and S. J. Holt

1957 On the dynamics of exploited fish populations.
Gt. Brit. Min. of Agric., Fish. and Food, Fish. Invest., Ser. II, 19: 533 pp., London.

Chapman, D. G.

Ms. Estimation of fishing and natural mortality rates from reconstruction of size of year class. Univ. of Washington, Seattle.

Chapman, D. G. and D. S. Robson

1960 The analysis of catch curve. (To appear in Biometrics).

Fry, F. E. J.

1949 Statistics of a lake trout fishery.
Biometrics, 5 (1): 27-67, Washington, D.C.

Jackson, C. H. N.

1939 The analysis of an animal population.
Jour. Anim. Ecol., 8 (2): 238-246, Oxford, Eng.

Paloheimo, J. E.

1958 A method of establishing natural and fishing mortalities.
Jour. Fish. Res. Bd. of Canada, 15 (4): 749-758, Ottawa.

Ricker, W. E.

1945 A method of estimating minimum size limits for obtaining maximum yield.
Copeia, 1945 (2): 84-94, Ann Arbor, Michigan.

1948 Methods of estimating vital statistics of fish populations.
Indiana Univ. Publ., Sci. Ser., No. 15: 101 pp., Indianapolis, Indiana.

1958 Handbook of computations for biological statistics of fish populations.
Fish. Res. Bd. of Canada, Bull., No. 119: 300 pp., Ottawa.

Silliman, R. P.

1943 Studies on the Pacific pilchard or sardine (*Sardinops caerulea*). A method of computing mortalities and replacements. U.S. Fish and Wildlife Service, Spec. Sci. Rept., No. 24: 10 pp., Washington, D.C.

Schaefer, Milner B.

1957 A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Inter-Amer. Trop. Tuna Comm., Bull., 2 (6): 247-268, La Jolla, Calif.

APPENDIX

Appendix Table 1. Catch in thousands of pounds for certain grounds in Areas 2 and 3 for various years.

Year	Goose Islands	Lower Hecate Strait	Upper Hecate Strait	Yakutat	Portlock-Albatross
1948	4060	—	—	—	—
1949	3240	—	—	—	—
1950	3110	—	5620	—	18070
1951	3900	—	7310	—	15410
1952	3460	—	7670	4130	16730
1953	4370	3840	8310	3380	14060
1954	7440	2220	7290	3550	19790
1955	5550	1620	5660	2370	15970
1956	4540	2430	6570	2180	17630
1957	2870	2400	6500	—	18740
1958	—	3440	7190	—	—

Appendix Table 2. Tag recoveries from some Area 2 and Area 3 experiments by years*.

Experiment		Month of Tagging	Number Tagged	0	I	II	III	IV	V	VI
Area 2										
1949	Upper Hecate Strait	July	47	0	6**	3	1	1	0	0
		Sept.	503	0	41**	41	20	11	5	3
1951	Upper Hecate Strait	Aug.-Sept.	1051	0	214	139	65	22	14	7
1952	Upper Hecate Strait	April	172	19	35	11	3	1	0	1
		July	618	0	86	60	19	12	8	10
1953	Upper Hecate Strait	May	437	40	94	22	17	11	4	1
		July	142	1	28	16	4	4	4	0
1952	Lower Hecate Strait	June-July	607	23	44**	27	18	8	7	2
1953	Lower Hecate Strait	June-July	1321	10	227	58	57	55	30	8
1947	Goose Islands Ground	May-June	411	7	59	32	10	5	2	3
1951	Goose Islands Ground	Sept.-Oct.	1729	0	52**	192	188	69	39	11
Area 3										
1949	Kodiak Island Region	July-Aug.	756	0	17	7	14	5	6	3
1950	Kodiak Island Region	Aug.-Sept.	810	0	17	13	5	4	3	5
1951	Kodiak Island Region	July	832	0	30	10	6	5	1	3
1952	Kodiak Island Region	May	903	5	31	20	20	7	7	4
1951	Yakutat	Aug.	1238	0	109	83	72	22	15	12

* Not including fish less than 80 cm. in length at tagging, trawl caught, tagging vessel recoveries retaken in area of tagging or those taken during the closed season except longline permit recoveries.

**First year recoveries not used in estimates.

Appendix Table 3. Number of fish per 10,000 skates and average weight at each age for Goose Islands grounds by year from 1935 to 1958 inclusive.

Age	1935		1936		1937		1938		1939		1940	
	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.	No.	Av. Wt.
3	—	—	673	4.4	283	6.1	—	—	—	—	—	—
4	—	—	1578	6.3	3007	7.2	1156	6.0	1702	7.2	538	7.4
5	241	5.0	1087	5.3	2973	7.9	4981	8.0	3036	8.6	4703	7.7
6	1668	7.3	4166	5.9	4114	7.7	7398	7.3	4544	9.1	5267	8.9
7	8763	9.4	14895	7.6	16819	7.8	19218	7.8	8886	8.9	9562	9.3
8	8783	11.5	8439	11.1	23737	9.6	24477	8.8	13382	10.7	8737	10.5
9	11231	13.7	4744	12.8	8195	13.1	19869	10.4	9572	12.5	9770	12.3
10	7192	17.5	3493	17.8	3481	17.5	4967	14.4	6672	14.9	7826	13.8
11	2420	20.6	2521	23.1	2430	21.5	2324	19.0	1711	27.7	4564	17.6
12	858	21.3	770	31.4	1933	23.0	1514	24.7	1441	24.5	1154	23.2
13	270	31.0	135	56.2	283	34.6	558	30.5	919	27.9	399	24.5
14	145	39.9	48	58.0	102	56.0	266	34.8	174	43.1	399	49.8
15	135	45.4	19	104.5	45	49.5	66	31.8	68	70.0	190	34.4
16	96	57.3	77	67.2	23	30.5	13	30.0	39	32.8	26	105.3
17	10	105.0	29	87.7	—	—	—	—	—	—	—	—
18	48	55.4	10	237.0	—	—	40	83.3	10	94.0	—	—
19	—	—	10	154.0	22	41.0	—	—	19	140.5	—	—
20	—	—	9	169.0	—	—	—	—	19	107.5	—	—
21	10	154.0	9	53.0	—	—	—	—	—	—	—	—
22	—	—	—	—	—	—	13	141.0	—	—	—	—
23	19	89.5	—	—	—	—	—	—	—	—	—	—

Appendix Table 3 (continued)

Age	1941 No.	1941 Av. Wt.	1942 No.	1942 Av. Wt.	1943 No.	1943 Av. Wt.	1944 No.	1944 Av. Wt.	1945 No.	1945 Av. Wt.	1946 No.	1946 Av. Wt.
3	—	—	79	6.6	87	5.1	—	—	—	—	—	—
4	1527	6.6	1778	7.6	628	6.5	349	5.7	—	—	79	9.4
5	2596	8.3	2555	8.4	3063	7.8	1708	7.7	1288	8.8	665	7.5
6	7137	8.8	5758	8.6	9537	7.6	9306	8.5	9899	8.3	4760	8.5
7	8656	9.9	13255	9.2	23315	8.1	14133	9.6	18650	9.6	16559	9.3
8	12213	10.6	6406	11.7	17242	10.7	25026	10.3	14670	11.5	24421	10.1
9	9191	12.8	7055	14.0	5820	14.2	12197	12.3	11838	13.7	15262	11.3
10	5332	15.8	4756	16.4	2748	20.6	4720	16.6	3559	19.0	8956	14.3
11	2844	17.6	3223	19.4	1510	20.7	2488	19.6	1072	23.1	3361	16.4
12	1875	21.6	2741	21.6	1824	20.3	2905	18.9	472	29.4	1410	22.5
13	333	27.2	1533	23.1	925	22.1	2098	23.0	140	62.2	361	26.8
14	264	25.5	560	30.7	375	24.3	874	26.5	293	34.9	519	27.6
15	372	33.6	285	34.9	201	27.0	713	25.3	89	91.6	113	49.5
16	85	47.1	59	29.8	44	26.0	255	25.6	13	67.0	68	25.7
17	39	86.2	157	48.1	35	54.0	161	40.3	38	124.3	34	87.7
18	8	94.0	88	32.4	—	—	13	60.0	—	—	34	30.3
19	—	—	29	73.7	8	76.0	67	48.6	38	104.7	—	—
20	—	—	20	94.0	—	—	—	—	13	154.0	11	169.0
21	15	201.0	30	87.3	8	169.0	—	—	—	—	45	40.5

Appendix Table 3 (continued)

Age	1947 No.	1947 Av. Wt.	1948 No.	1948 Av. Wt.	1949 No.	1949 Av. Wt.	1950 No.	1950 Av. Wt.	1951 No.	1951 Av. Wt.	1952 No.	1952 Av. Wt.
3	448	6.5	—	—	—	—	—	—	—	—	—	—
4	1932	8.1	823	7.8	71	9.3	65	8.3	66	8.3	—	—
5	1530	8.7	3234	8.9	615	9.7	120	12.7	264	8.8	903	10.5
6	5425	8.0	5306	9.0	1893	8.8	3129	10.3	770	9.5	1225	11.0
7	11020	9.5	11039	9.6	6389	9.3	7555	9.8	8097	10.2	2991	9.3
8	20262	10.5	19725	10.7	14802	10.6	19166	11.0	12740	11.8	15439	11.1
9	14853	11.8	17903	12.9	17595	12.1	23200	12.3	16887	13.9	19334	12.8
10	9474	14.4	10304	15.7	13075	13.3	12679	14.1	14599	15.9	16985	14.7
11	7496	16.7	3807	18.8	7360	14.5	6138	17.7	5963	18.7	13030	17.1
12	3462	19.6	2072	22.8	4555	18.4	3609	18.4	2574	21.5	7208	19.9
13	804	20.3	779	37.6	1680	26.8	1134	26.5	913	32.7	3815	20.8
14	927	23.2	706	22.2	663	24.1	720	30.3	176	47.8	1867	21.7
15	356	28.4	220	65.9	331	44.6	229	37.9	165	48.6	1004	22.3
16	325	29.6	206	42.5	178	51.1	185	59.5	77	53.1	683	25.7
17	386	25.1	176	72.8	107	42.1	65	30.7	11	116.0	161	62.4
18	155	50.0	73	26.0	130	40.4	33	65.7	22	141.0	20	94.0
19	46	78.7	59	30.5	130	29.8	—	—	11	169.0	20	169.0
20	46	74.0	—	—	—	—	11	169.0	33	136.7	—	—
21	—	—	—	—	—	—	22	140.5	11	218.0	—	—
22	—	—	—	—	—	—	—	—	11	105.0	—	—

Appendix Table 3 (continued)

Age	1953 No.	1953 Av. Wt.	1954 1st Season No.	1954 1st Season Av. Wt.	1954 2nd Season No.	1954 2nd Season Av. Wt.	1955 1st Season No.	1955 1st Season Av. Wt.	1955 2nd Season No.	1955 2nd Season Av. Wt.	1956 1st Season No.	1956 1st Season Av. Wt.
4	377	5.6	1780	8.1	6819	7.8	1466	8.0	2432	9.2	133	7.5
5	1130	9.3	1309	8.1	5314	9.2	5524	9.1	8859	10.4	1509	8.6
6	2322	10.1	1807	9.2	3587	9.0	5925	8.6	13318	9.9	6071	9.6
7	9886	9.6	7488	10.4	9609	9.9	12284	9.4	15142	10.6	10598	10.4
8	19208	11.1	16430	11.7	19306	11.0	13844	11.0	10770	11.9	10839	11.0
9	33205	12.8	19978	13.7	20900	11.9	13154	13.3	10133	14.2	7472	14.4
10	27619	16.2	23682	15.0	30465	15.1	12062	15.8	6717	17.8	8135	16.0
11	19522	17.8	13314	17.6	12398	15.9	10315	18.8	9380	21.5	5202	19.4
12	10953	22.4	8077	20.2	12443	22.3	4586	23.6	5182	22.7	6590	21.3
13	5492	27.2	2212	24.6	7793	25.3	2617	25.5	2837	30.2	3549	24.0
14	3390	26.3	2435	24.9	6111	23.8	1483	29.8	2924	24.9	2619	29.0
15	1444	32.7	1375	25.2	1727	32.7	460	32.5	1448	36.8	1062	35.4
16	722	32.7	301	24.5	1771	34.5	213	44.1	753	40.4	1026	36.3
17	282	44.3	236	34.4	797	39.6	179	60.5	811	43.0	628	41.5
18	126	22.3	236	22.3	—	—	43	100.0	405	31.2	410	48.3
19	—	—	—	—	177	92.0	—	—	—	—	169	37.6
20	—	—	66	22.2	44	69.0	—	—	—	—	72	93.7
21	—	—	—	—	—	—	—	—	—	—	12	94.0
22	—	—	—	—	—	—	—	—	—	—	24	67.5
23	—	—	—	—	—	—	—	—	—	—	—	—
24	—	—	—	—	—	—	—	—	—	—	—	—
25	—	—	—	—	—	—	—	—	29	201.0	12	116.0

Appendix Table 3 (continued)

Age	1956 2nd Season No.	1956 2nd Season Av. Wt.	1957 1st Season No.	1957 1st Season Av. Wt.	1957 2nd Season No.	1957 2nd Season Av. Wt.	1958 No.	1958 Av. Wt.
3	—	—	28	5.0	977	5.8	122	6.2
4	55	8.3	341	8.1	1711	7.5	9746	7.5
5	1448	8.9	1170	8.5	5586	9.7	3503	8.7
6	6592	9.0	5372	9.8	13056	10.3	3720	9.4
7	11487	10.5	11463	11.1	17734	12.3	14774	9.8
8	9156	11.9	10459	12.8	12533	14.7	10433	12.3
9	5599	14.3	7639	15.4	6424	16.8	7769	15.7
10	5157	16.0	3962	17.8	4224	18.0	4897	19.7
11	3337	22.6	2894	24.0	4853	22.5	2458	22.6
12	5833	25.2	2599	25.6	2269	29.5	2081	24.9
13	4289	32.8	2488	31.7	4119	29.5	1940	25.0
14	2923	32.2	1272	28.7	1746	46.3	2429	32.3
15	2041	41.5	1115	33.0	1850	35.1	1460	33.8
16	952	39.1	488	49.5	279	82.8	961	38.5
17	896	46.3	313	36.7	349	53.3	612	42.7
18	758	53.5	184	44.2	419	44.5	292	51.0
19	496	90.2	258	41.3	244	27.9	122	57.7
20	290	83.0	65	57.6	175	61.2	141	61.3
21	110	50.1	—	—	70	161.0	85	67.8
22	110	97.5	—	—	—	—	9	299.0
23	55	104.5	9	141.0	—	—	9	256.0
24	179	81.8	—	—	—	—	9	201.0
25	55	94.3	—	—	—	—	—	—
26	55	218.3	—	—	—	—	—	—
27	—	—	—	—	—	—	—	—
28	—	—	—	—	—	—	—	—
29	—	—	—	—	—	—	—	—
30	—	—	—	—	—	—	—	—
31	55	237.0	—	—	—	—	—	—

Appendix Table 4. Number of fish per 10,000 skates and average weight at each age for lower Hecate Strait grounds by year from 1951 to 1958 inclusive.

Age	1951 No.	1951 Av. Wt.	1952 1st Season No.	1952 1st Season Av. Wt.	1952 2nd Season No.	1952 2nd Season Av. Wt.	1953 1st Season No.	1953 1st Season Av. Wt.	1953 2nd Season No.	1953 2nd Season Av. Wt.	1954 2nd Season* No.	1954 2nd Season* Av. Wt.
3	—	—	529	6.4	95	10.2	—	—	125	8.3	—	—
4	98	9.4	831	9.0	478	10.9	—	—	453	11.8	1526	8.3
5	520	7.6	2645	11.4	1794	9.6	—	—	875	7.7	3051	12.3
6	748	10.1	3174	9.6	3924	12.1	1545	12.2	2516	11.1	3945	13.4
7	1735	10.6	3325	9.6	1629	15.2	3091	14.0	2532	14.8	7522	15.7
8	2884	14.5	14055	13.5	4976	14.2	1700	9.2	3407	14.8	8154	19.8
9	4099	17.1	10730	18.4	6627	18.0	9581	18.1	3813	18.3	5944	19.4
10	3849	19.4	11108	21.4	7536	22.4	9890	22.7	4470	24.6	14466	26.4
11	2093	24.3	7179	19.2	4570	24.1	5872	30.1	4939	25.5	7259	36.8
12	2852	35.6	2720	27.9	3230	21.0	10431	30.7	4611	30.7	5786	38.0
13	3437	38.0	4458	26.1	3493	27.3	3863	35.5	2829	33.4	4261	39.6
14	1984	53.2	3325	43.1	2512	26.9	3940	29.9	2079	47.2	1999	53.0
15	1583	62.6	2947	51.1	1914	28.9	2395	51.7	1375	52.1	1999	40.8
16	694	76.8	2796	33.5	1077	37.5	3013	40.0	1844	50.5	1736	54.7
17	477	69.7	604	61.6	957	53.7	1391	48.4	1047	61.4	684	85.2
18	412	92.2	604	65.4	191	49.8	850	53.0	1172	69.1	1000	87.2
19	184	69.5	151	116.0	454	61.9	309	40.5	469	67.1	526	69.0
20	119	81.4	378	30.4	239	49.6	—	—	391	74.3	158	92.0
21	76	71.1	454	59.7	167	45.4	155	104.5	219	120.8	210	164.5
22	98	86.0	—	—	—	—	—	—	109	153.6	105	134.5
23	—	—	—	—	—	—	—	—	125	143.0	158	112.0
24	33	94.3	—	—	48	75.5	—	—	125	106.5	158	113.7
25	—	—	—	—	—	—	—	—	141	126.4	—	—
26	—	—	—	—	—	—	—	—	—	—	—	—
27	—	—	—	—	—	—	—	—	—	—	—	—
28	—	—	—	—	—	—	—	—	—	—	—	—
29	—	—	—	—	—	—	—	—	31	128.0	—	—
30	—	—	—	—	—	—	—	—	31	116.0	—	—

*No 1st season data.

Appendix Table 4 (continued).

Age	1955 1st Season No.	1955 1st Season Av. Wt.	1955 2nd Season No.	1955 2nd Season Av. Wt.	1956 1st Season No.	1956 1st Season Av. Wt.	1956 2nd Season No.	1956 2nd Season Av. Wt.	1957 1st Season No.	1957 1st Season Av. Wt.	1957 2nd Season No.	1957 2nd Season Av. Wt.
4	—	—	505	8.4	—	—	—	—	685	7.9	660	8.4
5	6233	8.1	3738	9.8	2903	8.6	3815	8.2	2056	8.4	1741	10.6
6	7562	9.8	6971	13.1	8969	9.3	8233	10.7	6169	10.1	7143	11.8
7	5317	10.0	7577	18.6	10275	10.7	10375	14.4	9443	11.9	9575	17.3
8	10312	11.7	5253	21.9	9753	12.7	11111	15.4	6055	13.4	9905	21.9
9	11046	12.9	5152	22.7	6966	15.7	5556	20.0	6016	16.0	5913	26.2
10	5087	15.3	5455	37.2	6299	19.6	8768	29.9	3618	22.5	4652	35.3
11	9350	17.7	5455	41.5	3890	20.5	5689	30.0	2627	27.1	4112	41.4
12	5683	20.8	2627	50.8	5080	28.6	4953	36.8	2285	32.9	2671	51.2
13	2979	21.8	4344	40.0	3425	34.4	3614	52.5	2818	35.5	2882	57.0
14	1742	27.8	1414	53.9	2612	38.3	4418	58.3	1828	46.7	750	53.0
15	504	24.7	1515	80.1	1480	39.1	1406	68.7	1104	53.4	961	61.5
16	1008	35.4	404	95.5	1161	37.5	1339	75.0	457	37.2	210	93.4
17	1100	44.4	1617	79.1	639	51.1	937	54.6	495	63.5	60	147.5
18	321	41.6	606	64.3	493	44.2	402	53.0	114	83.7	480	70.6
19	229	49.4	808	55.6	232	56.6	268	94.5	190	98.6	—	—
20	—	—	—	—	203	43.9	134	46.5	229	62.3	—	—
21	—	—	—	—	116	46.2	—	—	76	116.0	—	—
22	—	—	—	—	87	94.3	—	—	38	46.0	—	—
23	—	—	—	—	—	—	—	—	—	—	—	—
24	—	—	—	—	87	30.3	—	—	—	—	—	—
25	—	—	—	—	—	—	—	—	—	—	—	—
26	—	—	—	—	—	—	—	—	—	—	—	—
27	—	—	—	—	—	—	201	59.7	—	—	—	—

Appendix Table 4 (continued).

Age	1958 1st season No.	Av. Wt.	1958 2nd season No.	Av. Wt.
3	266	6.7	1666	6.8
4	8014	8.1	25572	8.6
5	4327	11.9	9145	13.7
6	3288	13.5	8393	14.1
7	8715	14.7	9994	13.8
8	7398	21.1	8296	19.3
9	5742	25.3	4376	27.3
10	4267	37.3	2874	31.6
11	3324	43.5	2254	47.6
12	1499	51.7	1829	46.1
13	1294	51.4	1437	48.2
14	1366	54.5	1078	61.2
15	967	63.1	1600	64.9
16	568	75.0	1110	90.5
17	339	81.3	686	67.8
18	230	93.1	392	104.8
19	254	60.7	457	167.4
20	60	99.8	98	195.3
21	60	123.4	33	184.0
22	24	193.5	—	—
23	60	99.6	—	—
24	—	—	—	—
25	36	75.7	—	—
26	—	—	—	—
27	24	169.5	—	—

Appendix Table 5. Number of fish per 10,000 skates and average weight at each age for upper Hecate Strait grounds by year from 1950 to 1958 inclusive.

Age	1950 No.	1950 Av. Wt.	1951 No.	1951 Av. Wt.	1952 No.	1952 Av. Wt.	1953 No.	1953 Av. Wt.	1954 1st Season No.	1954 1st Season Av. Wt.	1954 2nd Season No.	1954 2nd Season Av. Wt.
3	—	—	—	—	—	—	123	6.6	492	8.4	—	—
4	—	—	—	—	662	7.8	—	—	1661	7.7	3621	7.7
5	264	9.2	—	—	2319	10.6	246	6.6	861	6.3	1431	9.3
6	709	13.8	148	6.1	2087	12.0	2194	9.1	4184	11.6	3621	9.1
7	3233	12.2	3296	10.4	3710	9.4	5079	11.0	5661	11.5	8294	9.8
8	6813	12.1	7864	11.6	22162	10.3	6755	12.3	12859	10.3	16292	12.0
9	13444	14.3	11617	14.3	19677	13.4	13904	13.5	8737	12.1	12461	15.7
10	8066	19.0	9407	15.5	11660	16.3	12253	16.6	14644	14.5	23449	17.2
11	5328	25.8	6358	15.5	9905	19.4	10034	21.3	11198	14.8	13261	26.5
12	3134	34.0	2716	21.6	3909	26.2	7495	22.3	4553	19.0	8883	31.8
13	1600	39.2	2469	31.9	2120	28.2	5572	28.1	3261	24.9	8799	40.1
14	1188	56.6	1272	35.1	530	83.7	1750	33.6	2215	22.2	4462	45.4
15	478	73.0	506	45.8	961	37.8	1035	36.6	861	54.9	4084	58.8
16	82	105.4	296	44.8	364	57.2	986	55.0	431	19.9	3747	53.3
17	33	135.0	679	61.0	298	55.9	592	62.2	923	39.2	1979	87.0
18	33	161.5	815	65.6	—	—	616	58.2	308	45.8	1221	100.6
19	17	169.0	49	151.0	—	—	—	—	185	115.7	589	73.7
20	—	—	25	161.5	—	—	—	—	—	—	379	129.1
21	17	201.0	49	147.8	—	—	—	—	—	—	505	118.9
22	17	201.0	—	—	—	—	—	—	—	—	84	227.5
23	—	—	—	—	—	—	—	—	—	—	42	237.0
24	—	—	—	—	—	—	—	—	—	—	126	182.0

Appendix Table 5 (continued).

Age	1955 1st Season No.	Av. Wt.	1955 2nd Season No.	Av. Wt.	1956 1st Season No.	Av. Wt.	1956 2nd Season No.	Av. Wt.	1957 1st Season No.	Av. Wt.	1957 2nd Season No.	Av. Wt.
3	—	—	—	—	—	—	711	6.6	—	—	—	—
4	173	6.6	1386	7.6	918	6.9	1280	8.3	—	—	4009	8.4
5	1366	9.1	6541	8.8	4791	9.2	6364	9.4	1081	7.8	4591	11.5
6	2839	10.4	7407	10.6	10195	10.0	14789	10.0	3210	10.3	9183	10.8
7	5050	8.9	10266	10.8	10594	11.1	15109	10.9	5667	11.1	18171	13.6
8	9168	10.3	12346	13.6	10262	11.9	12407	13.7	7010	12.6	14874	16.9
9	9905	12.9	15334	15.4	8545	15.2	10168	15.6	6093	14.0	9571	23.7
10	8778	15.8	6628	19.4	11419	16.5	14434	20.9	4292	18.0	6079	29.3
11	11249	17.2	12302	22.0	5364	21.5	5013	25.3	5241	20.8	5755	36.0
12	7521	20.8	9357	29.9	6349	23.3	7075	27.4	3145	22.6	2781	47.9
13	4097	22.5	4289	37.0	3780	30.5	4551	32.1	3505	27.9	3363	38.8
14	2666	33.0	4288	47.3	2036	33.3	3626	60.5	2326	26.5	2069	60.3
15	1821	33.3	1949	48.1	1012	48.9	1564	65.5	917	34.1	1099	51.5
16	607	32.2	1646	66.3	1158	49.1	1351	75.9	393	50.3	970	61.2
17	997	34.7	1776	65.7	293	88.5	604	92.3	884	65.1	517	57.3
18	260	61.0	866	88.0	359	34.7	462	117.0	262	58.6	194	116.7
19	260	62.9	260	52.2	439	68.3	249	112.8	131	35.3	194	96.3
20	43	84.5	390	118.6	80	86.7	249	132.5	393	61.4	—	—
21	—	—	303	132.4	27	122.0	320	160.8	66	67.5	—	—
22	—	—	43	154.0	93	94.1	284	138.6	131	84.5	—	—
23	43	209.5	43	154.0	13	201.0	36	185.0	164	68.4	—	—
24	—	—	217	63.2	106	37.9	—	—	33	154.0	—	—
25	—	—	87	246.5	—	—	36	237.0	—	—	—	—
26	—	—	—	—	—	—	—	—	—	—	—	—
27	—	—	—	—	27	201.0	—	—	—	—	—	—
28	—	—	87	169.0	—	—	—	—	—	—	—	—
29	—	—	—	—	—	—	—	—	66	154.5	—	—
30	—	—	—	—	—	—	—	—	33	322.0	—	—

Appendix Table 5 (continued).

Age	1958 1st season No.	Av. Wt.	1958 2nd season No.	Av. Wt.
3	—	—	190	7.5
4	5380	9.1	14649	9.6
5	6516	10.6	7324	12.5
6	2474	11.5	4185	13.1
7	7492	12.6	12493	14.0
8	7991	16.8	10400	19.1
9	8150	23.9	6881	23.0
10	4427	27.2	6215	33.4
11	2633	35.1	2124	37.2
12	2020	33.7	2505	44.9
13	1771	46.3	1998	56.2
14	1636	37.5	1998	62.5
15	863	44.4	1046	63.2
16	159	83.9	666	84.5
17	250	53.9	412	113.5
18	23	128.0	222	114.9
19	68	93.0	127	188.7
20	408	61.2	222	152.0
21	—	—	285	155.2
22	—	—	159	116.0
23	—	—	32	237.0
24	—	—	63	218.0
25	—	—	63	127.5
26	—	—	63	256.5
27	—	—	—	—
28	—	—	32	277.0

Appendix Table 6. Number of fish per 10,000 skates and average weight at each age for southeastern Alaska grounds in 1958.

Age	1958 Inside Grounds No.	1958 Inside Grounds Av. Wt.	1958 Outside Grounds No.	1958 Outside Grounds Av. Wt.
4	15	8.5	—	—
5	46	8.5	—	—
6	722	7.9	212	10.4
7	4408	9.9	2164	10.3
8	4909	13.1	2715	13.0
9	4278	16.3	5388	15.1
10	3564	19.9	5643	22.8
11	2196	26.8	5388	19.9
12	2135	30.2	5049	25.0
13	1155	49.3	2885	22.4
14	1550	52.0	5346	34.4
15	1186	59.0	3522	32.5
16	805	58.9	1358	43.6
17	844	71.0	2206	53.2
18	699	73.8	1315	47.7
19	410	81.6	382	55.4
20	258	79.0	170	99.8
21	258	89.6	212	91.6
22	167	103.4	—	—
23	137	162.1	85	52.5
24	15	192.5	—	—
25	8	201.0	—	—
26	23	148.7	—	—
27	—	—	—	—
28	8	201.0	—	—

Appendix Table 7. Number of fish per 10,000 skates and average weight at each age for Portlock-Albatross grounds by year from 1935 to 1944 and from 1949 to 1958 inclusive.

Age	1935 No.	1935 Av. Wt.	1936 No.	1936 Av. Wt.	1937 No.	1937 Av. Wt.	1938 No.	1938 Av. Wt.	1939 No.	1939 Av. Wt.	1940 No.	1940 Av. Wt.
6	—	—	217	5.7	—	—	11	5.1	—	—	189	8.3
7	840	8.5	1275	8.9	488	7.4	685	9.7	287	9.4	612	11.5
8	2155	9.3	2286	9.6	3732	9.1	2536	11.2	2526	12.5	2192	13.2
9	6062	11.7	3589	9.5	6602	11.2	6773	13.8	4179	13.7	4083	16.9
10	5806	15.8	5679	10.6	7240	13.2	4820	14.8	6869	16.2	8099	18.1
11	7231	16.8	6798	13.6	7390	17.5	5380	22.0	4793	22.6	7259	22.5
12	7614	21.0	6445	18.1	7408	19.9	4957	35.3	5135	34.3	5435	30.1
13	5514	31.5	5034	28.0	8571	22.5	6728	37.5	4629	39.4	3460	35.2
14	3049	31.7	3128	32.2	4464	36.7	4089	43.5	4479	43.0	3543	41.6
15	2483	33.3	2659	33.7	2738	43.6	2798	50.8	2417	42.2	3643	49.0
16	1388	48.4	1411	39.3	2063	35.3	1451	55.4	2062	50.5	1580	49.4
17	913	35.8	1126	46.1	975	55.2	525	64.9	901	57.5	1012	70.6
18	657	58.0	1052	55.0	488	29.3	263	78.1	587	79.7	629	60.2
19	256	28.4	360	54.3	263	81.5	274	60.7	14	115.8	122	75.5
20	475	41.0	373	68.6	169	49.6	57	67.3	137	49.4	172	87.6
21	55	91.0	502	70.8	375	37.4	137	52.7	41	127.8	89	53.9
22	37	59.7	407	55.0	188	69.5	—	—	82	79.7	39	81.2
23	—	—	68	85.3	206	59.7	183	58.5	—	—	28	168.9
24	18	94.2	20	190.0	94	22.2	91	146.0	41	52.7	44	67.3
25	—	—	136	81.0	37	67.3	80	72.7	14	168.9	—	—
26	18	94.2	41	105.0	19	140.6	69	95.7	96	75.6	—	—
27	18	168.9	20	75.6	—	—	—	—	—	—	50	84.8
28	—	—	—	—	—	—	—	—	—	—	—	—
29	37	75.6	68	124.9	—	—	—	—	—	—	—	—
30	—	—	75	22.1	—	—	—	—	—	—	—	—

Appendix Table 7 (continued).

Age	1941 No.	1941 Av. Wt.	1942 No.	1942 Av. Wt.	1943 No.	1943 Av. Wt.	1944 No.	1944 Av. Wt.	1949 No.	1949 Av. Wt.	1950 No.	1950 Av. Wt.
6	200	9.9	1090	8.0	193	10.7	1175	6.6	—	—	—	—
7	1277	12.7	3219	11.3	1305	11.8	613	22.2	562	11.0	56	9.9
8	1819	15.4	4205	14.5	7735	15.1	2197	17.7	1578	14.7	1027	18.4
9	3377	14.9	5010	19.8	5270	17.3	4241	15.5	1726	21.0	3461	20.8
10	5536	16.9	5478	26.1	4980	20.6	3781	20.6	4061	23.5	3397	25.8
11	6813	21.9	6490	25.8	3917	26.1	4037	27.6	4506	27.1	4553	34.0
12	7195	23.7	7450	29.7	3819	35.7	5314	33.6	3679	32.9	3846	38.7
13	4761	35.3	5010	42.7	4254	46.1	6029	42.9	3944	41.9	3814	41.5
14	3009	37.9	3115	46.9	2224	58.6	4854	46.0	2984	48.8	3324	50.4
15	2541	49.4	2129	49.6	1257	57.0	2759	69.3	1710	60.4	1212	58.8
16	2527	57.7	1532	51.7	1644	75.8	1686	76.1	1093	65.2	963	65.0
17	1324	59.0	1064	42.5	483	47.0	1124	58.3	906	68.8	1027	65.6
18	622	55.0	623	65.8	580	96.2	460	102.1	523	74.9	281	70.7
19	274	81.8	156	120.6	97	94.2	766	125.1	328	79.2	200	75.3
20	181	83.3	104	46.3	291	35.2	51	184.0	305	99.7	273	134.8
21	120	87.8	—	—	48	218.3	153	127.7	172	99.7	120	102.2
22	127	62.9	104	35.2	48	168.9	—	—	109	123.4	32	165.0
23	87	28.0	—	—	—	—	—	—	39	35.2	—	—
24	74	129.7	—	—	—	—	—	—	8	256.4	—	—
25	73	152.6	104	67.3	—	—	—	—	16	84.6	64	97.0
26	67	116.4	—	—	—	—	307	40.7	—	—	24	140.0
27	—	—	—	—	—	—	—	—	—	—	—	—
28	53	70.4	—	—	—	—	—	—	—	—	16	208.0
29	27	104.5	104	40.6	—	—	—	—	—	—	—	—
30	—	—	—	—	—	—	—	—	—	—	—	—
31	—	—	—	—	—	—	—	—	—	—	—	—
32	—	—	—	—	—	—	—	—	—	—	—	—
33	—	—	—	—	—	—	—	—	8	236.9	—	—

Appendix Table 7 (continued).

Age	1951 No.	1951 Av. Wt.	1952 No.	1952 Av. Wt.	1953 No.	1953 Av. Wt.	1954 No.	1954 Av. Wt.	1955 No.	1955 Av. Wt.	1956 No.	1956 Av. Wt.
5	—	—	—	—	—	—	—	—	—	—	72	7.1
6	96	8.0	21	6.4	—	—	70	9.8	77	10.3	372	10.1
7	301	11.3	68	17.3	316	10.2	240	12.3	249	13.7	930	12.9
8	2046	15.4	2006	11.6	1070	15.3	839	15.0	786	18.4	2642	20.5
9	3574	19.5	3077	19.1	4339	19.4	1551	22.0	1977	24.0	2131	24.2
10	5103	23.3	4033	20.0	4833	22.1	4494	27.0	1646	26.7	3820	31.5
11	4826	27.2	6421	23.1	4720	30.0	4215	32.0	4507	37.2	2770	40.4
12	4212	34.9	5343	33.2	5507	31.9	4409	39.3	3391	43.4	4883	44.8
13	4297	43.5	5827	36.4	4460	40.9	4262	48.5	3126	52.7	2680	57.0
14	2202	54.0	5268	45.1	3966	53.8	3388	55.3	2751	55.7	2522	63.3
15	2383	53.0	3732	46.8	3288	47.3	2800	61.2	2201	63.5	1946	73.4
16	867	55.0	2402	46.7	1881	57.7	2131	70.0	1638	71.5	1121	87.8
17	530	67.2	1160	53.5	1176	51.9	1326	71.6	1210	78.6	844	86.3
18	301	74.9	1003	61.4	965	68.5	762	55.8	823	80.5	563	96.9
19	—	—	464	57.3	235	62.1	507	81.0	432	81.2	410	106.0
20	36	65.7	273	70.9	81	85.1	197	88.5	257	68.6	277	114.1
21	36	75.6	55	53.9	227	96.9	159	115.0	143	108.8	95	105.5
22	169	51.8	21	156.8	114	89.4	62	126.7	143	124.4	57	116.4
23	24	127.8	27	165.5	114	107.0	39	132.6	49	95.5	19	137.6
24	—	—	—	—	24	59.7	19	102.0	45	149.3	29	105.2
25	—	—	27	105.8	49	73.7	54	107.0	—	—	33	92.6
26	—	—	—	—	8	277.1	12	127.5	—	—	5	168.9
27	—	—	—	—	49	112.6	—	—	12	104.2	5	154.3
28	—	—	—	—	8	154.3	—	—	—	—	—	—
29	—	—	—	—	—	—	—	—	—	—	—	—
30	—	—	—	—	—	—	4	34.0	—	—	—	—

Appendix Table 7 (continued).

Age	1957 No.	1957 Av. Wt.	1958 No.	1958 Av. Wt.
3	—	—	—	—
4	—	—	—	—
5	—	—	—	—
6	246	9.7	229	17.5
7	867	14.7	1388	15.0
8	1824	20.3	1979	20.6
9	2820	26.7	2754	28.8
10	2797	31.4	3588	32.0
11	4074	40.4	3499	42.7
12	2577	47.7	3820	50.9
13	4430	54.0	2898	63.2
14	2487	64.7	3968	63.4
15	2270	69.1	2340	75.9
16	1390	78.5	1436	87.8
17	840	84.9	963	85.1
18	646	87.5	650	99.7
19	304	85.2	461	105.0
20	298	101.2	251	96.0
21	133	104.7	89	109.4
22	23	137.6	78	131.1
23	29	135.0	26	142.6
24	6	104.5	41	125.6
25	17	135.0	4	237.0
26	—	—	11	121.0
27	8	146.7	—	—

Appendix Table 8. Number of fish per 10,000 skates and average weight at each age for Shumagin Islands grounds by year from 1950 to 1958 inclusive.

Age	1950 No.	1950 Av. Wt.	1952 No.	1952 Av. Wt.	1953 No.	1953 Av. Wt.	1954 No.	1954 Av. Wt.	1955 No.	1955 Av. Wt.	1956 No.	1956 Av. Wt.
5	—	—	—	—	—	—	—	—	20	8.3	91	11.4
6	1042	9.0	124	22.2	—	—	541	12.5	339	14.5	434	11.9
7	1137	11.2	207	8.3	182	20.4	368	14.0	777	20.5	1164	19.8
8	4340	13.0	1907	13.0	442	22.4	1751	17.8	1635	26.0	1804	26.0
9	7032	12.2	3524	14.9	3719	26.7	1906	23.3	3509	35.7	1782	31.7
10	10822	16.0	3400	24.0	4239	29.7	4007	29.1	2671	40.6	3654	40.4
11	13211	16.7	4063	31.5	4031	38.0	2274	38.0	5562	50.4	2581	49.9
12	5932	25.2	5888	35.1	5982	47.4	3032	47.2	3329	64.2	3815	49.3
13	4284	33.5	4271	48.7	3641	57.9	3032	48.0	2950	66.4	2650	60.6
14	3980	38.5	3566	61.2	2783	63.8	2058	61.5	2213	77.6	2764	63.7
15	1535	51.7	2115	53.9	2341	71.5	1819	76.1	1854	90.7	1987	63.2
16	550	73.1	829	53.6	1326	65.8	2101	67.9	1236	99.7	1096	82.0
17	815	61.5	539	62.3	598	64.4	1278	76.9	937	104.4	845	90.5
18	417	93.9	415	121.2	858	56.5	866	93.2	558	118.2	1028	74.9
19	76	96.0	663	104.4	494	103.7	390	108.4	359	125.1	206	60.9
20	76	144.2	332	138.0	260	90.4	433	98.2	359	128.3	320	112.5
21	57	96.3	290	96.4	26	184.4	260	94.0	80	152.7	23	184.4
22	76	139.3	124	97.6	—	—	65	131.1	20	218.3	—	—
23	—	—	41	218.3	52	115.8	217	98.9	80	140.6	46	115.8
24	19	168.9	—	—	26	236.9	22	200.8	—	—	—	—
25	38	76.0	83	200.8	—	—	65	127.8	20	218.3	46	104.5
26	—	—	41	184.4	—	—	87	112.6	—	—	—	—
27	—	—	—	—	—	—	—	—	—	—	—	—
28	—	—	—	—	—	—	—	—	—	—	—	—
29	19	46.3	—	—	—	—	—	—	—	—	—	—
30	—	—	—	—	—	—	—	—	—	—	—	—

Appendix Table 8 (continued).

Age	1957 No.	1957 Av. Wt.	1958 No.	1958 Av. Wt.
4	45	12.6	—	—
5	75	9.5	32	8.3
6	1273	13.7	408	11.9
7	1782	15.6	2616	18.8
8	2351	24.0	3305	23.5
9	2381	31.4	3686	31.6
10	2082	36.5	3861	39.3
11	3909	46.8	2764	46.4
12	1618	56.1	4263	58.0
13	3565	67.4	2166	68.4
14	2636	73.6	3829	72.1
15	1887	72.4	1737	79.0
16	1453	80.8	1313	81.1
17	509	105.9	620	90.1
18	524	92.6	471	100.7
19	180	99.8	249	100.2
20	120	142.9	265	105.9
21	15	168.9	180	110.8
22	—	—	32	168.7
23	—	—	21	185.0
24	—	—	37	162.7
25	30	209.6	11	116.0

Appendix Table 9. Number of fish per 10,000 skates and average weight at each age for Bering Sea Edge in 1956 and 1958.

Age	June 1956 No.	June 1956 Av. Wt.	June 1958 No.	June 1958 Av. Wt.
5	112	2.0	—	—
6	224	5.1	—	—
7	869	9.5	200	11.1
8	2214	13.2	1625	13.5
9	2466	17.6	3205	18.5
10	7062	24.6	7256	23.3
11	5773	30.8	6722	27.8
12	17822	34.4	8903	32.5
13	10789	39.8	5854	38.7
14	11517	41.2	7523	40.7
15	7454	42.6	4719	37.8
16	5633	49.3	3539	39.7
17	4708	54.0	3094	37.8
18	5464	49.3	3227	39.3
19	3615	56.5	2894	47.6
20	4119	61.7	3094	58.6
21	3195	58.3	1847	46.4
22	1289	62.5	623	68.8
23	1541	70.4	579	69.7
24	672	75.1	423	73.7
25	897	81.6	200	59.1
26	392	84.9	267	74.3
27	364	89.7	22	116.0
28	280	100.5	223	55.1
29	140	97.1	—	—
30	196	97.1	—	—
31	168	94.4	22	128.0
32	—	—	44	84.5

Appendix Table 10. Number of fish at each age for various grounds in Area 3 in various years.

Age	Portlock 1927	Shumagin 1929	Shumagin 1950	Yakutat 1951	Bering Sea 1956
4	11	3	—	—	—
5	115	16	—	8	4
6	226	47	39	10	8
7	199	168	40	17	31
8	279	171	138	30	79
9	348	215	179	112	88
10	298	269	264	158	252
11	328	377	261	320	206
12	345	340	106	337	636
13	342	149	50	480	385
14	281	77	41	394	411
15	137	62	15	255	266
16	62	30	11	171	201
17	32	15	7	68	168
18	28	29	6	47	195
19	32	25	—	25	129
20	5	7	1	24	147
21	11	7	2	19	114
22	7	3	1	4	46
23	3	4	—	5	55
24	2	3	—	4	24
25	—	—	—	1	32
26	1	—	—	—	14
27	—	—	—	—	13
28	—	—	—	—	10
29	—	—	—	—	5
30	—	—	—	—	7
31	—	—	—	—	6

Appendix Table 11. Age groups used in calculation* of the Goose Islands mortality rates.

Between Years	Age Groups 8-9	9-10	10-11	11-12	12-13	Av. i
1935-36	—	x	x	x	—	1.11
1936-37	—	x	x	x	—	.31
1937-38	—	x	x	x	—	.46
1938-39	—	x	x	x	—	.91
1939-40	—	x	x	x	—	.19
1940-41	—	x	x	x	—	.82
1941-42	—	x	x	x	—	.36
1942-43	—	x	x	x	—	.84
1943-44	—	x	x	x	—	.09
1944-45	—	x	x	x	—	1.42
1945-46	—	x	x	x	—	.10
1946-47	—	x	x	x	—	.20
1947-48	—	x	x	x	—	.78
1948-49	—	x	x	x	—	.20
1949-50	—	x	x	x	—	.58
1950-51	—	x	x	x	—	.67
1951-52	—	x	x	x	—	.10
1952-53	—	x	x	x	—	.17
1953-54	—	x	x	x	—	.62
1954-55	—	x	x	x	—	.76
1955-56	—	x	x	x	—	.58
1956-57	—	x	x	x	—	.78
1957-58	—	x	x	x	—	.42

*Using Equation 2.

Appendix Table 12. Age groups used in calculation* of the Goose Islands mortality rates.

Between Years	Age Groups 8-10	9-11	10-12	Av. i
1935-37	—	x	—	.77
1936-38	—	x	—	.36
1937-39	—	x	—	.78
1938-40	—	x	—	.74
1939-41	—	x	—	.61
1940-42	—	x	—	.56
1941-43	—	x	—	.90
1942-44	—	x	—	.52
1943-45	—	x	—	.85
1944-46	—	x	—	.64
1945-47	—	x	—	.23
1946-48	—	x	—	.69
1947-49	—	x	—	.35
1948-50	—	x	—	.54
1949-51	—	x	—	.54
1950-52**	—	—	—	—
1951-53	—	—	x	.14
1952-54	—	—	x	.37
1953-55	—	—	x	.90
1954-56	—	—	x	.64
1955-57	—	—	x	.77
1956-58	—	—	x	.68

* Using Equation 3.
**Change in age groups used.

Appendix Table 13. Age groups used in calculation* of Hecate Strait mortality rates.

Between Years	Age Groups 8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	Av. i
1950-51	—	—	x	x	x	x	x	—	.44
1951-52	—	—	—	x	x	x	x	—	.64
1952-53	x	x	x	x	—	x	—	—	.31
1953-54	—	—	x	x	x	x	x	—	.62
1954-55	—	—	x	x	x	x	x	—	.21
1955-56	—	—	x	x	x	x	x	—	.54
1956-57	—	—	x	x	x	x	x	—	.84
1957-58	—	—	x	x	x	x	x	x	.09

*Using Equation 2.

Appendix Table 14. Age groups used in calculations* of Portlock-Albatross mortality rates.

Between Years	Age Groups 13-14	14-15	15-16	16-17	17-18	18-19	19-20	Av. i
1935-36	x	x	x	x	x	x	x	.22
1936-37	x	x	x	x	x	x	x	.54
1937-38	x	x	x	x	x	x	x	.94
1938-39	x	x	x	x	x	x	x	.76
1939-40	x	x	x	x	x	x	x	.15
1940-41	x	x	x	x	x	x	x	.27
1941-42	x	x	x	x	x	x	x	.76
1942-43	x	x	x	x	x	x	x	.63
1943-44	x	x	x	x	x	x	x	.10
1944-49			no samples					
1949-50	x	x	x	x	x	x	x	.58
1950-51	x	x	x	x	x	x	x	1.42
1951-52	x	x	x	x	x	x	x	**
1952-53	x	x	x	x	x	x	x	.82
1953-54	x	x	x	x	x	x	x	.37
1954-55	x	x	x	x	x	x	x	.53
1955-56	x	x	x	x	x	x	x	.60
1956-57	x	x	x	x	x	x	x	.25
1957-58	x	x	x	x	x	x	x	.26

* Using Equation 2.
**Negative value.

Appendix Table 15. Age groups used in calculation* of Shumagin Islands mortality rates.

Between Years	Age Groups 10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	Av. i
1950-52	x	x	x	x	x	x	x	x	x	x	—	.34
1952-53	—	—	x	x	x	x	x	—	—	x	—	.51
1953-54	x	x	x	x	x	x	x	x	—	x	—	.40
1954-55	—	—	x	x	x	x	x	x	x	x	—	.43
1955-56	—	x	x	x	x	x	x	—	x	x	—	.34
1956-57	—	x	x	x	x	x	x	x	x	x	—	.54
1957-58	—	—	—	—	x	x	x	x	x	x	x	.49

*Using Equation 3, 1950-52, and Equation 2, 1952-1958.

Appendix Table 16. Calculated thousands of skates fished on various grounds in various years.

Year	Goose Islands	Lower Hecate	Upper Hecate	Portlock-Albatross	Shumagin Islands	Total Area 3
1925	—	—	—	91*	48	283
6	—	—	—	97*	57	282
7	—	—	—	110*	80	357
8	—	—	—	123*	66	384
9	71	—	—	140	114	431
1930	76	—	—	129	124	425
1	93	—	—	90	93	305
2	83	—	—	80	56	265
3	52	—	—	82	44	284
4	50	—	—	87	47	272
1935	48	—	—	69	38	241
6	51	—	—	67	48	250
7	43	—	—	63	39	211
8	54	—	—	58	37	212
9	87	—	—	63	32	201
1940	73	—	—	75	31	224
1	66	—	—	78	43	220
2	62	—	—	69	36	195
3	56	—	—	77	52	212
4	44	—	—	76	43	179
1945	39	—	—	88	67	222
6	41	—	—	94	65	250
7	38	—	—	73	51	236
8	40	—	—	81	59	239
9	34	—	—	97	65	272
1950	29	39	46	99	57	275
1	41	39	58	70	42	236
2	28	33	45	74	30	237
3	22	31	47	55	28	199
4	44	24	36	86	29	251
1955	45	14	30	70	44	244
6	40	20	29	71	54	238
7	30	25	32	76	57	236
8	27	17	27	67	54	218

*Estimated as same proportion of total Area 3 gear as in years 1929 and 1930.