101-1

#6

Department of Research
Fish Commission of the State of Oregon

Contribution No. 1

Local Populations and Migration in Relation to the Conservation of Pacific Salmon in the Western States and Alaska

by

WILLIS H. RICH

(Reprinted from "The Migration and Conservation of Salmon", Publication No. 8 of the American Association for the Advancement of Science, Science Press, Lancaster, Pa., 1939.)

with a

FOREWORD

by

JOHN C. VEATCH
Chairman of the Commission

STATE PRINTING DEPARTMENT
SALEM, OREGON
1939

Kiska

Foreword

The Department of Research of the Fish Commission of Oregon was established in March, 1938. Some fishery investigations had been carried on by the Commission during the previous two years consisting of a study of the pilchard and the Oregon pilchard fishery by Mr. Vernon Brock; but there had been no general program of research. Dr. Willis H. Rich of Stanford University was temporarily appointed Director of Research and it is expected that a permanent Director will be appointed when adequate funds are available. In the meanwhile an effort is being made to develop a sound and useful program with the available facilities. Dr. Rich's extensive experience in fishery research has included studies of the salmon of the Columbia River and well fits him to outline and initiate a program of practical research such as the Commission has had in mind. The present staff consists only of Dr. Rich, Mr. Vernon Brock, Fishery Biologist, and Mr. Stanley G. Jewett, Jr., Research Assistant.

The general features of the present program of research have been presented in the Annual Report of the Commission for the biennium 1937-38. These will include (1) Studies relating to the biology of Oregon fishes particularly in relation to the conservation of the commercially valuable species; (2) Exposition of the principles and fundamental facts that are of importance to the development of a sound conservation program; and (3) Studies relating primarily to the state of the fishery resources on which the fishery industries of Oregon are dependent for their raw material.

In preparing a research program it has been important to consider facilities for publication of the results as a means of recording these in such form that they may be permanently available, not only to the members of this commission but to State administrators and legislators and to others who may be concerned with the conservation of the commercial fisheries of Oregon. There are certain advantages in publishing papers of this character in a regular series of bulletins but the expense of this has seemed likely to be prohibitive. Furthermore there are certain other advantages to be obtained by publishing such results in already established series and periodicals. The results are thus given a more general distribution than would be possible with a new series and specialized papers may appear in series devoted to the particular field in which they fall. Flexibility and at least most of the advantages of both systems can, we believe, be secured by a combination of the two methods of publishing the results of research.

We have therefore established a series entitled "Contributions from the Department of Research of the Fish Commission of Oregon". The papers appearing in this series are to be serially numbered in the order in which they are accepted for publication—which will, in general, approximate the order of publication. Papers of general importance or of wider interest will, when possible, be published in established series and periodicals. Others, particularly those that are chiefly of local importance, will be published by the State Printing Department. It is thought that such a system of publication will provide a maximum of advantage at a minimum of cost to the Commission.

The predominant importance of the Columbia River salmon runs in the fishery resources of the state has determined that an important feature of the research program shall be a study of these runs for the purpose of determining their present state and the effect that any change in conditions, whether favorable or adverse, may have. The present paper by Dr. Rich presents briefly some of the fundamental facts of salmon biology upon which a sound conservation program must be built. Future contributions will present similar fundamental facts and specific data bearing on the solution of the various practical problems that arise continually in the effort to conserve these resources.

JOHN C. VEATCH, *Chairman,*

Fish Commission of Oregon.

Reprinted from Publication No. 8 of THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, pages 45–50.

LOCAL POPULATIONS AND MIGRATION IN RELATION TO THE CONSERVATION OF PACIFIC SALMON IN THE WESTERN STATES AND ALASKA*

By WILLIS H. RICH

DEPARTMENT OF BIOLOGY, STANFORD UNIVERSITY, CALIF., AND DEPARTMENT OF RESEARCH, FISH COMMISSION OF OREGON

THE study of the migrations of the salmon of Alaska and the Pacific states has been actuated by the conviction that a knowledge of the movements of these fish is essential to the formation of a sound conservation program. The conservation of any species may be defined as the maintenance of the abundance of that species at a level that, with due regard for the requirements of the future, appears to be the most desirable from the point of view of Man. Such maintenance of a population, whether of mice or men or of fishes, requires that the births and deaths shall be equal over a period of time. It is the function of conservation efforts to produce this condition and it is the function of conservation research to provide the information necessary to guide these efforts.

The requirements of practical conservation demand a knowledge of the fluctuations in the birth and death rates and of the events and forces that may cause fluctuations in the birth-death ratio. But any study of the factors affecting the birth-death ratio must take into consideration (1) the extent to which the species is broken up into self-sustaining groups; (2) the fluctuations in the birth-death ratio of each independent group at each stage in the life-history; and (3) the causes of these fluctuations, again for each independent group and for each life phase because these causes need not be and often are not the same for all of the population groups that go to make up the species.

In the conservation of any natural, biological resource it may, I believe, be considered self-evident that the population must be the unit to be treated. By population I mean an effectively isolated, self-perpetuating group of organisms of the same species regardless of whether they may or may not display distinguishing characters and regardless of whether these distinguishing characters, if present, be genetic or environmental in origin. Given a species that is broken up into a number of such isolated groups or populations, it is obvious that the conservation of the species as a whole resolves into the conservation of every one of the component groups; that the success of efforts to conserve the species will depend, not only upon the results attained with any one population, but upon the fraction of the total number of individuals in the species that is contained within the populations affected by the conservation measures. On the other hand, the conservation of a species that is not so broken up into isolated, self-perpetuating groups obviously presents entirely different problems, simpler in some ways, more difficult in others. More general conservation measures may be effective for such species. These population groups have commonly been termed by biologists on the Pacific coast "races," entirely without any implication that the groups show demonstrable and heritable differences. It is true that, in certain instances, the population groups do show demonstrable and heritable differences but it is also true that in many other cases no such differences have been shown. The latter is not surprising in view of the fact that there are certainly scores or hundreds of such population groups in each of the five species of the genus *Oncorhynchus*.

It is apparent then that one of the first requirements of a sound conservation pro-

* Contribution No. 1, Department of Research, Fish Commission of Oregon.

gram must be the determination of the extent to which the species to be conserved is broken up into local populations. The defining of specific populations is concerned to a considerable extent with the determination of the geographical limits occupied by each. This is relatively simple in the case of plants and of other fixed or non-migratory organisms but may prove to be a problem of great intricacy in the case of migratory animals especially such animals as fish which cannot readily be observed directly. Proof of the existence of local populations of migratory species does not, however, depend necessarily upon a knowledge of the extent, direction and duration of the migrations in question; adequate proof may be given by entirely different evidence.

A knowledge of the extent, direction and duration of the migrations is, however, essential to the determination and understanding of the events and forces that affect the birth-death ratio and, therefore, to a sound conservation program. As specific examples the fact that Columbia River Chinook salmon are to be found off the coasts of southeastern Alaska and British Columbia during their oceanic migrations is of the greatest importance to an understanding of the causes affecting the abundance of these fish. It is of importance because, in these northern waters, the fish are subjected to an intensive fishery carried on by hook and line in the ocean and the development of this fishery has undoubtedly increased the rate of mortality although a measure of the effect has not, and perhaps cannot be secured.

Similarly the fact that the red-salmon fishery in the Ikatan-Shumagin Islands district south of the Alaska Peninsula draws almost exclusively upon the runs to Bristol Bay is important to an understanding of the forces affecting abundance and to the outlining of effective conservation measures.

Only through a knowledge of the migrations of these fish could we know the drain that such distant fisheries make on the particular runs.

In general it is obviously important to discover causes of fluctuations in the birth-death ratio. Such causes and their influence on the population may be exceedingly difficult to determine and measure under the best of circumstances, but it is certainly impossible without a knowledge of the movements of migratory animals such as the salmon.

There has been some confusion of these two problems—that is to say, the problem of the existence of local populations and the problem of the nature of the migrations. This is perhaps due to the fact that information on both is so essential to practical conservation and because any complete study of migrations must be preceded or accompanied by a determination of whether local populations exist or not. But in our consideration of the problems relating to the migrations and conservation of salmon it is important that we keep clearly in mind the distinction between the two. A knowledge of both is important to sound conservation, but there is this distinction: While, as I have already pointed out, the demonstration of the existence of distinct populations does not depend on a knowledge of the migrations, a study of the movements of fish requires a knowledge of the population groups to which the fish belong.

Turning now to a consideration of the salmon of the Pacific states and Alaska, I shall take up first the evidence relating to the existence of local populations and then that bearing on the nature of the movements of certain of these populations.

Evidence of the existence of local populations of Pacific salmon may be considered under three heads: (1) morphological and chemical, (2) statistical and (3) experimental.

1. A list of demonstrated morphological and chemical differences between fish running into different streams would be long and varied. It can only be stated here that there have been shown to be constant differences in size, both with and without differences in age; significant differences have been observed in the size of the mature eggs; differences in chemical composition especially as regards the oil content of the flesh have been shown—differences that exist at comparable stages of the spawning migra-

tion and so cannot be ascribed to differences in the length of time elapsed after leaving the feeding grounds; small but statistically significant differences exist in respect of such characters as proportional measurements and counts of vertebrae, fin rays, etc. Of a somewhat different nature are the differences observed in the scale markings which, in effect, provide a permanent and continuous record of the rate of growth throughout the life of the fish.

2. What I have chosen to call the statistical evidences of local populations include the persistence over long periods of time of distinctive age group ratios (as determined from scale examinations) and of distinctive cycles of abundance. The two are often related especially in cases, as that of the famous Fraser River sockeye run, in which the size of the breeding population is the chief determinant of future abundance. Such distinctive cycles of abundance have been demonstrated with statistical significance for a number of Alaskan streams and for at least two species, the red and pink salmon (*O. nerka* and *O. gorbuscha*).

3. Experimental evidence of local populations of Pacific salmon rests chiefly upon the results of numerous large marking experiments involving an aggregate of some three or four million young salmon. These have been marked by clipping fins before or during the seaward migration and the adults were recovered from the commercial fisheries or from the spawning areas. I started a series of such experiments on the Columbia River in 1916 and since then hardly a year has passed in which additional experiments have not been started. Most of these have had to do with the Chinook salmon (*O. tschawytscha*) and the sockeye or blueback (*O. nerka*). The results have shown beyond any reasonable doubt that the marked fish return in overwhelming proportions to the stream and even to the tributary in which they spent the early part of their existence. Aside from the evidence indicating the return of the adults to their home streams these experiments have provided evidence on a number of other problems that do not bear so directly upon the main subject of this discussion. Other evidence, experimental in nature, is that provided by the establishment of salmon runs in streams where no runs previously existed; as in the case of the Chinook salmon run into Spring Creek and that of the red salmon runs that were maintained for a number of years in Herman and Tanner Creeks, all in the Columbia River basin; similarly the gradual rehabilitation of depleted runs when properly protected over a period of years. The mere fact that the run of one stream may be depleted by too intensive exploitation while that of a neighboring stream is not is strong evidence in favor of the existence of local populations. Such a case is presented by the maintenance of a good run of red salmon into the Karluk River on Kodiak Island while the runs into Red River, Uganik River and Little River were being depleted to the point of commercial exhaustion.

To summarize: Diverse evidence points so clearly to the existence of local, self-perpetuating populations in the Pacific salmon that any hypotheses that do not conform must be subject to considerable doubt. This, I believe, must be accepted as a proved fact regardless of what may or may not be discovered about the extent of the oceanic migrations, regardless of how the migrations and particularly the return to the home stream may be accomplished and regardless of the reasons why the movements are made. Practical conservation measures must be based upon the acceptance of the "home stream theory" as an essentially correct statement.

Turning now to consider the nature and extent of the migrations: The general features of the migrations of the Pacific salmons are well known and are summarized in the mere statement that these are anadromous fishes. The details of the seaward migration as to time, rate of travel, age of the fish and so on, have been, and still are, under investigation but are not of particular concern at this time. The details of the oceanic migrations, however, are of major importance both on account of their bearing on certain interesting problems in animal behavior and on account of their great importance in practical conservation of the salmon fisheries.

There have been two opposing theories: First that the fish, on entering the ocean remain throughout their lives at sea close to the mouth of their home stream—perhaps spreading fanwise but always within the influence of the home-stream water. This was a theory at one time advanced by Dr. David Starr Jordan. The second theory states, in effect, that the fish range widely, far beyond any conceivable influence of the home stream to which, however, they predominantly return.

It was not until an extensive series of experiments involving the tagging of Pacific salmon was started in 1922 that satisfactory data began to accumulate bearing on this question. In these experiments fish were taken with as little injury as possible, usually from traps of the commercial fishery, tagged with standard, serially numbered stock tags and released. On recapture the fishermen were asked to report the tag to the fishery officials with information as to where and when taken. In 1922 and 1923 the late Dr. C. H. Gilbert and myself tagged 14,000 salmon, chiefly reds (*O. nerka*) along the western portion of the Alaska Peninsula from the Shumagin Islands in the south to the region of Port Moller on the north.

When the experiments were begun it was supposed that the fish taken in this region were bound for local streams, although no important local spawning grounds were known. The results, however, showed conclusively that the red salmon were a part of the important runs that spawned in the rivers of the Bristol Bay region over 300 miles to the north and east of the narrow, shallow passage between the peninsula and the first of the Aleutian Islands and 400 miles from Unimak Pass between the first and second of the islands and the first broad, open passage from the north Pacific to the Bering Sea. Later statistical analysis showed a high correlation between the catches of red salmon at Ikatan and in Bristol Bay for the years 1913 to 1925 inclusive. The coefficient of correlation (r) was $+0.79$—a value that would not occur as a result of "sampling error" alone once in a hundred times.

Incidentally it is this run of red salmon that the Japanese have begun to exploit by gill-net fishing in the open sea along the route of migration between the passes of the Aleutian Islands and Bristol Bay. The importance of a knowledge of the movements of fish in the ocean is well shown in this case in which the results of the tagging experiments of 1922 and 1923 showed clearly the danger to the fisheries of Bristol Bay and the Ikatan-Shumagin Island districts of an additional and unrestricted drain on the natural resources such as would most certainly result from the development by the Japanese of a pelagic salmon fishery in this district.

Another series of tagging experiments has shown that many of the Chinook salmon taken by the troll fishery off the coasts of southeastern Alaska and British Columbia eventually enter the Columbia River to spawn. More of the tagged fish in these experiments were taken in the Columbia River than in all other streams together and the Columbia is from 300 to 800 miles southeast of the points of tagging.

The question arises as to whether we can assume that the fish that travel these long distances in the ocean are actually returning to their home streams from the oceanic feeding grounds. I believe that this can be answered in the affirmative on the basis of the following argument:

(1) The return of the adult fish, predominantly, to their home streams may be accepted as proved beyond any reasonable doubt.

(2) It is also known that large numbers of Chinook salmon that eventually enter the Columbia River and large numbers of red salmon that eventually enter the streams of Bristol Bay are to be found at sea great distances from the mouths of the streams that they enter.

(3) The only simple theory that can possibly reconcile these two facts is that the fish of the Columbia and of Bristol Bay do return to their home streams even when they

have gone such great distances at sea that they would seem to be beyond any possible hydrographic influence that their home streams might have. If this is true of the Columbia River Chinooks and the Bristol Bay red salmon it seems reasonably certain that it is a pattern of behavior generally common to the Pacific salmon.

As a matter of practical conservation it is obviously of importance to the troll fishermen of southeastern Alaska and of British Columbia that the Columbia River Chinook salmon runs be conserved; and it is of importance to those who are interested in the conservation of the Columbia River salmon to know what is happening on the distant fishing grounds lest the developments there negative the influence of any conservation measures that may be effected in the Columbia River itself. Not that, at present, anything is likely to be done about it; but perhaps, in the fullness of time, some wise legislator will decide that something ought to be done. If that should happen he will likely turn to some biologist and expect an immediate answer to his question as to what ought to be done. Which reflection, however, is beside the point.

My primary interest in this subject is, obviously, that of the practical fishery conservationist, and I suppose that I am inclined to be somewhat impatient with theories and attitudes that I fear may provide ammunition to those opposed, for one reason or another, to true conservation. The entire program for the conservation of the salmon of the Pacific coast and Alaska, so far as it depends from scientific information and not from political exigencies, is based upon the acceptance of the "home stream theory"—in other words, of the theory that the several species each consists of a large number of independent local populations or races and that the adults return from the ocean predominantly to the streams of their nativity. I feel that this theory is on solid ground and must be accepted as fundamental. The practical conservationist must assume, in the absence of any conflicting evidence, that the Pacific salmon do return to their home streams from whatever distance they may go at sea; he must determine the drain upon the salmon runs by fisheries at such distant points as may prove to be in the path of the migration and he must apply his conservation measures throughout the range of the populations in question to the end that each may be maintained at the most productive level.

Summary

1. A rational conservation program for such migratory fishes as the salmon must be based on a knowledge of (a) whether or not the species consists of local, self-perpetuating populations and (b) the nature and extent of the oceanic migrations.

2. The conservation of a species that is broken up into local self-perpetuating populations involves the determination of the causes of mortality at all stages in the life-history of each group.

3. Species that are not so broken up may be conserved by measures of more general application.

4. In the case of migrating species the routes traversed by the individuals of each population group must be known in order that the causes of mortality may be determined and that appropriate conservation measures may be applied.

5. In the case of the Pacific salmon, the evidence shows clearly the existence of local, self-perpetuating populations.

6. The evidence also shows clearly that the Pacific salmon return from their life in the sea predominantly to their home streams thus justifying acceptance of what is known as the "home stream theory."

7. It has also been shown that many of the Pacific salmon travel hundreds of miles in the ocean, by the nearest route, from places where they have been captured and tagged, before they enter streams for the purpose of spawning.

8. In the absence of any conflicting evidence it is believed that the "home stream theory" applies to these fish that travel long distances in the ocean as well as to those that may not travel so far and that the basing of practical conservation measures upon an ac-

ceptance of the "home stream theory" as of general application is justified.

References Cited

CLEMENS, W. A. 1937. Contributions to the Life-history of the Sockeye Salmon. No. 23. Ann. Rept. Provincial Fisheries Dept. British Columbia for 1937. 1929. Summary of the Results of Tagging of Spring Salmon Along West Coast Vancouver Island and Queen Charlotte Islands in 1925, 1926 and 1927. *Prog. Repts. Pac. Biol. Sta. Biol. Bd. Canada,* No. 4, 11–13.

CLEMENS, W. A., AND CLEMENS, LUCY S. 1925 to 1936. Contributions to the Life-history of the Sockeye Salmon. Nos. 11 to 22. *Ann. Repts. Fish. Dept. B. C.,* 1925 to 1936.

DAVIDSON, F. A. 1934. The Homing Instinct and Age at Maturity of Pink Salmon (*Oncorhynchus gorbuscha*). *Bull. U. S. Bur. Fish.,* No. 15, 27–39.

DILL, D. B. 1925. The Proximate Composition of Certain Pacific Coast Fishes. *Ind. and Eng. Chem.,* 17: 6, 629.

GILBERT, C. H. 1913. Age at Maturity of the Pacific Coast Salmon of the Genus Oncorhynchus. *Bull. U. S. Bur. Fish.,* 32: 1–22.

———. 1914 to 1925. Contributions to the Life-history of the Sockeye Salmon. Nos. 1 to 10. *Ann. Repts. Fish. Dept. B. C.*

———. 1923. Experiment in Tagging Adult Red Salmon, Alaska Peninsular Fisheries Reservation, Summer of 1922. *Bull. U. S. Bur. Fish.,* 39: 39–50.

GILBERT, C. H., AND RICH, W. H. 1925. Second Experiment in Tagging Adult Red Salmon, Alaska Peninsula Fisheries Reservation, Summer of 1923. *Bull. U. S. Bur. Fish.,* 42: 27–75.

———. 1927. Investigations Concerning the Red Salmon Runs to the Karluk River, Alaska. *Bull. U. S. Bur. Fish.,* 43: 1–69.

PRITCHARD, A. L. 1931. Summary of the Results of Tagging of Spring Salmon in 1929 and 1930. *Prog. Repts. Pac. Biol. Sta. Biol. Bd. Can.,* No. 8, 15–20.

RICH, W. H., AND BALL, E. D. 1928, 1931, 1932 and 1933. Statistical Review of the Alaska Salmon Fisheries. Parts 1 to 4. *Bull. U. S. Bur. Fish.,* 44: 41–95; 46: 643–712; *Bull.* No. 7, 187–247, and *Bull.* 13, 437–673.

RICH, W. H., AND HOLMES, HARLAN B. 1929. Experiments in Marking Young Chinook Salmon on the Columbia River, 1916 to 1927. *Bull. U. S. Bur. Fish.,* 44: 214–264.