The Fishes of the Willamette River System in Relation to Pollution

By

R. E. DIMICK

and

FRED MERRYFIELD

Bulletin Series No. 20

June 1945

Cooperating Agencies

Oregon State Sanitary Authority
League of Oregon Cities
Oregon State Game Commission
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I. INTRODUCTION

1. **Authorization.** The study herein reported on the fish life of the Willamette River system constitutes a survey setting forth the present existing menace to this resource due to the pollution of rivers and streams by industrial and domestic wastes. This phase of the investigation is a part of the comprehensive survey of pollution conditions reported in the concurrently issued Bulletin No. 19. In that publication are set forth the data of organization, which will not be repeated here. The overall survey was authorized on June 30, 1944, by a resolution, approved by Governor Earl Snell, of the Postwar Readjustment and Development Committee for the state of Oregon. This resolution, participated in by the official representatives of the State Sanitary Authority, State Game Commission, State Board of Health, and Hydro-Electric Commission, called on the Engineering Experiment Station of Oregon State College to furnish facilities and to organize the joint survey.

While all of the above named cooperating agencies contributed funds to the general project, the part here reported having to do with fish life was the special concern of the State Game Commission and was supervised and carried through principally by employees of that organization.

2. **Purpose and scope of study.** Field studies were made of the fishes of the Willamette River system during August and September 1944, as an integral part of the general pollution investigation of which Professor Fred Merryfield was the project engineer in general charge. During the past ten years, occasional observations had been made of the fishes of the river, and the biological notes recorded have been used to supplement this report.

The main purpose of this phase of the study, in the limited time available, was to list the various fishes inhabiting the river and to ascertain the general effects of pollution on the game and commercial species. Since some of the fishes, especially salmon and trout, are migratory at various seasons of the year, a field study limited mainly to the seasonal time of the low water volume of the river is not wholly indicative of the effects of pollution on the fish fauna. For example, Chinook salmon on their way to the spawning grounds in the spring pass the dangerously polluted areas at a time of considerable water volume. Hence adult salmon usually escape death from the effects of pollution, which would undoubtedly have been their fate if the upriver migration coincided with a period of low water volume.

3. **Acknowledgments.** The biological aspects of this pollution study were largely guided by Mr. E. E. Wilson, chairman of the Oregon State Game Commission. In this project, he again demonstrated the same caliber of guidance that has made the Oregon State Game Commission in recent years one of the foremost state conservation agencies of the nation.

Direct supervision of the project was under the Oregon Engineering Experiment Station of which Professor S. H. Graf is director. Under his supervision differences in viewpoints were molded into a working team of biologists and engineers in which a coordinate effort for clean waters recognized that the fishing interests are among the primary values of the river system.

The splendid cooperation of the engineers working concurrently on the pollution survey made possible the fish studies of the project in the limited time available. Mr. W. G. Wilmot, field engineer, gave generously of his time and support to the biological phase of the study. Dr. C. A. Mockmore, head of the Civil Engineering Department, was a real inspiration to the project, for he demonstrated by actions and expressions a keen understanding of the many biological problems involved in the river system. These individuals were more than engineers assigned to a pollution study. They continuously emphasized that a clean river is an ecological necessity for good fishing and that the recreational values of the Willamette River system constitute one of the great natural resources of Oregon, if properly protected by pollution control.

Considerable information as to the seasonal times of salmon and steelhead trout runs in the river system was obtained from Messrs. M. E. Christenson, Hugh Mitchell, and M. T. Hoy, employees of the Fish Commission of Oregon. Orrel Ballantyne and Robert Borland, students of the Fish and Game Management Department at Oregon State College, made extensive fish collections and recorded hydrographic data. Dr. O. H. Muth, associate veterinarian of the Agricultural Experiment Station, photographed the fishes illustrated in this report.

The final manuscript was prepared for publication by Professor S. H. Graf with the assistance of Mrs. Alura Paul.

II. PROCEDURES

1. **Observation and sampling stations.** Various locations on the main river from the confluences of the Middle and Coast Forks, just above Springfield, to the Sellwood Bridge at Portland were selected as study stations (see Figure 1). Sampling points were established also on the important tributary streams. In addition, random fish collections and general observations were made of inimical conditions affecting fish life over most of the tributaries. Usually, the sampling stations were located above and below focal points of major pollution and in relation to the confluences of tributary streams flowing into the main river.

Most of the sampling points used in the sanitary survey of the Willamette River made in 1928 by Rogers, Mockmore, and Adams (1930)* were included in the present study. The locations of the study areas visited in 1944 are given in Table 1.

2. **Collection of data.** An automobile with boat-trailer was driven as near as practicable to the locations selected as study stations. At each station a field laboratory was made ready. Then the data usually recorded in stream surveys as described by Davis (1938) were obtained. These included such

* Dates in parentheses refer to bibliography in Section VII.

items as width and depth of the river, velocity of the water, bottom types, visibility depths of the water, air and water temperatures, etc. Water samples for chemical analyses and bacterial counts were collected and fish food samples were obtained. In addition, attention was directed to locating pollution sources in the area and other conditions detrimental to fishes.

Temperature readings of the air, the surface of the water, the bottom of the river, and mid-distance from the surface to the bottom were recorded. Air temperatures were taken in the shade approximately 3 feet above the surface of the water. The water temperatures were obtained in the middle of the river,

Table 1. LOCATIONS OF STUDY STATIONS USED IN 1944.

Designation	Station number used in 1928 by Rogers, Mockmore, and Adams (1930)
Main River	
Springfield, 1 mile above	3
Springfield, 1 mile below	4
Eugene, 3.5 miles below	5
Harrisburg	....
Peoria Ferry	7
Corvallis, 1 mile below	10
Albany, at Bryant Park	11
Albany, 4.5 miles below	12
Buena Vista	14
Independence, 2 miles below	15
Salem, 1 mile above	16
Salem, 2 miles below	17
Wheatland Ferry	19
Mission Landing, near St. Paul	....
Newberg, 0.8 mile above	22
Wilsonville Ferry	23
Willamette, 0.2 mile above confluence with Tualatin River	24
Oregon City, 1.2 miles below Willamette Falls	27
Portland, 0.3 mile above Sellwood Bridge	28
Eastside Tributaries	
Clackamas River, 0.5 mile above railroad bridge	26
Molalla River, approximately 4 miles above Molalla	11
Pudding River, approximately 3 miles below Woodburn	....
Santiam River, 300 yards above highway bridge at Jefferson	13
North Santiam River, below Mill City Dam	....
North Santiam River, Stayton Power Canal	....
South Santiam River, Crabtree highway bridge below Lebanon	....
South Santiam River, below dam above Lebanon	....
Middle Fork Santiam River, at Fish Commission Hatchery	....
Roaring River, Santiam River drainage, 0.5 mile below Game Commission Hatchery	....
Calapooya River, 0.5 mile below Brownsville	....
Calapooya River, 8 miles above Holley	....
McKenzie River, at old bridge above Coburg	9
McKenzie River, 300 yards above Walterville Bridge	....
Middle Fork, at Homestead	....
Westside Tributaries	
Tualatin River, 100 feet above junction with Willamette River	25
Yamhill River, 100 feet above junction with Willamette River	21
Mill Creek, tributary of Yamhill	....
Yamhill River, approximately 4 miles above Willamina	....
Rickreall Creek, approximately 2 miles below Dallas	....
Rickreall Creek, approximately 4 miles above Dallas	....
Rickreall Creek, near junction with Willamette River	....
Luckiamute River, approximately 5 miles below Kings Valley	....
Luckiamute River, approximately 7 miles above Hoskins	....
Mary's River, at Wren Bridge	....
Rock Creek, Mary's River drainage, south of Philomath	.....
Long Tom River, 3 miles below Monroe	8
Long Tom River, immediately below Fern Ridge Dam	....
Long Tom River, impounded water of Fern Ridge Dam	....
Coast Fork, 2.8 miles below Cottage Grove	2
Coast Fork, 3 miles above Cottage Grove	1

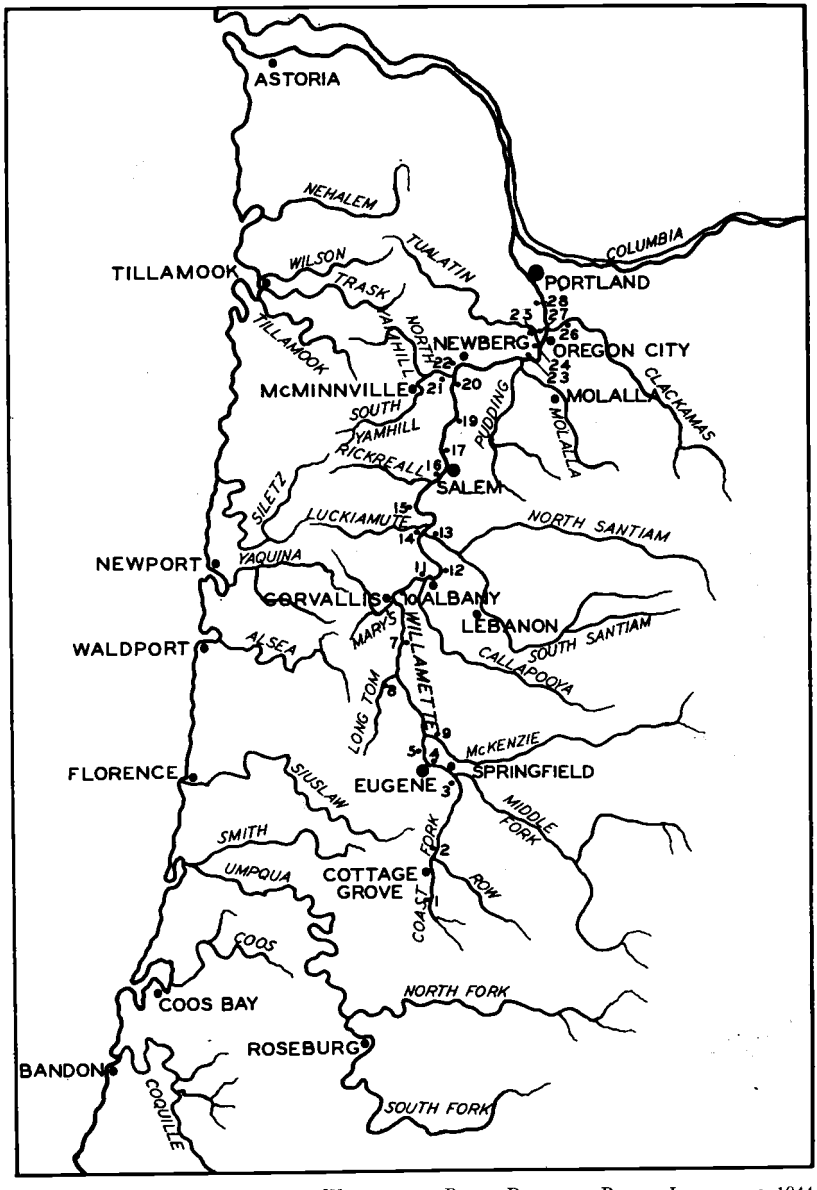

Figure 1. Sketch Map of the Willamette River Drainage Basin, Indicating 1944 Study Stations.

usually from a boat. The water collecting apparatus was the same instrument employed by Rogers, Mockmore, and Adams (1930) and by Gleeson (1936) in the sanitary survey of the Willamette River from the Sellwood Bridge to the Columbia River made in 1934. The water samples for chemical analyses were taken in the middle of the river at a depth of six-tenths the distance from the surface to the bottom. Two bottles of water were carefully handled and were sent or delivered to the laboratory at Corvallis for determination of dissolved oxygen and biochemical oxygen demand. One of the bottles of water was treated chemically in the field to set the dissolved oxygen. Final titration of this sample was usually made within a few hours at Corvallis. The untreated water sample for determining the biochemical oxygen demand was delivered to the laboratory at the same time as was the sample for dissolved oxygen determination and an allowance was made for the elapsed time from collection until arrival at the laboratory.

Hydrogen-ion concentration of a water sample obtained in midstream was determined at each study station by means of a standard colorimetric set. Water samples for bacterial count were immediately placed in a portable icebox until delivered to the Corvallis laboratory.

Fish food collections of bottom organisms were obtained at each station. A riffle area was usually selected and a square-foot bottom sampler was employed. In locations in which no suitable riffle areas occurred an Ekman dredge was used and four representative bottom samples were made so as to equal a square foot of area. In addition, invertebrate organisms were obtained by hand picking from submerged stones, sticks, and vegetation. All fish food organisms were later examined and those collected from a square-foot area were classified to order and in some cases to families and then measured volumetrically. In addition, the stomach contents of several fish from each station were analyzed in order to ascertain whether aquatic food organisms not obtained from bottom samples and by hand picking were present in the immediate water area.

Extensive fish collections were made at each location visited. This was accomplished by seining, angling, set lines, and even in a few cases by dynamiting. Some fish were obtained from the anglers encountered. The specimens were immediately preserved and were later given thorough study at Corvallis.

III. HYDROGRAPHIC DATA

Since one of the main objectives of the field studies was to obtain general information on the fitness of the various portions of the river system for fishes, some hydrographic data were obtained. These included records of water temperatures, dissolved oxygen, biochemical oxygen demand, and hydrogen-ion concentration of the water. From these occasional records, it was hoped that rough correlations might be made with the presence, absence, or relative abundance of the fish species in the different water locations.

At the same time, it was realized that factors other than pollution might determine the presence or absence of certain fishes from different areas. Consequently, attention was given to the bionomics of some of the fishes in relation to their environmental requirements within the river system. In addition, cursory examinations were made of stream barriers, fish ladders, diversion ditches, entrapment of fish in overflow ponds, law violations, fishing intensity, silt deposits, logging operations, and the like. All these conditions should be thoroughly investigated and evaluated before it can be definitely known whether pollution is the main or only one of the several contributing causes for trout and salmon decrease in the Willamette River system. Obviously, only bare

indications of the effects of these inimical factors could be made during the limited time of this study.

1. **Temperatures.** Water temperatures may be the limiting factor for some species of fish in particular portions of the river system. For examples, Dolly Varden trout probably could not survive in the lower portion of the river during the summer months because of high water temperatures, and the spawning of largemouth bass would not be successful in some tributary streams because of the prevailing low water temperatures.

This ecological factor is perhaps more responsible for the differences in seasonal distribution of the various fish species than any other environmental condition. Some fish apparently select habitats having temperature ranges of optimum comfort which in most cases are in keeping with the seasonal biological demands of the species. Trout, salmon, and white fish prefer the colder waters of the river system during the summer and thus do not usually frequent at that time of year the warm water areas of the lower stretches of the main river in which pollution is more pronounced. On the other hand, carp, bullhead catfish, largemouth bass, bluegills, and crappies prefer the warmer, slower moving waters of the lower river. Fortunately, these warm water fishes have a greater tolerance of pollution than trout and salmon.

The maximum and optimum temperatures for the important fishes of the Willamette River system are not well known. A few general approximations have been suggested from time to time but lack confirmation. Eighty-three degrees Fahrenheit is considered as about the upper temperature limit for rainbow trout (Needham 1938) and coastal cutthroat trout. Largemouth bass usually suspend feeding when the water temperatures are below 48 F and do not spawn in the spring or early summer until the water reaches 60 F.

Temperature influences the amount of dissolved oxygen in water that is available to fish. Other factors being equal, more free oxygen is present in cold water than in warm water. For example, at an atmospheric pressure of 760 mm, water may have a dissolved oxygen content of 14.62 parts per million at 32 F and 8.38 parts per million at 77 F. Besides temperature and pressure, the dissolved oxygen content of the water may be influenced by the oxygen consuming materials and organisms present, the amount of oxygen liberated by green plants in the process of photosynthesis, and the degree of aeration taking place in the river system.

The oxygen demand of fishes increases with a rise in temperature. Thus, in polluted waters having a reduced oxygen content, an increase in temperatures not only reduces the amount of available oxygen but increases the amount of oxygen required by the fish. Another aspect of the problem not generally understood is that toxicity of poisonous materials in the water is accelerated with an increase in water temperatures and with a decrease in dissolved oxygen. This is brought about by the increase in the breathing rate of fish to compensate for unfavorable conditions.

Through the assistance of several persons, daily water temperatures were obtained from six different river locations from August 1 to October 31, 1944. Daily maximum and minimum recordings were made at the Eugene Power Plant where hourly readings of the water from the Willamette River as it entered the building were recorded. Three daily readings were made at the Walterville power house of water in the power ditch diverted from the McKenzie River. Records were obtained on the main river from the Peoria Ferry at 6:00 am., 10:00 am., 2:00 pm, and 6:00 pm; the Independence Ferry at the same hours and at 10:00 pm; the Wheatland Ferry at the same times; and the Wilsonville Ferry at 6:00 am., 10:00 am., and occasionally at 2:00 pm.

From these daily water temperature records supplemented with those obtained at the study stations, the following significant items were evident:

a. The highest water temperatures recorded were obtained on the Long Tom River. Eighty-nine degrees F was registered three miles below Monroe on August 10. This unusually high water temperature apparently resulted from a reduced water flow caused by extensive construction operations taking place on the stream. Although no cutthroat trout were found from this point to the confluence with the main river, the high water temperature would have been lethal to this species which is the only salmonoid normally inhabiting the Long Tom River. On the other hand, largemouth bass, pumpkinseed sunfish, bluegill, white crappie, bullhead catfish, and carp did not appear to be distressed.

Seventy-six degrees F was obtained from a surface reading of the impounded waters of Fern Ridge Dam on September 11. At the same time the water temperature at the base of the dam was 70 F. Some of the feeder tributaries of the Long Tom River in wooded areas of the Coast Range ranged in water temperatures from 62 to 65 F on the afternoon of the same date. These temperature readings would indicate that impounded waters of shallow depth increased in water temperatures during the warm period of the year.

b. The highest water temperature recorded in the main river was 75 F, which was obtained several times at Eugene and at Wilsonville. This temperature is not lethal to rainbow trout, cutthroat trout, or young Chinook salmon, as was demonstrated by laboratory tests made at Corvallis.

c. The eastside tributaries such as the Middle Fork, McKenzie River, Santiam River above industrial areas, Molalla River, and the Clackamas River are about 6 to 10 degrees colder than the main river. This condition has a slight cooling effect upon the main river in certain stretches as, for example, the area from the confluence of the McKenzie River to Kiger Island above Corvallis.

d. The westside tributaries and some slow moving eastside tributary streams such as the Pudding and Calapooya rivers are usually 4 to 8 degrees colder in wooded, mountainous areas than in the main river, but the water warms up in their lower stretches to approximately the same temperature as that of the main river. Consequently, no modifying influence of water temperatures is obtained from these tributaries in the main river.

e. During the warm season of the year, the maximum and minimum daily temperatures at any one point may vary from 1 to 6 degrees F in the main river. This range in daily temperature variation is more pronounced at upriver areas such as Eugene and Peoria Ferry than at downriver areas such as Wheatland and Wilsonville where the daily variations during August and September were 1 to 4 degrees.

f. The maximum daily temperatures during the summer in the main river usually increased 1 to 4 degrees from Eugene to the Sellwood Bridge.

g. In a number of locations on both east- and westside tributary streams it was noted that reduced water volumes resulting from diversion dams caused a marked rise in water temperatures below such structures. For example, the water temperature on September 8 was 66 F at 3:20 pm in the South Fork of the Santiam River above the diversion dam upstream from Lebanon, and the water temperature approximately six miles below the city was 75 F at 4:00 pm on this date. The maximum water temperature of the main river on the same date was 72 degrees at Eugene, 70 degrees at Peoria, 72 degrees at Independence, 72 degrees at Wheatland, and 75 degrees at Wilsonville.

h. No salmonoid fish was observed in the Willamette River system in water of 73 degrees F or above. Rainbow trout, cutthroat trout, and fingerling

Chinook salmon in healthy condition were obtained near Peoria Ferry in water of 72 degrees F on August 29.

i. Adult Chinook salmon were observed during August and early September in Abiqua Creek and the Calapooya River in unusually good condition in water registering 66 degrees F. In the majority of cases, cutthroat trout, rainbow trout, and Chinook salmon were observed and collected during August and September in waters having a temperature range of 55 to 66 F. They were always less numerous in water ranging from 67 to 72 F.

j. Largemouth bass, bluegills, black and white crappie, and pumpkinseed sunfish were obtained during August and September in water ranging from 59 to 89 degrees. Not any of these fishes were found during August and September in water 58 degrees or below. In one case, numerous bullhead catfish were obtained in a small isolated pool along the river in which the water temperature was 93 degrees F.

2. **Oxygen.** An adequate supply of dissolved oxygen in the water is a prime requisite of fishes. Species differ in their requirements of oxygen and there may even be oxygen differences for the various life stages of some fishes. With an increase in temperature, the metabolic processes of fish are generally accelerated, thus requiring greater amounts of free oxygen in warm than in cold water.

It has been known generally that such fish as trout and salmon require more oxygen than many of the other kinds of fish in the Willamette River system, such as carp, other cyprinids, and bullhead catfish. Also, it has been known that trout and salmon may survive for brief periods of time in water having a very low oxygen content, if the water contains little or no toxic substances. Generally, in water of low oxygen content for the species, the breathing rate is increased, and under such circumstances the toxicity to the fish of poisonous materials may be greatly intensified.

The establishment of a minimum safe limit of dissolved oxygen for the fish fauna of the Willamette River is complicated by a variety of fish species, seasonal and locational water temperature differences, the toxicity of various chemical wastes discharged in the water, and the irregularity in time and volume of wastes discharged from sulphite paper mills, canneries, flax plants, creameries, and other industrial plants. Using the work of Ellis (1937), which was based on thorough field studies and substantiated by laboratory tests and observations, it appears that " . . . 5 ppm dissolved oxygen is the lowest value which may reasonably be expected to maintain in good condition varied fish fauna of warm-water fishes in our inland streams, if the water temperature be 20 degrees C or above." Ellis further pointed out that 5 ppm dissolved oxygen was not lethal to freshwater fishes but was approximately the lower limit of favorable conditions. In this connection no live trout or salmon were found in the Willamette River at any time during August and September in water having less than 5.2 ppm of dissolved oxygen, and a majority were collected in water ranging from 7.8 to 10.6 ppm of dissolved oxygen.

A group of cutthroat trout, rainbow trout, and fingerling Chinook salmon were maintained in good health for 30 days in experimental tanks at Corvallis in water having approximately 5 parts per million dissolved oxygen at temperatures ranging from 60 to 70 F. The water used in the tests contained no known toxic substances. The lowest limits of good condition for these species of fish as expressed in dissolved oxygen of water free of toxic substances has not as yet been determined.

Various pollutants entering the Willamette River and several of the tributary streams from many sources alter the dissolved oxygen by increasing the

biochemical oxygen demand. Domestic sewage and other substances subject to putrefaction such as organic wastes from canneries, creameries, flax retting plants, tanneries, slaughter houses, and the vegetation from newly impounded waters utilize dissolved oxygen in the process of decomposition. Then too, some chemical materials such as sulphite liquors from pulp mills and acids from flax retting plants kill some kinds of vegetation, which further depletes the water of dissolved oxygen. In a number of locations from Salem to the Sellwood Bridge at Portland organic sludge from domestic sewage, pulp mills, and canneries was found in large quantities below outlet points. Parts of this accumulation were observed to break up from time to time during the summer and drift downstream. Especially was this drifting of organic sludge noticeable in the vicinity of Wheatland Ferry during periods that water temperatures were 70 to 74 F. There is a good possibility that much of the organic sludge on the bottom of the river may be carried downstream during the winter and early spring freshets.

Some chemical effluents from industrial plants which enter the river not only increase the biochemical oxygen demand, directly and indirectly, but are apparently toxic to some fish and some of their food organisms. Especially noted in this connection during August and September 1944 were the areas of the main river from Newberg to the Sellwood Bridge and of the South Fork of the Santiam river from just below Lebanon to its confluence with the North Fork of the Santiam River. In these two outstanding pollution areas, sulphite liquor wastes from pulp mills were particularly noticeable during the low water volumes of summer and early fall. Although a few fish species apparently possessing considerable tolerance were collected in both these locations, dead specimens of less tolerant kinds were found. Healthy cutthroat trout of fry size placed in a wire basket and submerged in the water of the South Fork of the Santiam River in August 1940 a few miles below Lebanon succumbed in two minutes time. Death in this test presumedly was from the toxicity of sulphite liquor wastes coupled with a very low dissolved oxygen content of the water.

Throughout the field studies, water samples were collected for determining dissolved oxygen and biochemical oxygen demand as outlined under the section on procedure. Working separately but cooperatively the investigators from the city sewage and industrial waste survey obtained river samples for chemical analyses at periodic intervals from Cottage Grove, Springfield, Eugene, Peoria Ferry, Corvallis, Albany, Independence, Salem, Wheatland Ferry, Newberg, Wilsonville Ferry, and Oregon City. The results of these more thorough collections covering a number of samples over a period of several months are published in the companion report (Bulletin No. 19) giving the engineering aspects of the pollution conditions. The single samplings obtained at or near these main collection locations by the field crew studying the biological aspects were in good agreement with those obtained by the engineering investigators.

Table 2 presents the dissolved oxygen and biochemical oxygen demand of the water samples obtained at the various study stations visited on the main river and tributary streams from August 10 to September 30, 1944. The dissolved oxygen is recorded in parts per million (ppm), which is frequently presented as the number of pounds of atmospheric oxygen in one million pounds of water. The biochemical oxygen demand (BOD) was expressed as the amount of atmospheric oxygen used by a measured volume of water in the biological and chemical oxidation of organic material in the sample when incubated for 20 days at 68 F. The significance of the biochemical oxygen

Table 2. Dissolved Oxygen, Biochemical Oxygen Demand, and Hydrogen-Ion Concentration of Water Samples at Study Stations During August and September 1944.

Date 1944	Location	Station number	Dissolved oxygen	Saturation	Biochemical oxygen demand	pH	Remarks
			Ppm	*Per cent*			
Main River							
8/15	Springfield, above	3	7.0	75	0.6	7.5	Fish plentiful.
8/15	Springfield, below	4	7.6	83	0.6	7.2	Fish plentiful.
8/15	Eugene, below	5	8.8	102	4.5	7.7	Fish moderately numerous.
8/22	Harrisburg, above	....	9.0	93	3.7	7.7	Fish plentiful.
8/10	Peoria	7	8.2	84	2.7	7.6	Fish plentiful.
8/17	Corvallis, below	10	7.4	83	2.4	7.7	Fish plentiful.
8/17	Albany, above	11	8.2	90	1.8	7.7	Fish plentiful.
8/17	Albany, below	12	7.8	87	1.5	7.7	Fish plentiful.
8/21	Buena Vista	14	8.4	92	3.0	7.7	Fish plentiful.
8/21	Independence, below	15	8.8	95	0.9	7.8	Fish moderately numerous.
8/21	Salem, above	16	8.8	95	0.9	7.7	Fish moderately numerous.
8/23	Salem, below	17	7.0	77	2.4	7.3	Fish moderately numerous.
8/23	Wheatland Ferry	19	7.0	76	7.2	7.3	Fish moderately numerous.
8/30	Mission Landing	....	5.8	66	4.8	6.8	Fish moderately numerous.
8/30	1 mile below confluence with Yamhill River	....	4.8	50	4.6	....	Fish few.
8/24	Newberg, above	22	4.4	48	3.7	6.8	Fish few.
8/24	Wilsonville	23	1.4	15	6.8	6.1	Fish few, dead fish obtained.
8/24	Oregon City, above	24	0.6	7	8.2	6.5	Fish very few, dead fish obtained.
8/29	Oregon City, below	27	2.6	29.3	13.6	6.4	Fish very few.
8/29	Portland, Sellwood Bridge	28	0.8	9	6.6	6.5	Fish very few, dead fish obtained.
Eastside Tributaries							
8/26	Clackamas River, above Gladstone	26	9.2	98	0.3	7.7	Fish plentiful.
9/21	Molalla River, above Molalla	....	9.4	92	1.5	7.9	Fish plentiful.
8/30	Pudding River, below Woodburn	....	5.8	64	3.0	7.7	Fish moderately numerous.
9/22	Pudding River, below Woodburn	....	0.2	2	23.2	6.0	No fish, dead fish obtained.
8/17	Santiam River at Jefferson	13	8.8	94	2.4	7.7	Fish plentiful.
8/18	South Fork, Santiam River, Crabtree Bridge	....	0.0	0	15.0	6.0	Fish extremely scarce, dead fish obtained.
9/8	South Fork, Santiam River, Crabtree Bridge	....	0.0	0	10.8	6.0	Fish extremely scarce, dead fish obtained.
8/18	South Fork, Santiam River above Lebanon	....	8.8	91	.....	7.8	Fish plentiful.
9/8	South Fork, Santiam River above Lebanon	....	7.8	87	0.3	7.8	Fish plentiful.
9/8	Middle Fork, Santiam River, Fish Hatchery	....	8.8	92	0.3	7.8	Fish plentiful.
9/8	Roaring River, Santiam drainage	....	10.0	94	2.1	....	Fish plentiful.
9/9	Calapooya River, at Brownsville	....	8.2	86	0.3	7.7	Fish moderately numerous.
9/18	Calapooya River, below Brownsville	....	8.8	90	4.8	....	Fish moderately numerous.
9/9	Calapooya River, 8 miles above Holley	....	9.2	94	9.6	7.9	Fish plentiful.
8/15	McKenzie River, Coburg Bridge	9	8.8	89	0.6	7.8	Fish plentiful.

Table 2. DISSOLVED OXYGEN, BIOCHEMICAL OXYGEN DEMAND, AND HYDROGEN-ION CONCENTRATION OF WATER SAMPLES AT STUDY STATIONS DURING AUGUST AND SEPTEMBER 1944.—*Continued*

Date 1944	Location	Station number	Dissolved oxygen	Saturation	Biochemical oxygen demand	pH	
			Ppm	*Per cent*			
9/14	McKenzie River, Walterville Bridge	....	10.6	102	1.2	7.8	Fish plentiful.
9/14	Middle Fork, Homestead	....	10.2	100	1.2	7.8	Fish plentiful.
Westside Tributaries							
8/24	Tualatin River, near mouth	25	8.8	94	8.1	7.8	Fish plentiful.
9/13	Mill Creek, tributary Yamhill River	....	9.4	97	0.3	7.9	Fish plentiful.
9/13	South Yamhill River, above Willamina	....	9.0	96	0.9	7.8	Fish plentiful.
8/23	Yamhill River, near mouth	21	4.0	41	3.9	7.8	Fish very few.
9/6	Rickreall Creek, Independence Railroad Bridge	....	2.2	27	2.9	....	No fish collection made.
9/12	Rickreall Creek, 2 miles below Dallas	....	5.2	53	1.8	7.7	Fish plentiful.
9/12	Rickreall Creek, 4 miles above Dallas	....	9.6	98	0.3	7.9	Fish plentiful.
9/13	Luckiamute, below Kings Valley	....	8.2	86	0.6	7.8	Fish plentiful.
9/13	Luckiamute, Fisherman's Camp	....	9.4	94	0.3	7.8	Fish plentiful.
9/13	Mary's River, Wren Bridge	....	8.6	87	0.9	7.8	Fish plentiful.
9/13	Rock Creek, tributary Mary's River	....	8.2	81	0.6	7.8	Fish plentiful.
8/10	Long Tom River, below Monroe	8	5.8	64	3.6	7.0	Fish moderately numerous.
9/11	Long Tom River, below Monroe	8	5.8	64	2.7	7.5	Fish moderately numerous.
9/11	Long Tom River, outlet Fern Ridge Dam	....	4.3	47	0.8	7.8	Fish abundant.
9/11	Long Tom River, impounded water, Fern Ridge Dam	....	5.0	55	0.9	7.7	Fish moderately numerous.
8/14	Coast Fork, Saginaw	2	8.8	100	0.6	7.8	Fish plentiful.
9/9	Coast Fork, Saginaw	2	6.8	79	3.6	....	Fish moderately numerous.
8/14	Coast Fork, 3 miles above Cottage Grove	1	9.0	87	1.5	7.2	Fish moderately numerous.

demand in pollution studies is explained fully in Bulletin No. 19. Some of the significant items from these tests were as follows:

a. Dissolved oxygen expressed in parts per million of water varied in different parts of the river system from 0.0 to 10.6.

b. Dissolved oxygen, using 5 ppm as a basis for a lower limit of a favorable condition for fish, was adequate in the river system during the low water stages downstream to just above the confluence with the Yamhill River, with the exception of the South Fork of the Santiam River below Lebanon, the lower portions of Rickreall Creek and Yamhill River, and bottom water of the Fern Ridge Dam on the Long Tom River.

c. In the main river from the confluence of the Yamhill to the Sellwood Bridge the dissolved oxygen was not adequate for favorable conditions for fish. The dissolved oxygen just above Newberg was 4.4 ppm and decreased downstream, except for a small rise after the river passed over the Willamette Falls, to 0.8 ppm at the Sellwood Bridge.

d. The most markedly polluted area encountered in the entire system was the South Fork of the Santiam River from just below Lebanon to its confluence with the North Fork of the Santiam River. The dissolved oxygen as measured on several occasions was 0.0 ppm. The main contributing causes for this condition are a reduced waterflow in this section of the river, sulphite liquor wastes, and domestic sewage.

e. Pudding River below Woodburn is subjected to marked pollution at various times as illustrated by a 5.8 ppm water sample on August 30 and 0.2 ppm water sample in the same location on September 22. The main cause in this case appears to be the seasonal discharging of cannery wastes into the river.

f. The lower portion of Rickreall Creek appears subject to occasional periods of low oxygen content as is the Yamhill River.

g. From a fish standpoint, the areas of the main river at Eugene, Corvallis, Albany, and Salem appear adequate for fish life as measured on a dissolved oxygen basis; but the organic materials entering the river at these points add greatly to the biochemical oxygen demand of the water as it proceeds downstream. Especially does this biochemical demand rise greatly after leaving Salem.

Following the seasonal rains in fall, winter, and early spring, the dissolved oxygen throughout the main river and in marked pollution areas of the tributary streams becomes adequate for fish. This was substantiated from occasional water samples collected during November and December 1944 and during January and February 1945.

3. **Hydrogen-ion (pH) concentration.** The designation pH represents a range from 0 to 14 expressing the intensity of acidity and alkalinity of the water samples. A pH 7 is designated as a point of neutrality; values between 0 and 7 represent acid reactions and between 7 and 14 the reactions are alkaline. A table giving the increased intensity in acidity and alkalinity readings from the neutral pH 7 is given in Bulletin No. 19.

Experimental tests by a number of investigators have demonstrated that fish may tolerate wide variations in hydrogen-ion concentration. For example, Eastern brook trout were demonstrated by Creaser (1930) to have a tolerance in the range of pH 4.6 to 9.5. Nevertheless, pH readings may be important aids in pollution studies since excess variations in hydrogen-ion concentration may indicate harmful changes in the dissolved substances of the water. Ellis (1937) has stated concerning pollution studies " . . . it has been found advisable to view with suspicion any stream water having a hydrogen-ion concentration outside the limits of pH 6.7 to pH 8.6, until it could definitely be shown that such extra limital pH values were due to natural causes rather than to human agencies, as even badly polluted streams were usually within these limits."

The occasional pH readings of water samples at the several stations during August and September 1944 are presented in Table 2. The range of pH recordings obtained was from 6.1 to 7.9. In the more pronounced pollution areas the pH was less than 6.7 as recorded from below Newberg to the Sellwood Bridge at Portland, from Pudding River below Woodburn on September 22, and in the South Fork of the Santiam River below Lebanon.

IV. THE FISHES OF THE RIVER SYSTEM

Since pollution is known to have an important bearing on the fishes of a waterway, a study was made of the kinds of fish present, their locations, and relative abundance in the Willamette River system. Table 3 presents a distri-

butional list of the species inhabiting the main river and most of the tributary streams.

In the summer of 1894, Messrs. Frank Cramer and Keinosuki Otaki, then students at Stanford University, collected fishes at a number of points from near Oregon City to Eugene and from several of the tributary streams (Storey 1945). The distributional results of this collection together with taxonomic data were published by Dr. John O. Snyder in 1908. In that publication 16 species of fish were listed from the river system but no mention was made of the trout and salmon. Earlier, in 1879, David Starr Jordan described 7 species of fish collected by Mr. Livingston Stone from the Clackamas River. These included the Chinook salmon, the rainbow trout, the coastal cutthroat trout, the Dolly Varden trout, and 3 cyprinids which were also recognized by Snyder.

In the Willamette River system 34 kinds of fishes were found belonging to 13 different families. At least 19 of these are of game or commercial importance. Some of the 15 minor fishes may have important bearing on recreational and commercial species as competitors, as predators, and as food for these desirable fishes.

Twenty-three species of fish are indigenous and 11 are exotic. At least 7 kinds have been planted in the river system from time to time but apparently they did not become established. These failures included the Montana black-spotted cutthroat, *Salmo clarkii lewisi* (Girard); the European brown trout, *Salmo trutta* Linnaeus; the Eastern brook trout, *Salvelinus fontinalis* (Mitchill); the goldfish, *Carassius auratus* (Linnaeus); the channel catfish, *Ictalurus lacustris* (Walbaum); the smallmouth bass, *Micropterus dolomieu dolomieu* Lacépède; and the Northern rock bass, *Ambloplites rupestris rupestris* (Rafinesque).

A LIST OF THE FISHES, WITH NOTES:

Family 1. Petromyzonidae. Lampreys

Entosphenus tridentatus (Gairdner). Pacific lamprey. Three-toothed lamprey.

Range: Unalaska, Alaska, to Southern California. Freshwater and marine.

The Pacific lamprey is an elongated, cylindrical, eel-like animal that reaches a length of 2 feet or more. The presence of 3 conspicuous teeth in a circular funnel-like mouth characterizes this species.

The adults migrate up the Willamette River from the ocean in the spring. They pass over the falls at Oregon City by using their suctorial mouths. Then they enter east and west side tributary streams. Adult specimens have been taken in Mary's River near Corvallis in May and the fore part of June, in several different years. The lampreys excavate depressed saucer-like areas in gravel riffles by means of their sucking mouths; in these depressions small, whitish eggs are deposited and fertilized. The adults die following spawning and their decomposing bodies are frequently seen in early summer in pools of tributary streams, or drifting in the current of the main river.

The eggs apparently hatch in a few weeks time into small grayish colored larvae, known as ammocoetes. These wormlike larvae, which are blind and toothless, work their way into mud and sand and feed on small plant and animal organisms that drift near their projecting mouths. The period of time spent in the ammocoetes stage is not definitely known, but it is probably 2, or perhaps 3 years long, after which time the larvae undergo a metamorphosis in which teeth and eyes appear in the young lamprey. Then it migrates down river into the ocean where it becomes parasitic on fishes.

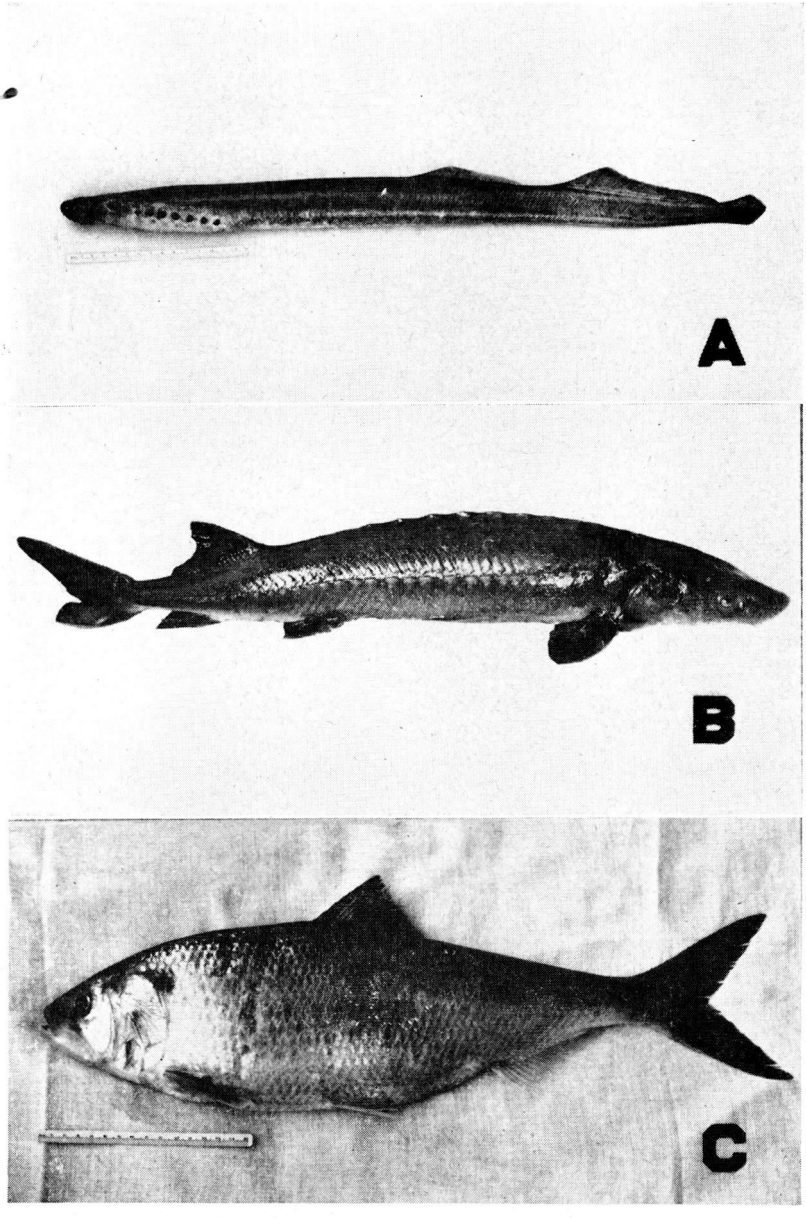

Figure 2. A. Pacific lamprey, *Entosphenus tridentatus;*
B. White sturgeon, *Acipenser transmontanus;*
C. Shad, *Alosa sapidissima.*

Table 3. Distributional Records of the Fishes in the Willamette River System.

X indicates presence in August and September 1944.
O indicates specimens collected at times other than August and September 1944.
R indicates species reported but not confirmed by specimens.

	Entosphenus tridentatus	*Lampetra planeri*	*Acipenser transmontanus*	*Alosa sapidissima*	*Oncorhynchus kisutch*	*Oncorhynchus tshawytscha*	*Salmo clarkii clarkii*	*Salmo gairdneri gairdneri*	*Salvelinus malma spectabilis*	*Prosopium oregonium*	*Catostomus macrocheilus*	*Cyprinus carpio*	*Acrocheilus alutaceus*	*Mylocheilus caurinus*	*Ptychocheilus oregonensis*	*Richardsonius balteatus balteatus*	*Oregonichthys crameri*	*Rhinichthys cataractae dulcis*	*Apocope oscula nubila*	*Apocope falcata*	*Ameiurus nebulosus nebulosus*	*Ameiurus natalis natalis*	*Columbia transmontana*	*Gasterosteus aculeatus microcephalus*	*Perca flavescens*	*Huro salmoides*	*Chaenobryttus coronarius*	*Lepomis gibbosus*	*Lepomis macrochirus macrochirus*	*Pomoxis annularis*	*Pomoxis nigro-maculatus*	*Cottus asper*	*Cottus rhotheus*	*Cottus gulosus*
Main River																																	
Springfield, above city						R		R			X		X		X	X										X							X
Eugene, above dam						R	R	R			X		X		X	X																	X
Eugene, below city						R	R	R			X		X		X																		
Harrisburg						O	X	X			X		X		X	X										X							X
Peoria Ferry	O					X	X	X			X		X		X	X										X							X
Ponds in area						O						O		O	O		O			O						O							
Corvallis, below city						O	O				X		X		X	X																	X
Ponds and sloughs in area						O					X	O		O	O		O			O						O							
Albany, above city						O	O				X		X		X																		
Albany, below city						O					X		X		X																		
Buena Vista	O					O	O				X	R	X		X	X		X															
Ponds in area											X	R	X		X	X																	
Independence, below city						O					X	X	X		X	X																	
Salem, above city											X	X	X		X	X																	
Salem, below city						O					X	X	X		X	X																	
Wheatland Ferry						O	R				X	R	X		X	X																	
Pond in area											X	X	X		X	X																	
Mission Landing, St. Paul						O							X		X	X																	
Pond in area													O		O	X																	
Confluence Yamhill River													X		X	X																	
Newberg, above city						O							X		X	X																	
Wilsonville Ferry						O						X			X	X																	
Oregon City, above falls						O						X			X	X																	

Table 3. DISTRIBUTIONAL RECORDS OF THE FISHES IN THE WILLAMETTE RIVER SYSTEM.—*Continued*

X indicates presence in August and September 1944.
O indicates specimens collected at times other than August and September 1944.
R indicates species reported but not confirmed by specimens.

	Entosphenus tridentatus	*Lampetra planeri*	*Acipenser transmontanus*	*Alosa sapidissima*	*Oncorhynchus kisutch*	*Oncorhynchus tshawytscha*	*Salmo clarkii clarkii*	*Salmo gairdnerii gairdnerii*	*Salvelinus malma spectabilis*	*Prosopium oregonium*	*Catostomus macrocheilus*	*Cyprinus carpio*	*Acrocheilus alutaceus*	*Mylocheilus caurinus*	*Ptychocheilus oregonensis*	*Richardsonius balteatus balteatus*	*Oregonichthys crameri*	*Rhinichthys cataractae dulcis*	*Apocope oscula nubila*	*Apocope falcata*	*Ameiurus nebulosus nebulosus*	*Ameiurus natalis natalis*	*Columbia transmontana*	*Gasterosteus aculeatus microcephalus*	*Perca flavescens*	*Huro salmoides*	*Chaenobryttus coronarius*	*Lepomis gibbosus*	*Lepomis macrochirus macrochirus*	*Pomoxis annularis*	*Pomoxis nigro-maculatus*	*Cottus asper*	*Cottus rhotheus*	*Cottus gulosus*
Oregon City, below falls	O	..	O	O	R	O	..	O	..	..	O	X	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..
Portland, Sellwood Bridge	O	..	O	O	R	O	O	O	..	..	O	X	..	..	X	..	..	..	..	..	X	..	..	..	..	X	..	O	O	O	O	..	..	..
Ponds and sloughs in area	..	..	..	..	..	..	..	..	..	..	..	O	..	..	O	..	..	..	..	..	O	..	..	..	..	O	O	O	O	O	O	..	..	..
Eastside Tributaries																																		
Clackamas River	O	..	..	..	X	X	X	X	R	R	O	..	..	..	X	X	..	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
Molalla River	O	..	..	..	X	X	X	..	..	X	X	..	..	..	X	X	..	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
Pudding River	O	..	..	..	..	X	X	..	..	..	X	O	..	..	X	X	..	O	X	..	..	..	..	..	..	X	..	..	..	..	..	..	..	X
Santiam River, Jefferson	O	..	..	..	..	O	O	O	..	..	X	..	X	..	X	X	..	..	X	..	..	..	X	X	..	..	..	..	..	..	..	..	..	X
N. Santiam R., Mill City	..	..	..	..	..	X	X	X	R	X	..	..	..	..	X	X	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	X	X
S. Santiam R., below Lebanon	O	..	..	..	..	O	O	O	..	..	O	..	O	..	X	O	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	O
S. Santiam R., above Lebanon	X	..	..	..	..	X	X	X	..	..	X	..	X	..	X	X	..	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	X	X
Middle Fork	O	..	..	..	..	X	X	X	..	..	X	..	..	..	X	..	..	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..
Calapooya River above Albany	..	..	..	..	..	..	..	..	..	..	X	..	..	..	X	X	..	..	X	..	..	..	..	..	..	X	..	..	..	..	..	..	X	..
Below Brownsville	..	..	..	..	..	..	..	..	..	..	X	..	..	..	X	X	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
Finly Dam	..	..	..	..	..	X	X	R	..	..	X	..	..	..	X	X	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	X	X
Above Holley	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
McKenzie River, Coburg Bridge	R	..	..	..	..	X	X	X	..	X	X	..	X	..	X	X	..	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	X	X
Walterville Bridge	..	..	..	..	..	X	X	X	R	X	X	..	X	..	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
Leaburg Dam, below	..	..	..	..	..	X	X	X	R	X	X	..	..	..	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	X
Leaburg Dam, above	..	..	..	..	..	..	X	X	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	X
Middle Fork, Homestead	..	..	..	..	..	X	X	X	R	R	X	..	..	..	X	..	..	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
North Fork	..	..	..	..	..	X	X	X	X	X	..	..	..	..	X	X	..	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	X	X

Table 3. DISTRIBUTIONAL RECORDS OF THE FISHES IN THE WILLAMETTE RIVER SYSTEM.—*Continued*

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Western Tributaries																																		
Tualatin River, near mouth	O	..	..	..	O	..	O	..	..	..	X	..	X	..	X	X	..	..	X	..	..	X	..	..	..	X	..	..	..	..	..	..	..	X
Scroggin Creek	O	..	..	..	R	..	X	..	..	..	X	..	..	..	X	X	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
Yamhill River, near mouth	O	..	..	..	..	..	O	..	..	..	O	..	..	..	X	..	..	..	X	..	..	..	..	..	..	X	..	..	..	..	..	..	..	O
Salt Creek	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
Mill Creek	..	O	..	..	..	..	X	..	..	..	X	..	..	..	..	..	..	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
Above Willamina	O	..	..	..	..	..	X	..	..	..	..	..	..	..	X	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
Rickreall Creek, below Dallas	O	..	..	..	..	..	X	R	..	..	X	..	..	..	..	..	..	..	X	..	..	..	X	..	..	..	..	..	..	..	..	..	..	X
Above Dallas	..	..	..	..	..	..	X	R	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
Luckiamute River, Pedee	O	..	..	..	..	..	X	..	..	..	X	..	..	..	X	O	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	X	X
Above Hoskins	O	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
Mary's River, Corvallis	O	..	..	..	..	..	O	..	..	O	X	X	..	..	X	X	..	..	X	..	..	..	X	..	..	X	..	..	..	..	..	..	..	X
Muddy Creek, Brice	O	..	..	..	..	..	X	..	..	..	X	..	..	..	X	X	O	..	X	..	X	X	O	..	..	..	..	..	..	..	..	..	..	X
Rock Creek	O	..	..	..	..	..	X	..	..	..	O	..	..	..	X	X	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	X	X
Wren Bridge	O	..	..	..	..	..	X	..	..	..	X	..	..	..	O	X	..	..	X	..	..	..	X	..	..	..	..	..	..	..	..	..	X	X
Long Tom, below Monroe	..	..	..	..	..	..	O	..	..	O	..	X	..	..	..	..	..	..	O	..	..	..	..	..	..	X	..	X	X	X	..	..	..	..
Below Fern Ridge Dam	..	..	R	..	..	..	O	..	..	..	..	X	..	..	..	..	..	..	..	..	X	..	..	..	..	X	..	X	X	..	..	..	..	..
Coast Fork, Saginaw	..	..	..	..	..	..	R	..	..	..	X	..	..	..	X	X	..	..	X	..	..	..	X	..	..	..	..	..	..	..	..	..	..	X
Above Cottage Grove	R	..	..	..	..	..	O	..	..	..	..	..	..	..	O	X	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
Above Dam	..	..	..	..	..	..	O	..	..	..	..	..	..	..	O	O	..	..	O	..	..	..	..	..	..	..	..	..	..	..	..	..	..	O

The time of the downstream migration in the Willamette River was not ascertained, as only one young lamprey was collected in the main river near Buena Vista during August. It is doubtful whether pollution as it now exists in the river is detrimental to the Pacific lamprey. The upstream migration of adults occurs at a time of considerable water volume. For some unknown cause, the 1944 run of adults from the ocean into the Willamette River was far below normal.

The adult lampreys were extensively used as food by the Indians. At one time a few lampreys were canned at The Dalles and the product was reported as an excellent article of food but did not become popular. Some years back, adult lampreys were trapped at the Willamette Falls and used as fish food for young salmon in a few hatcheries. During the past two years adult lampreys have been processed on a small scale for vitamin oil but the vitamin A content is probably relatively low.

Lampetra planeri (Bloch). Nonparasitic brook lamprey.

Range: Western North America and Eurasia. Freshwater.

A single male specimen of the nonparasitic lamprey was collected by C. R. Hess in Mill Creek, a tributary of Yamhill River, on April 15, 1945. Although the species is abundant in the Puget Sound drainage of Washington, the only previously known Oregon locality was from near Reedsport (Schultz and DeLacey 1935).

The adults do not have a functional digestive system and feeding takes place only during the ammocoetes stage. The length of the larval stage is presumably several years and it is surmised that adults die soon after spawning. Detailed life history information is lacking.

Family 2. Acipenseridae. Sturgeons.

Acipenser transmontanus Richardson. White sturgeon.

Range: Alaska to Monterey. Freshwater and marine.

The white sturgeon of the Pacific Coast is the largest fish found in fresh water in North America. The biggest specimen on record was a female taken in 1929 from the Columbia River near Vancouver, Washington. It measured 12½ feet long and weighed 1,285 pounds. Large fish were taken in former years in the Willamette River up to the falls at Oregon City. The big sturgeons of the Columbia River system are mainly objects of the past, for the fish now caught seldom exceed 5 feet in length and 125 pounds in weight.

In early times, the sturgeon of the Columbia and Willamette rivers were regarded with despair by the salmon fishermen who became annoyed by these fishes getting into the nets. Since sturgeons then had no commercial value, they were killed in large numbers and thrown away. About 1884 their value as food began to be realized and many tons of sturgeon were shipped annually to eastern United States. By 1894, the sturgeon fishery was on a marked decline and had practically failed by 1908. Today the fishery is of minor significance because of scarcity of fish.

Although the white sturgeon originally frequented the Willamette River to the falls at Oregon City at the various seasons of the year, its presence now appears to be restricted to highwater periods, especially at the time of the backwater period from the Columbia River during spring and early summer. No specimens were found in the river during August and September 1944, and it is doubtful whether they could have survived between Oregon City and the confluence with the Columbia River because of the low dissolved oxygen prevailing during that time.

Two white sturgeons were reported by residents of Eugene as seen at the

base of the Fern Ridge Dam on the Long Tom River during the fall of 1943. This was an unusual distribution record since sturgeon were not known to inhabit the Willamette River above the falls at Oregon City. There is the possibility that these two sturgeons were released above the falls by fishermen or they might have traveled through the locks at Oregon City.

The depletion of the sturgeon in the Willamette and Columbia rivers was not the result of pollution since the decline occurred many years before marked pollution became evident. Polluted conditions evidently now, however, limit the presence of this fish in the lower portions of the Willamette to periods of high water.

Family 3. Clupeidae.

Alosa sapidissima (Wilson). Shad.

Range: Atlantic coast of North America from the St. Lawrence River to Alabama. Introduced on the Pacific Coast, Kodiak Island, Alaska, to San Diego Bay, California. Freshwater and marine.

The shad was first introduced into the Sacramento River on the Pacific Coast in 1871 from the Atlantic Coast. The first authentic record of this fish in the Columbia River was in 1880 (Jordan 1916). About 500,000 shad fry were planted in the Willamette River near Portland in 1886 and approximately the same number were liberated at Albany during that year. By 1894, shad were plentiful in the Willamette River and fish dealers in Portland handled 165,000 pounds in 1895 (McGuire 1896).

Mature shad frequent the Willamette River as far as the falls at Oregon City in June usually following the Chinook salmon run. Reports from residents of the area indicate that some of the fish may go over the fish ladder of the falls into the upper river. This could not be verified by collected specimens or persons who had caught shad above the falls. Although the shad is almost entirely a commercial species, limited sports fishing with streamer flies takes place below the falls.

The shad is an anadromous fish ascending rivers from the ocean to spawn. After the eggs and sperm are deposited, the adult fish return to the ocean. The young, after hatching, may remain in fresh water for a few months feeding on insects and crustaceans before migrating to the ocean. No young of the species were found in August and September in the Willamette River.

It was not learned whether reproduction takes place in the Willamette River, or if it does, whether the fry escape the inimical effects of pollution in the lower portions of the river during the summer and early fall months. There is a possibility that fry, if they occur, migrate out of the Willamette River before seasonal pollution conditions become detrimental. Pollution has frequently been cited as one of the causes for conspicuous decline of the species in the streams of the Atlantic Coast.

Family 4. Salmonidae. Salmon, trout, and charr.

Salmonidae are represented in the Willamette River system by two species of salmon, three kinds of trout, and one charr. These constitute the most important group of game and commercial fishes of the river and those most likely to be detrimentally affected by pollution or by other changes of the environment.

Although no commercial fishing is now allowed in the Willamette River for salmon, some of the tributaries were formerly exceedingly productive as natural spawning areas for Chinook salmon. Some of the tributaries, once world famous as trout streams, today possess greatly reduced numbers of rain-

bow, steelhead, and cutthroat trout in spite of decreased creel limits and increased hatchery operations.

Oncorhynchus tshawytscha (Walbaum). Chinook salmon.

Range: San Francisco Bay to Alaska and to Northern China. Freshwater and marine.

Chinook salmon of the Columbia River spring run enter the Willamette River in March, April, and May. It is thought that the few early adults present in March go into the Clackamas River. Most of the fish run continues over the fish ladder of the Willamette Falls at Oregon City usually from about April 20 to May 30 with a few going upriver as early as April 1 in some years. A limited number may pass upstream through the locks at Oregon City. In some seasons, when the spring freshets are delayed, or the water volume over the fish ladder is too swift, salmon may be held up at the falls until as late as June 20. The adults then enter the large-sized tributary streams flowing from the Cascade Mountains, the first arriving at the spawning areas usually during the first two weeks in May. Adult Chinook salmon were found during the summer of 1944 in the following tributaries: Clackamas River, Molalla River, Abiqua Creek of Pudding River, North and South Forks of the Santiam River, Calapooya River, McKenzie River, and the Middle Fork. In all these streams young fish also were collected. Reports from local residents in the Cottage Grove area indicated that a few Chinooks formerly may have entered Row River which rises in the Cascade Mountains, but no adults or young could be found in that stream in 1944.

No young Chinook salmon have been taken in any of the westside tributaries of the Willamette River that flow from the Coast Range, in spite of considerable fish collecting activities during the past ten years. Infrequent reports of an occasional adult Chinook salmon observed in the Tualatin, Yamhill, Mary's, and Long Tom rivers have been received but have not been verified by specimens. Apparently, such accidental strays into westside tributaries are unusually rare.

After reaching the spawning areas, or being stopped by barriers, which are surprisingly numerous on the tributary streams, the adults usually remain in deep holes below riffle areas until fall. Spawning takes place from early September into October. The time of initial spawning varies over a period of one to two weeks in different years. From field observations made in 1944, there was an indication that spawning did not begin until there was a slight drop in water temperatures that followed the first few cool nights in early fall.

Differences in the size lengths of young Chinook salmon collected from the Clackamas and Molalla rivers indicated that a small amount of spawning may take place in these two streams before September and October, perhaps as early as the last of July. This is somewhat substantiated by reports of old residents that some Chinook salmon eggs were taken in early days for hatchery purposes on the Clackamas River during the last of July and the first of August, and that "a few salmon spawned many years back in early August in the Molalla."

The time required for hatching of eggs varies from three to four months, depending on the prevailing water temperature. Young with yolk sacs were collected in different years as early as January 10 and as late as February 25 in the tributary streams.

Large numbers of fry have been found during the past five years in February, March, and sometimes in early April in locations of the main river from Harrisburg to Independence. On February 20 and 21, 1945 many fry

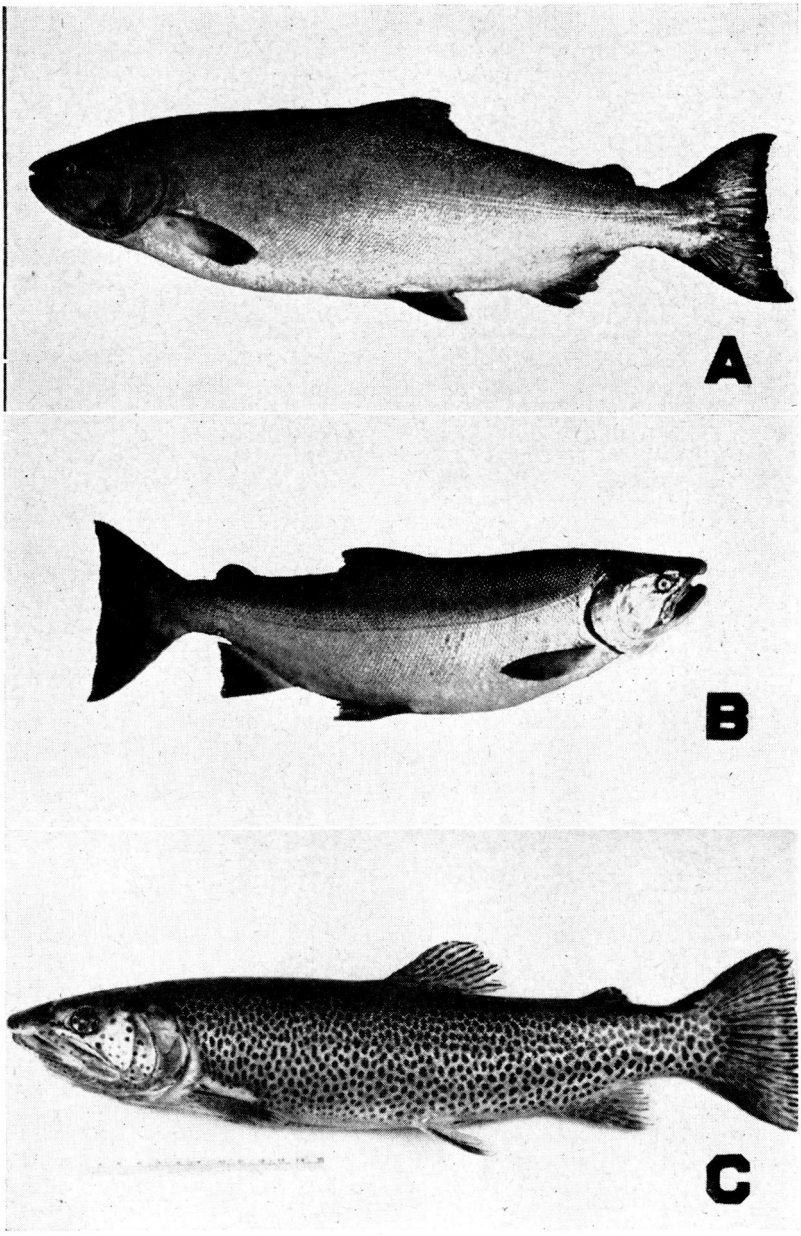

Figure 3. A. CHINOOK SALMON, *Oncorhynchus tshawytscha;*
B. SILVER SALMON, *Oncorhynchus kisutch;*
C. COASTAL CUTTHROAT TROUT, *Salmo clarkii clarkii.*

were collected in several areas from Corvallis to the Sellwood Bridge at Portland. The fry in this marked migration seaward at this time of year are the progeny of adult fish that spawned naturally, for the usual artificial propagation practice has been to hold hatchery reared salmon until May or June before releasing them.

During the summer months of June, July, and August there is apparently no downstream migration of young salmon in the main river. This is a fortunate biological situation because it is unlikely that any of the downstream migrants could survive in the heavily polluted zone from Newberg to the Columbia River during the low water period of summer.

Numbers of young salmon remain in the spawning streams during the summer months. They normally begin dropping down into these tributaries the last of August and the fore part of September. Some of these fish reached Kiger Island in the main river a few miles south of Corvallis by August 29, 1944. With the freshets that follow, these fingerlings migrate seaward at least until sometime in January and perhaps into February of some years. Freshets, accompanied by muddy water, appear to accelerate the downstream migration. This factor should be taken into consideration in the future release of water from storage dams, for an abnormal downstream migration of young salmon might be induced without sufficient water volume to overcome the low oxygen content present from Newberg to the Columbia River. This coinciding of the downstream migration with times of roily water, especially in the case of the small fry, is a fortunate biological adaptation, for there are myriads of large predatory fish inhabiting the main river.

Large losses of fry have been noted during the past few years in water holes along the river banks. There fish become trapped in the depressions as the water recedes after a rise in volume. South of Corvallis, following a severe flood, many young salmon have been found in holes at least a mile from the river. Thousands of small salmon could be saved each year by a systematic salvage. In this connection, it was noted that the recent bank improvement operations by the United States Engineer Department, in various locations from Albany downstream, had greatly reduced the "pothole" hazard in areas of construction.

At least up to fifty years ago, an annual run of salmon occurred in the Willamette River during September and October. Most of these fish that escaped the commercial fishery of the Willamette at that time spawned soon after entering the Clackamas River. This fall run has been practically eliminated; although reports of an occasional Chinook salmon "fresh from the ocean" taken after the early fall rains have been received from the Clackamas River in recent years. Presumably, pollution in the past may have been one of the causes for the destruction of the fall run in the lower Willamette River. No salmon could have lived during August and September 1944 in the stretch of water from the Columbia to the Clackamas because of the low dissolved oxygen prevailing during that period. The Clackamas River experienced in the 80's and 90's, however, a number of destructive activities such as dams without adequate fishways and intensive commercial fishing below such structures.

The number of adult Chinook salmon found in the spawning areas of the Willamette River system in 1944 were alarmingly few as compared to former years. Several reports from local residents living along spawning streams indicated that the 1943 run was also far below normal. On all the spawning areas visited in 1944, it was noted that there was approximately a 2 to 1 predominance of males over females. After viewing many of the barriers, diversions, loss of fry in overflow ponds, dead adult salmon wantonly killed by

shooting and other means, and the critical pollution conditions, it is a wonder that any Chinook salmon exist within the river system.

Oncorhynchus kisutch (Walbaum). Silver salmon. Coho salmon.

Range: Monterey Bay, California to Alaska and to Japan. Freshwater and marine.

A few adult silver salmon enter the Willamette River in the fall and early winter months, following periods of considerable rainfall. The majority of these fish turn into the Clackamas River and some pass the falls at Oregon City to spawn in the Molalla and Tualatin rivers. The run into the Tualatin, which was of more marked size in 1944 than in previous years, is of particular interest, for it probably is an artificial establishment from hatchery reared fish. No record from local residents of the area could be obtained of silver salmon in this stream previous to 1931. This is the only known westside tributary of the Willamette River in which salmon are known to reproduce. Two specimens of young of this species were collected from the Tualatin River during March 1940. A few fingerlings have been collected from the Clackamas and Molalla rivers during the past five years.

Spawning generally takes place soon after the adults reach the breeding areas. Hatching occurs during early spring. While a few fry may migrate seaward during the first year of life, the majority are thought to move to the ocean as fingerlings early in their second year.

From observations made on the coastal streams of Oregon, but not substantiated for the Willamette River, it would appear that the majority of adult silver salmon migrate to the spawning areas near the end of the third year of life and a lesser number mature at the end of their fourth year. A few small-sized males mature at the end of the second year and are known locally as jack salmon.

There is a good possibility that adult silver salmon migrating upstream in the Columbia River in August, September, and early October, especially during seasons of low rainfall, would be blocked from entering the Willamette River because of pollution conditions. Also, there is the probability that at least a portion of the downstream migrants may be killed by the lack of oxygen in the lower portion of the Willamette River, if some of the young fish enter the main river during summer or early fall. Two fingerling specimens in their first year of life were collected at the mouth of the Clackamas River on July 10, 1940, and one specimen of this same age group was obtained on that date from the Molalla River within six miles from the confluence with the Willamette River.

With the elimination of serious pollution from the lower Willamette River there is a good possibility, with adequate fish management, that the present insignificant silver salmon population might be built up in importance.

Salmo clarkii clarkii Richardson. Coastal cutthroat trout. Speckled trout.

Range: Chichagof Island, Alaska, to Northern California. Freshwater and marine.

The coastal cutthroat trout has the greatest over-all distribution of any of the salmonoids in the Willamette River system. In some areas the distribution overlaps that of the rainbow trout. In several of the tributary streams and in many of the small creeks, the cutthroat trout is present while the rainbow is entirely lacking. A few tributary streams such as the McKenzie River and portions of the Middle Fork of the Willamette River have the rainbow trout more numerous than the cutthroat trout. No tributary stream in the Willamette River system is without cutthroat trout unless blocked by natural barriers. Oddly, the cutthroat trout is the only salmonoid, except for an occasional stray

salmon and the presumably artificial establishments of silver salmon in the Tualatin River and of the steelhead trout in Rickreall Creek, inhabiting the westside tributaries having their sources in the Coast Range. These streams include the Tualatin River, Yamhill River, Rickreall Creek, Luckiamute River, Mary's River, Long Tom River, and the Coast Fork above Cottage Grove.

Apparently there are two biological phases of the coastal cutthroat trout in the Willamette River system. One phase remains in the tributary streams, usually in the upper stretches, and does not migrate to the main portion of the Willamette River. This group is designated as the nonmigratory type for convenience of reporting. The other form is more migratory in habits, dropping down to the lower stretches of the eastside tributary streams and into the main river in late spring, remaining there until late fall or early winter. It is suspected that some, if not all, of the migratory phase from the Clackamas River may migrate to the ocean.

Perhaps these two phases of the coastal cutthroat trout represent distinct subspecies or races, but as yet no morphological characters have been found, except size, to separate the two types. The main difference appears to be biological rather than structural.

From observations made in the westside tributaries, Mary's River in particular, supplemented with occasional records from the eastside streams, it would appear that the nonmigratory phase remains small in size, usually not exceeding 7 or 8 inches in total length, whereas the migratory phase may reach 18 to 20 inches in total length. Specimens of the nonmigratory phase, 5½ inches in total length and in the fourth year of life, have been taken with fully developed eggs in the ovaries ready for spawning.

Both phases usually spawn in creeks smaller in width than those normally utilized by rainbow trout. The migratory phase spawns in January, February, and perhaps in early March, and the nonmigratory phase spawns in May, June, and, in some of the colder water, as late as July.

As observed in the westside tributaries, practically all of the migratory phase having a total length of about 8 inches or more migrate to the main portion of the Willamette River soon after spawning. Practically all have left the westside tributary streams by the last of May. This movement to the main river is not so marked from most of the eastside tributaries. Presumably, the first and second year age groups of the migratory phase do not drop down into the Willamette River.

There are some grounds to surmise that the more marked movement of large-sized cutthroat trout from westside streams may be correlated with food conditions. Generally speaking, trout food organisms are more plentiful in eastside tributaries than is the case in the westside tributaries. This lack of food organisms, however, is perhaps compensated by the enormous numbers of small-sized forage fish inhabiting the main Willamette.

Although large-sized cutthroat trout are present in the main Willamette River in late spring near the confluences of practically all tributaries, the majority of the population in the main river during summer and early fall appears more concentrated from Independence to the confluence of the Middle Fork of the Willamette. As the summer progresses, the concentration becomes greater from about Kiger Island south of Corvallis to the entrance of the McKenzie River. A temperature factor coupled with food conditions may be involved and perhaps the effects of pollution in late years may have contributed in modifying the food conditions so as to cause a greater upriver movement than was the case in former times.

Although cutthroat trout in fresh water feed largely on insects, both of

terrestrial and aquatic origin, and crayfish, they are more predacious on small fish than are rainbow trout (Dimick and Mote 1934). The movement of large-sized individuals to the main river may be a biological adaptation that minimizes predation on the fry of its own species. Further, it was of interest to note that the large-sized cutthroat trout were not present in the main river at the period of the year in which Chinook salmon fry were migrating seaward, from January through March.

The indications are that if the serious pollution were eliminated from Newberg to the Columbia River, conditions would be greatly improved for the migratory phase of the cutthroat trout originating from the Clackamas, Tualatin, and Molalla rivers as well as from a few small creeks entering the main river in that area. In addition, salvage operations could save many small cutthroat trout from entrapments in spawning and brood creeks. Many of these small creeks have a more reduced water volume in summer than was formerly the case when the surrounding vegetative cover was undisturbed. Also, adequately constructed and functional fishways are needed over barriers on a number of tributary streams during the season of the year when the trout of the migratory phase pass from the main river into the tributaries. So far as is known, no cutthroat trout spawn in the main river.

Salmo gairdnerii gairdnerii Richardson. Steelhead trout. Rainbow trout or "red-side."

Range: California to Bering Sea, Alaska. Freshwater and marine.

Two biological phases of the rainbow trout inhabit the Willamette River system, and at the present time they are commonly regarded as constituting a single species. They are the anadromous steelhead trout and the nonocean going rainbow trout, locally called "red-side." There is some basis for suspecting that this difference in tendency to migrate to the ocean or to remain in fresh water is largely controlled by hereditary factors. Definite studies should be made to ascertain an evaluation of the influences of environment and inheritance factors of this species in Oregon waters for a sound foundation in artificial propagation and management program for rainbow and steelhead trout.

Both phases inhabit the eastside tributaries and normally are not present in westside streams. During the past eight years, occasional reports have been received, not verified by specimens, of a few steelhead trout in Rickreall Creek. Presumably, if this fish is present in that stream, it is an artificial establishment from hatchery operations. Rainbow and steelhead trout were formerly liberated in large numbers in westside tributaries without success.

Although all spawning activities take place in tributary streams, a number of rainbow trout frequent the main river from just south of Corvallis to the confluence with the Middle Fork during the summer and fall months. It is suspected that this group of fish originates from the McKenzie River and the Middle Fork of the Willamette. Perhaps a few may come from Row River which empties into the Coast Fork. Although rainbow trout of the resident type were formerly reported as abundant in the Clackamas and Calapooya rivers, no specimens were found in 1944. Neither were any obtained from the Molalla. Only young steelheads were collected from these three streams. Both types, steelhead and resident rainbows, were obtained in the North and South forks of the Santiam. Resident rainbow trout were collected in the McKenzie River and in Middle Fork.

Adult steelhead trout from the ocean enter the Willamette River from October until May with the bulk of the run occurring in January and February. These fish pass into the Clackamas, Molalla, both Forks of the Santiam, and the Calapooya rivers. None normally pass up the main river beyond Albany.

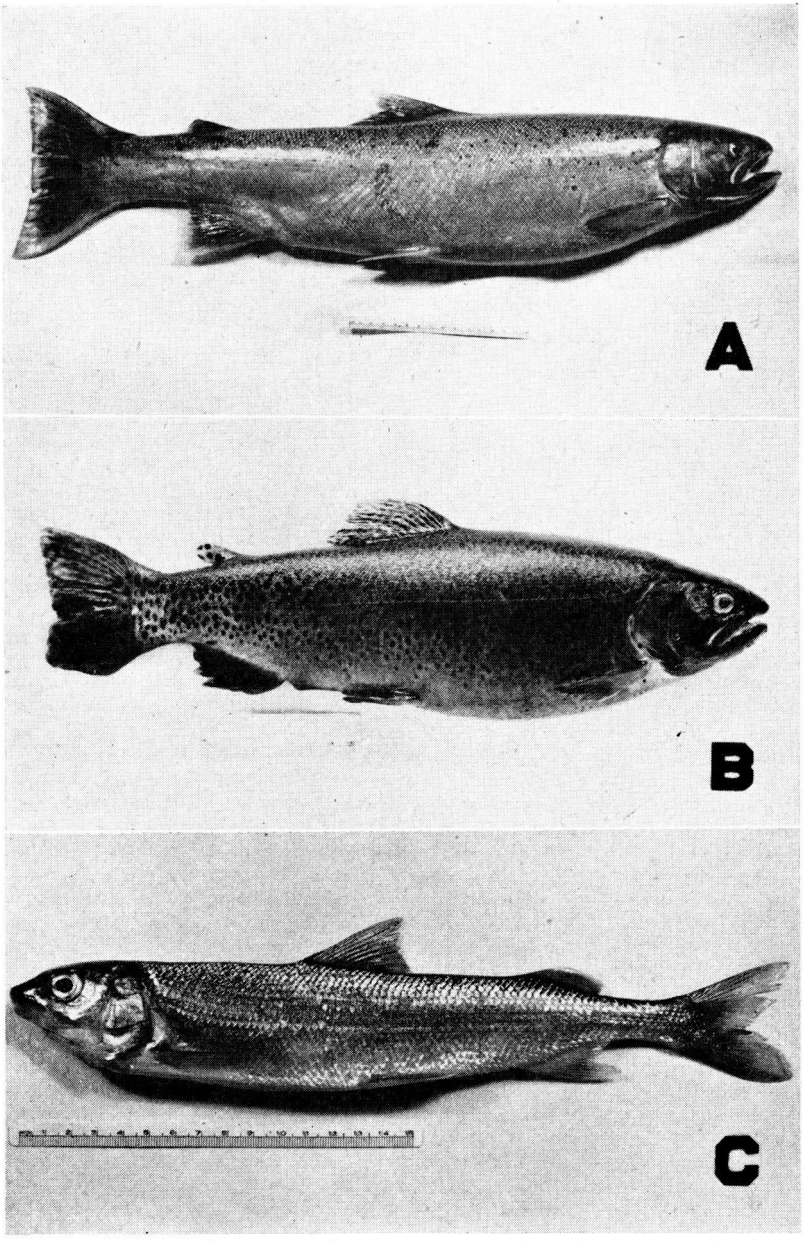

Figure 4. A. Steelhead trout, *Salmo gairdnerii gairdnerii;*
B. Rainbow trout;
C. Oregon whitefish, *Prosopium oregonium.*

Some of the steelheads reach the upper stretches of the Santiam River by the last of March and as late as the first of May. Spawning usually takes place from April to about the first of June. Spawning of resident rainbow trout generally occurs in March, April, and May.

The seasonal time that young steelhead trout migrate seaward through the main river was not ascertained. A few small-sized steelhead trout were found in the Clackamas River near its confluence with the Willamette during the last of August. If these young fish were migrating seaward, death could be expected soon after entering the main river, because of the low dissolved oxygen prevailing at that time. There is a good possibility that the bulk of seaward migrants may pass down the main Willamette during the spring months and thus escape the detrimental effects of pollution present in the lower river during late summer and early fall.

During August 1944, several young steelhead trout were collected in the South Fork of the Santiam River immediately above Lebanon. Not any of these trout could be found in pollution areas below the city to the confluence with the North Fork of the Santiam River. A few dead adult steelhead trout were found at that time within the pollution zone. Presumably, these fish were killed while returning downstream to the ocean. It is quite likely that many young steelhead and a few adult steelhead trout are killed by pollution each summer in this area.

An additional type of rainbow trout may be established in parts of the Santiam River, McKenzie River, and the Middle Fork of the Willamette. It is known as the fall-spawning rainbow trout. For several years this fish has been raised in a few hatcheries of the Oregon State Game Commission and it makes an excellent growth under hatchery conditions. No morphological characters are known that will identify this fish from the native rainbow trout, largely because the necessary studies have not as yet been undertaken. Several specimens were collected in the Middle Fork during October 1944 with ovaries and testes well developed which indicated that spawning might take place sometime in December. Presumably, these were the fall spawning type of rainbow trout. No additional specimens were found in other tributaries that indicated spawning would take place before the normal period of the native rainbow trout.

Salvelinus malma spectabilis (Girard). Dolly Varden trout. Oregon charr. Range: Alaska to Northern California. Freshwater and marine.

The Dolly Varden trout is in the North Fork of the Santiam River, the McKenzie River, and portions of the Middle Fork of the Willamette. This fish was known to inhabit the Clackamas River in early days (Jordan 1879) and unconfirmed reports indicate that a few may still be present in that stream. It is no longer abundant in the North Fork of the Santiam River. In these streams this fish is confined to colder waters. A few may drop down into the lower stretches of the tributaries during the winter months. In the McKenzie River an occasional Dolly Varden trout has been seen in recent years during the winter as far down as Walterville.

In many Alaskan streams, the Dolly Varden trout is anadromous. In the Willamette River system it apparently does not enter the main river at any season of the year. This behavior of the species removes this species from being detrimentally affected by pollution in the Willamette River.

The Dolly Varden trout has acquired a bad name in Oregon as a fish predatory, especially of small trout and salmon. Stomach analyses of 25 large-sized specimens collected over a number of years from the McKenzie River and the Middle Fork failed to disclose any trout or salmon present. The

food contents were largely insects, crayfish, and a few trash fish. Surprisingly, one fish had swallowed a small squirrel. Most of the Dolly Varden trout are present in the upper stretches of tributary streams beyond the salmon collecting racks; consequently, they would have little opportunity to prey on naturally spawned salmon fry.

Family 5. Coregonidae. White fishes.

Prosopium oregonium (Jordan and Snyder). Oregon whitefish.

Range: Columbia River and tributaries. Freshwater.

The Oregon whitefish, frequently misnamed locally as "grayling," is present in the Molalla River, Santiam River, McKenzie River, and the Middle Fork of the Willamette. There were reports of a whitefish in the Clackamas River, presumably this species, but its presence in that tributary was not confirmed by specimens.

The Oregon whitefish is present in the main river at least as far down as the entrance of the Santiam River near Buena Vista during the winter months. Although the species is not present in any of the westside tributary streams during late spring, summer, and fall, specimens have been obtained in Mary's River and the Long Tom River in January, February, and early March. The run up the Long Tom in 1945 was of large size and there was considerable fishing activity near Monroe. The gonads of several specimens obtained on March 3, 1945 from the Long Tom River indicated that the spawning period had passed some time back. Extensive seining operations at this late date failed to collect any young of this species in that stream. From these incomplete data, it would appear that fish that inhabit the main river, Mary's River, the Long Tom River, and perhaps other westside tributary streams during the winter, migrate back to eastside tributaries in the spring or early summer. Spawning is thought to take place in the fall of the year.

This species is not designated as a game fish by the Oregon Game Code, although the Rocky Mountain whitefish, *Prosopium williamsoni* (Girard) is so listed. So far as is known, the Rocky Mountain whitefish does not inhabit the Willamette River system but is present in Columbia River tributaries in eastern Oregon. Both species are occasionally taken by anglers and possess fair "fighting" qualities. The flesh is somewhat sweet and some people consider it very delectable.

So far as could be ascertained no harm is encountered by the Oregon whitefish because of pollution in the river system. The lack of information on the movements of this species from the Clackamas and Molalla rivers, however, does not rule out pollution damage in the river area from Newberg to the confluence with the Columbia River.

Family 6. Catostomidae. Suckers.

Catostomus macrocheilus Girard. Columbia coarse-scaled sucker.

Range: Columbia River system, Puget Sound drainage, and some coastal streams of Washington and Oregon southward to Sixes River. Freshwater.

The coarse-scaled sucker is numerous and well distributed throughout the Willamette River system. It is present in all tributary streams, but is not numerous or is absent from some of the upper stretches of mountain streams.

During the field studies of August and September 1944 no live specimens were found in the main river from Newberg to the Sellwood Bridge nor in the heavily polluted waters of the South Fork of the Santiam River. In both these locations dead specimens were frequently observed. On the other hand, this fish was exceedingly numerous at sewer outlets at Salem, West Salem, Albany, Corvallis, Harrisburg, and Eugene.

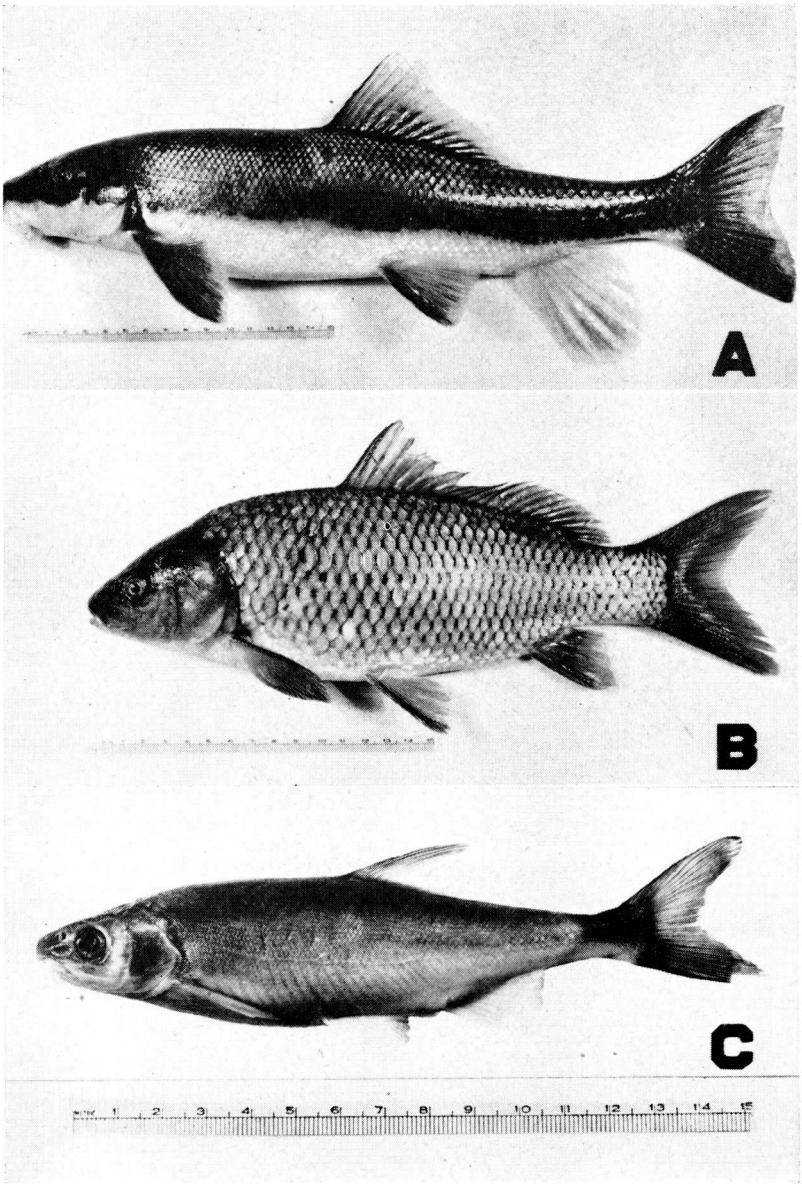

Figure 5. A. Coarse-scaled sucker, *Catostomus macrocheilus;*
B. Carp, *Cyprinus carpio;*
C. Chiselmouth, *Acrocheilus alutaceus.*

During April and May, adult coarse-scaled suckers, some measuring 16 inches or more, may be seen moving upstream in large schools to spawning areas. The yellowish colored eggs are deposited in riffle areas of creeks where they adhere to gravel. It is thought that the young hatch in about two weeks time and then drift downstream into quieter waters.

Family 7. Cyprinidae. Dace, minnows, squawfish, carp, etc.

The Cyprinids are represented by nine species in the Willamette River. Although the squawfish and introduced carp are now and then taken by anglers and used occasionally for food, the members of this family in Oregon are not usually considered as game and commercial fishes.

Cyprinus carpio Linnaeus. Common carp.

Range: Eurasia and introduced in North America.

The common carp, a native of Asia which was introduced into North America from Europe in 1877, has been well established in the Willamette River for about sixty years. It is now present in the main river from Harrisburg to the Columbia River, in the quiet waters of the lower portions of some tributary streams, and in practically all sloughs and overflow lakes along the Willamette. The carp is especially numerous in the Long Tom River and in the impounded water of the Fern Ridge Dam.

Although this fish is greatly esteemed as a food fish in parts of Europe and is of commercial importance in some midwestern states, it is generally despised by most Oregon fishermen. In the lower portion of the Willamette River from Oregon City to the Sellwood Bridge, however, several persons, including small boys and family groups, were earnestly fishing for carp. Their hooks were baited with dough balls and sometimes worms. With light tackle, considerable fishing excitement was experienced by these fishermen when a large-sized carp was hooked. One specimen weighed 18½ pounds. In this area large carp were observed leaping from the water apparently in a playful mood.

Carp are omnivorous feeders, feeding largely on vegetable material and some animal matter. They ingest mud which contains organic material. Since they frequently root up vegetation growing in shallow muddy bottoms, carp become important destroyers of food plants of waterfowl and cover for some spiny rayed fishes. Also, this action causes turbid water conditions and disturbs bottoms, which may be destructive to spawning and to egg development of some other fishes.

The observations of this fish made in the river from Oregon City to the Sellwood Bridge would indicate that this species is not injured by pollution as it now exists.

Acrocheilus alutaceus Agassiz and Pickering. Chiselmouth.

Range: The Columbia River system as far up as Spokane Falls and Shoshone Falls, and in the Malheur Lake drainage.

The chiselmouth, which reaches a length of about 12 inches, is very numerous throughout the main river from Springfield to Newberg. It was present in lower stretches of most of the eastside tributary streams but only one was found in a westside tributary near the mouth of the Tualatin River.

No live specimens were found in the main river below Newberg but a few dead individuals were collected in that area. Neither were live chiselmouths found below Lebanon in the heavily polluted area of the South Fork of the Santiam, although they were present in this stream immediately above the sources of pollution.

Mylocheilus caurinus (Richardson). Columbia River chub.

Range: In some streams from the Fraser River to the Columbia River system.

The Columbia River chub, which may reach a length of about 12 inches, appears to be nowhere abundant in numbers and is limited in habitat to only a portion of the main river from about Harrisburg to Buena Vista. It is a relatively rare fish in the Willamette River system and is sometimes present in the overflow lakes south of Corvallis.

The Columbia River chub has been reported by Jordan and Evermann (1896-1900) as frequenting "the spawning beds of salmon where it devours their eggs." The limited habitat and the scarcity of its numbers preclude such widespread depredations of salmon eggs in the Willamette River system.

Ptychocheilus oregonensis (Richardson). Squawfish.

Range: The Columbia River drainage system, the Malheur Lakes drainage, the Puget Sound drainage, and some coastal streams of Washington.

The squawfish, sometimes locally called "chub," is the most abundant and the most widely distributed fish in the Willamette River system. With only a few exceptions, it was present in relatively large numbers in practically every seine haul made during the fish collecting operations. Its absence was observed above impassable barriers, in the main river immediately below Oregon City, and in some of the fast flowing mountain creeks of tributary streams.

The squawfish is reported to reach 3 feet in length; however, the largest specimen taken during the summer of 1944 in the Willamette River system measured 23½ inches long.

Thorough food habit studies have been made of this species in British Columbia by W. A. Clemens and J. A. Munro (1934). These investigators reported their findings in summary as follows:

"The size of the squawfish ranged from one and one-half to 12 inches. Of the 119 individuals, 67 had eaten fish and of this number 27 were definitely found to have eaten salmon, kokanees, and trout. Small squawfish up to 4 inches appear to feed entirely upon aquatic insects and other invertebrates, but individuals as small as four and one-half inches have been found to contain fish in their stomachs . . . "

The stomach contents of a few large-sized squawfish from various locations of the Willamette River system collected at various seasons of the year were examined. The food items found were fish, including trout, salmon fry, and several species of cyprinids, insects, salmon eggs, and crayfish. The squawfish is perhaps an important fish predator in the Willamette River and its tributaries. This predation on small trout and young salmon occurs only at points where the seasonal habitats coincide. In this connection, it was not determined to what extent squawfish feed on the downstream migrants of Chinook salmon that occur seasonally in the Willamette River.

There was no indication that pollution was particularly detrimental to squawfishes, except that they were not numerous from Newberg to the Sellwood Bridge at Portland. A few squawfish were collected at the Sellwood Bridge in water having a free oxygen content of 0.8 ppm. Numerous small specimens of this species in good condition were taken in the South Fork of the Santiam River in water having no detectable free oxygen. In this particular case, these fish were observed swimming immediately under the surface. Apparently, the thin upper layer of water contained a small amount of free oxygen which was not detectable in the water sample taken a few feet under the surface.

A thorough biological study of the squawfish in the Willamette River system should be made to determine its importance as a predator of salmon, trout, and spiny rayed fishes. Such an investigation should ascertain whether pollution, especially domestic waste, has favored this species ecologically.

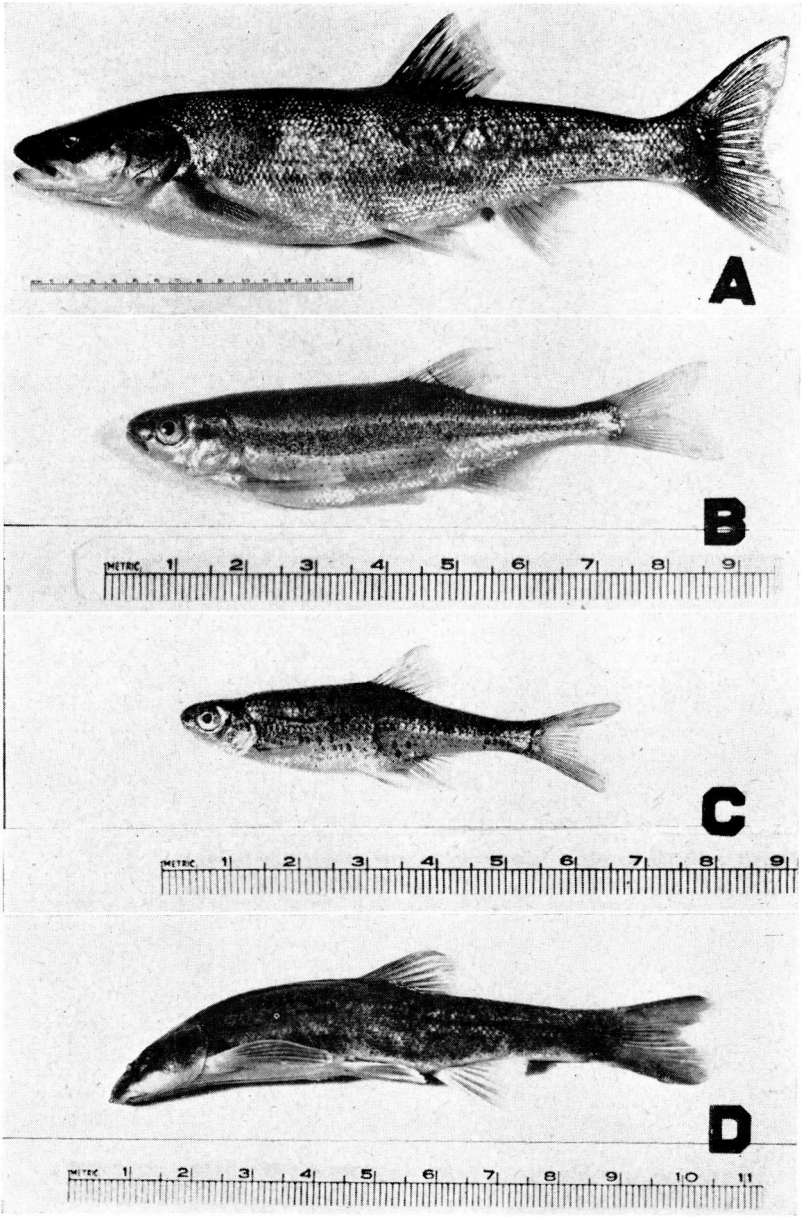

Figure 6. A. Squawfish, *Ptychocheilus oregonensis;*
B. Red-sided bream, *Richardsonius balteatus balteatus;*
C. Oregon minnow, *Oregonichthys crameri;*
D. Long-nosed dace, *Rhinichthys cataractae dulcis.*

Richardsonius balteatus balteatus (Richardson). Red-sided bream.
Range: The Columbia and Fraser River systems, Malheur lakes drainage, and some of the coastal streams of Oregon and Washington.

The red-sided bream, like the squawfish, is exceedingly numerous and has a wide distribution in the Willamette River system. It is not plentiful and is frequently absent in the fast, colder portions of tributary streams. During August 1944 it was not present from Newberg to the Sellwood Bridge at Portland nor in the South Fork of the Santiam River below Lebanon.

Fortunately, the red-sided bream attains a length of only about 5 inches and apparently is not predacious on other fishes. A cursory examination of stomach contents from several individuals indicated that the species is largely insect feeding.

This species has been observed spawning over gravel riffles in small creeks of Mary's River and the Luckiamute River during the month of May in several different years. There is a good probability that the red-sided bream may be an important forage fish for large-sized cutthroat trout and largemouth bass, as specimens have been found in stomachs of these two game fishes collected in the Willamette River near Corvallis.

Oregonichthys crameri (Snyder). Oregon minnow.
Range: Willamette and Umpqua rivers of Oregon.

The small Oregon minnow with an unusual distribution, being confined, so far as is known, to the Willamette and Umpqua rivers, is apparently not numerous in the Willamette River system. It has only been collected in two localities, an overflow pond of Muddy Creek of Mary's River and at Peoria Ferry, in recent years. No specimens were obtained during the entire fish collecting operation in the summer of 1944. There is the possibility its habitat may be in quieter waters of sloughs and overflow ponds, as these areas were not seined to any extent.

The limited known distribution of the Oregon minnow in the Umpqua and Willamette rivers strongly suggests that in past geological times there might have been a fresh water connection between these two river systems. This is further substantiated by the presence of other species or closely related species of fish in both rivers, and some of these fish are absent from all coastal streams southward from the mouth of the Columbia River to the Siuslaw and Umpqua rivers.

Rhinichthys cataractae dulcis (Girard). Long-nosed dace.
Range: Columbia River system, Puget Sound drainage, coastal streams of Washington, Malheur lakes drainage, Utah basin, Upper Missouri, Platt, Arkansas, and Rio Grande rivers.

Although the long-nosed dace is sparingly present in the Willamette River system, its wide distributional range in North America is of considerable scientific interest. A closely related subspecies, *Rhinichthys cataractae cataractae* (Valencienes), perhaps identical with the form in the Willamette River, occurs in southern Canada and southward to North Carolina, the Great Lakes drainage basin, and Iowa. A closely related subspecies, *Rhinichthys evermanni* (Snyder), is present in the Umpqua River but is absent from the intervening coastal streams northward to the Columbia River. The long-nosed dace is an outstanding example of a fish that has become distributed through geological time from coast to coast by traveling over mountain ranges through fresh water connections.

The long-nosed dace was collected in the main river at Buena Vista and Eugene and in the Clackamas, South Fork of the Santiam, Calapooya, McKen-

zie, Middle Fork of the Willamette, Tualatin, and Yamhill rivers. Nowhere was this fish abundant but it was usually present in clear, swift water.

Apocope oscula nubila (Girard). Black-sided dace.

Range: Lower Columbia River system and coastal streams of Oregon and Washington.

The black-sided dace was present in the main river from a few miles below Independence to above Eugene and in all tributary streams. Its absence from Salem to the Sellwood Bridge during the summer and early fall months could not be explained on the basis of pollution for the fish was present in the heavily polluted waters of the South Fork of the Santiam River below Lebanon under the same conditions as were the squawfish in the same area.

Apocope falcata (Eigenmann and Eigenmann). Dace.

Range: Columbia River system east of the Coast Range.

This dace, in the Willamette River system, appears to be localized in the main river from about the mouth of the Yamhill River to Peoria Ferry south of Corvallis. It was not collected in any of the tributary streams nor in the main river from Newberg to the Sellwood Bridge. Even in the areas of its occurrence it does not appear to be abundant.

Family 8. Ameiuridae. Catfish. Bullheads.

The two species of catfish found in the Willamette River were introduced from the eastern part of the United States. These fish afford considerable sports fishing in the slow moving waters with muddy bottoms from Fern Ridge Dam on the Long Tom River to Portland, in the lower portions of westside tributaries, in a few eastside streams with sluggish water, in overflow ponds, and in sloughs and backwaters.

There was no indication that catfish were adversely affected by pollution as it now exists in the river system. They were present and in good condition from Newberg to the Sellwood Bridge at Portland during August 1944.

So far as is known, the two species of bullheads present in the river are quite similar in their biologies. In feeding habits, they are omnivorous, eating live and dead organisms such as aquatic insects, crayfish, *Daphnia,* small fish, and plants. Eggs are deposited during early summer in shallow nests with sand or muddy bottoms. The male parent guards the nest and the young in schools for a time.

Ameiurus nebulosus nebulosus (LeSueur). Northern brown bullhead.

Range: Eastern United States, introduced into Western United States. Freshwater.

The Northern brown bullhead has a more elongate but less robust body than does the Northern yellow bullhead. The general color is variable from black to dark yellow. The barbles under the jaw vary in color from gray to black. A noticeable difference between the two species when dressing them for cooking is that this fish has a noticeably thicker skin than the Northern yellow bullhead.

Although the Northern brown bullhead is less numerous than its companion species in upriver locations, it is the dominant form from Oregon City into the Portland area.

Ameiurus natalis natalis (LeSueur). Northern yellow bullhead.

Range: Eastern United States, introduced into Western United States. Freshwater.

The Northern yellow bullhead has a short, heavy body and the yellow coloring on the belly is especially noticeable. The whitish barbles under the jaw readily distinguish it from the Northern brown bullhead.

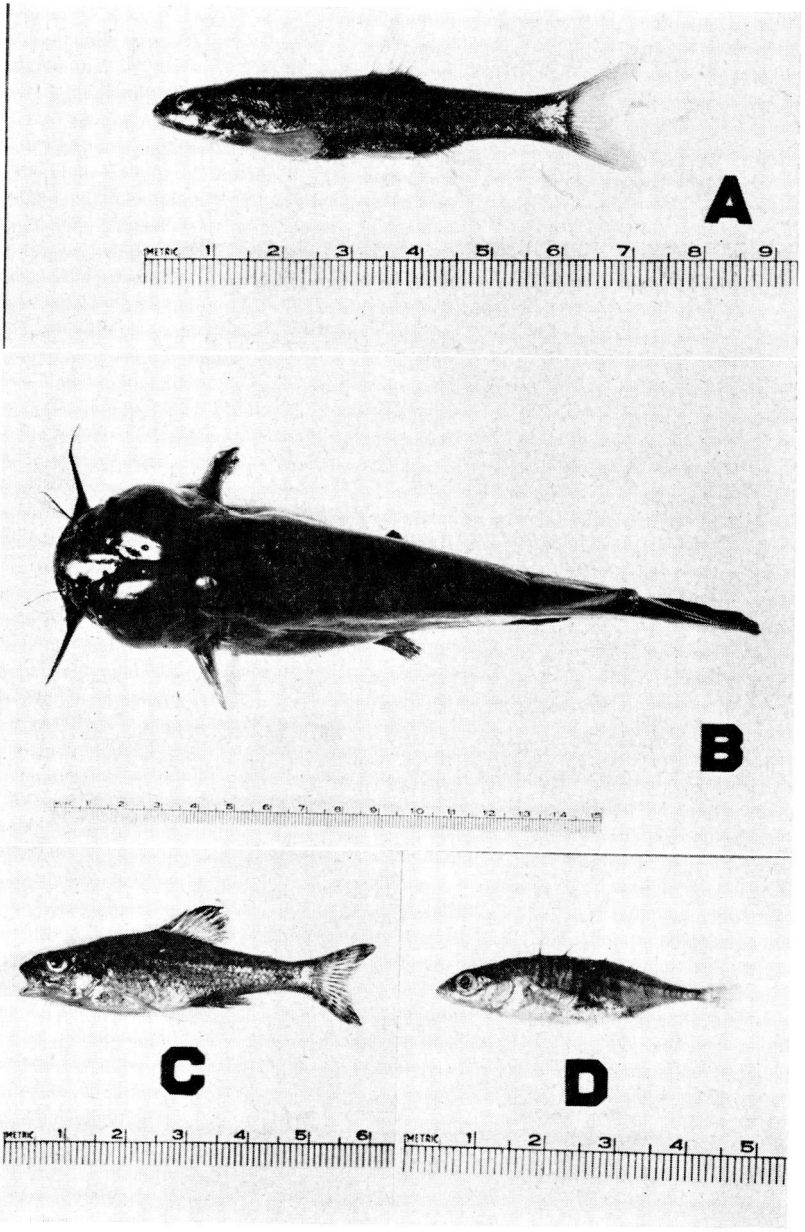

Figure 7. A. Black-sided dace, *Apocope oscula nubila;*
B. Northern yellow bullhead, *Ameiurus natalis natalis;*
C. Columbia River Troutperch, *Columbia transmontana;*
D. Three-spined stickleback, *Gasterosteus aculeatus microcephalus.*

The yellow bullhead was not found from the Willamette Falls to the Sellwood Bridge. It is, however, the predominant catfish in upriver locations above Oregon City.

Family 9. Percopsidae. Troutperch.

Columbia transmontana Eigenmann and Eigenmann. Columbia River troutperch.

Range: Columbia River system.

The Columbia River troutperch is somewhat of a biological oddity, for it belongs to a small family of fishes, which apparently is " . . . a transition form from the soft rayed to the spiny rayed fishes" (Jordan 1923). This family contains two genera, each with a single species. The stoneroller or Eastern troutperch, *Percopsis omiscomaycus* (Walbaum) is present in eastern North America, while the Columbia troutperch is the only known species in western North America.

This small fish (the largest specimen obtained measured 4 inches in length) superficially resembles a small trout or whitefish in possessing an adipose fin but has spines in both the dorsal and anal fins. In the Willamette River it appears to be localized from near Albany upstream to Springfield. It was also found in the Santiam River, Mary's River, Rickreall Creek, and the Coast Fork. There is no biological information on this species.

Family 10. Gasterosteidae. Sticklebacks.

Gasterosteus aculeatus microcephalus Girard. Three-spined stickleback.

Range: Europe, Asia, and North America. Freshwater.

The three-spined stickleback appears to have restricted distribution in the Willamette River system from about Buena Vista to near Harrisburg. It was found in only one tributary stream, the Santiam River near Jefferson. Many specimens have been collected at various times of the year in overflow ponds from Harrisburg to Buena Vista.

Family 11. Percidae. Perch.

Perca flavescens (Mitchill). Yellow perch.

Range: Eastern North America, introduced into Western United States. Freshwater.

The yellow perch was not collected in the main river nor in any of the tributaries. All specimens were obtained in overflow ponds at various locations from Wheatland Ferry to the Peoria Ferry. From various unconfirmed reports, it would appear that this fish is probably also present in ponds, sloughs, or lakes along the main river downstream from Wheatland Ferry.

This introduced game fish does not appear to be numerous in any location on the Willamette River system. Occasionally, specimens are brought in for identification by anglers who think they have found a "new fish," which would not be the case if they were common.

The yellow perch is considered a good panfish of excellent flavor and easy to catch. It is probably fortunate that it is not numerous, for it has been reported from some midwestern lakes as seriously competing for the foods of more desirable game fishes. (Eddy and Surber 1943.)

Family 12. Centrarchidae. Sunfish family.

The six species of the sunfish family present in the Willamette River system have been introduced from central United States. At least one and perhaps two kinds were established before the Lewis and Clark Exposition held

in Portland in 1905. It has been generally reported that most of these exotic fishes were liberated at or near Portland during or shortly after the close of the exhibition.

This important group of game fishes is fast growing in popular angling appeal throughout Oregon, particularly in the freshwaters not usually inhabited by trout. Bass, crappies, and bluegill sunfish will undoubtedly become game fishes of the future in many parts of the Willamette River system, as the trout resources further decline with changing environmental conditions and with increased fishing efforts which accompany an enlarged human population. These exotic game fishes now give angling in many locations of the river that otherwise would be practically barren of any game fishes. Some, but not all, of these locations were once good trout waters.

These warm water game fishes are particularly well adapted to the slow moving stretches of the river, impounded waters, overflow ponds, and sloughs. As the temperatures of the river increase in the future with the greater projected impounding of water and with the continued denuding of the vegetative cover on the watersheds and along the river banks, the optimum habitats for trout will probably be decreased but conditions will be enhanced for largemouth bass, crappies, and bluegill sunfishes. Further, sunfish are less affected adversely by barriers and diversions because of their more limited migratory habits than are most of the salmonoids of the Willamette River system.

The present habitats selected by largemouth bass, crappies, and bluegill sunfish in the Willamette River appear to be those that do not encroach to any extent on trout waters. They are more tolerant of polluted conditions than are trout. These warm water game fishes are generally residents in portions of the river system in which the effects of untreated sewage and industrial effluents are more pronounced.

Huro salmoides Lacépède. Largemouth bass. Black bass.

Range: Eastern North America, introduced into western United States.

The largemouth bass has been in the Willamette River system for at least fifty years. Specimens were collected from many places in the main river from Springfield to the Sellwood Bridge at Portland. They were also present in the slow moving waters of the lower stretches in Pudding, Calapooya, Tualatin, Yamhill, Mary's, and Long Tom rivers. Excellent bass fishing exists in some of the overflow ponds, sloughs, and lakes along the river.

Reports of smallmouth bass, *Micropterus dolomieu dolomieu* (Lacepede), taken by fishermen were occasionally received, especially from the Harrisburg area. No specimen of this species was collected from the Willamette River system. So far as is known the smallmouth bass is present in only one locality in the state, Tahkenitch Lake on the Oregon coast.

The largemouth bass spawns in the spring or early summer months when the water temperatures reach 60 to 65 degrees F. Usually, spawning takes place in quiet, clear water from 2 to 6 feet deep. The eggs are deposited in small areas cleaned of silt on gravel, roots of plants, and the like. The male guards the nest against intruders until the fry have dispersed.

The food of the largemouth bass in the Willamette River system consists largely of fish, insects, and crayfish. The fish found in the stomachs of fifty largemouth bass collected during the summer of 1944 were minnows, dace, and cottids. No game or commercial fish were present in the stomach contents. There were no salmon or small trout fry in the areas, however, at the times the bass were collected. An adequate food study of largemouth bass should include specimens obtained at the time salmon fry migrate seaward through bass waters. There is a good possibility that the water temperatures may be sufficiently low

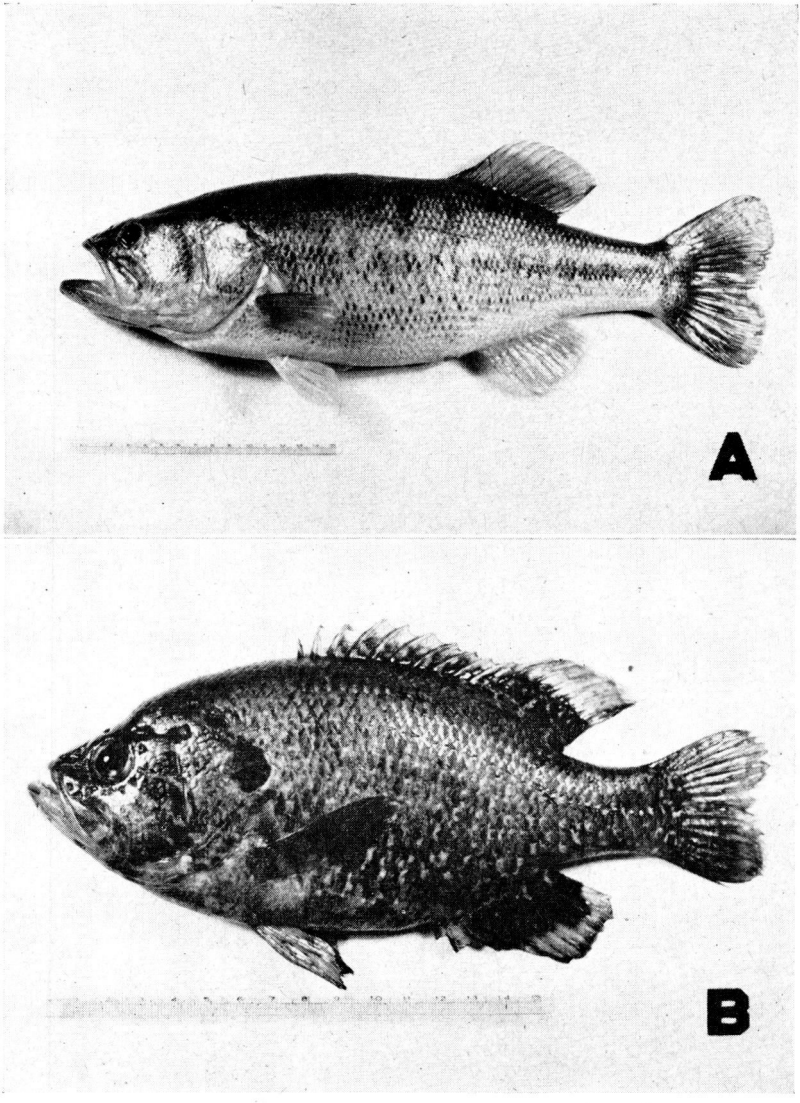

Figure 8. A. LARGEMOUTH BASS, *Huro salmoides;*
B. WARMOUTH BASS, *Chaenobryttus coronarius;*
(See next page for C and D.)

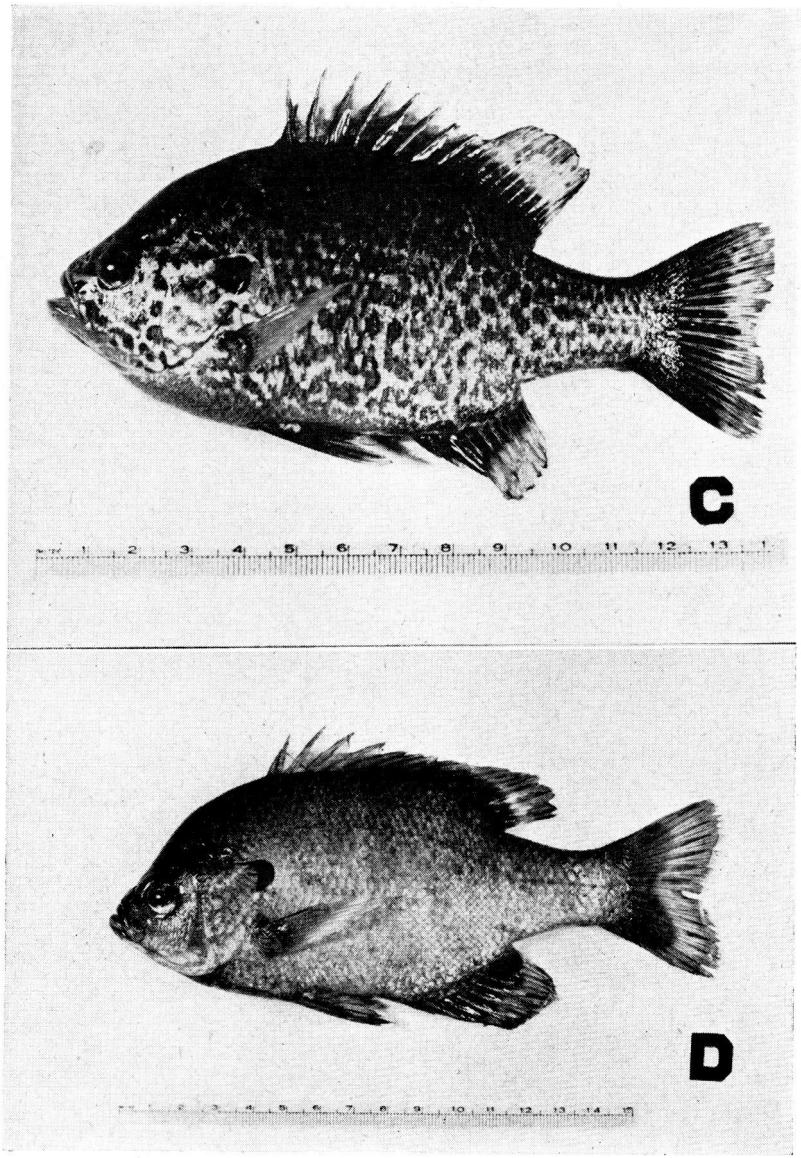

Figure 8. (*Concluded*)

C. PUMPKINSEED, LEPOMIS GIBBOSUS;

D. BLUEGILL, *Lepomis macrochirus macrochirus*.

(See preceding page for A and B)

during the last of January, February, and March so as to prevent bass from feeding on Chinook salmon fry present in the main river at that period of the year.

There was no direct evidence that pollution was detrimental to largemouth bass in the river. Nevertheless, bass were comparatively less in numbers in the heavily polluted areas than in locations of less pollution. Largemouth bass were relatively scarce from Newberg to the Sellwood Bridge. Also, there was a noticeable decrease in lengths and weights of the young bass of the year or same age class proceeding from Salem downstream to the Sellwood Bridge. These conditions suggest that a reduction in foods caused by pollution may be detrimental to largemouth bass in the Willamette River, especially from Salem downstream.

Chaenobryttus coronarius (Bartram). Warmouth bass.

Range: Eastern United States, introduced into western United States.

The warmouth bass, an introduced panfish, is nowhere abundant in the Willamette River system. A few specimens have been taken from overflow ponds along the main river from Peoria Ferry to Buena Vista over a period of several years and one was obtained from Oswego Lake. An occasional warmouth bass has been obtained in the main river from Corvallis to below Albany. This fish may occur in other parts of the main river but only in limited numbers.

A warmouth bass having a total length of 5½ inches was collected from the Willamette River at Albany on February 18, 1945. Chinook salmon fry were migrating seaward in that location at that time. The water temperature was 44 degrees F. In the stomach contents of this specimen were 2 Chinook salmon fry, 5 mayfly nymphs, and 2 midge larvae.

Lepomis gibbosus (Linneaus). Pumpkinseed.

Range: Eastern North America, introduced into western United States.

The pumpkinseed is a common fish of the overflow ponds and sloughs of the Willamette River, especially in weedy areas. Although it is frequently taken by bait fishermen, the small size attained in the Willamette River system precludes its general usefulness as panfish. In eastern United States this fish apparently reaches a larger size and is considered a good game fish.

Lepomis macrochirus macrochirus Rafinesque. Bluegill.

Range: Eastern United States, introduced into Western United States.

The bluegill is a popular game fish of the sloughs and overflow ponds of the Willamette River and slow moving stretches of several westside tributaries. It is occasionally taken in the main river from Harrisburg to Portland.

Although live bluegills were obtained at Wilsonville during August 1944, none could be collected from the Willamette Falls to Portland. Two dead specimens were found in the river near the Sellwood Bridge at Portland. A river location in that area which had many bluegills during the summer of 1915 was visited on August 29, 1944, and no specimens could be obtained by angling or seining. Presumably, this fish is seriously affected by pollution in the lower main river.

Pomoxis annularis Rafinesque. White crappie. Crappie.

Range: Eastern North America, introduced into western United States.

The white crappie is an excellent panfish of the sloughs and overflow ponds along the main river from Portland upstream to Harrisburg, and in some lower portions of the westside tributary streams. Dead specimens were obtained in the main river during August 1944, at Wilsonville, just above Oregon City and below Oregon City. No live fish of this species could be found in these loca-

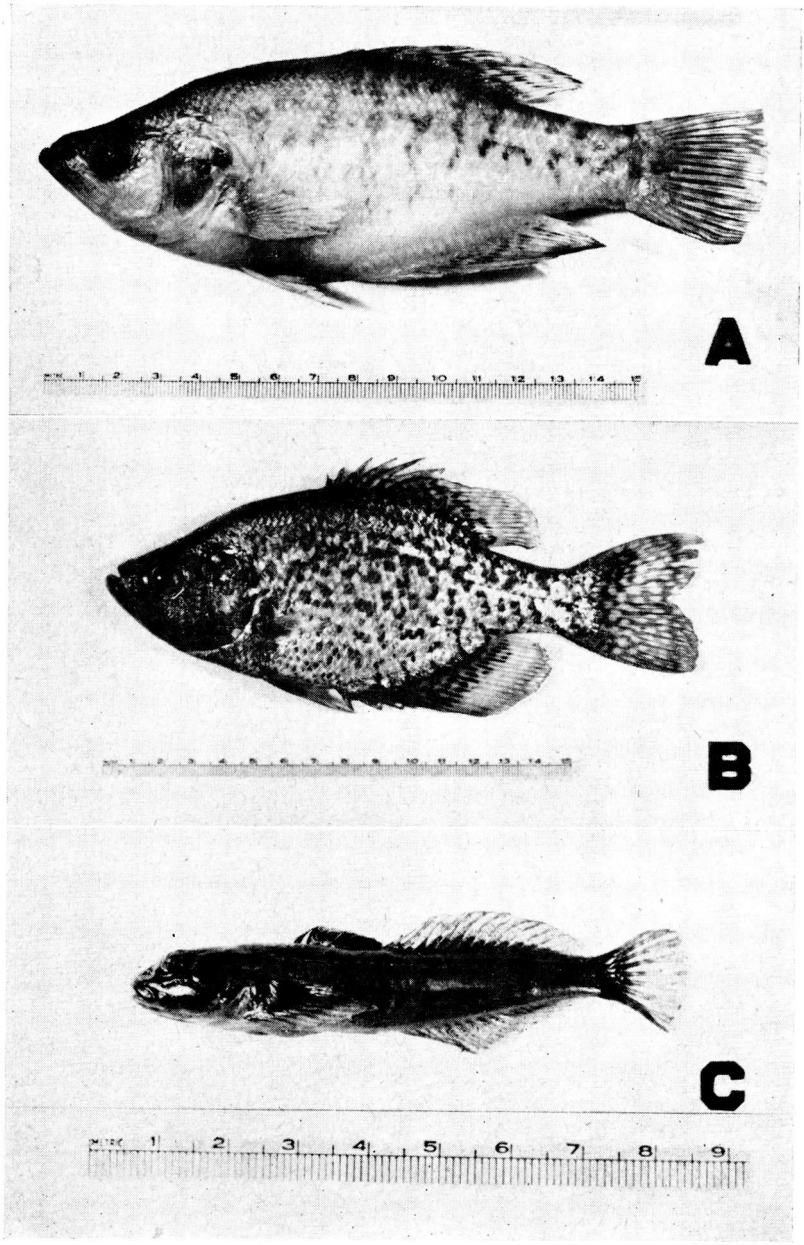

Figure 9. A. White crappie, *Pomoxis annularis;*
B. Black crappie, *Pomoxis nigro-maculatus;*
C. Sculpin, *Cottus gulosus.*

tions. Presumably, the white crappies from Newberg downstream in the main river are seriously affected by pollution during the period of low water volume.

Pomoxis nigro-maculatus (LeSueur). Black crappie.

Range: Eastern United States, introduced into western United States.

The black crappie panfish is found in approximately the same locations as the white crappie in the Willamette River system. It apparently is not so abundant, however, as the latter fish. Two dead specimens were found above the Willamette Falls and no live specimens were collected in the main river during the summer of 1944.

Family 13. Cottidae. Sculpins.

Cottus asper Richardson. Prickly bullhead.

Range: Coastal streams from Alaska to Ventura County, California. Freshwater and estuaries.

The prickly bullhead is not numerous in the Willamette River system. Specimens were collected north of Corvallis to Harrisburg. This fish was not found in the tributary streams.

Cottus rhotheus (Rosa Smith). Sculpin.

Range: Columbia River system, Kootenai River, Puget Sound Drainage, and Nehalem River. Freshwater.

The bullhead *cottus rhotheus* appears to be mainly a resident of the tributary streams. Specimens were obtained on the Santiam, Calapooya, McKenzie, Luckiamute, and Mary's rivers. Only one specimen was found in the main river and that was obtained in an overflow pool at Buena Vista.

Cottus gulosus (Girard). Sculpin.

Range: Coastal streams from Alaska to California. Freshwater.

The bullhead, *Cottus gulosus,* is the most numerous and widely distributed cottid in the Willamette River system. It was plentiful from just below Corvallis upstream to above Springfield. Except for one specimen collected in an overflow pool at Mission Landing, this species was not found from Albany to the Sellwood Bridge during August 1944. It was present in large numbers in all tributaries except in the South Fork of the Santiam River. The complete absence of the species from Newberg to the Sellwood Bridge and in the South Fork of the Santiam River below Lebanon would indicate that this fish may not be very tolerant of polluted conditions.

V. FISH FOODS

Previous studies of trout foods in Oregon showed that the important organisms in the diets of rainbow, steelhead, and cutthroat trout in streams were the aquatic insects, mayflies, stoneflies, caddis flies, midges, blackflies; insects of terrestrial origin; crayfish; and fish (Dimick and Mote 1934). Subsequent stomach analyses of fry and fingerling Chinook salmon from the Willamette River system indicated that the organisms above listed were also the major foods, with the exception of forage fishes. Since the trout and salmon are the most important fishes of the river system, special consideration was given to the kinds and amounts of the important aquatic invertebrate groups found at various sampling points that were potential sources of fish food. Attention was directed to the presence or absence of certain aquatic insect orders and other invertebrate animals in the various portions of the river that might serve as biological indicators of pollution.

Figure 10. A MAYFLY NYMPH.
(Enlarged 3 times.)

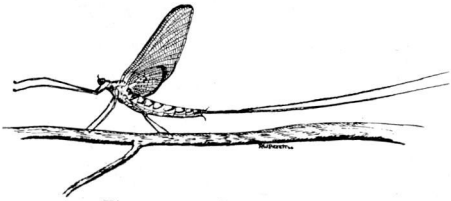

Figure 11. ADULT MAYFLY.
(Natural size.)

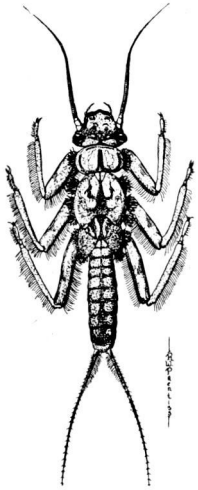

Figure 12. A STONEFLY NYMPH.
(Enlarged 2 times.)

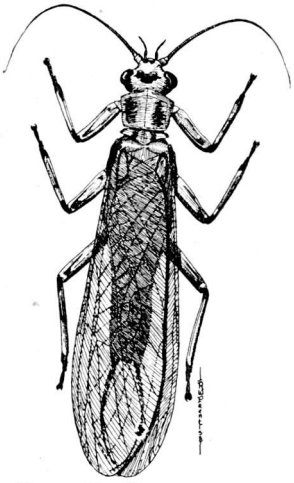

Figure 13. ADULT STONEFLY.
(Enlarged 2 times.)

Figure 14. A CADDIS FLY LARVA.
(Natural size.)

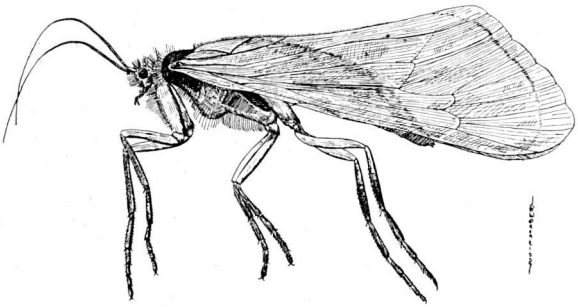

Figure 15. ADULT CADDIS FLY.
(Enlarged 2 times.)

A summary of the general kinds and numbers of fish food organisms, omitting molluscs, obtained at sampling stations during August and September 1944 is presented in Table 4. The data for each location are based on 1 square foot of river bottom collected either by a square foot sampler or an Ekman dredge. The sample for each station which had the greatest variety in kinds of aquatic organisms and was judged to be the most representative in quantity of bottom organisms was used in the table.

The stomach contents from 5 fish were examined at each study station visited during August and September 1944. The objective of these analyses was to determine whether aquatic food organisms not represented in the bottom samples and by hand picking were present in the immediate area. There were no bottom organisms of importance found in any of the stomach contents examined that were not represented in the square foot or in hand picking samples, except for crayfish. Crayfish and small forage fishes are also important food organisms of large trout, largemouth bass, and other fishes of the river, but these were usually obtained by seining operations. Records were made of the presence, absence, and relative abundance of crayfish, forage fishes, and molluscs at each study station.

From the fish food samples obtained by the different methods employed, it was evident that pollution noticeably affected the quality and, to a lesser degree, the quantity of fish food organisms. The absence of certain important aquatic insect groups from some river areas, however, could not be correlated well with low dissolved oxygen, high biochemical oxygen demand, or extremes in hydrogen-ion concentration of the water samples taken at the time and place that food samples were collected. This situation suggested that pollution in some form previous to the time of the field studies may have been inimical to some food organisms and that such effluents were not always detectable at the particular times that collections of samples were made.

Significant observations made of fish food organisms of the Willamette River system during August and September 1944 were as follows:

a. Stonefly nymphs were not found in the river from below Corvallis to Portland. This aquatic insect group, which apparently is the least tolerant of pollution of the fish food organisms, was not found from below Eugene to the confluence with the McKenzie River; in the Pudding River below Woodburn; in the South Fork of the Santiam River below Lebanon; in the Santiam River at Jefferson; in the Calapooya River below Brownsville; in the lower stretches of the Tualatin and Yamhill rivers; in the Long Tom River from the impounded waters of Fern Ridge Dam to the confluence with the main Willamette River; nor in the Coast Fork of the Willamette for several miles above and below Cottage Grove. All these areas of stonefly absence were suspected and occasionally proved to be polluted areas. The only exception encountered was in Rickreall Creek below Dallas on September 9 where stonefly nymphs were found in water suspected of being polluted. The dissolved oxygen of the water at that location was 5.2 ppm.

b. No mayfly nymphs could be found in the main river from below Salem to Portland, and caddis fly larvae were apparently absent from the Wheatland Ferry downstream. These two groups of aquatic organisms could not be found in the Long Tom River downstream from below the flax retting plant near Monroe; in the South Fork of the Santiam River below Lebanon; nor in Pudding River below Woodburn. The observations on Pudding River were of particular interest for mayfly nymphs and caddis fly larvae were obtained by hand picking on August 30 when the water had 5.8 ppm of dissolved oxygen,

but they were absent on September 22 when the dissolved oxygen was 0.2 ppm in the same location.

c. In areas of pronounced pollution from sulphite liquor effluents and cannery wastes, midge larvae, and aquatic annelids (slugworms) were usually present in significant numbers but the important insect groups of stoneflies, mayflies, and caddis flies were absent.

Table 4. INVERTEBRATE FISH FOOD ORGANISMS PER ONE SQUARE FOOT OF BOTTOM AT VARIOUS LOCATIONS IN THE WILLAMETTE RIVER SYSTEM, AUGUST AND SEPTEMBER 1944.

Location	*Stonefly nymphs*	*Mayfly nymphs*	*Caddis fly larvae and pupae*	*Midge larvae and pupae*	*Blackfly larvae and pupae*	*Other aquatic insects*	*Freshwater shrimps*	*Freshwater Isopods*	*Sludgeworms (Annelids)*	*Volume (cc)*
Main River										
Springfield, above city	2	6	1	3	2	4	4	....	....	2.4
Eugene, above dam	1	5	1	5	....	2	1	....	....	0.9
Eugene, below city	....	3	1	5	....	....	....	....	3	0.5
Harrisburg	1	8	4	4	....	4	1	....	....	2.1
Peoria Ferry	3	9	9	2	....	2	....	....	....	2.8
Corvallis, below city	....	7	3	15	....	2	1	....	....	2.1
Albany, above city	....	9	6	2	....	1	....	1	....	1.9
Albany, below city	....	5	24	3	....	4	....	1	1	2.7
Buena Vista	....	3	14	5	....	10	....	....	....	2.6
Independence, below city	....	2	8	3	....	3	1	....	....	2.3
Salem, above city	....	8	2	4	....	3	1	2	....	2.1
Salem, below city	....	....	2	4	....	2	....	....	2	0.5
Wheatland Ferry	....	....	....	8	....	....	....	....	14	0.6
Mission Landing	....	....	....	12	....	....	....	....	5	0.5
Newberg, above city	....	....	....	6	....	....	....	....	15	0.7
Wilsonville	....	....	....	7	....	1	4	2	6	0.8
Oregon City, above falls	....	....	....	8	....	1	4	....	2	0.7
Oregon City, below falls	....	....	....	5	....	....	....	....	23	1.0
Portland, Sellwood Bridge	....	....	....	3	....	....	....	....	30	1.8
Eastside Tributaries										
Clackamas River, Gladstone	5	6	13	6	1	5	....	....	....	1.9
Molalla River, above Molalla	2	8	11	4	4	....	....	....	....	1.6
Santiam River, Jefferson	....	3	11	10	2	....	....	....	1	1.1
N. Santiam River, Mill City	4	6	4	3	7	....	....	....	....	2.1
S. Santiam River, above Lebanon	....	....	....	32	....	....	....	....	28	2.6
S. Santiam River below	14	10	20	8	....	4	....	....	2	2.8
Middle Fork	3	15	38	4	4	2	....	....	....	2.2
Calapooya River, below Brownsville	....	3	2	....	3	....	....	....	....	0.6
Above Holley	14	2	18	2	2	9	....	....	....	1.2
McKenzie River, Coburg Bridge	5	13	4	3	....	2	....	....	....	1.8
Walterville Bridge	3	17	37	....	4	2	....	....	....	2.7
Middle Fork, Homestead	11	8	99	6	3	....	....	....	....	2.9
Westside Tributaries										
Tualatin, near mouth	....	8	12	6	....	....	12	6	....	1.7
Yamhill River, above Willamina	1	12	5	....	....	1	....	....	....	1.4
Mill Creek	5	3	8	....	2	....	....	....	1	1.3
Rickreall Creek, below Dallas	3	3	9	1	3	4	....	....	....	1.1
Above Dallas	2	3	10	4	2	1	....	....	....	1.0
Luckiamute, Pedee	1	5	11	....	2	2	....	....	....	1.3
Above Hoskins	1	4	3	....	3	2	....	....	....	1.0
Mary's River, Rock Creek	8	13	5	2	1	8	....	....	....	1.6
Wren Bridge	2	9	9	2	....	6	....	....	....	1.1
Long Tom, below Monroe	....	....	....	....	....	....	....	....	....	0.0
Below Fern Ridge Dam	....	3	....	....	16	....	....	....	....	0.6
Coast Fork, Saginaw	....	3	2	18	....	....	....	....	....	0.8
Above Cottage Grove	....	2	1	11	....	2	....	....	....	0.7

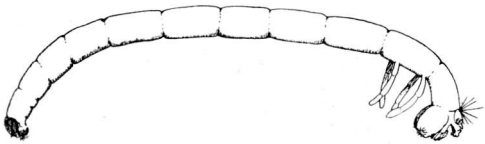

Figure 16. A MIDGE LARVA.
(Enlarged 4 times.)

Figure 17. ADULT MIDGE.
(Enlarged 5½ times.)

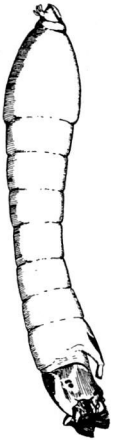

Figure 18. A BLACKFLY LARVA.
(Enlarged 7 times.)

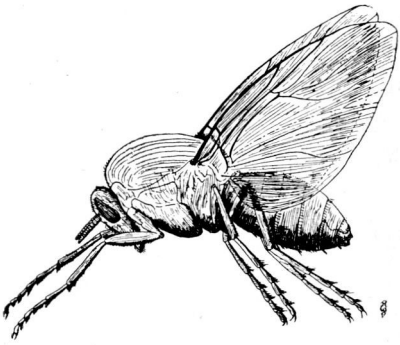

Figure 19. ADULT BLACKFLY.
(Enlarged 10 times.)

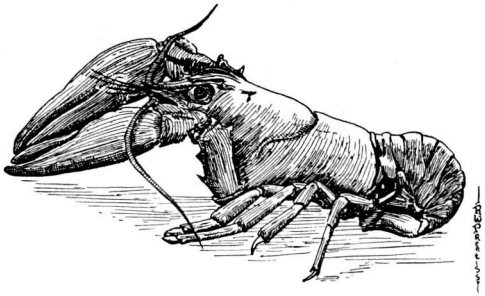

Figure 20. CRAYFISH.
(Reduced ½ size.)

d. The quantity of bottom organisms as measured on a volume basis was noticeably less in the main river from below Salem to Portland than was the case generally in upper river locations. Other areas of marked low food grade were found below Eugene, in the Calapooya River below Brownsville, and in the Long Tom River below Monroe. In the case of the Long Tom River, repeated bottom samples failed to disclose any invertebrate food organisms on the bottom, although some forms such as dragon fly and damsel fly nymphs and midge larvae were present on aquatic plants. The explanation in this case was that the heavy silt deposits from extensive river construction had destroyed the bottom organisms.

e. Crayfish were found at all locations except from below Oregon City to the Sellwood Bridge, in the Pudding River below Woodburn on September 22, but were present on August 30, and in the South Fork of the Santiam River below Lebanon.

f. Largemouth bass that hatched during 1944 and were collected at practically every station from above Springfield to the Sellwood Bridge were noticeably smaller in size and in poorer condition from below Salem to the Sellwood Bridge than from locations upriver from Salem. This difference in growth appears to be correlated with available fish foods. Most of the food found in stomachs of bass collected from the Willamette Falls to the Sellwood Bridge contained plankton organisms, mostly *Daphnia,* with a few midges; those from Oregon City to the Wheatland Ferry fed predominantly on midges, with an occasional crayfish; and those from Salem to Eugene included caddis fly larvae, mayfly nymphs, and stonefly nymphs in areas in which these aquatic insects were available.

g. The scarcity of fish in species and in numbers from about the Wheatland Ferry to the Sellwood Bridge at Portland may be the result of food depletion in amount and kinds, resulting from the effects of pollution in that area.

Stonefly nymphs, mayfly nymphs, and caddis fly larvae are present in the winter and perhaps the spring months in the polluted areas that lacked these forms during late summer. The stomach contents from a series of Chinook salmon fry collected during February 1945 in several main river locations between Peoria Ferry and Portland and in the South Santiam River below Lebanon were examined. This analysis disclosed that seaward migrants have been feeding on these important insect groups that were absent from these particular areas during August and September 1944. The only explanation which appeared tenable was that these aquatic organisms were carried downstream at times of high water.

VI. CONCLUSION

Pollution in the Willamette River system is a State shame. Oregonians have long prided themselves in having an outstanding, if not the best, recreational Mecca of the Nation. Yet, this magnificent river is at present in part an open sewer in which tremendous quantities of untreated human sewage and industrial wastes are disposed. Pollution in Oregon's great river, along with other detrimental activities, has depleted a world-famous commercial and game fish fauna. The Willamette River and many of its tributaries are a story of lost miles of fishing waters and of lost important spawning grounds for Chinook salmon. Not only has the fishing interest suffered in the maltreatment of a natural resource, but all the people of Oregon have sacrificed a heritage in the aesthetic value of clean water.

Untreated pollutants from many and varied sources have at times killed desirable fishes by depleting the oxygen supply of the water. The toxic action of some effluents is a major cause of fish and fish food decrease in various areas. Although some wastes that enter the river and tributaries are frequently not detrimental to fish life at points of discharge, their cumulative effects become inimical further downstream. The productivity of the river has been reduced. Several additional causes have contributed to the decline of trout and salmon. These are the barriers that have cut off many miles of excellent spawning areas; unscreened or improperly screened diversion ditches; the entrapment of small fishes in overflow pools; nonfunctioning fishways; the former practice of planting artificially reared fishes originating in the Willamette River system into other water courses; and perhaps an over-reliance for many years on artificial propagation activities to offset the detrimental effects of pollution, overfishing, barriers, and the like.

Portions of the river system are seriously affected by pollution. During the season of low water volume, in summer and early fall, these areas are extremely poor fish habitats, and some of the areas are at times lethal for trout, salmon, and other fishes. These locations are in particular the section of the main river from Newberg downstream and the South Fork of the Santiam River below Lebanon. Other areas showing evidence of decreased productivity because of pollution are from Salem to Newberg; Eugene to the confluence with the McKenzie River; the lower portions of the Yamhill River, Pudding River, Long Tom River, and Rickreall Creek. Over these locations trout and in some cases salmon pass seasonally on their way to and from spawning grounds. There the lack in kind and in quantity of preferred food organisms may have profound consequences on survival rates.

If in the future management of pollution for the river 5 ppm becomes the lowest value of dissolved oxygen acceptable for a satisfactory fish habitat, an additional provision should include a biological index of suitability by determining the presence of mayfly nymphs, caddis fly larvae, and stonefly nymphs. Then too, no effluent or waste toxic to fishes and their preferred foods should be discharged into the river. The specific toxic actions of sulphite liquors, cannery refuse, creamery wastes, sawdust, bark, flax retting waters, alcohol plant discharges, and others should be thoroughly determined at once.

Remnants of the native fish still remain from which the resource can be rebuilt. No substitution in kind should be made for rainbow and steelhead trout, cutthroat trout, and Chinook salmon, except in river locations beyond repair. Definite action in pollution abatement is needed to accompany the progressive program of the Oregon State Game Commission for rebuilding the game fish resources. Even a sound management program based on research will fail if the environment is adversely affected for fishes. Pollution as it now exists in parts of the river system is one of the most serious contributing causes of unsatisfactory fish habitat.

VII. BIBLIOGRAPHY

CLEMENS, W. A., and MUNRO, J. A.
The food of the squawfish. Biological Board of Canada, Progress Reports Pacific Station, No. 19, p 3-4, 1934.

CREASER, C. W.
Relative importance of hydrogen-ion concentration, temperature, dissolved oxygen and carbon dioxide tension, on habitat selection by brook trout. Ecology 11, p 246-262, 1930.

DAVIS, H. S.
Instructions for conducting stream and lake surveys. U. S. Bureau of Fisheries, Fishery Circular 26, p 1-55, 1938.

DIMICK, R. E., and MOTE, D. C.
A preliminary survey of the food of Oregon trout. Oregon State Agricultural College, Agricultural Experiment Station, Bulletin 323, p 1-23, 1934.

EDDY, S., and SURBER, T.
Northern fishes. University of Minnesota Press, p 1-252, 1943.

ELLIS, M. M.
Detection and measurement of stream pollution. U. S. Bureau of Fisheries, Bulletin 22, p 365-437, 1937.

GLEESON, G. W.
A sanitary survey of the Willamette River from the Sellwood Bridge to the Columbia River. Oregon State Agricultural College, Engineering Experiment Station Bulletin Series 6, p 1-32, 1936.

JORDAN, DAVID STARR
Notes on a collection of fishes from the Clackamas River, Oregon. Proc. U. S. National Museum 1 (1878), p 69-85, 1879.

JORDAN, DAVID STARR
The first shad taken in the Columbia. California Fish and Game, 2 (3), p 152, 1916.

JORDAN, DAVID STARR
A classification of fishes. Stanford University Publication, Biology Series 3, No. 2, p 80-243, 1923.

JORDAN, DAVID STARR, and EVERMANN, B. W.
The fishes of North and Middle America. U. S. National Museum Bulletin 47 (1-4), p 1-3313, 1896-1900.

MCGUIRE, H. D.
Report of fish and game protector; first, second, third, fourth, fifth, and sixth annual reports. Oregon State Printers, Salem, 1894-1898.

NEEDHAM, P. R.
Trout streams. Comstock Publishing Co., p 1-233, 1938.

ROGERS, H. S., MOCKMORE, C. A., and ADAMS, C. D.
A sanitary survey of the Willamette Valley. Oregon State College, Engineering Experiment Station Bulletin Series, No. 2, p 1-55, 1930.

SCHULTZ, L. R., and DELACY, A. C.
Fishes of American Northwest. Journal Pan-Pacific Research Institution, Vol. X, Oct-Dec, p 365-380, 1935.

SNYDER, JOHN O.
The fishes of the coastal streams of Oregon and Northern California. U. S. Bureau of Fisheries Document 638, p 153-189, 1908.

STOREY, MARGARET
Personal communication, February 19, 1945.

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