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By GEORGE A. ROUNSEFELL
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RACES OF HERRING, *CLUPEA PALLASII*, IN SOUTHEASTERN ALASKA[1]

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INTRODUCTION

The reasons underlying this attempt to study the individuality and distribution of each population of herring are many, and for the most part, rather obvious. When a locality where herring have been abundant fails to produce its wonted supply, a question always arises as to the causes of such a failure. Aside from natural fluctuations in abundance or unusual unavailability to the fishermen, the apparent causes are migration or depletion. Without an intimate knowledge of the herring stocks either explanation is possible. For example, Whale Bay (Rounsefell, 1930, p. 238) on the outer coast of Baranof Island, produced a tremendous run of herring in 1925 but failed the following year. No herring have been caught in this bay since that time. It is now practically certain that this temporary run was caused by the summer herring schools that normally congregate about Cape Ommaney shifting farther north. On the other hand, the failure of the once important fishery in Kootznahoo Inlet, on Admiralty Island, may be fairly ascribed to depletion of the stocks from overfishing (Rounsefell, 1931, p. 35–36).

Only by an intimate knowledge of the areas inhabited by each stock of herring is it possible to know whether fishing in one area is affecting the supply in another. It may now be said with certainty, for instance, that the heavy fishing in lower Chatham Strait can in no wise be blamed for the scarcity of herring tvat has been noticeable for several years in the "inside" waters of Behm Canal, Ernest Sound, Zimovia Strait, and upper Frederick Sound (Rounsefell, 1930, p. 236, 237 and 307;

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Rounsefell, 1931, p. 35–36). The herring of these "inside" waters belong to populations quite distinct from those of Chatham Strait.

It is well known that different populations may exhibit different structural peculiarities owing to differences in environment or to differences in heredity arising during long periods of isolation. The study of the individuality of the populations has been based largely on these structural differences. Whether the differences in the characters chosen are due to heredity or to environment has not been considered as being of great importance, as long as the characters are fairly stable within each population so that significant differences indicate very slight intermingling, if any, between adjacent stocks of herring.

Success has finally been achieved for the direct method of tracing migrations by the release and recovery of tagged herring (Rounsefell and Dahlgren, 1933). This method may be called the direct method of racial investigation in contradistinction with the indirect method in which the movements or lack of movement of a population are inferred from the statistical analysis of morphological characters. Owing to the newness of this method which was first attempted in 1932, only a few results have been attained. Yet these few results offer such corroboration of our racial work as to inspire confidence in our results.

In the determination of the individuality of populations by indirect methods it was deemed advisable, profiting by the experience gained in the preliminary racial work (Rounsefell, 1930), to concentrate on vertebral counts. This was the more necessary, owing to the difficulty of securing enough samples of fresh herring from various localities in the nearly perfect condition necessary for body measurements. The rates of growth and relative abundance of year classes have also been employed as indicators of populational differences.

SPAWNING AND FEEDING LOCALITIES

At the present time there are 3, or perhaps 4, spawning areas in southeastern Alaska, where the herring may be counted upon to spawn in abundance each spring. (See fig. 1.) Of these, the spawning grounds in Sitka Sound, on the outside of Baranof Island are probably the largest. Those at the entrance to Klawak Inlet in San Alberto Bay are undoubtedly a close second, and those centering near Juneau in Stephens Passage are easily third. The spawning grounds in Kootznahoo Inlet were once of great importance but have declined.

As indicated in figure 1, there are a number of minor spawning grounds, a few of which were considered of importance in the past. There are certainly additional localities, not noted, where a few herring occasionally spawn.

It may be of interest to note here the distances between the four major spawning grounds. These distances, measured approximately from the centers of spawning, are as follows: Sitka to Craig (Klawak Inlet), 120 miles; Sitka to Kootznahoo Inlet, 70 miles by Peril Strait; Sitka to Kootznahoo Inlet, 140 miles by Cape Ommaney; Sitka to Juneau, 150 miles by Icy Strait; Sitka to Juneau, 120 miles by Peril Strait; Juneau to Kootznahoo Inlet, 65 miles; Craig to Kootznahoo Inlet, 140 miles; and Craig to Juneau, 210 miles.

It is difficult to theorize as to the significance of the considerable distance between any major spawning grounds. It may mean that some of the minor spawning grounds are used merely by occasional schools straying from the main body of herring of any particular race. On the other hand it may indicate that there are two kinds or types of herring populations. One type would be those races inhabiting the major spawning grounds, and, by inference, some of the minor spawning grounds of importance in the past. This type of race might be rather migratory in its habits, thus accounting for the distances between major spawning grounds. Many of the minor spawning grounds might then be inhabited by herring of local character, rather nonmigratory in habits. Such a type is suggested by the herring found spawning at the head of Gut Bay (see fig. 2) in the middle of June, at least 6 weeks after the normal cessation of spawning at Craig and Sitka. Such small bodies of herring might seldom stray from a single inlet or fiord. Possibly a herring population may change gradually from a nonmigratory to a migratory habit, or vice versa, according to its abundance, as spatial considerations are known to affect the migrations of mammals.

There are two quite distinct herring fisheries in southeastern Alaska—the minor fishery for halibut bait, carried on during the halibut fishing season throughout the whole area; and, secondly, the major fishery of the herring plants which produces salt herring and fish meal and oil. The second fishery operates only from June 1 to September 30 and its fishing operations are confined to the western portion of southeastern Alaska.

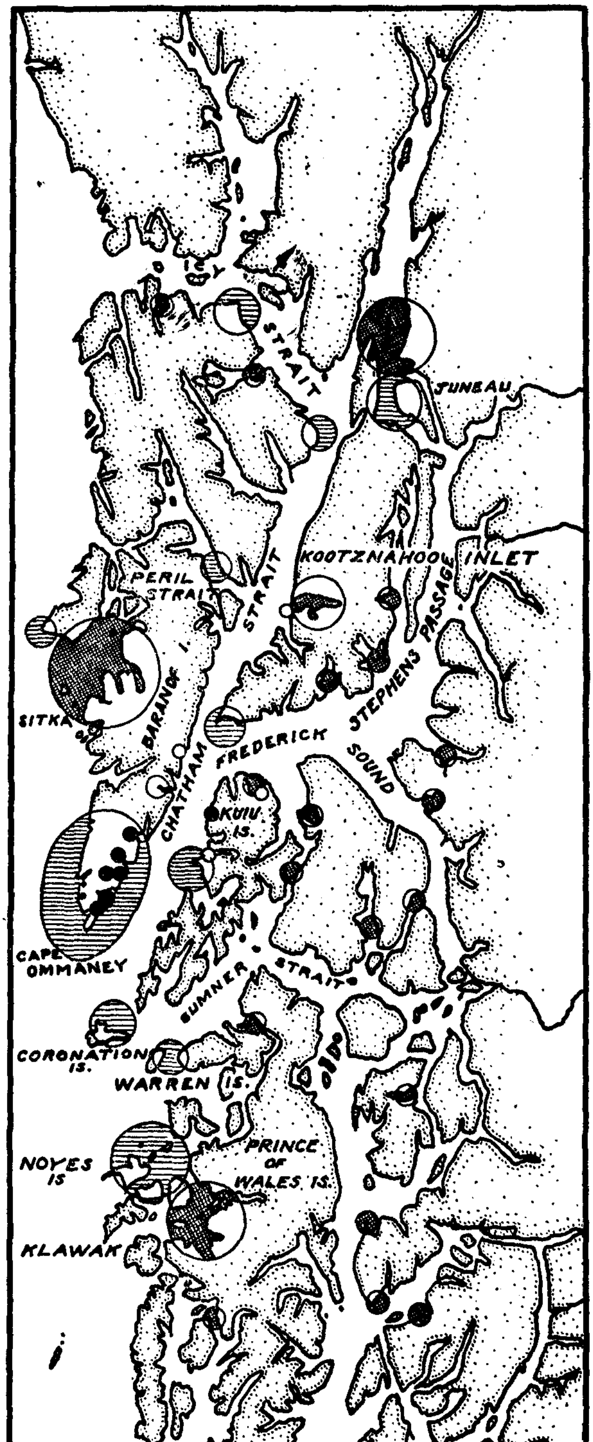

FIGURE 1.—Southeastern Alaska, showing spawning grounds and feeding grounds of herring. Cross-hatched areas indicate spawning grounds; horizontally barred areas indicate feeding grounds of importance to summer fishery of salt herring and fish oil and meal industry. The importance of both types of areas is roughly proportional to size of circles. Black dots show location of 7 herring plants operating in 1934; small circles give location of 4 herring plants remaining inactive in 1934.

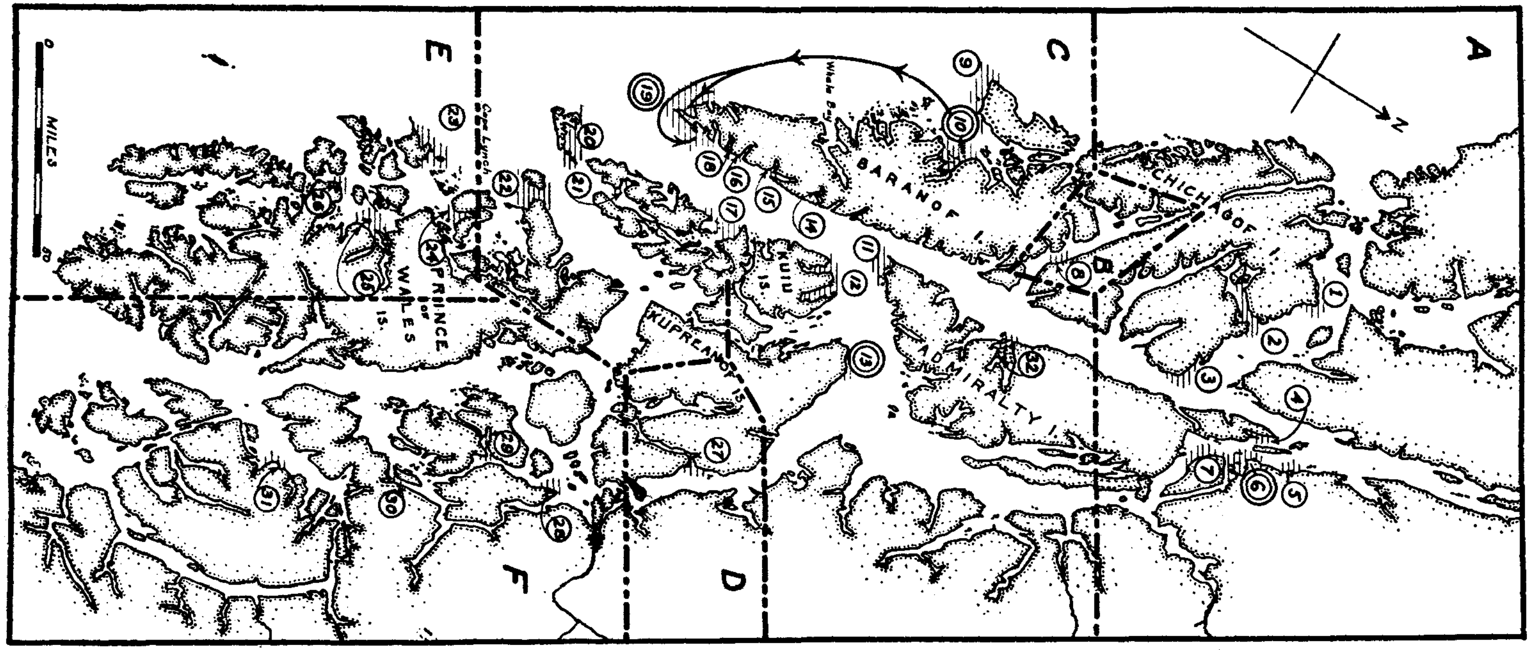

FIGURE 2.—Map of Southeastern Alaska. Heavy dot-and-dash lines separate areas whose herring populations have been shown to be independent. Circles indicate localities from which samples of not less than 50 vertebral counts were obtained from any 1-year class. Double circles indicate localities in which herring were also tagged and released. Main bodies of water are Chatham Strait—east of Baranof and Chichagof Islands; Icy Strait—north of Chichagof Island; Frederick Sound—south of Admiralty Island; Stephens Passage—east of Admiralty Island; Sumner Strait—north of Prince of Wales Island; Keku Strait—between Kupreanof and Kuiu Islands; Wrangell Narrows—very narrow channel east of Kupreanof Island and Clarence Strait east of Prince of Wales Island. Localities numbers in circles are as follows: 1. Point Adolphus, Icy Strait; 2. Hoonah, Icy Strait; 3. Point Augusta, Icy Strait at junction with Chatham Strait; 4. Barlow Cove, vicinity of Juneau; 5. Eagle Harbor, vicinity of Juneau; 6. Auke Bay, vicinity of Juneau (tagging locality); 7. Douglas Island, vicinity of Juneau; 8. Todd, Peril Strait; 9. Cape Edgecumbe, Kruzof Island; 10. Sitka, in Sitka Sound (tagging locality); 11. Point Gardner, junction of Chatham Strait and Frederick Sound (tagging locality); 12. Meade Point, Frederick Sound between Security and Saginaw Bays; 13. Cape Bendel, Frederick Sound (tagging locality); 14. Gut Bay, Chatham Strait; 15. Deep Cove, Chatham Strait; 16. Port Herbert, Chatham Strait; 17. Tebenkof Bay, Chatham Strait; 18. Big Port Walter, Chatham Strait; 19. Cape Ommaney, includes Larch Bay west of cape and Port Alexander and Port Conclusion east of cape (Port Conclusion a tagging locality); 20. Coronation Island, junction of Chatham Strait and Sumner Strait; 21. Kell Bay, Affleck Canal; 22. Warren Island, entrance to Sumner Strait; 23. Noyes Island, includes small islands between the Pacific and the Gulf of Esquibel; 24. Culebra Island, Gulf of Esquibel; 25. Klawak, San Alberto Bay; 26. Port Estrella; 27. Petersburg, junction of Wrangell Narrows and Frederick Sound; 28. Wrangell, eastern end of Sumner Strait; 29. Anita Bay, Zimovia Strait; 30. Santa Ana Inlet, Ernest Sound; 31. Frances Cove, Behm Canal, and 32. Favorite Bay, entrance to Kootznahoo Inlet, Chatham Strait.

This fishery has not in recent years been conducted eastward of a line from Juneau to Klawak, or south of Noyes Island. So closely is this fishery identified with Chatham Strait, the great waterway that extends with its continuation, Lynn Canal, for two-thirds the length of southeastern Alaska, that if a straight line is drawn down Chatham Strait and extended southward it will be noted that the summer fishery operates on both sides of this line from Noyes Island to Juneau, a distance of 180 miles, yet practically the entire catch is made within 35 miles of this line, the only exception being occasional fishing in Sitka Sound 65 miles from the line through Peril Strait.

These summer feeding grounds fished by the herring plants are shown in figure 1. The importance of each to the fishery is roughly indicated by the size of the circles. The most important fishing ground, by far, is the area surrounding Cape Ommaney, the southern tip of Baranof Island. This is due largely to the abundance of herring around the cape, but also, in some measure, to the proximity of the herring plants. Of the herring plants now in operation the one farthest from the cape is that at Washington Bay, on Kuiu Island, 35 miles distant; all of the others are on the eastern side of Baranof Island, 25 miles being the greatest distance any of them are from Cape Ommaney. (See fig. 1.)

The area along the north shore of Noyes Island, including the waters surrounding the Maurelle Islands, is another great herring feeding ground. Tebenkof Bay, Coronation Island, and Warren Island also contribute a share of the catcn, but their importance fluctuates, some years being practically blanks (Rounsefell, 1931). The feeding grounds at the juncture of Frederick Sound and Chatham Strait were once important fishing grounds but have declined tremendously (Rounsefell, 1931, pp. 33 and 34) and are now of minor importance. The feeding grounds in Icy Strait and near Juneau in Stephens Passage are heavy producers of herring on occasion, but are too distant from the plants to warrant fishing when herring are abundant elsewhere.

Analyses of the catch statistics to determine the relative abundance on these various spawning and feeding grounds cannot be accurately made without knowledge of the interrelationships of the populations inhabiting different areas. The next section takes up a discussion of the methods of determining the individuality of these populations by means of the vertebral count.

ANALYSIS OF VERTEBRAL COUNTS

DISCUSSION OF FACTORS INFLUENCING VERTEBRAL COUNT DISTRIBUTIONS WITHIN A POPULATION

In an earlier report on the herring of Prince William Sound (Rounsefell and Dahlgren, 1932) it was shown that a high negative correlation (in that case −0.85) exists between the average temperature during the developmental period and the average number of vertebrae in different year classes or "brood years" of herring from the same locality. Comparison of the means of samples of herring without division into year classes is thus shown to introduce variation other than that expected in random sampling. Therefore all of our samples have been divided into year classes so that only vertebral counts of herring hatched during the same spring are compared.

The vertebral count of samples of a year class caught in any one year could not be compared with samples of the same year class taken during ensuing years without showing that there was not, due to selection, a tendency for the mean vertebral count to rise or fall with advancing age. To determine this point, samples of the 1926 and 1927 year classes from eight localities, caught in their fourth summer, were compared with samples of the same year classes from the same localities taken during their fifth summer (neglecting samples of less than 25). Between the two series the average difference in vertebral count was 0.042, which was obviously of no significance as the chances were 1 in 8 that the means were the same.[2] (See table 1.)

Having thus failed to note any correlation between age and number of vertebrae in our samples, the means of the 4-year-olds of each year class were compared with the means of the 5-year-olds for the same year classes in each of the eight localities. Of these eight comparisons, none showed a significant difference,[3] although one might be regarded as doubtful, the chances being 1 in 25 that the two means are the same.

TABLE 1.—*Means of vertebral counts of 1926 and 1927 year classes from various localities compared at 4 and at 5 years of age*

Locality	Year class	Mean		Difference	Locality	Year class	Mean		Difference
		Age 4	Age 5				Age 4	Age 5	
Inside Cape Ommaney	1926	52.411	52.408	0.003	Hoonah	1926	52.364	52.474	−0.110
Larch Bay	1927	52.573	52.750	−.177	Petersburg	1927	52.488	52.408	.080
Do	1926	52.478	52.433	.045	Do	1926	52.147	52.253	−.106
Coronation Island	1926	52.404	52.482	−.078					
Point Gardner	1926	52.472	52.464	.008	Average		52.417	52.459	−.042

To determine if sex had any effect on the number of vertebrae, the mean vertebral count for both sexes was determined for each of a series of 24 samples of the 1926 year class caught during the summer of 1930 at Larch Bay, containing 491 males and 493 females. The mean of the 24 unweighted means for males was 52.431; for females, 52.435. The difference between these means was of no statistical significance. In making this comparison, the means of the males and of the females were not weighted because the presence of more than one population amongst the samples would then cause a weighting of the data according to the number of individuals in the samples.

EXISTENCE OF RACES PROVEN BY HETEROGENEITY OF SAMPLES FROM ALL LOCALITIES

Proof of the existence of independent stocks of herring is furnished by an analysis of the averages of all samples of vertebral counts of herring of the 1926 year class in southeastern Alaska. (See table 3 for total samples of each locality.) The object of this analysis is to prove whether or not all of the samples could have been drawn from the same population. From localities where many samples are available some of the samples are statistically different from others. This is to be expected according to the laws of probability. Before comparing the samples of one locality with those from another, it is essential that it be known whether any differences found may be due merely to such expected random variation or may be ascribed to a difference between the populations from which the samples are drawn. Therefore, it was necessary to test the data as a whole to determine if all of the samples could have been drawn from one population.

[2] Quoting from Fisher (1930, p. 111), "In cases in which each observation of one series corresponds in some respects to a particular observation of the second series, it is always legitimate to take the differences and test them * * *". In this method the test shows whether the mean difference differs significantly from O, which is taken successively as each mean of the first series. t is the mean difference divided by its standard error, which in this case was 1.54 which yields a probability of 0.12 or approximately 1 to 8.

[3] This method of comparison is explained by Fisher (1930, p. 107), see section on "Segregation of races." Probability was 0.04 or 1 to 25.

The method used in testing the homogeneity of the means of all of the samples is merely an extension of the method of comparison of two means to the comparison of several means. This method is called the "Analysis of variance" by Fisher (1930, p. 196). Wollaston (1933) in an article in the Journal du Conseil, with a foreword by R. A. Fisher, expounds the use of this method and its applicability to herring race problems. Quoting from Wollaston:

There are two fundamentally different ways of approaching observational scientific data. The first is to lay out the data as graphically as possible and see what they suggest; the second, to formulate, without examining the data in detail, hypotheses which the data may be expected to prove or disprove, and then to test the agreement of the data with the hypotheses. The first result remains but a suggestion, and the actuality of the suggested phenomena cannot be stated in terms of probability. The second allows definite statement of probability that the hypotheses are true or not true. The great majority of fishery workers, including Dr. Schnakenbeck in his work criticized in this paper, have adopted the first way. His conclusions may be right, but his method of approach, which I will call the *a posteriori* method, includes no test whatever as to the probability of his being right.

* * * * * * *

Sound statistical tests of probability can *only* be applied to data treated in the second way. It is even better to formulate hypotheses to be tested by the data before these are collected than to do so before they are worked up. The research can then be given the exactness of pure experimental science, giving equally definite positive or negative results.

* * * * * * *

The main object of this paper is to introduce into fishery research some of the most important methods developed by R. A. Fisher, of Rothamsted Laboratory. These are offered as alternative and far preferable to empirical methods which take no account of the variability which occurs between samples drawn from a larger population. For the purpose in question I have used the data collected by Dr. Schnakenbeck from the North Sea, and I propose to show that Dr. Fisher's methods are perfectly adequate to deal with such data and to extract all the information from them which they are capable of giving. As I have not had access to subsidiary data, collected by other workers and used by Dr. Schnakenbeck in his report, it cannot be said definitely whether these would have modified my conclusions and brought them more nearly into line with Schnakenbeck's. It is hoped that all available data bearing on the herring race question will eventually be combined in a complete statistical analysis on the lines laid down here. This must be considered merely as an introduction to such analysis.

* * * * * * *

Though the mathematical theory on which the present paper is founded is somewhat advanced, the methods introduced herein are very simple in application. The first part deals almost exclusively with Fisher's methods for finding the best-fitting Curve of Error to fit to highly grouped data. Readers who have not to deal with such data may prefer to omit this part. The second part (from p. 23 on) deals with Fisher's method of the Analysis of Variance, which is of almost universal application in testing the significance of variations in any phenomenon under different conditions. There is no other method so ideally fitted for this kind of test. This second part will be therefore found worth reading by anyone who is engaged in fishery research and who is not familiar with Fisher's work. Every step in the application of the method to the present problem is shown in detail, and described as far as possible in nonmathematical language.

* * * * * * *

We have then an ideal set of conditions for the application of Fisher's Analysis of Variance,[4] which is a powerful weapon for distinguishing between real differences between samples and those which are probably due to variation "within samples."

[4] The term "Analysis of Variance" is somewhat misleading. It is the total sum of squares which is analyzed. If, however, each estimate of variance is considered as weighted by its degrees of freedom, the term Analysis of Variance is quite correct, as will be seen later.

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This is not the place to give a full description of the Analysis of Variance, but I propose to discuss shortly in nonmathematical language the assumptions on which it is founded, since I did not myself find Fisher's own description (Fisher (4)) very easy to follow, nor do I consider that the logical bases of the method were sufficiently emphasized in the work cited.

Supposing then for the moment that every single one of our vertebral counts is a sample from a strictly normal population of vertebral counts, we can take *at random* from the whole set of counts any given number of counts n_1', and calculate for the set the mean number $\bar{x}_1$, and the variance, $\frac{S(x_1-\bar{x}_1)^2}{n_1}$ where $n_1=n_1'-1$. This variance, which we will call S_1^2, is an *estimate* of the variance σ^2 of the whole population, founded on the number of degrees of freedom n_1. The term degrees of freedom means the number of ways in which the frequencies of the counts may be varied at will, provided that given fixed relations between the data are adhered to. In calculating S_1^2 we have used $\bar{x}_1$ as an estimate of the true mean, $\bar{x}_1$ being calculated from the data themselves. As $\bar{x}_1$, or the sum of all the n_1' x_1's, is fixed, only $n_1'-1$ of them may be varied at will, the last being fixed by the sum of the $n_1'-1$, whatever its value.

We can take any other random sample of n'_r counts and obtain another estimate s^2_r of the variance σ^2, based on n_r degrees of freedom. We can also obtain s^2_t from our total set of N' counts and this is an estimate of σ^2 based on $N'-1$ degrees of freedom. All these values of s^2 may be shown to be *efficient* estimates of σ^2, provided that our total set of counts is normally distributed, and our choice of subsamples is strictly random and not influenced in any way by the counts themselves. Besides these groups of counts chosen singly, we may separate all the counts into any number of n's of sets, containing, say, $n'_1, n'_2 \ldots n'_r$ counts, and find their means $\bar{x}_1, \bar{x}_2 \ldots \bar{x}_r$. Then, if $\bar{\bar{x}}$ be the grand mean of all the counts,

$$\frac{n'_1(\bar{x}_1-\bar{\bar{x}})^2+n'_2(\bar{x}_2-\bar{\bar{x}})^2+\ldots+n'_r(\bar{x}_r-\bar{\bar{x}})^2}{n'_s-1}$$

or

$$\frac{Sn_p(\bar{x}_p-\bar{\bar{x}})^2}{n'_s-1}$$

is an estimate of σ^2, based on n_s degrees of freedom. We have here assumed that the individual counts in each set are concentrated at their means, and used the weighted means instead of the individual counts. This is perfectly allowable if the sets are random samples from a normal population.

Thus we may *analyse* the total sum of squares in many ways on the assumption of normal distribution, the various sums of squares being divided (within errors of random sampling) proportionately to the degrees of freedom involved.

Fisher has shown that if

$$z=\log_\epsilon\sqrt{\frac{s^2_m}{s^2_n}} \text{ or } 1/2(\log_\epsilon s^2_m-\log_\epsilon s^2_n)$$

when s^2_m and s^2_n are two estimates of σ^2 based on m and n degrees of freedom respectively, then z is distributed in a known manner. If the value of z, found from two estimates of σ^2, calculated from data, lies too far away from the centre of this distribution, it may be reasonably concluded that s^2_m and s^2_n are *not* estimates of the *same* variance σ^2, indicating that the samples from which they were calculated were not randomly chosen but show an effect of the method of choice. This is the fundamental principle of the Analysis of Variance, but some of its applications involve very complex parceling of the data into groups, and groups within groups. In all these cases, the method is used to test suspected effects of particular ways of parceling the data, causing differences between some groups or means etc., and others, allowance being made automatically for variance *within* groups, i. e., for differences between the parcels which could arise by chance. The z-test offers a sound criterion for judgment as to whether the suspected effects are real or not, without personal opinions having the slightest influence on our judgment. The distribution of z is a function of n_m and n_n, the degrees of freedom involved in the two estimates of σ^2 to be compared. Fisher has tabulated (4) the 5% points and 1% points in the z-distribution for various values of n_m and n_n. If our value of z lies outside the 5% points, the two variances s^2_m and s^2_n are considered significantly different; if z is outside the 1% point, the difference is considered doubly significant, as a value of z beyond our value would only occur by chance, if s^2_m and s^2_n are not really different, 1 in 20 times in the former case and 1 in 100 times in the latter. The main advantage of using variance as a measure of variability lies in the additive property of the sums of squares, and of the degrees of freedom. Thus we may add together $S(x_m - \bar{x}_m)^2$ and $S(x_n - \bar{x}_n)^2$ and obtain an efficient estimate of σ^2 founded on $n_m - n_n$ degrees of freedom, or we may divide our whole sample of counts into n'_s sets, with $n'_1, n'_2 \ldots n'_r$ counts in the different sets, as we did when considering weighted means and obtain

$$\frac{S(x_1-\bar{x}_1)^2+S(x_2-\bar{x}_2)^2+\ldots+S(x_r-\bar{x}_r)^2}{n+n_2+\ldots n_r}$$

or $\frac{SS(x_p-\bar{x}_p)^2}{N'-r}$ as an estimate of σ^2 based on $N'-r$ degrees of freedom. This last estimate is usually called the variance "within classes" while that based on weighted means is called the variance "between classes." It should be mentioned that, in adding the sums of squares about the group means and dividing by the total number of degrees of freedom involved, we are assuming that the variances *within* the different groups are not significantly different. If significant differences are suspected, the *z*-test should be applied, since the Analysis of Variance is not sound if such differences are found.[5]

To clarify the exact steps in testing the data on the hypothesis of homogeneity, the following table has been inserted:

TABLE 2.—*Analysis of vertebral counts of samples of the 1926 class year from Noyes Island (see 23, fig. 2) to illustrate method of testing for homogeneity of the population*

A	B	C	D	E	F	G
June 21, 1930	51.786	14	—0.402	0.161604	2.262456	6.357
Do	52.250	24	.062	.003844	.092256	12.500
June 23, 1930	52.348	23	.160	.025600	.588800	15.217
June 24, 1930	52.226	31	.038	.001444	.044764	13.419
Do	52.000	9	—.188	.035344	.318096	2.000
June 27, 1930	51.857	7	—.331	.109561	.766927	2.857
June 28, 1930	52.240	25	.052	.002704	.067600	10.560
July 18, 1930	52.231	39	.043	.001521	.059319	16.923
July 28, 1930	52.214	14	.026	.000676	.009464	4.357
Total		186			4.209682	84.190

NOTE.—General mean, 52.188; column A, date of sampling; column B, mean of sample; column C, number in sample; column D, column B minus general mean; column E, column D squared; column F, column C times column E; and column G, sum of squared deviations from mean of sample.

Variance	Degrees of freedom	Sum of squares	Mean square	Loge mean square
Between arrays	8	4.209682	0.5262	—0.6420
Within arrays	177	84.190	.4756	—.7433

Difference	0.1013
Observed z (half of difference) [6]	.0507
Calculated z for probability of 0.05 [6]	.3322

[5] The variance "within classes" is the weighted mean of all the sample variances, the weights being the numbers of counts in the samples, less one in each case.

[6] The value of observed z being less than that of calculated z (methods of calculating z are given by Fisher, 1930, p. 201) at a probability of 0.05 shows the population to be homogeneous.

TABLE 3.—*Vertebral distributions for various year classes from all localities*

[Data from 1928 to 1931; no samples under 50 included]

Locality	Year class	Number of vertebrae [1]									No.	Mean	$S(x-\bar{x})$ [1]
		47	48	49	50	51	52	53	54	55			
Vicinity of Juneau	1923	1		2	4	75	446	334	45	2	909	52.370	541.802
Sitka Sound	1923					1	21	38	8		68	52.779	29.691
Vicinity of Juneau	1924			1		7	31	31	4		74	52.392	51.635
Wrangell	1924				1	12	32	13	2		60	52.050	36.850
Sitka Sound	1924					2	24	33	3		62	52.597	24.919
Fish Egg Island	1924					7	51	24	5		87	52.311	42.621
Vicinity of Juneau	1925			1	1	15	61	54	4	1	137	52.328	92.219
Petersburg	1925					16	61	43	4		124	52.282	65.121
Wrangell	1925				1	27	104	50	5		187	52.166	95.861
Tebenkof Bay	1925		1			5	29	44	7		86	52.570	85.081
Cape Ommaney	1925						25	42	3		70	52.686	21.086
Vicinity of Juneau	1926				1	37	183	150	18		389	52.378	207.450
Point Augusta	1926					9	53	40	2		104	52.337	45.221
Hoonah	1926					4	37	26	4		71	52.423	33.324
Point Adolphus	1926					8	27	18	2		55	52.255	30.436
Favorite Bay	1926					2	27	25	3		57	52.509	24.246
Point Gardner	1926					10	89	81	9		189	52.471	85.090
Petersburg	1926			1	3	64	274	144	7	1	494	52.178	250.324
Wrangell	1926				3	37	67	35	1		143	51.958	87.748
Jamestown Bay	1926			1		8	37	36	4	1	87	52.414	63.103
Cape Edgecumbe	1926					21	84	81	7		193	52.384	101.627
Deep Cove	1926					9	48	26	3		86	52.267	40.849
Port Herbert	1926				1	7	66	37	5		116	52.328	55.552
Big Port Walter	1926					4	36	44			84	52.476	28.952
Tebenkof Bay	1926				3	24	197	171	16		411	52.421	198.180
Cape Ommaney	1926			3	10	141	1,013	877	97	2	2,143	52.423	1,107.123
Coronation Island	1926					22	221	186	19	1	449	52.457	199.403
Warren Island	1926		1	1	1	21	190	145	8		367	52.357	156.371
Kell Bay	1926			1		9	36	27	1		74	52.230	45.095
Noyes Island	1926				1	25	100	58	2		186	52.188	88.414
Port Estrella	1926					8	34	11		1	54	52.111	27.333
Meade Point	1926					2	20	25	4		51	52.608	24.157
Vicinity of Juneau	1927			1	1	11	77	64	11	1	166	52.440	108.898
Point Augusta	1927					6	28	26	7	1	68	52.544	48.868
Hoonah	1927			1	3	20	97	83	15	1	220	52.395	158.595
Point Adolphus	1927				1	7	32	27	1		68	52.294	36.118
Todd	1927			1		13	75	62	9		160	52.394	102.194
Petersburg	1927			1	1	29	245	212	36	2	526	52.487	291.407
Wrangell	1927					6	30	23	5		64	52.422	37.609
Anita Bay	1927					2	29	24	4		59	52.508	26.746
Port Herbert	1927					13	23	18	6		60	52.283	50.183
Gut Bay	1927			1		5	46	21	5		78	52.295	48.218
Cape Ommaney	1927				1	11	134	193	22	1	362	52.627	162.655
Warren Island	1927					1	37	41	3	1	83	52.590	34.072
Culebra Island	1927				1	4	27	21	2		55	52.346	30.436
Noyes Island	1927					17	104	81	3		205	52.342	86.098
Klawak	1927					6	33	19	1		59	52.254	25.186
Hoonah	1928					2	24	47	11		84	52.798	39.560
Anita Bay	1928					20	113	63	4		200	52.255	85.995
Santa Ana Inlet	1928					13	80	40	4		137	52.255	60.058
Frances Cove	1928					11	71	32	2		116	52.216	45.612
Gut Bay	1928					4	26	24	4		58	52.483	30.483
Gut Bay	1929					10	28	26			64	52.250	32.000
Cape Bendel	1929				1	16	107	63	7		194	52.304	93.057

[1] Excluding the hypural.

In using this method, as pointed out by Wollaston, the distribution of the variances of the samples must approach normality. Accordingly, before analyzing these samples their variances were tabulated, table 4, and the 4 samples indicated were discarded, their variances obviously being far outside of the normal range. A test of the homogeneity of the remaining 158 samples, comprising 5,964 vertebral counts showed definitely that these samples could not all have been drawn from the same population, since the observed z of 0.3387 far exceeds 0.1256, the value of z calculated at a probability of 0.01.

Therefore, it must be concluded that the herring of southeastern Alaska are composed of more than one population.

TABLE 4.—*Frequency of variances of 162 individual samples of the vertebral count from various localities in southeastern Alaska*

Variance	Number	Variance	Number	Variance	Number	Variance	Number
0.1600-0.2300	1	0.5600-0.6300	19	0.9600-1.0300		1.3600-1.4300	[1] 2
0.2400-0.3100	16	0.6400-0.7100	15	1.0400-1.1100		1.4400-1.5100	[1] 1
0.3200-0.3900	25	0.7200-0.7900	9	1.1200-1.1900		1.5200-1.6000	
0.4000-0.4700	38	0.8000-0.8700	3	1.2000-1.2700	[1] 1		
0.4800-0.5500	30	0.8800-0.9500	2	1.2800-1.3500			

[1] These samples omitted in analysis of variance.

HOMOGENEITY OF MATERIAL FROM INDIVIDUAL LOCALITIES

Evidence tending to prove a lack of admixture in the samples from the individual localities is shown in table 5, in which a test of the homogeneity of samples of the vertebral count of the 1926 year class has been made for each of the 7 localities from which sufficient data were available for such a test. In contrast to the results obtained when the southeastern Alaska material was considered as a whole, none of the 7 localities have an observed z exceeding the value of the calculated z at a probability of 0.05, indicating the homogeneity of the population sampled in each locality.

However, the observed z for the Warren Island samples, 0.2768, is only slightly less than that of the calculated, 0.3448, for a probability of 0.05. Therefore the Warren Island samples must be regarded with some suspicion, especially as the proportion the observed z forms of the calculated z is larger in the Warren Island samples than in those from the other localities.

TABLE 5.—*Analysis of variance of vertebral count samples of the 1926 year class from various localities in southeastern Alaska taken from 1929 to 1931, inclusive*

Locality	Mean	Number	Number of samples	Mean square		Observed z	Calculated z for probability of 0.05 [1]
				Between arrays	Within arrays		
Cape Ommaney	52.423	2,143	60	0.6465	0.5247	0.1044	0.1414
Tebenkof Bay	52.421	411	19	.4215	.4862	.0714	.3279
Coronation Island	52.457	449	12	.3828	.4467	.0785	.4409
Warren Island	52.357	367	8	.8397	.4829	.2768	.3448
Point Gardner	52.471	189	6	.6426	.4474	.1810	.4052
Noyes Island	52.188	186	9	.5262	.4756	.0507	.3322
Vicinity of Juneau	52.378	389	11	.6977	.5304	.1370	.3054

[1] The observed value of z is less than the calculated value at a probability of 0.05 in every case, thus showing that the population of each locality is homogeneous.

SEGREGATION OF RACES

Since the above evidence supports the hypothesis that the population of each locality is homogeneous, the vertebral counts from each locality have been compared to those of adjacent localities. (See fig. 3 and tables 3 and 6.) Only counts of fish of the same year class have been compared, necessitating the limiting of samples to those containing 50 or more counts. Smaller samples were not used, owing to the probability that occasional errors enter into our age determinations.

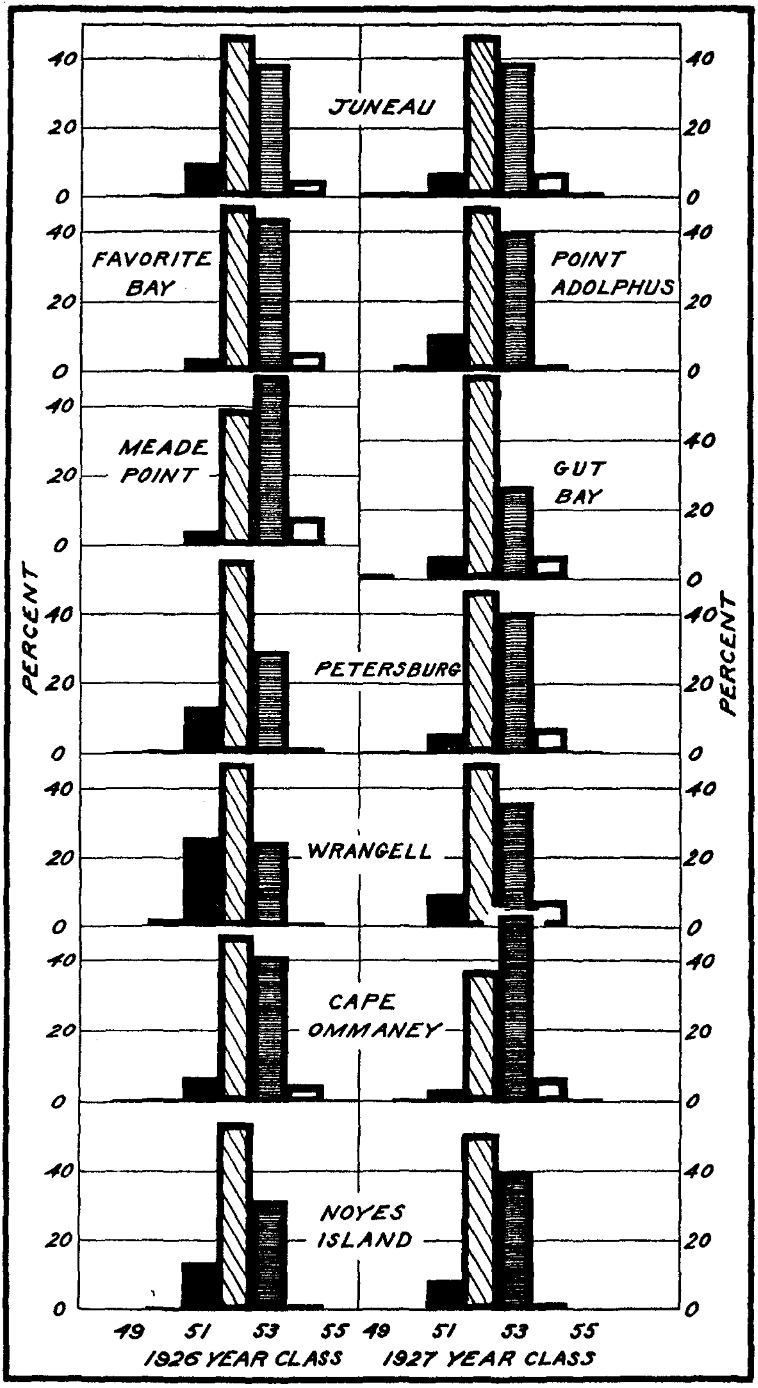

FIGURE 3.—Percentage vertebral count distributions of 1926 and 1927 year classes from some of chief localities.

TABLE 6.—*Comparisons of the means of the vertebral counts of each year class in southeastern Alaska*

Localities compared	Year class	Difference between means	Summation of populations	Standard error of difference between means	Difference between means divided by standard error
Juneau and Point Augusta	1927	0.104	234	0.119	0.87
Do	1926	.041	493	.079	.52
Juneau and Hoonah	1927	.045	386	.086	.52
Do	1926	.045	460	.094	.48
Juneau and Petersburg	1927	.047	692	.068	.69
Do	1926	.200	883	.049	[1] 4.08
Do	1925	.046	261	.097	.47
Juneau and Point Gardner	1926	.093	578	.062	1.50
Hoonah and Point Adolphus	1927	.101	288	.114	.89
Do	1926	.168	126	.129	1.30
Hoonah and Point Augusta	1927	.149	288	.118	1.26
Do	1926	.086	175	.104	.83
Favorite Bay and Point Augusta	1926	.172	161	.109	1.58
Favorite Bay and Point Gardner	1926	.038	246	.101	.38
Todd and Point Augusta	1927	.150	228	.118	1.27
Todd and Gut Bay	1927	.099	238	.110	.90
Point Gardner and Petersburg	1926	.293	683	.060	[1] 4.88
Point Gardner and Meade Point	1926	.137	240	.107	1.28
Point Gardner and Deep Cove	1926	.204	275	.088	[2] 2.32
Point Gardner and Tebenkof Bay	1926	.050	600	.060	.83
Meade Point and Petersburg	1926	.430	545	.104	[1] 4.13
Meade Point and Tebenkof Bay	1926	.187	462	.103	1.82
Meade Point and Deep Cove	1926	.341	137	.122	[1] 2.80
Tebenkof Bay and Deep Cove	1926	.154	497	.082	1.88
Tebenkof Bay and Port Herbert	1926	.093	527	.072	1.29
Tebenkof Bay and Big Port Walter	1926	.055	495	.081	.68
Tebenkof Bay and Cape Ommaney	1926	.002	------	------	------
Do	1925	.106	156	.134	.79
Tebenkof Bay and Coronation Island	1926	.036	860	.046	.78
Deep Cove and Port Herbert	1926	.061	202	.099	.62
Port Herbert and Gut Bay	1927	.012	138	.146	.08
Port Herbert and Big Port Walter	1926	.148	200	.094	1.57
Big Port Walter and Cape Ommaney	1926	.053	2,227	.079	.67
Cape Ommaney and Port Herbert	1927	.344	422	.098	[1] 3.51
Do	1926	.095	2,259	.068	1.40
Cape Ommaney and Deep Cove	1926	.156	2,229	.079	[2] 1.97
Cape Ommaney and Coronation Island	1926	.034	2,590	.037	.92
Cape Ommaney and Warren Island	1927	.037	445	.080	.46
Do	1926	.066	2,510	.040	1.65
Cape Ommaney and Meade Point	1926	.185	2,194	.102	1.81
Cape Ommaney and Point Gardner	1926	.048	2,332	.053	.91
Cape Ommaney and Jamestown Bay	1926	.009	------	------	------
Cape Ommaney and Cape Edgecumbe	1926	.039	2,336	.053	.74
Cape Ommaney and Gut Bay	1927	.332	440	.087	[1] 3.82
Jamestown Bay and Cape Edgecumbe	1926	.030	280	.099	.30
Jamestown Bay and Favorite Bay	1926	.095	144	.134	.71
Jamestown Bay and Point Adolphus	1926	.159	142	.141	1.13
Cape Edgecumbe and Favorite Bay	1926	.125	250	.107	1.17
Cape Edgecumbe and Point Adolphus	1926	.129	248	.112	1.15
Coronation Island and Kell Bay	1926	.227	523	.086	[1] 2.64
Coronation Island and Warren Island	1926	.100	816	.047	[2] 2.13
Coronation Island and Noyes Island	1926	.269	635	.059	[1] 4.56
Warren Island and Kell Bay	1926	.127	441	.086	1.48
Warren Island and Culebra Island	1927	.244	138	.120	[2] 2.03
Warren Island and Noyes Island	1927	.248	288	.084	[1] 2.95
Do	1926	.169	553	.060	[1] 2.82
Warren Island and Wrangell	1927	.178	147	.117	1.52
Do	1926	.399	510	.068	[1] 5.87
Warren Island and Meade Point	1926	.251	418	.103	[2] 2.44
Warren Island and Petersburg	1927	.103	609	.086	1.20
Do	1926	.179	861	.046	[1] 3.89
Culebra Island and Noyes Island	1927	.004	260	.102	.04
Culebra Island and Klawak	1927	.092	114	.132	.70
Noyes Island and Klawak	1927	.088	264	.096	.92
Noyes Island and Port Estrella	1926	.077	240	.108	.71
Wrangell and Petersburg	1927	.065	590	.098	.66
Do	1926	.220	637	.069	[1] 3.19
Do	1925	.116	311	.084	1.38
Wrangell and Anita Bay	1927	.086	123	.132	.65
Santa Ana Inlet and Anita Bay	1928	.000	------	------	------
Santa Ana Inlet and Frances Cove	1928	.039	253	.082	.48

[1] Statistically significant.

[2] Approaching statistical significance.

Any two means are compared by dividing their difference by the standard error estimated by the formula

$$\sigma=\sqrt{\frac{S(x-\bar{x})^2+S(x'-\bar{x}')^2}{n_1+n_2}\left(\frac{1}{n_1+1}+\frac{1}{n_2+1}\right)}$$

if $x_1, x_2 \text{--------}, x_{n_2}+1$ and $x'_1, x'_2 \text{--------} x'_{n_2}+1$ be two samples,

and $$\bar{x}=\frac{1}{n_1+1}\ S(x),\ \bar{x}'=\frac{1}{n_2+1}\ S(x')$$

Of the 71 comparisons between the mean vertebral counts given in table 6, 36 are between localities not over 25 miles apart, and the remaining 35 are from localities over 25 miles apart.

The results of the comparisons are listed in table 7.

That there is such close agreement between the results of the two group of comparisons is surprising considering the difference in distance. The median distance apart in the close group is only 17 miles as contrasted with 52 miles in the group of distant comparisons. These results tend to indicate that ordinarily there is probably little intermingling between herring of different races, the boundaries between racial areas being quite abrupt.

TABLE 7.—*Summarized comparisons of vertebral counts*

Distance apart in miles	Probability of means being the same		
	0.99–0.05	0.05–0.01	0.01 or less
0–25	27	3	6
26 and over	26	2	7

The mean vertebral counts of herring from Petersburg, in the northern entrance to Wrangell Narrows, for instance, differ by over 4 standard errors from those of Juneau, Point Gardner, or Meade Point, by 3.89 standard errors from Warren Island, and by 3.19 from those of Wrangell. This is rather definite evidence that herring do not migrate through Wrangell Narrows or Dry Strait, and that migrations in Frederick Sound must be largely confined to that body of water.

The samples taken in the area south of Sumner Strait and east of Clarence Strait, including Wrangell, Anita Bay, Santa Ana Inlet, and Frances Cove, do not differ amongst themselves, so that, until additional evidence is collected, it can only be assumed that the herring of these localities may intermingle. That this group of herring does not intermingle with herring of the outer coast through Sumner Strait is clearly indicated by a difference between the Warren Island and Wrangell averages of 5.87 standard errors.

On the west coast of Prince of Wales Island the means of the samples from 4 closely adjacent localities, Klawak, Port Estrella, Noyes Island, and Culebra Island, do not differ amongst themselves, but differ from those of the localities to the north. The agreement of the herring of the adjacent localities (captured during the summer months) with those taken while spawning, on the important spawning grounds near Klawak, is quite in keeping with expectations. Noyes Island differs from Coronation Island by 4.56 standard errors and from Warren Island by 2.82 and 2.95 standard errors in the 2 available comparisons. However, Warren Island and Culebra Island differ by only 2.03 standard errors which gives a probability of 0.04 of the populations being the same. This is not sufficiently great odds to be able to state definitely that Warren Island and Culebra Island represent distinct populations. Thus while the significant differences between Warren Island and Noyes Island and between Coronation and Noyes Islands tend to indicate the lack of migration across Iphigenia Bay, the lack of a statistically significant difference between Warren Island and Culebra Island averages does not confirm this view.

A test of the homogeneity of the Prince of Wales Island samples with the Warren Island data included, made by above-described methods, yielded an observed z of 0.3247 which happens to be exactly the same as the calculated z for a probability of 0.01, thus indicating that this group of samples is not all drawn from one population. The same test made without the Warren Island samples gives an observed z of 0.0248 which is many times less than the calculated z of 0.4420 for a probability of 0.05. Therefore, it must be concluded that the data point to the lack of migration between localities lying north and those lying south of Cape Lynch (Iphigenia Bay).

Samples from Warren Island, at the mouth of Sumner Strait, differ from those of Meade Point, near the mouth of Frederick Sound, by 2.44 standard errors which yields a probability of 0.014. Even if this difference were significant, it could not be assumed to give definite information on migration through Keku Strait as neither locality is very close to the entrance to this channel. It does, however, suggest that the herring at the mouth of Frederick Sound do not migrate to the ocean by this route.

A sample from Kell Bay, in Affleck Canal, differs significantly in vertebral count from Coronation Island, but does not show a significant difference from Warren Island, which is about the same distance as Coronation Island from the mouth of the canal.

The vertebral count comparisons of table 6 also indicate differences between the Cape Ommaney herring and those from Port Herbert and Gut Bay, but not from those caught in Big Port Walter. The Big Port Walter herring also do not show differences from Port Herbert. Therefore these localities cannot be classified without more material.

ANALYSIS OF GROWTH RATES

In analyzing the growth rates from the various localities for racial purposes no data were used except those from freshly caught purse-seined specimens, all of which were obtained during the summer months.

Many of the body length distributions are slightly skewed, and in addition cover a wide range, with a tendency in a few cases for slight modes to form near the upper or lower range of the distribution. These disturbing factors are probably caused in large measure by errors in age reading whereby a length distribution may contain a few fish belonging to younger or older age groups. Since these doubtful measures near the extremes of the range exert a large influence in the determination of the arithmetic mean, whereas, being of doubtful authenticity they should not carry as much weight as the more centrally located items, it was decided not to use the arithmetic mean but to employ the median for the measure of central tendency. In keeping with the use of the median the interquartile range has been used as the measure of dispersion.

To gain an insight into the growth increments during the summer months the data have been grouped by 10-day periods. (See table 8.) For Larch Bay 5-year-olds (herring in their fifth summer) taken during 1930, a consecutive series of 8 periods shows no consistent changes in length during the first 5 periods (from June 21 up to and including Aug. 10). There is an abrupt increase in length, however, between the fifth and sixth periods, the fish of the last three periods averaging about a half centimeter greater in body length. Such a sudden increase in length can scarcely be ascribed to growth but is probably due to an influx of new schools of herring onto the fishing grounds.

That such a sudden change in body length is not due to growth is supported by the Noyes Island data, in which both the 4- and 5-year-olds taken toward the end of July were considerably smaller than those taken during the last of June, the largest difference, that between the 5-year-olds, being 6 millimeters.

TABLE 8.—*Body lengths in various localities for 1929 and 1930 by 10-day periods*

Locality	Age	Date	Number of specimens	Median	Q_1	Q_3	Q_3-Q_1
		1929					
Larch Bay	4	June 11-20	226	199.2	193.7	204.6	10.9
Port Alexander	4	June 1-10	212	193.5	188.0	198.7	10.7
Do	4	June 11-20	190	194.5	189.7	200.1	10.4
Do	4	June 21-30	68	198.7	193.8	204.5	10.7
Tebenkof Bay	4	do	226	199.6	195.1	204.6	9.5
Do	4	July 1-10	131	200.9	196.6	206.0	9.4
Do	4	July 11-20	51	203.4	199.3	207.6	8.3
Do	4	July 21-31	39	202.4	198.3	206.1	7.8
Big Port Walter	4	May 31	85	191.7	185.1	198.3	13.2
Off Port Herbert	4	June 1-10	60	194.5	187.7	202.0	14.3
Deep Cove	4	June 11-20	87	190.4	185.1	197.1	12.0
Hoggatt Bay	4	do	38	194.2	187.4	198.0	10.6
Coronation Island	4	do	147	203.4	199.2	208.5	9.3
Affleck Canal	4	June 1-10	74	186.9	183.7	191.0	7.3
Port Estrella and Culebra Island	4	June 8-12	95	185.9	178.8	190.9	12.1
Point Gardner	4	July 1-10	59	200.0	195.8	204.9	9.1
Do	4	July 11-20	65	201.2	196.3	205.1	8.8
Do	4	July 21-31	37	201.6	198.1	208.9	10.8
Favorite Bay	4	do	57	201.8	192.8	205.3	12.5
Point Adolphus	4	do	44	184.5	175.5	189.5	14.0
Douglas Island	4	do	36	187.5	179.5	191.0	11.5
		1930					
Larch Bay	4	July 21-31	65	204.6	198.1	208.9	10.8
Do	4	Sept. 1-10	132	206.4	201.5	211.5	10.0
Port Alexander	4	June 21-30	34	194.8	191.1	200.0	8.9
Off Port Herbert	4	July 11-20	47	198.4	194.3	208.1	13.8
Warren Island	4	July 1-10	37	197.8	194.8	204.4	9.6
Do	4	July 21-31	28	196.0	191.5	202.0	10.5
Noyes Island	4	June 21-30	121	192.8	188.3	197.2	8.9
Do	4	July 11-20	53	187.6	181.3	190.7	9.4
Do	4	July 21-31	34	188.5	181.3	190.4	9.1
Todd	4	June 1-10	160	176.0	169.5	181.9	12.4
Larch Bay	5	June 21-30	80	210.8	204.2	214.8	10.6
Do	5	July 1-10	98	213.0	206.8	217.4	10.6
Do	5	July 11-20	157	212.1	207.4	218.0	10.6
Do	5	July 21-31	284	211.5	206.1	218.1	12.0
Do	5	Aug. 1-10	46	212.9	208.8	217.3	8.5
Do	5	Aug. 21-31	67	219.1	213.2	223.0	9.8
Do	5	Sept. 1-10	334	216.0	210.7	222.0	11.3
Do	5	Sept. 11-20	38	216.5	207.3	222.7	15.4
Port Alexander	5	June 11-20	70	211.8	206.1	214.8	8.7
Do	5	June 21-30	145	209.9	200.1	214.7	14.6
Do	5	Aug. 21-31	43	213.3	209.8	219.6	9.8
Off Port Herbert	5	July 11-20	63	207.1	201.7	210.8	9.1
Coronation Island	5	do	68	215.2	209.5	218.8	9.3
Do	5	July 21-31	188	214.7	209.3	220.4	11.1
Do	5	Aug. 11-20	48	212.5	204.8	217.2	12.4
Warren Island	5	June 21-30	38	212.2	209.5	218.9	9.4
Do	5	July 1-10	119	209.1	203.9	212.8	8.9
Do	5	July 11-20	162	211.1	205.3	215.5	10.2
Do	5	July 21-31	51	213.0	208.4	217.3	8.9
Noyes Island	5	June 21-30	134	204.5	199.6	210.8	11.2
Do	5	July 11-20	39	197.1	193.9	201.8	7.9
Point Gardner	5	July 1-10	29	214.0	209.8	217.8	8.0
Cape Edgecumbe	5	do	195	213.6	208.0	218.8	10.8

Because of these large variations in the size of herring of the same age taken from the same locality, it was adjudged unwise to attempt any careful statistical comparisons between localities. The medians and quartiles are given for each month in table 9. Figures 4, 5, and 6 give the length distributions for some of the localities. In these figures the lengths have been grouped by 3-millimeter categories and smoothed once by three's. The figures and the table reveal at once that the herring from 4

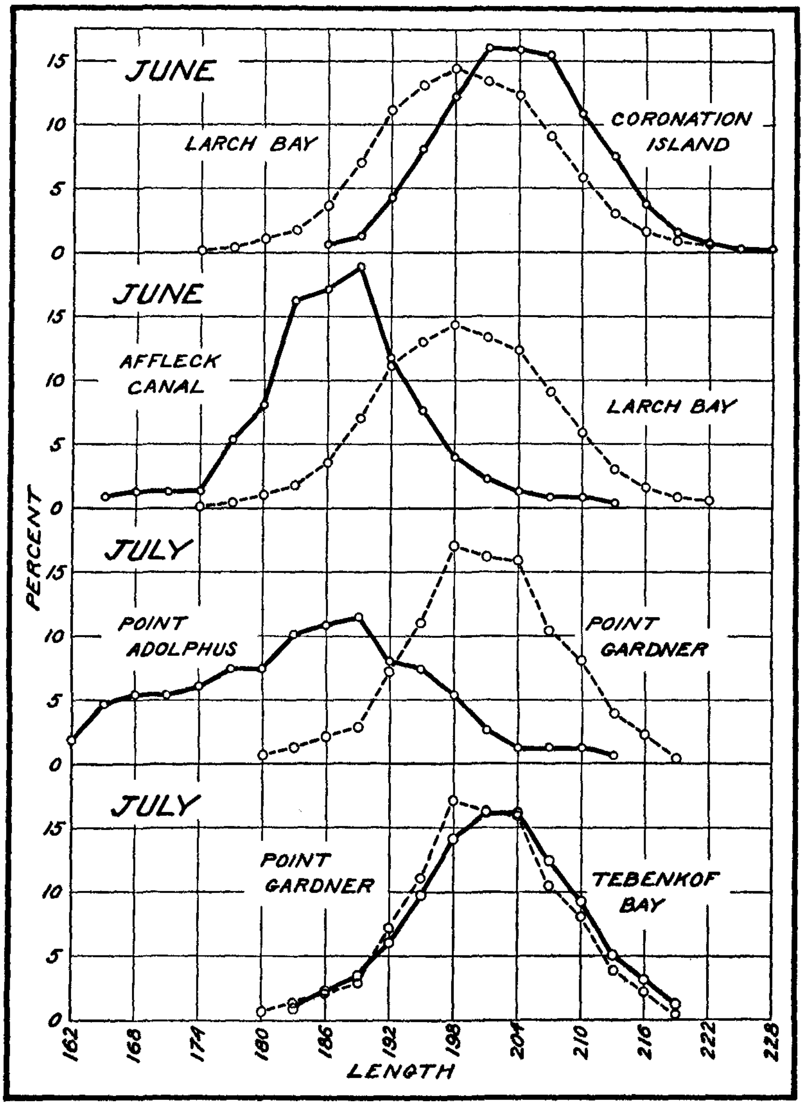

FIGURE 4.—Percentage length distributions, grouped by 3-millimeter categories and smoothed once by three's for herring of 1926 year class caught in 1929 (their fourth summer).

localities: The Noyes Island area (including Culebra Island and Port Estrella), the Douglas Island-Icy Strait area, Affleck Canal (Kell Bay) and Peril Strait (Todd) are all much slower growing than those of the other localities. These differences are so great that we have considered these 4 localities to represent groups of fish separate from the neighboring stocks or populations. The Peril Strait herring appear to be the slowest growing of any we have so far encountered in Alaska, the median of the 4-year-olds taken in June 1930 being only 176.0 millimeters.

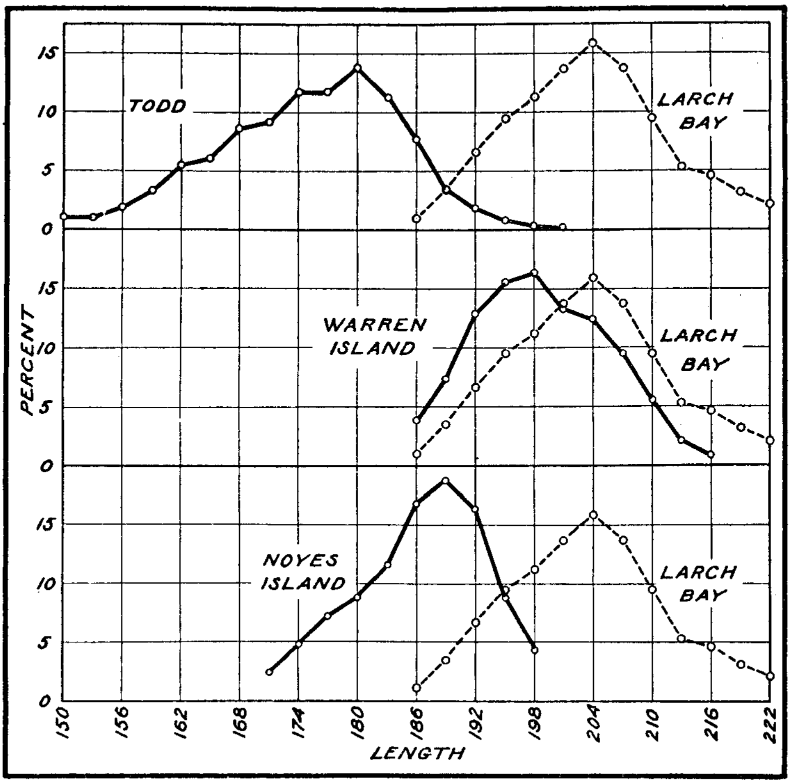

FIGURE 5.—Percentage length distributions, grouped by 3-millimeter categories and smoothed once by three's for herring of 1927 year class caught in 1930 (their fourth summer).

TABLE 9.—*Body lengths in various localities for 1929 and 1930 by months*

Locality	Age	Date sampled		Number of specimens	Median	Q_1	Q_3	$Q_3—Q_1$
		Year	Month					
Larch Bay	4	1929	June	226	199.2	193.7	204.6	10.9
Port Alexander	4	1929	do	470	194.2	189.4	200.1	10.7
Tebenkof Bay	4	1929	do	226	199.6	195.1	204.6	9.5
Do	4	1929	July	221	202.0	197.2	206.3	9.1
Big Port Walter	4	1929	May 31	85	191.7	185.1	198.3	13.2
Off Port Herbert	4	1929	June	60	194.5	187.7	202.0	14.3
Deep Cove	4	1929	do	87	190.4	185.1	197.1	12.0
Hoggatt Bay	4	1929	do	38	194.2	187.4	198.0	10.6
Coronation Island	4	1929	do	147	203.4	199.2	208.5	9.3
Affleck Canal	4	1929	do	74	186.9	183.7	191.0	7.3
Port Estrella and Culebra Island	4	1929	do	95	185.9	178.8	190.9	12.1
Point Gardner	4	1929	July	161	200.8	196.4	205.7	9.3
Favorite Bay	4	1929	do	57	201.8	192.8	205.3	12.5
Point Adolphus	4	1929	do	49	185.8	176.1	191.4	15.3
Douglas Island	4	1929	do	71	188.3	182.4	198.1	15.7
Larch Bay	4	1930	do	96	203.5	197.3	207.9	10.6
Do	4	1930	September	152	206.4	201.4	211.6	10.2
Port Alexander	4	1930	June	45	196.8	191.8	201.9	10.1
Off Port Herbert	4	1930	July	47	198.4	194.3	208.1	13.8
Warren Island	4	1930	do	80	197.7	193.8	204.5	10.7
Noyes Island	4	1930	June	121	192.8	188.3	197.2	8.9
Do	4	1930	July	87	187.8	181.3	190.5	9.2
Todd	4	1930	June	160	176.0	169.5	181.9	12.4
Larch Bay	5	1930	do	80	210.8	204.2	214.8	10.6
Do	5	1930	July	539	212.0	206.8	217.9	11.1
Do	5	1930	August	113	216.3	211.5	221.0	9.5
Do	5	1930	September	372	216.0	210.6	222.1	11.5
Port Alexander	5	1930	June	215	210.4	204.2	214.8	10.6
Do	5	1930	August	43	213.3	209.8	219.6	9.8
Off Port Herbert	5	1930	July	63	207.1	201.7	210.8	9.1
Coronation Island	5	1930	do	256	214.8	209.3	219.8	10.5
Do	5	1930	August	48	212.5	204.8	217.2	12.4
Warren Island	5	1930	June	38	212.2	209.5	218.9	9.4
Do	5	1930	July	332	210.4	204.9	214.9	10.0
Noyes Island	5	1930	June	134	204.5	199.6	210.8	11.2
Do	5	1930	July	54	198.5	194.7	206.0	11.3
Point Gardner	5	1930	do	29	214.0	209.8	217.8	8.0
Cape Edgecumbe	5	1930	do	195	213.6	208.0	218.8	10.8

That the northern slow-growing group of herring found in Icy Strait and the vicinity of Juneau all belong to the same race cannot be assumed from growth rates. A test of the homogeneity of the vertebral count distributions in this area (see *A*, fig. 2) gives an observed z (see illustration in section on vertebrae) of 0.4069. The

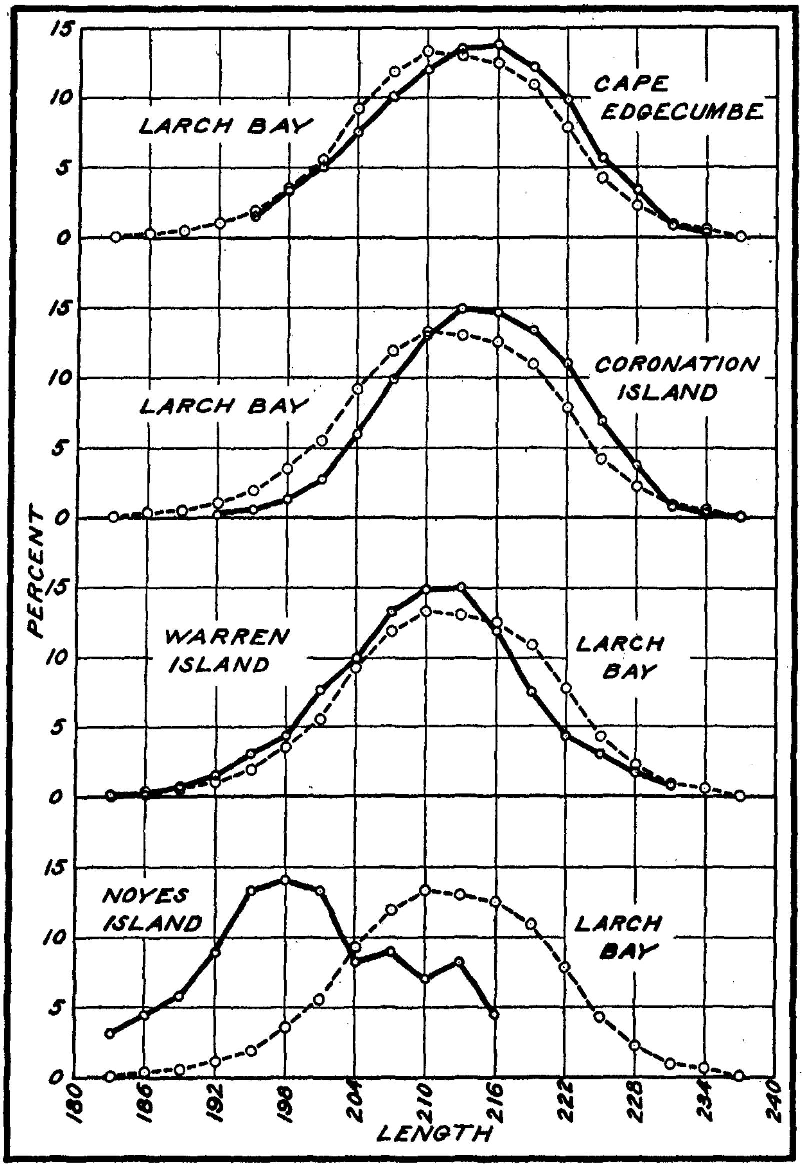

FIGURE 6.—Percentage length distributions, grouped by 3-millimeter categories and smoothed once by three's, for herring of the 1926 year class caught in 1930 (in their fifth summer).

calculated z for a probability of 0.05 is 0.3388, and for a probability of 0.01 it is 0.4909. Therefore, in this case, the observed z is large enough to be of doubtful significance. In this test the mean square between the arrays 0.2268 is less than that within the arrays 0.5117 which may indicate a difference in variance. It must be realized that no definite conclusions as to the racial homogeneity of this area can be reached without further data.

ANALYSIS OF YEAR CLASSES

Differences in the relative proportions of different year classes present in the populations may be of value as an indication of the extent of intermingling. The relative abundance of any particular year class in the catch is influenced chiefly by three factors: First, the relative number of larvae of that year class hatching and surviving through the juvenile period until of an age or size to enter the catch; second, by the rate of natural mortality; and third, by the increased rate of mortality induced by the fishery. However, the relative abundance of any particular year class in the catch may change during the season. Such a progressive change from younger to older age groups is apparent as the season advances, for instance, in Prince William Sound. Owing to such fluctuations in the relative proportions of each age group present at any particular time, only the major differences between localities can be emphasized without further data.

In figure 10 are given histograms of the percentage age distributions for the major fishing grounds during the 1929 and 1930 seasons. Several features are worthy of emphasis. These are (1) the approximate equality of the 1926 and 1927 year classes at Noyes Island as contrasted with the overwhelming dominance of the 1926 year class at most of the other localities, (2) the great dominance of the 1927 year class at Todd, (3) the dominance of the 1923 year class at Douglas Island and Favorite Bay, (4) the large percentage of the catch older than the 1923 year class at Douglas Island.

These salient facts all support the indications given by the analyses of the vertebral counts and of the growth rates which separate the Noyes Island area, Todd, and the Juneau-Icy Strait area (including Douglas Island) as independent of neighboring areas. Whether Favorite Bay is independent of Point Gardner we hesitate to say without further data.

TAGGING

Curtailment of fishing operations during 1932 and 1933, due to economic conditions, and an increased abundance in the Cape Ommaney tribe of herring, owing to the accession to the catch of certain dominant year classes, caused fishing during 1932 to be carried on almost wholly in the area between Noyes Island and the lower end of Baranof Island. During 1933 the boats did not fish farther south than Warren Island. This condition, which was in contrast to the widespread fishing conducted for several years previously, made our tagging work of less value than it would have been under normal conditions, as obviously the presence of tagged herring cannot be detected where no fishing operations are being conducted. However the results are presented for what they are worth. For a full discussion of tagging methods and manner of recovery of the tags, see Rounsefell and Dahlgren (1933).

During the fishing season of 1933 (June 1 to September 30) 101 belly tags and 7 opercle tags were recovered from 2,499 of the former and 1,470 of the latter affixed to herring released at Jamestown Bay (Sitka) between April 21 and April 25, 1933. All of these tags were recovered around Cape Ommaney, between Larch Bay and Port Alexander, giving the first definite proof of a migration of some length, as it is approximately 66 miles by water from Jamestown Bay to Port Alexander.

On the other hand, out of 996 belly tags and 824 opercle tags affixed to herring released at Cape Bendel, just under 60 miles from Port Alexander, on August 17, 1932, not a tag has been recovered. This may be considered rather definite evidence of a lack of migration between Cape Bendel and Cape Ommaney.

FIGURE 7.—BLUESTONING A SEINE.

At frequent intervals throughout the season a seine is dipped into a solution of copper sulphate to kill the marine growths that cause the web to rot.

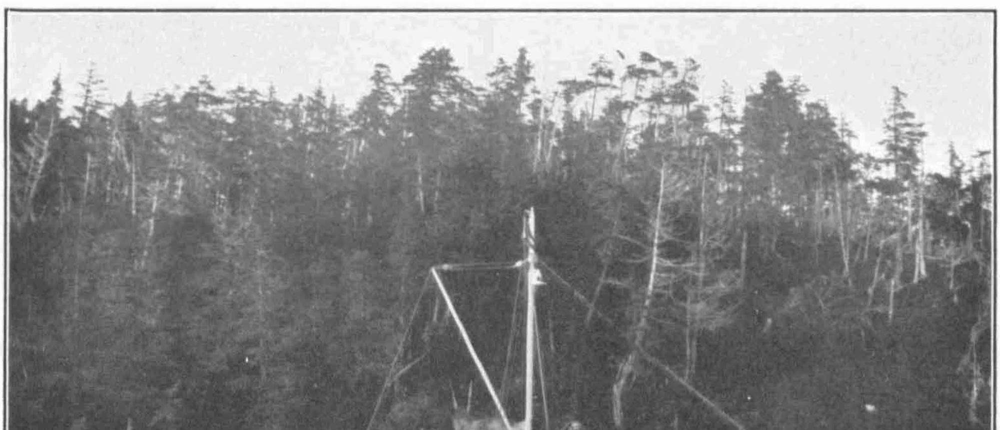

FIGURE 8.—THE SCIENTIFIC VESSEL "HERON" AT ANCHOR IN PORT CONCLUSION.

Note the live box used in tagging operations moored astern. The acquisition of this motor launch in 1932 permitted the carrying out of the herring tagging program.

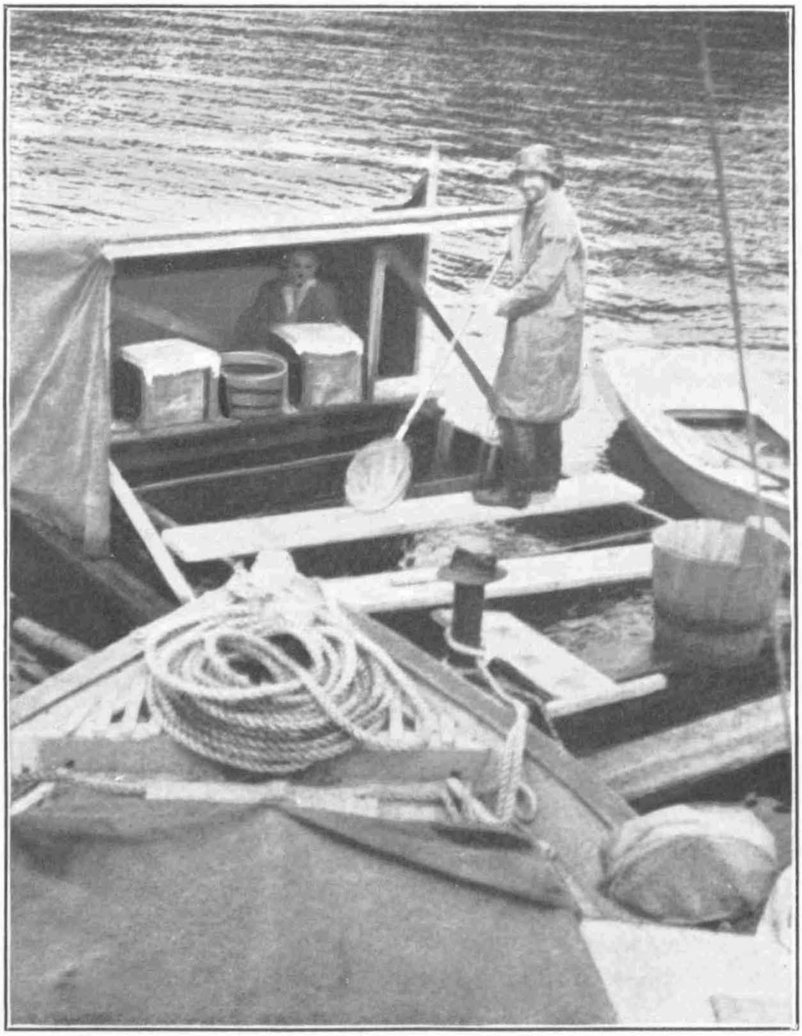

FIGURE 9.—HERRING TAGGING OPERATIONS.

The tagging live box is filled with herring which the man with the net dips a few at a time into the half barrel of sea water under the shelter. From this half barrel the herring are removed one at a time by hand and placed on damp cheesecloth stretched over a frame. A sharp arrow-pointed knife is used to puncture a small hole through the wall of the belly and the flat metal tag is inserted within the body cavity of the herring, the small wound healing completely within a few days.

In another tagging experiment at Auke Bay near Juneau, 800 belly tags and 772 opercle tags were affixed to spawning herring released on May 3, 4, and 5, 1933.

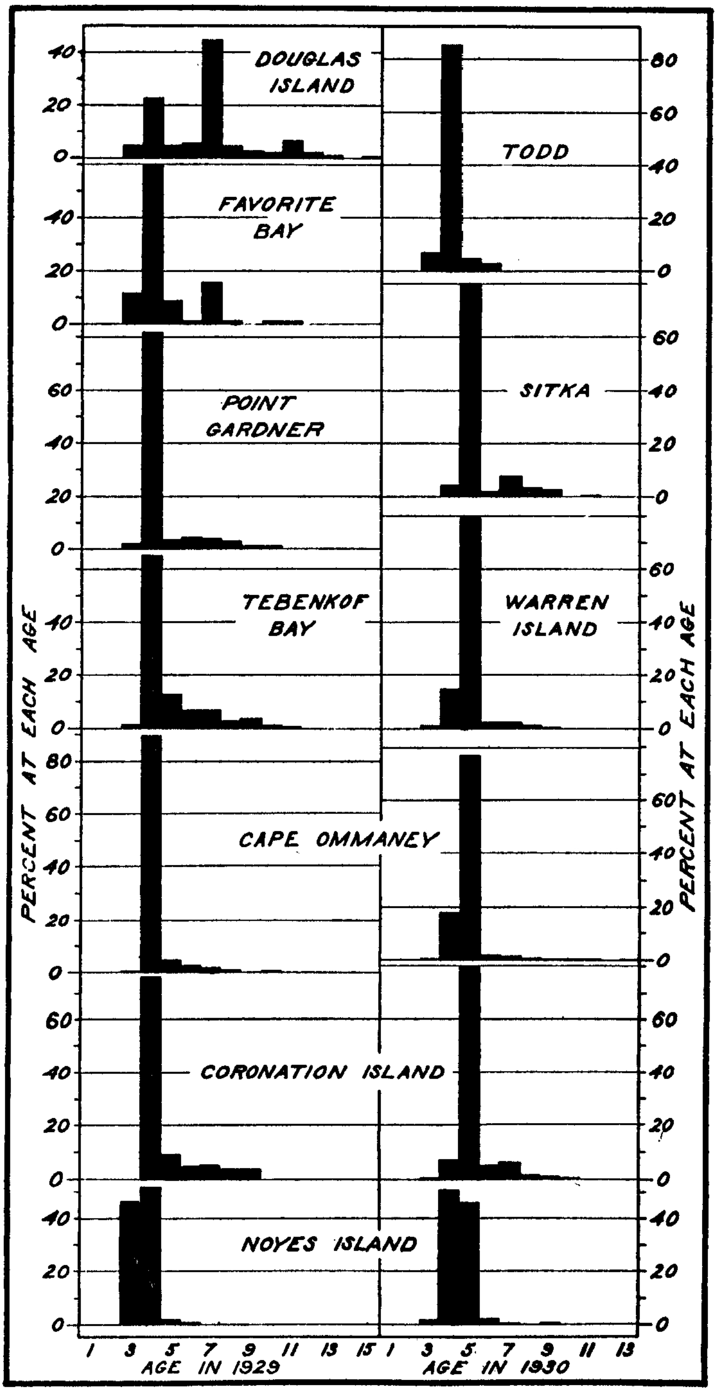

FIGURE 10.—Percentage age distributions of herring taken during 1929 and 1930 in some of the principal fishing grounds.

No recoveries have been made, supporting the previous conclusion of a lack of migration between Juneau and Cape Ommaney.

SUMMARY

The results so far attained in determining the herring populations and the areas inhabited by them serve to show the immense complexity of the problem. Although much remains to be done, the present work has set apart some of the chief areas and answered many pressing questions. It must be borne in mind that where morphological differences have not been shown we can only assume that the populations are the same, until such time as we obtain evidence to the contrary. Such evidence may come from tagging experiments. It must be further noted that the area boundaries shown in figure 2 are merely lines across which neighboring populations do not migrate according to positive evidence. They are not intended to convey the impression that each area necessarily contains only one race. Indeed, the section on tagging shows that area *C* very probably does contain more than one race. With these restrictions in mind the following results are listed:

1. Differences in vertebral count between Wrangell and Warren Island herring indicate that there is no migration through Sumner Strait.
2. Differences in vertebral count between Petersburg and Wrangell herring show a lack of intermingling through Dry Strait or Wrangell Narrows.
3. Differences in vertebral count between Point Gardner and Petersburg show no migration through Frederick Sound.
4. Differences in growth rate and vertebral count indicate a lack of migration along the outer coast between localities lying north and those lying south of Cape Lynch (Heceta Island).
5. The presence of very slow-growing herring in Peril Strait indicates a distinct race and shows a lack of migration through this waterway.
6. Differences in growth rate and vertebral count indicate that the herring of Icy Strait and the vicinity of Juneau do not migrate down Chatham Strait or through Stephens Passage. Failure to recover any of the herring tagged at Auke Bay in the Cape Ommaney fishery tends to confirm this view.
7. A difference of 2.44 standard errors, giving a probability of 0.014 between the mean vertebral counts of Warren Island and Meade Point indicates that there is probably no migration through Keku Strait.
8. Failure to recover any of the tagged herring released at Cape Bendel in the Cape Ommaney fishery indicates a lack of migration between lower Chatham Strait and Frederick Sound.
9. Recovery of tagged herring proves that the great spawning grounds in Sitka Sound are the mainstay of the tremendous herring fishery at Cape Ommaney.

LITERATURE CITED

Buchanan-Wollaston, H. J. 1933. Some modern statistical methods: their application to the solution of herring race problems. With foreword by R. A. Fisher. Jour. du Cons., Cons. Perm. Intern. Explor. Mer. vol. VIII, no. 1, pp. 7–47, 4 figs. Copenhague.

Fisher, R. A. 1930. Statistical methods for research workers. No. V. Biological monographs and manuals. 3d edition, 283 pp., 12 figs. Edinburgh.

Rounsefell, George A. 1930. Contribution to the biology of the Pacific herring, *Clupea pallasii*, and the condition of the fishery in Alaska. Bull., U. S. Bur. Fish., vol. XLV, 1929 (1930), pp. 227–320, 53 figs.

Rounsefell, George A. 1930a. The existence and causes of dominant year classes in the Alaska herring. Contr., Marine Biol., 1930, pp. 260–270, 5 figs. Stanford University, Calif.

ROUNSEFELL, GEORGE A. 1931. Fluctuations in the supply of herring, *Clupea pallasii,* in southeastern Alaska. Bull., U. S. Bur. Fish., vol. XLVII, 1931 (1932), pp. 15–56, 26 figs.

ROUNSEFELL, GEORGE A. 1934. Several distinct races of herring are found in southeastern Alaska. Pacific Fisherman, vol. 32, no. 3, February 1934, p. 31. Seattle.

ROUNSEFELL, GEORGE A., and EDWIN H. DAHLGREN. 1932. Fluctuations in the supply of herring, *Clupea pallasii,* in Prince William Sound, Alaska. Bull., U. S. Bur. Fish., vol. XLVII, 1932, pp. 263–291, 15 figs.

ROUNSEFELL, GEORGE A., and EDWIN H. DAHLGREN. 1933. Tagging experiments on the Pacific herring. Jour. du Cons., Cons. Perm. Intern. Explor. Mer., vol. VIII, no. 3, pp. 371–384, 6 figs. Copenhague.

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