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UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. Krug, Secretary

FISH AND WILDLIFE SERVICE
Albert M. Day, Director

Special Scientific Report No. 51

A SURVEY OF THE COLUMBIA RIVER AND ITS TRIBUTARIES WITH SPECIAL REFERENCE TO THE MANAGEMENT OF ITS FISHERY RESOURCES

By

Willis H. Rich

Issued May, 1948

Washington, D. C.

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1. Introduction

Edited by

Willis H. Rich
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History of the Survey

In 1934 the United States Fish and Wildlife Service (then the Bureau of Fisheries) began a study designed to provide the information needed as a basis for a complete program for the maintenance and rehabilitation of the fisheries of the Columbia River. These fisheries depend almost entirely upon migratory or anadromous species, especially the salmon and the steelhead trout, and the investigations have been directed primarily toward ascertaining facts bearing on the conservation of these species. The general purpose and need for these investigations has been described in an earlier publication 2/ which gives a full account of the history and methods of the Columbia River fisheries.

One of the phases of this study has been a detailed survey of all the streams of the Columbia Basin that provide, or have provided in the past, suitable areas for the spawning and the rearing of the young of the several species of salmon and the steelhead trout. It is this survey that is the subject of this series of reports.

The immediate purpose of this survey is different from that of the usual biological stream survey where the information acquired is to be used in setting up planting programs for trout or other game fishes. In the latter the primary object is to obtain data which can

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1/ Several present and former members of the staff of the Fish and Wildlife Service prepared introductory sections for parts of the main body of this report. This general introduction is largely compiled from these. Particularly to be mentioned as contributors are Joseph A. Craig (now Chief Biologist, Washington State Department of Fisheries), Arnie J. Suomela (now Master Fish Warden, Fish Commission of Oregon), Zell E. Parkhurst, Reed S. Nielson, Floyd G. Bryant, and Mitchell G. Hanavan.

2/ Craig, Joseph A. and Robert J. Hacker. The History and Development of the Fisheries of the Columbia River. U. S. Bureau of Fisheries, Bulletin No. 32, vol. XLIX, 1940, pp. 133-216.

be used to determine what species of fish are suited to the water in question and what the carrying capacity of the streams and lakes is in numbers of the species indicated. The purpose of the Columbia River survey has been to determine the present condition of the various tributaries with respect to their avail bility and usefulness for the migration, breeding and rearing of migratory fishes.

The physical and chemical conditions of the streams which directly affect the migrations and survival of the anadromous fishes are of immediate and practical importance and throughout the survey, attention has been concentrated on these factors of the environment. The ultimate purpose is, of course, to provide a basis for improving present conditions to the end that the basin can be made more productive of fish. Nearly all of the populations of salmon and steelhead trout in the Columbia Basin are depleted and there is no doubt that runs of much larger size than those of the present time were common in former years throughout most of the watershed. If these populations can be restored to the former levels, or even partially restored, it will mean a major economic gain to the nation as a whole and to the states of Oregon and Washington in particular.

The survey has attempted to determine "the extent and quality of available spawning grounds, the location and character of natural or man-made obstructions which block or interfere with the migration of fishes, the species and number of fish inhabiting various tributaries, sources of pollution, number and location of irrigation diversions, water temperatures and flows of the tributaries, and many other pertinent facts that are needed to make the picture of the fresh-water habitats complete." 3/

The first surveys were made in the fall of 1934 and the work is still continuing. Lack of men and transportation prevented much activity during the war period. All of the survey work was under the direction of Joseph A. Craig from its beginning until May 1943. Messers. Arnie J. Suomela, Mitchell G. Hanavan and Zell E. Parkhurst also supervised much of the field work and personally took part in the surveys of many streams. Other members of the staff of the U. S. Fish and Wildlife Service who participated in the field survey at various times were: Charles H. Baltzo, Floyd G. Bryant, Roger E. Burrows, Leroy R. Christey, David G. Frey, Frank W. Jobes, Lawrence N. Kolloen, Ray Langton, Milton J. Lobell, William M. Morton, Robert Peterson, Richard F. Shuman, Richard T. Whiteleather, James L. Wilding and Paul D. Zimmer.

3/ Craig and Hacker, loc. cit. p. 134.

The continuation of the survey is now under the general direction of Joseph T. Barnaby, Aquatic Biologist, Chief, North Pacific Fishery Investigations, with Zell E. Parkhurst supervising the field work, and is closely integrated with the investigations that are being carried on in connection with the Columbia Basin Fisheries Maintenance Program of the Fish and Wildlife Service. Special attention is being given to streams that, for one reason or another, are of special importance to this Program. Such are the tributary streams below the site of the proposed McNary (Umatilla) Dam. It is planned to develop the runs into these lower tributaries as fully as possible by a combination of stream improvements and artificial propagation and the present survey work is directed primarily to aid in this practical work.

Certain phases of the survey will doubtless be continued for many years but the work has now progressed to the point where the results are sufficiently complete to warrant publication. At this time practically all of the important salmon producing streams in the Columbia Basin that are readily accessible have been surveyed and this is also true of many streams to which there is no ready transportation but where problems of immediate importance to the maintenance of migratory fish are known to exist. Much remains to be done, especially in the more remote and inaccessible tributaries, and changes in conditions have taken place since the surveys were made. Several major programs for the protection of salmon and steelhead spawning areas have been put into effect during the past few years; some of them since the streams were visited. The present report, therefore, is not strictly up to date--and, in the nature of things, it could never be. But further delay in publication is not desirable because of the urgent need for the data that are now available. As time and opportunity offers, unsurveyed areas will be covered and the changes in other areas recorded. As data of these kinds accumulate, supplementary reports will be issued that will add to the information to be presented in this series and will keep it as nearly current as possible.

The Columbia River Basin

Only a brief description of the Columbia River Basin need be given here and this may be quoted from the so-called "308 Report" of the Corps of Engineers 4/ which is also quoted in part by Craig and Hacker (loc. cit.)

4/ Columbia River and Minor Tributaries. House Document No. 103, 73rd Congress, 1st Session. Washington: 1933.

"Columbia River is about 1,210 miles long. Four hundred twenty-five miles of its course is in the United States between the International boundary and the mouth of Snake River, and three hundred twenty-three and one half miles between the latter point and the Pacific Ocean. Its basin has an area of about 259,000 square miles, including about 39,000 square miles in Canada. About 64,000 square miles of the Columbia's basin above the Snake lies within the United States and embraces all of Washington east of the Cascade Range except the southeastern corner, northern Idaho and Montana west of the Rockies. The basin of the Snake, the longest tributary of the Columbia (1,036 miles), covers about 109,000 square miles, embracing the extreme western part of Wyoming, southern Idaho, eastern Oregon, southeastern Washington, and small parts of Utah and Nevada. Below the mouth of the Snake the basin of the Columbia includes about 46,500 square miles in Washington and Oregon. About 27,000 square miles of this area lies between the Snake Basin and the Cascade Range, about 1,000 square miles through the Cascades and 18,500 square miles west of the Cascades. About 11,000 square miles of the last-mentioned area is in the basin of the Willamette River.

"Three principal systems form the headwaters of the Columbia River: First, the Columbia River proper, which, rising in Columbia Lake in British Columbia near the international boundary, flows northwesterly for nearly 200 miles then turns abruptly to the west and south, circling Selkirk Range, and enters the United States at the northeastern corner of Washington; second, Kootenai River (spelled Kootenay in Canada) which also rises in British Columbia near the source of the Columbia proper, but flows in an opposite direction (southeasterly), paralleling the Continental Divide, enters the United States at the Idaho-Montana-British Columbia corner for a short curved course of 167 miles, and empties into Columbia River proper about 30 miles north of the international boundary after flowing through Lake Kootenay in Canada; and third, Clark Fork, which, with its tributaries, drains the strip of Montana between the Continental Divide and Idaho. Clark Fork rises in western Montana, flows northwest between the Continental Divide and Bitterroot Mountains, crosses the panhandle of Idaho and the northeast corner of Washington, and, after a short course in British Columbia, empties into Columbia River very close to the international boundary and a short distance below the mouth of Kootenai River.

"Columbia River thence flows southwest and south through northeast and central Washington, is joined by Snake River at Pasco, Washington, and a short distance below Pasco turns west, forming the Washington-Oregon boundary to the Pacific Ocean."

"The outstanding characteristics of the Columbia and its basin are: (a) The great fall in the river, amounting at low water to 975 feet between the international boundary and the mouth of the Snake, and 309 feet from the latter point to tidewater. This condition, with the existence of dam sites and usable low water flow is the basis of a large potential hydroelectric development, but the swift water resulting from the fall makes it adverse to navigation above tidewater. (b) The large area of semiarid country in the basin, partly within economic reach of irrigation waters from the Columbia, a condition that, with the fertility of the soil, offers considerable possibilities of irrigation. (c) The minor extent of area subject to flood damage."

It may be added that the flow of the main Columbia River at The Dalles, Oregon, varied over the period 1879 to 1930 inclusive from a low of 40,000 cubic second feet (January 18 and 21, 1930) to an estimated maximum of 1,160,000 c.s.f. (June 6, 1894). The average during this period was 202,400 c.s.f.

Additional details will be found in the "308 report" and also in the forthcoming sections of this report. Extensive data on stream flow and run-off in the main Columbia River and its principle tributaries are given in the "308 report", Part 2, Report of the District Engineer, Seattle, Washington, p. 602 ff. and Part 3, Report of the District Engineer, Portland, Oregon, p. 1423 ff.

Habits and life-cycles of Columbia River salmon and steelhead trout

Four species of salmon and the steelhead trout form by far the most important commercial fishery resources of the Columbia Basin. The importance of the fisheries for these species has been recorded by Craig and Hacker (loc. cit.) and by Craig and Townsend.5/ The latter have also shown the important contribution made by the chinooks and steelhead to the sport fisheries of the area. All of these fish spawn in streams that pass through or lie wholly within settled districts; farming communities and more densely populated industrial centers. As the human population increases in the Columbia Basin these streams are being more and more developed for uses inimical to the maintenance of the stocks of anadromous fishes.

5/ An Investigation of Fish-Maintenance Problems in Relation to the Willamette Valley Project. By Joseph A. Craig and Lawrence D. Townsend. Special Scientific Report No. 33 (1946).

The conservation of the salmon and steelhead trout is only a part of a complex problem in the "wise use" of natural resources. The intimate way in which the problems involved in providing for sound management of the fishery resources are associated with developments in the nature of water-use projects is only clear when the habits and life-histories of the several species of fish are understood. it is, therefore, pertinent to the purposes of this report to present a brief account of these habits and life-cycles. The following account is modified from that given by the editor at a meeting of the Northwest Science Association in 1934. 6/

The four species of the Pacific Salmon of the Genus *Oncorhynchus* that are found in the Columbia River in commercial quantities are as follows: (1) the chinook, *O. tschawytscha*; (2) the blueback, *O. nerka*; (3) the silver, *O. kisutch*; and (4) the chum, *O. keta*. There is a fifth species, the pink salmon, *O. gorbuscha*, that occurs only rarely in the Columbia River but is abundant in Puget Sound, British Columbia and Alaska. In addition to the four species of salmon, the Steelhead trout, *Salmo gairdneri*; (or *S. irideus*) is one of the more important elements in the commercial and sport catches of the Columbia Basin.

All of these fishes are anadromous; that is to say, they spend a large part of their lives in the sea but enter fresh water for reproduction. The eggs are laid in the gravel of streams, or occasionally along the shores of lakes, are covered with gravel by the parent fish, and remain there until hatching. The length of time required for incubation varies with the temperature of the water. In the case of chinook salmon, the eggs will hatch in about 50 days at a temperature of 50° Fahrenheit. Within a short range around this temperature each degree higher shortens the time of incubation by about two and a half or three days and each degree lower increases the time of incubation by the same amount. A more complete statement is that the relationship is such that the product of the temperature, in degrees Fahrenheit above freezing, and the time of incubation is approximately constant and equal to 900; or that the time in days is approximately given by dividing 900 by the temperature in degrees Fahrenheit above freezing.

6/ The Biology of the Columbia River Salmon. By Willis H. Rich. Northwest Science, Vol. IX, No. 1, February, 1935, pp. 3 - 14.

Upon hatching the young fish are encumbered by a relatively enormous yolk sac and are practically helpless. They remain, therefore, in the gravel until this yolk sac has become almost completely absorbed, after which they work their way up through the gravel, emerge into the stream, and begin to feed. They remain in fresh water for varying lengths of time but ultimately migrate down stream to the sea. The growth in fresh water is relatively slow so that the seaward migrants range in length from only about an inch to some six or eight inches. The size at migration depends in part on the length of time spent in fresh water and in part on the favorableness of the environmental conditions, particularly the abundance of food and the maintenance of temperatures favorable to growth.

Upon entering the sea, the relatively great abundance of food, and possibly other factors, reacts promptly and vigorously upon the rate of growth and the fish increase in size with great rapidity. After one or more seasons spent in the sea the fish return to fresh water for spawning. The length of time spent in the sea differs considerably with the species and with the locality and, in the case of some of the species, there is a considerable difference with individuals even in the same locality. The size of the fish when they mature and return to spawn varies with the species and the length of time spent in the ocean. On entering the streams for the spawning migration, some of the species in some localities may pass up only a few yards while others ascend the streams for hundreds of miles to the headwaters of such large rivers as the Columbia.

Except in rare instances and under peculiar circumstances the adult fish after leaving the sea do not feed but live throughout the spawning journey upon the fat that was stored during the period of heavy feeding in the sea. This source of energy is drawn upon for the journey up stream to the spawning grounds and for materials for the development of the large masses of eggs and sperm. As a result, the fish are greatly emaciated by the time the spawning activities are over; they weigh perhaps not more than half what they did on leaving the sea, are often infected with fungus as a result of injuries received on the journey or on the spawning grounds and are altogether in a sad state. A small percentage of the steelhead survive this period of stress, make the return journey to the sea and live to spawn again. But nature has evidently failed to provide for such survival in the case of the salmon of the genus *Oncorhynchus*. No one of these ever returns to the sea to recover, produce another lot of eggs or sperm and return to fresh water to spawn a second time. Without exception these fish die after spawning.

It is a fact of primary importance to any program for the conservation of the Columbia River salmon and steelhead that these fish, in common with most other anadromous salmonoids, return from the sea to spawn in the same rivers where they spent the early part of their lives. The statement of this fact is variously known as the "Parent Stream Theory" or the "Home Stream Theory". It is not necessary to present here in detail the evidence on which this theory has been based; it will suffice to state that it was originally based on the observation that fish of the same species in different streams were different morphologically and in habits and that these differences were constant year after year. This has been amply verified by experiments in which young salmon and steelhead were marked by clipping off certain of the fins. The adults showing these marks have returned predominantly to their "parent" streams.

Observations and experiments have shown further that the salmon and steelhead return, not only to the same stream, but to the very tributary of a large river system in which they spent their early life. Fish marked at the hatcheries at Bonneville, Hermann Creek, Little White Salmon, Spring Creek, the McKenzie and the Willamette Rivers have returned to their home tributaries in large numbers and have only rarely been taken on the spawning grounds of any other tributary. It is probably true that the Parent Stream Theory does not hold quite as rigidly in the case of tributary streams as it does for separate river systems but the evidence is overwhelming that, for all practical purposes, we must consider that the fish return to the tributaries from whence they came.

The importance of the fact that the salmon and steelhead return as adults to their home streams and tributaries is obvious; it is essential that each independent, self-perpetuating population of fish be preserved if depletion is to be avoided. Populations of fish that are prevented from reaching their native streams by dams must be artificially transferred to other, favorable streams or they will die out. If conditions in the streams where the adults spawn and the young are reared become unfavorable the populations will be reduced or may be entirely eliminated. It has been a primary purpose of this survey to discover the existing conditions in all streams that support or have supported runs of salmon and steelhead and to determine the size of present and, so far as possible, of past populations of these fish.

The simplest life-history of the several species of Pacific salmon is that of the pink salmon --the species that is found only rarely in the Columbia River. The young of this species leave the fresh water for the sea almost immediately after the yolk sac is absorbed--usually in the early spring--and the fish remain in the sea about a year and half. Then they mature and return to fresh water to spawn and die. So far as known there is no variation from this simple life history.

The chum salmon introduces one kind of variation into the cycle. The young of this species also leave the fresh water as soon as they emerge from the gravel but their stay in the ocean is more variable--some return to spawn in their second year, as do the pink salmon, but the majority do not spawn until they are in their third, fourth or fifth year.

In the life-history of the silver salmon we find another kind of variation. These fish invariably remain in fresh water for at least one year before migrating to the sea, by which time they are from three to five inches in length. The silver salmon of the Columbia River usually make the seaward migration in the second spring of their lives--approximately 18 months from the time the eggs are laid down. Some of them, however, do not migrate to the sea until the spring of their third year. In their life in the ocean this species resembled the pink salmon in that the fish almost always remain in the sea about a year and a half; they return to fresh water as mature adults in the second fall following the spring in which they went to sea. A few of the male silver salmon mature in the fall immediately following the seaward migration. These precociously mature males are often referred to as "grilse" or "Jack salmon"--or just as "Jacks".

The habits of the blueback salmon and of the chinook salmon are considerably more complicated because both of these species remain in fresh water for varying lengths of time and also vary greatly in the number of years spent in the ocean before maturing.

The blueback salmon differs from all of the other species in that the eggs are invariably laid down in streams that are tributary to lakes, or along the shores of the lakes themselves. The young, on emerging from the gravels of the spawning beds, descend promptly to the lake and live there for at least one year, often for two or three years before undertaking the seaward migration. During this period of life in the lake they feed upon the small floating organisms known as plankton and their rate of growth and survival is directly dependent upon the abundance of these forms.

When they finally migrate to sea in the spring or early summer they range in length from three to six inches. In the sea this species continues to feed chiefly upon plankton but, of course, the oceanic plankton is much more abundant and the organisms are larger so that the food supply is adequate for the much more rapid growth that takes place in the sea. Some few of the males may mature as grilse in the fall of the same year in which the seaward migration was made; but usually these fish spend from two to three years at sea and sometimes do not return until the fifth year after entering the sea. With such a range of variation in both fresh water and ocean life it is obvious that there may be a great number of age groups. Thus there may be fish that left the stream during their second year and returned in either the second third, fourth, fifth or sixth years. Or fish that left the stream during their third year and returned either in their third, fourth, fifth or sixth years, and so on.

The chinook salmon varies as widely as does the blueback in respect to its life in the sea but there is not the same kind of variation in the fresh-water life. The young of this species may pass on to life in the sea soon after emerging from the gravel, just as in the case of the pinks and chums; or they may remain in fresh water an entire year. They do not have such a definite time for the seaward migration as do the other species. Especially during the first year of their lives the chinook of the Columbia River may migrate at any season of the year; young fish of the brood of the previous fall may be found, even in the estuary, during every month of the year. This is apparently true only in relation to the entire population of this species in the Columbia River; each distinct, self-perpetuating population of a tributary stream tends to have its own fairly well marked time for the seaward migration. This characteristic has an important bearing on any effort to maintain the salmon runs by means of artificial propagation. In any such effort the imposed conditions must accord with the requirements of the race of salmon handled. With respect to the point in question this means that the young fish must be released from the hatchery and permitted to migrate at the time that is normal for the particular race.

The life-history of the steelhead trout resembles in general that of the chinook salmon with this difference that, so far as known, the young never migrate to sea until at least the spring of their second year when they are about a year old. The steelhead spawns usually in the winter and spring instead of in the fall as do the salmon of the genus Oncorhynchus. The young steelhead may remain in fresh water for from one to three years, possibly more, and the fish may remain in the sea for from one to three or four years before returning to spawn. There is the additional complication that these fish may survive the stress of spawning and return to the ocean. This may happen several times so that a few steelhead may spawn three or even four times.

This very brief outline of the biology of the Columbia River salmon will give point to many of the observations noted in the sections of the report to follow. The effects on the fish of changes in the environment brought about by dams, irrigation ditches, power diversions, deforestation, cultivation, pollution, reduced flows and various other conditions imposed by advancing civilization are conditioned by these biological facts; they are, indeed, due to the interaction of the changing environment with the relatively stable requirements of the fish. With respect to any specific problem many biological details remain to be worked out; but these will lie within the framework of the general facts outlined above.

Methods

Most of the field work of the survey was accomplished by teams of two men, each of which was provided with a small truck and the necessary equipment and supplies. Field headquarters were established as near as possible to the streams to be examined--usually in places where living facilities were available; but if none were available a camp was set up. From such headquarters the streams in the immediate neighborhood were covered and when this had been done new headquarters were established at another convenient point.

Each stream was examined on foot if warranted by its existing or potential value in a program of fishery maintenance. It was customary to start at the mouth and work up to a point at which the stream ceased to be important. The "survey" was commonly terminated if the stream became too small to be of value, at total barriers such as high waterfalls, or wherever other conditions were such that the stream was of no present value and there was no reasonable hope of improvement. Beyond such points a more cursory "inspection" was frequently made although not always.

In examining a stream it was common procedure for the men to drive as close as possible to the mouth where one of the men would leave the truck and start the survey on foot. The other man would drive on to a point from which he could conveniently reach the stream some two or three miles above the point at which the other man had started. He would leave the truck and start on foot to survey up stream from this point. If necessary a marker was left so that the first man would know where to leave the stream and, in turn, go ahead with the truck. This "ride and tie" procedure was continued as far as the survey was carried, with such variations as might be dictated by circumstances.

As the stream was traversed on foot, field observations were recorded on forms provided for the purpose--the "Observation Blank" (Figure 2). Records were made at approximately 100-yard intervals. Distances were estimated by counting steps (recorded by a hand tally) when conditions were favorable for pacing and, otherwise, by estimating short distances "by eye". When possible the sums of such estimated distances have been checked against maps, particularly when the surveys were made by boat, and any substantial discrepancy has been noted on the card record (see below). At the upper end of each 100-yard section a record was made of such things as stream size, character of bottom, fish observed, etc. The location of barriers to the upstream migration of fish, such as log jams, falls or dams was also recorded and an estimate made of the degree of obstruction.

"Stations" were designated, usually at intervals of several miles, at important landmarks or where stream conditions exhibited a marked change. At these stations special data were obtained and recorded on a "Station Blank" (Figure 3) that included measurements of width, depth, flow and temperature. Record was also made of general conditions observed between stations that were not recorded on the "Observation Blank". These included such items as the nature of the marginal vegetation, evidences of erosion and of fluctuations in water level, gradient, character of the valley, type and amount of cultivation and of forest utilization, source and extent of pollution, number and species of fish observed and other pertinent data.

Width was measured by a tape. Average depth was determined from a series of 10 or more actual measurements by a rule (for small streams) or a sounding line. Temperatures were determined by calibrated thermometers shaded from the direct rays of the sun and, in water, immersed at least one inch. Flow, in cubic feet per second was estimated by the usual method: average width times average depth times average speed of water in feet per second times a constant correction for "drag". The speed was determined by floats traversing a measured distance. The product of the first three factors was corrected for "drag" by multiplying by 0.8 if the bottom was rough and irregular, and by 0.9 if the bottom was fairly smooth. When available, stream flow records were taken from the Water Supply Papers of the U. S. Geological Survey.

A special blank, "Obstructions", (Figure 4) was provided on which to record data relative to obstructions, both natural and artificial. When dams were encountered, measurements were taken or obtained from the operators of the height, length of crest, spill, etc. In the case of power dams the type and speed of the power units was recorded, because these are important factors in the safe passage of downstream migrants. Especial attention was paid to the condition and adequacy of fish ladders and other fish protective devices installed at dams.

OBSERVATION BLANK

Stream ______________________ Observer ______________________

Start ______________________ Date ______________________

Yards	Bottom % LR	MR	SR	MS	Width Ft.	Rest. Pools	Sp. rfls.	Sp. area %

Figure 2

STATION BLANK

Stations

Stream Date Observer

Station Location

Av. Width Av. Depth Flow

Water stage Max. Min.

Turbidity Gradient

Temp. water Air Hour Weather

Character of terrain

Hills Height Cover

Valley Width % cultivated

Stream banks - Height Slope Comp.

Extent of erosion - Banks Hills

Remarks

Figure 3.

On a "Diversions" blank, (Figure 5) data were recorded that included the type of each diversion, its location, description of the headworks, amount of water diverted, character of screens and other fish protective devices if present, etc.

The record blanks used in the field have undergone various changes during the several years of the survey; but the data recorded has been fundamentally the same. The forms now in use are those illustrated in Figures 2 to 5.

For convenience in working with the data obtained in the field the more pertinent information has been transferred to a series of 5 X 8 filing cards. There are 17 of these cards in a complete set (see below) but not all of them are required for each stream. For streams of little or no value from the standpoint of the maintenance of fishery resources, or that have been only briefly inspected, the available information is recorded by brief statements on blank cards. These are filed in order with the more complete filing cards of the regular survey. The original card file was not as complete as that now in use, which was adopted in 1941. At the top of each card is a heading giving the name of the river system and the name of the individual stream in addition to specific information as shown below.

Changes and additions frequently have been made on the cards as additional information was obtained. Sometimes this has involved the insertion of additional cards. Usually these changes in the card file were made without making corresponding changes in the field records. This has been particularly true in regard to stream improvements and engineering developments such as the construction of new dams and/or diversions. It has been the policy to keep the card record as nearly up-to-date as possible despite resulting differences with the original field notes. It has been the practice that no one should make changes on the cards without consulting all members of the crew that had carried out the survey of the stream in question. At the present time, whenever changes are made, the person making the change is supposed to record the date of the change, his name and the source of the information on which the change is based.

In addition to the name of the river system and the name of the stream the successive cards of a set carry the following information:

1. <u>General</u>. (1) Date of survey and names of surveyors; (2) Stream Source; (3) General direction of flow; (4) Total length; (5) Length surveyed.

DIVERSIONS

Stream ____________________ Date________Observer________________

Diversion No. __________ Name ____________________________________

Location ____

____

Return ____

____

Use ____________________ Date Built__________Owner____________________

Present Diversion_______c.f.s. Max.Capacity ____________ c.f.s.

Str. Flow above Div.______c.f.s. Str.Flow below Div._______c.f.s.

By-Pass ____

____

Headgate Description____

____

Protective Devices ____

____

REMARKS AND SKETCHES:

Figure 5.

2. Station data. In columns for each successive station are given:

(1) Station designation (A, B, C, etc.); (2) Landmarks; (3) Map locations; (4) Distance above previous station (5) Distance above mouth of stream; (6) Width; (7) Average depth.

3. Character of watershed. Station to station records are given of:

(1) the general character of the watershed (mountainous, flat, wooded, cultivated, etc.); (2) character of the banks (slope, composition etc.); (3) nature and composition of marginal vegetation; (4) extent of erosion (if any) of banks or watershed.

4. Gradient. Station to station data are given for (1) station elevations; (2) distance between stations; (3) difference in elevation; (4) average slope in feet per mile; (5) source of data. (When available, topographic or plan and profile maps were used to determine the gradients. In other cases the observers estimated the gradient.)

5. Stream flow and fluctuations. In upstream order are given for each measurement or estimate; (1) location; (2) date; (3) observed flow; (4) fluctuation in water level as given by Water Supply Papers, the records of operators of dams, reports of local residents or as indicated by debris, erosion, marginal vegetation etc.; (5) time and variation in seasonal runoff; (6) causes of variations; (7) effect of fluctuations on migratory fish. (If published records are used the reference is given.)

6. Temperatures. For each observation is given: (1) station; (2) location; (3) date and hour; (4) air temperature; (5) water temperature; (6) weather conditions; (7) any observed influence of temperature on fish.

7. Pools and riffles. Station to station totals are given for pools and riffles. The distance between stations is given and the pools and riffles are classified. Three types of pool are recognized: "Good", those over 6 feet deep and, therefore, of possible use as resting pools by salmon and steelhead between the time of arrival in the spawning streams and the actual spawning; "Fair", those two to six feet deep serving chiefly as temporary resting

pools, and "Poor", those small pools in cascades and behind large boulders that can be used briefly by the fish during their ascent of the steeper portions of the streams. Riffles are classified as "Good", "Fair" and "Poor" on the basis of the observer's judgment as to the relative value for natural spawning purposes. Characteristics on which this classification was based were size, gradient, size of rubble, etc.

8. Character of bottom. In columns are given the station to totals for: (1) Distance between stations; (2) total area of bottom; (3) area of large rubble and percentage that this forms of the total bottom area; (4) area and percentage of medium rubble; (5) area and percentage of small rubble; (6) area and percentage of mud and sand; (7) area and percentage of "suitable spawning rubble". (The term "rubble" instead of the more correct "gravel" was adopted early in the survey and has been so extensively used throughout the field notes and in the preparation of the forthcoming sections that it has seemed wise to let it stand). Rubble is defined as "large" if estimated to average over 6 inches in diameter, as "medium" if between 3 and 6 inches, and as "small" if less than 3 inches in diameter but larger than coarse sand.

9. Suitable spawning area available. This is defined as that part of the medium and small rubble recorded on Card 8 that possesses the water conditions and other characteristics that are necessary if the area is to be used for spawning purposes. The station to station totals are given for: (1) Distance between stations; (2) total area of bottom; (3) area and percentage of suitable spawning rubble available (the totals of medium and small rubble from Card 8); (4) estimate of the total of suitable spawning area available at low water; (5) estimate of total available at high water only. (The last 2 items are not always given.)

10 Suitable spawning area not available. So far as determined the station to station totals are given for: (1) Distance between stations; (2) total area of bottom; (3) area and percentage of total of suitable spawning rubble not available (inaccessible); (4) stages of water during which the area is inaccessible; (5) reason for unavailability (nature of obstructions and their location).

11. Obstructions. The data recorded on the field form "Obstructions" are all given on this card. (See Figure 4).

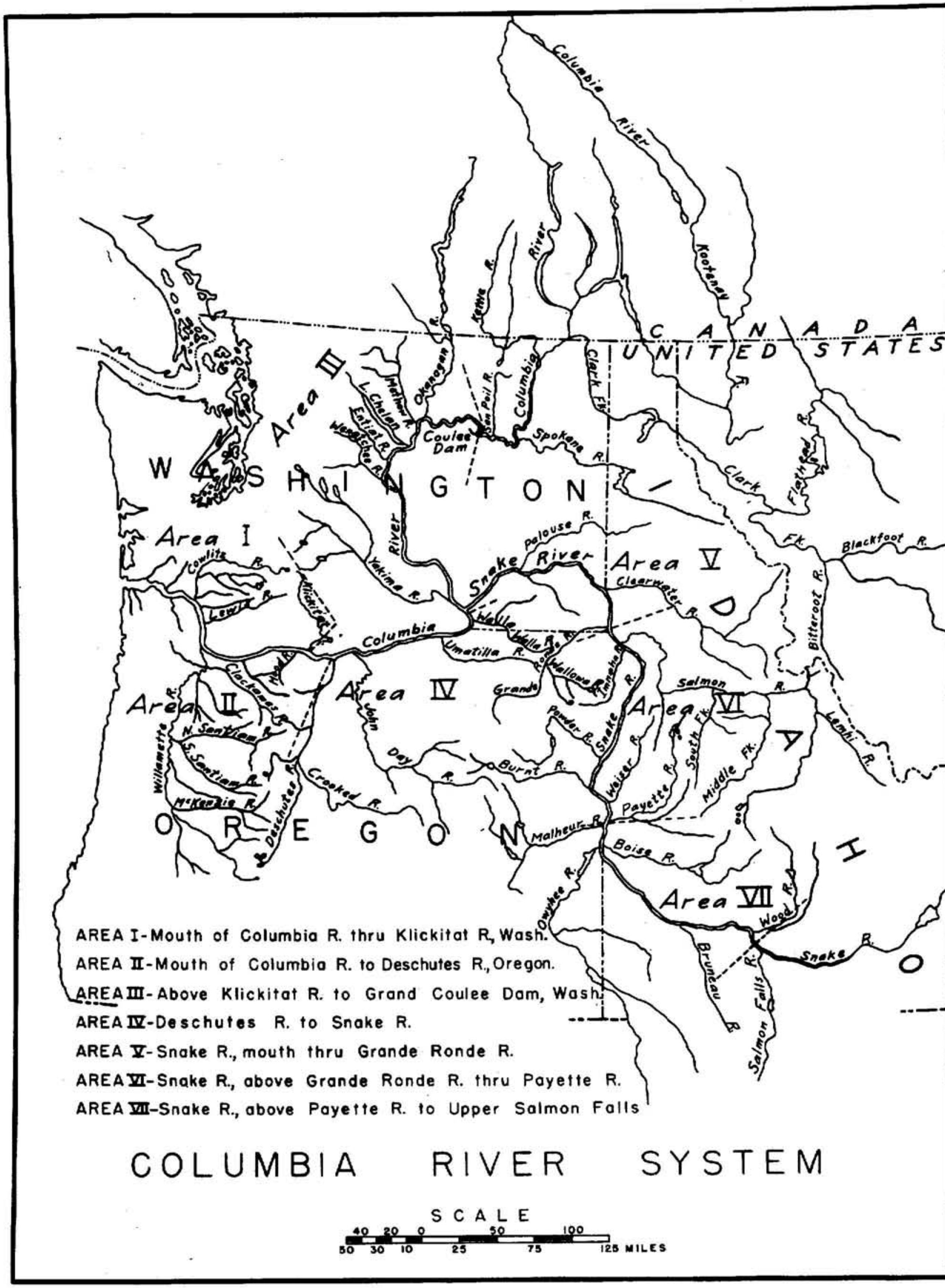

Figure 1 - Columbia River System

OBSTRUCTIONS

Stream____________________ Date________ Observer______________

Obstruction No.________ Name __________________________________

Location____

____

Type __________________ Degree of Obstruction___________________________

Construction____

____

Date Built__________________ Owner ___________________________

Dam Length _________________ Dam Height ________________________

Spillway width_______________ Spillway Depth ____________________

Apron Width _________________ Jump Height ______________________

Spillway Drop to Upper End of Apron_____________ Spillway Drop to Lower End of Apron ______________

FISHWAY: ____

____

REMARKS AND SKETCHES:

Figure 4.

12. Diversions. The data recorded on field form "Diversions" (Figure 5) are all given on this card.

13. Pollution. (1) Portion of stream polluted; (2) type of pollution; (3) source of pollution; (4) effect on fish; (5) recommendations.

14. Salmon and Steelhead. The station to station records are given for: (1) Distance between stations; (2) date of each observation; (3) visibility at time of observation; (4) number of fish counted (a) alive and (b) dead; (5) number of redds (nests) counted (a) occupied and (b) unoccupied and (b) unoccupied; (6) estimate of total number of fish present; (7) data on runs secured from local residents; (8) summary estimate of present populations and stream capacity for each species of fish. (Stream capacities are based on the observation that approximately 20 square yards of suitable spawning rubble is required for the average chinook salmon redd, allowing for the necessary spacing between redds). (9) time of appearance of runs and approximate spawning periods; (10) information on young fish.

15. Fish other than salmon and steelhead. (1) Species; (2) estimates of abundance; (3) observations bearing on the ecological relations of these fish to the salmon and steelhead; (4) extent of sport fishing.

16. Tributaries. All direct tributaries are listed in upstream order by name. The location and size of each is given and any available information on its value as a fish stream.

17. General remarks. Summaries and miscellaneous field observations not appearing on the other cards are given and the opinions of the surveyors as to the potential development of the fishery resources in the stream in question.

The immediate purpose of this stream survey has been, as stated, to determine the present value of the various tributaries for the migration, breeding and rearing of migratory fishes, especially salmon and the steelhead trout. An important element in determining this value is the extent of the presently available spawning areas. The capacity of a stream to produce salmon is not necessarily determined by the number of spawning adults that can find room to spawn; but it is a reasonable assumption that this capacity is roughly in proportion to the potential breeding population. The extent of suitable spawning area is certainly one limiting factor although other important factors are the extent of areas providing adequate food and other suitable conditions for rearing the young salmon to the migrating state and favorable conditions along the routes of migration.

On account of the importance that the determination of the extent of presently available and suitable spawning area has in evaluating a stream for salmon production, special attention has been given to this feature of the survey. The classification of stream bottom as "suitable spawning area" necessarily is based on the judgment of the observer and it is pertinent to inquire into the extent to which stream bottom designated as "Suitable spawning area" is actually used by spawning salmon. One test of this was made in 1940 and 1941 on the Molalla River, a tributary of the Willamette River.

The lower 32 miles of the Molalla River, between stations A and P (see below), was surveyed early in September 1940, while most of the salmon were still in the resting pools. The upper six miles of the river to the confluence with the Middle Fork between stations P & S (see below), was surveyed late in September 1941 at which time the salmon were at the peak of the spawning activity. Advantage was taken at the time of the survey in 1941 to check that portion of the stream surveyed in September 1940 in order to determine the extent to which the fish actually utilized the bottom designated as "suitable spawning area". The data and certain derived statistics are given in Table 1.

An examination of these data shows, first, that the "suitable spawning area" situated in the lower part of the river, below Station I, was not used by salmon to any appreciable extent. The first real concentration of spawning salmon was approximately 21 miles above the mouth; but, from this point to the upper limit reached by the salmon, spawning fish were well distributed. Approximately 75 percent of the "suitable spawning area" was below Station I; but less than 4 percent of the spawning fish were in this section of the river. Over 96 percent of the salmon were spawning in the 25 percent of "suitable spawning area" above Station I.

These figures seem to contradict the hypothesis that the surveyors could, by observation, determine what stream bottom was "suitable spawning area" and what was not. However, it is commonly true that the first fish in a spawning run of salmon tend to go to the higher spawning areas and that the lower areas are only utilized as the higher areas become more or less well occupied. The survival value of this habit is obvious. When spawning populations are reduced by depletion or by heavy fishing--which is true of the salmon runs of the Columbia River as a whole--it is to be expected that most of the spawning will take place in the upper reaches of the spawning streams. Doubtless, also the higher areas in such a stream as the Molalla River are more favorable in respect of other factors, such as temperature, than are the lower areas. It fairly may be assumed, therefore, that the failure of the salmon to utilize the apparently suitable areas of the stream below Station I was due to the action and interaction of biological and environmental factors other than the presence of suitable spawning gravel.

If, now, the data for the stream above Station I are analyzed it is clear that there is a very good correlation between the extent of areas designated by the surveyors as suitable for salmon spawning and the number of salmon actually observed on these areas. Between Stations I and S were estimated about 37,000 square yards of "suitable spawning area" and in these same sections were observed 901 spawning salmon. A Pearsonian Coefficient of Correlation (r) was calculated for the number of spawning fish and the number of square yards of "suitable spawning area" in each section (between Stations I and J, J and K etc.). The value of r is .75, 8 degrees of freedom, P = .02. This is clear evidence that the estimates of "suitable spawning area" are sufficiently accurate so that they were proportional to the number of salmon spawning in the various stations of the stream in 1941.

How well this would work out on other streams and with other observers may be questioned but it is believed that the survey on the Molalla River was quite typical of those conducted elsewhere in the Columbia Basin. Men new to the survey were trained with the more experienced men and it is reasonably certain that approximately the same methods were used by all.

Plan of the report series

It is the purpose of this series of reports to present a brief and condensed account of conditions as they were at the time the surveys were made, with the addition of such later information as is available; to outline the accomplishments of the last few years in the field of spawning ground improvement; and to give briefly recommendations for future action designed to improve conditions affecting the migratory fish populations of the Columbia Basin.

For convenience in organizing the data and writing and publishing the reports, the Columbia Basin has been divided into seven main areas and a number of sub-areas each of which is to be treated as a unit in the report series. An endeavor has been made to have each of these areas and sub-areas include a group of tributaries whose characteristics and problems of migratory fish conservation are similar. The main areas are shown in Figure 1 and are listed below with the included sub-areas.

AREA I - Washington side of the Columbia River from the mouth through the Klickitat River
- Sub-area 1. - Cowlitz River

AREA II- Oregon side of the Columbia River from the mouth up to but not including the Deschutes River
- Sub-area 1. - Willamette River
- Sub-area 2. - Sandy River

AREA III-Above the Klickitat River to Coulee Dam (Washington side only below the mouth of the Snake River).
- Sub-area 1. - Yakima River
- Sub-area 2. - Wenatchee and Entiat Rivers
- Sub-area 3. - Methow and Okanogan Rivers

AREA IV - Oregon side of the Columbia River from the Deschutes River to the Snake River
- Sub-area 1. - Deschutes River
- Sub-area 2. - John Day River

AREA V -Snake River from its mouth through the Grande Ronde River.
- Sub-area 1. - Tucannon and Asotin Rivers
- Sub-area 2. - Clearwater River
- Sub-area 3. - Grande Ronde River

AREA VI - Snake River from above the Grande Ronde River through the Payette River.
- Sub-area 1. - Salmon River
- Sub-area 2. - Weiser and Payette Rivers
- Sub-area 3. - Oregon streams in Area VI

AREA VII- Snake River from above Payette River to Upper Salmon Falls
- Sub-area 1. - Malheur and Owyhee Rivers
- Sub-area 2. - Boise River

The report will be issued in sections as the writing up of each area or sub-area is completed. As nearly as possible the sections will appear in the order in which the areas have been listed above. Sub-areas may or may not appear separately. The report covering the Sandy River, Sub-area 2 of Area II, was issued several years ago (7/) and will not appear directly in this series.

In order to keep the reports on these surveys within a reasonable volume only the more important data are included. Many more detailed data are in the files of the Fish and Wildlife Service. They are to be found in the general field notes report by participants in the survey, in the field forms and in the card file. These will be made available to anyone wishing to see them at the Fisheries Laboratory, 2725 Montlake Boulevard, Seattle, Washington.

7/ A survey of the Sandy River and its tributaries, 1940, with reference to fish management. By Joseph A. Craig and A. J. Suomela. Special Scientific Report No. 14, U. S. Fish and Wildlife Service, 1940. (Mimeographed)

TABLE 1.--Relation between stream bottom designated as "suitable spawning area" and actual utilization by spawning chinook salmon, Molalla River, 1940 and 1941

Section	Length of section (miles)	Distance above mouth (miles)	Total Bottom (sq. yd.)	"Suitable Spawning Area" (sq. yd.)	Number of Chinook Spawners, 1941	Average Area per fish (sq. yd)	Average number of fish per 100 square yards
Mouth - A	1.0	0.0	(Deep and muddy - unsuitable for spawning)				
A - B	2.6	1.0	99,800	12,700	....	....	....
B - C	2.4	3.6	135,900	19,900	....	....	....
C - D	2.4	6.0	59,800	20,600	....	....	....
D - E	1.9	8.4	49,900	9,800	....	....	....
E - F	3.6	10.3	113,500	18,800	....	....	....
F - G	1.7	13.9	53,000	7,100	2	3,550	.03
G - H	2.3	15.6	61,400	10,500	18	583	.17
H - I	1.7	17.9	60,600	5,400	13	415	.24
I - J	1.8	19.6	62,700	12,900	212	61	1.64
J - K	1.1	21.4	33,800	3,800	49	77	1.30
K - L	1.6	22.5	53,600	3,000	53	57	1.75
L - M	1.6	24.1	53,100	500	46	11	9.10
M - N	2.2	25.7	52,000	2,700	122	22	4.54
N - O	1.7	27.9	53,000	6,000	211	28	3.57
O - P	2.6	29.6	70,000	3,500	84	42	2.38
P - Q	1.3	32.2	40,500	1,000	30	33	3.03
Q - R	2.1	33.5	69,500	3,000	69	43	2.32
R - S	2.2	35.6	54,300	800	34	24	4.17