PRELIMINARY SURVEYS OF ROOSEVELT LAKE IN RELATION TO GAME FISHES

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UNITED STATES DEPARTMENT OF THE INTERIOR
J. A. Krug, Secretary
FISH AND WILDLIFE SERVICE
Albert M. Day, Director

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PRELIMINARY SURVEYS OF ROOSEVELT LAKE IN RELATION TO GAME FISHES

by

Harold A. Gangmark and Leonard A. Fulton

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INTRODUCTION

This preliminary limnological study of Roosevelt Lake was undertaken by North Pacific Investigations at the request of Mr. Hillory Tolson, Acting Director of the National Park Service to Albert M. Day, Director of Fish and Wildlife Service, December 23, 1947. The Park Service, charged with the development of the recreational potentialities of Roosevelt Lake, was vitally interested in having good sport fishing in the lake. At the time the request was made, and up to the present time (1949), game fish were and are in small abundance with good fishing scattered and mostly occurring outside the main tourist season. As a first step toward rectifying this situation a thorough survey of the existing fish populations, water conditions and fish food supplies was needed.

Grateful acknowledgment is due Mr. Claude E. Grieder and assistants of the National Park Service, Lieut. Comm. J. T. Jarman of the U. S. Coast and Geodetic Survey, and Mr. Don Earnest of the Washington State Game Department for their cooperation and assistance.

GENERAL INFORMATION ABOUT THE AREA

Grand Coulee Dam, largest man made structure in the world, is located in the northeastern section of the State of Washington. It is a United States Bureau of Reclamation project which will ultimately irrigate 1,200,000 acres of land, and at the present time is a major source of electrical power in the Pacific Northwest.

Roosevelt Lake, the impoundment behind Grand Coulee Dam is 151 miles long and extends north to the Canadian boundary. It has an average width of 4,000 feet, an average surface area of 82,000 acres, and a storage capacity of 10,000,000 acre-feet. The lake has 600 miles of shoreline of which the greater part has been established as a National Park for recreational purposes. Unlike most reservoirs the lake has not been drawn down in summer, thus providing more desirable conditions than other impoundments for recreation and the growth of aquatic organisms.

Source of water supply for the storage reservoir and dam originates in three principal systems: (1), Columbia River proper, which rises in Columbia Lake in British Columbia, flows northwesterly thence south and west around the Selkirk Range and enters the United States in the northeastern corner of the State of Washington where it flows into Roosevelt Lake; (2), Kootenai (Kootenay) River, which rises in British Columbia near the source of the main

Columbia, flows in an opposite direction (southeasterly) parallel to the continental divide, enters the United States at the Idaho, Montana, British Columbia corner, follows a curved course for 167 miles, flows through Lake Kootenay in Canada, and finally empties into the Columbia River proper about 30 miles north of the international boundary, (3), Clark Fork, which rises in Montana, crosses Idaho and the northeast corner of Washington and joins the main Columbia close to the International boundary just below the mouth of Kootenai River. The lake has 74,100 square miles of drainage area of which 39,000 square miles is in Canada.

Roosevelt Lake is located 92 miles west and north of Spokane, Washington and about 240 miles east of Seattle. It is easily accessible by good highways and less than a day's drive from other major tourist attractions in the Pacific Northwest. Larger towns adjacent to or easily accessible to the lake include the following:

	Population
Grand Coulee	3,659
Colville	2,418
Davenport	1,337
Wilbur	1,011

Counties surrounding the lake and their populations are: Ferry county, 4,701; Stevens county, 19,275; and Lincoln county, 11,361.

The lake is bordered by the Colville National Forest on one side and Kaniksu National Forest on the other side in the northern part. South of the National Forest area is the Colville Indian Reservation on the west side and the Spokane Indian Reservation on the east. Principal industries of the region are stock grazing, wheat farming, diversified farming on a small scale, lumbering and mining.

The climate of Roosevelt Lake is influenced by the prevailing westerly winds, which produce five to ten inches of precipitation in the lower twenty miles of its watershed. This moisture supports a growth of bunch grass of the type characteristic of plains grassland.

The remaining portion of the reservoir, with ten to thirty inches of rainfall, is forested with yellow pine, Douglas fir, Western larch, and Western white pine. Normal air temperatures are 32° F. in January and 68° F. in July (Goode, 1948).

THE SURVEYS

Three separate surveys were made, during the 1948 periods July 6-16, August 16-20, and September 7-9. During the first survey work was done from a 23 foot diesel powered workboat supplied by the National Park Service. Use of this boat, however, proved unduly time consuming and the second two surveys were made by means of an outboard motor powered skiff which was moved from place to place with an automobile and trailer. Points at which data were taken and the dates upon which they were visited were as follows:

Station	First Survey	Second Survey	Third Survey
San Poil River	July 8	August 17	September 8
Spokane River	July 15	August 18	September 9
Hall Creek	July 13	--	--
Colville River	July 12	--	--
Kettle River	July 9	August 19	September 10
Flat Creek	July 10	--	--

PHYSICAL CHARACTERISTICS

At each station on the first two surveys the temperature, oxygen content, free carbon dioxide, acidity, hydroxide, carbonate, bicarbonate, alkalinity, pH, and turbidity were measured. During the third survey only temperature and turbidity were measured, as it was felt that more time should be spent on gill netting. All of the above variables except turbidity were measured at a number of different depths, in order that their vertical distribution might be ascertained.

In interpreting the data presented in the tables, it should be kept in mind that all of the stations were located near streams, so that the characteristics of the water at the stations could be influenced to some extent by the inflowing stream water. An idea of the influence upon lake water to be expected from streams emptying near stations can be gained from the following list of percentages of total flow through Roosevelt Lake:

Stream	Percentage of Total Flow
San Poil River	0.2
Spokane River	7.1
Hall Creek	Less than 0.1
Colville River	2.4
Flat Creek	Less than 0.1

Temperatures

Table 1 lists the subsurface temperatures taken at various stations along the lake. The instrument used for these determinations was a Foxboro Portable Indicator manufactured by the Foxboro Company of Foxboro, Massachusetts. Inspection of Figure 1, showing temperature curves at three different stations, indicates that no thermocline was present in Roosevelt Lake at the time of the observations.

In Figures 2 and 3, temperature curves for days of maximum temperature gradient were plotted from data taken near Grand Coulee Dam by the Bureau of Reclamation during the years 1943 to 1947. During that period the maximum temperature gradient occurred in August, just before surface cooling began. In 1946 and 1947 a second maximum temperature gradient occurred in early spring before the spring runoff (figure 3). In these years the observed gradients were very slight, with the single exception of May 5, 1947 (Figure 3) when temperatures between the five and ten foot depths were indicative of a poorly developed thermocline.

The reason for the absence of thermal stratification lies in the ratio of inflow to storage capacity; although the lake can retain 10,000,000 acre-feet of water, the average annual flow of the river is 80,000,000 acre-feet. Thus the reservoir could be refilled eight times in one year by the flow of the river into it.

Chemical Constituents

The following paragraphs set forth the results of chemical analyses that were made at the mouths of the various streams flowing into Roosevelt Lake.

Determination of pH

Table 2 includes all of the pH readings, which were made by means of a standard colorimeter set. The pH of all waters tested ranged between pH 7.2 and 8.2, well within the pH 6.3 and 8.5 range considered readily tolerable by most fresh-water fishes (if the variations result from relatively small amounts of carbon dioxide and carbonates as was true in Roosevelt Lake).

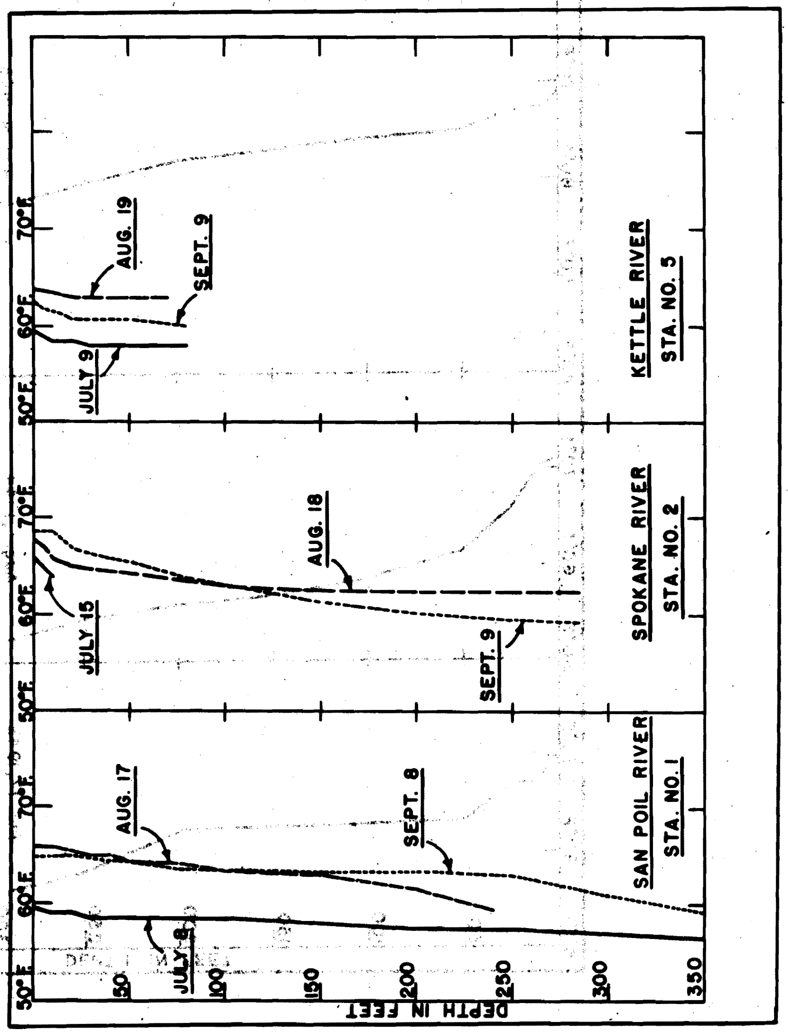

Figure 1. --Water temperatures in Roosevelt Lake at three different observation dates in 1948.

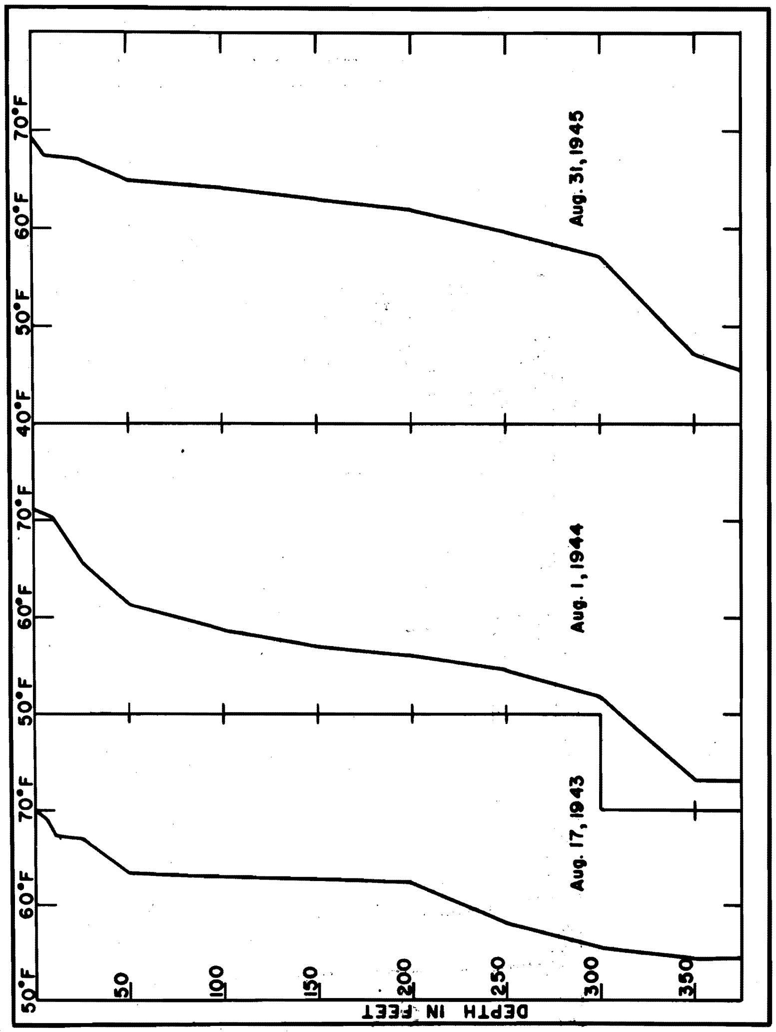

Figure 2. -- Water temperature at the time of greatest degree of stratification before surface cooling, Grand Coulee Dam, 1943 to 1945.

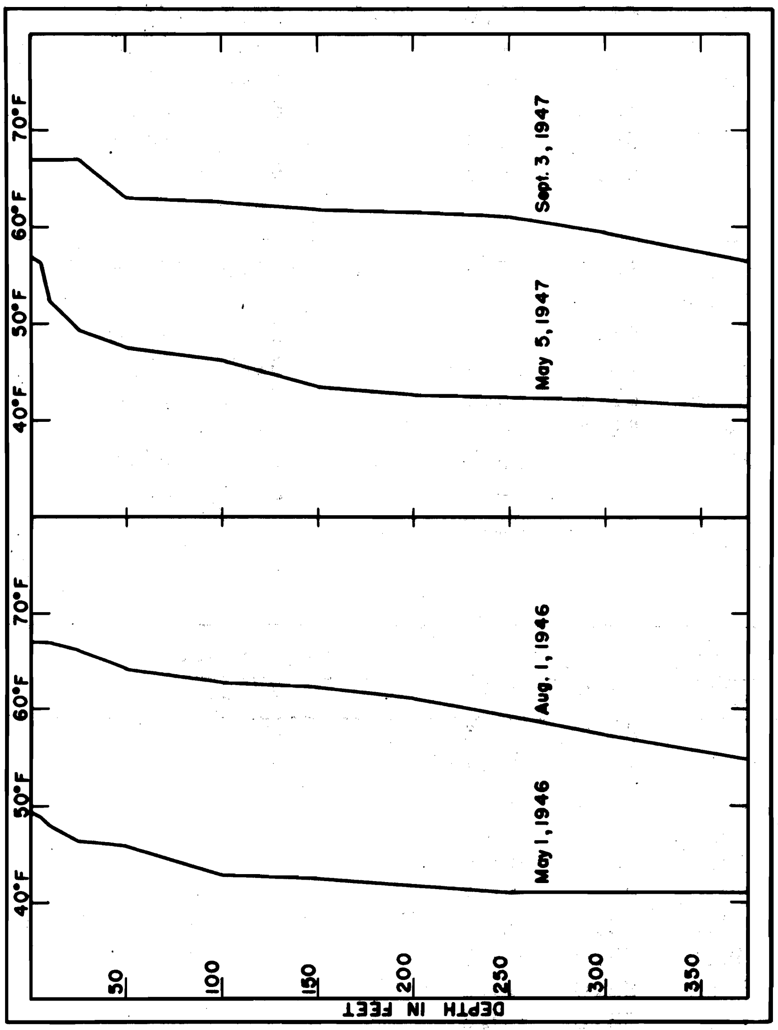

Figure 3. -- Water temperature at the time of greatest degree of stratification before surface cooling, Grand Coulee Dam, 1946 and 1947.

TABLE 1. Temperatures at stations in Roosevelt Lake, 1948, in degrees Fahrenheit.

Depth in Feet	San Poil River 7/8	San Poil River 8/17	San Poil River 9/8	Spokane River 7/15	Spokane River 8/18	Spokane River 9/9	Hall Creek 7/13	Colville R. 7/12
0	59.5	66.0	65.0	66.0	68.7	67.8	66.0	60.0
5	-	-	65.0	-	-	67.0	-	1/
10	59.0	66.0	65.0	64.0	68.7	65.9	63.0	
15	-	-	-	1/	-	65.5	1/	
20	59.0	65.4	65.0		66.9	65.0		
30	58.5	65.0	64.8		66.2	64.8		
40	58.5	65.0	64.4		65.8	64.6		
50	58.5	64.4	64.3		65.3	64.3		
60	-	-	-		-	-		
70	-	-	-		-	-		
75	58.5	64.2	63.8		64.0	63.8		
80	58.5	-	-		-	-		
100	58.5	63.5	63.5		63.0	63.0		
150	58.0	63.0	63.4		61.2	62.6		
200	57.5	61.5	63.4		60.1	62.3		
240	-	59.5	-		-	-		
250	57.5	-	63.0		59.4	62.3		
285	-	-	-		59.2	62.3		
300	57.0	-	61.0		-	-		
352	56.5	-	59.1		-	-		

Depth in Feet	Kettle River 7/9	Kettle River 8/19	Kettle River 9/9		Flat Creek 7/10
0	59.5	63.7	62.3	0	60.0
5	-	-	61.7		1/
10	58.5	63.5	61.5		
15	-	-	61.1		
20	58.5	63.0	60.7		
30	58.0	63.0	60.7		
40	58.0	63.0	60.7		
50	58.0	63.0	60.7		
60	58.0	63.0	60.5		
70	58.0	63.0	60.2		
75	-	-	-		
80	58.0	-	60.0		
100					
150					
200					
240					
250					
285					
300					
352					

1/ No temperatures at this level and below, due to failure of thermometer.

TABLE 2. Colorimetric determinations of Hydrogen-ion concentration, and accompanying temperatures, Roosevelt Lake, 1948.

Depth in Feet	San Poil River 7/8 Temp. F.	pH	San Poil River 8/17 Temp. F.	pH	Spokane River 7/15 Temp. F.	pH	Spokane River 8/18 Temp. F.	pH
0	59.5	7.6	66.0	8.0	66.0	7.5	68.7	7.8
10	59.0	7.5	66.0	8.0	-	7.5	68.7	7.8
20	59.0	7.5	65.4	8.0	64.0	7.5	66.9	7.8
30	58.5	7.5	65.0	8.0	1/	7.5	66.2	7.8
40	58.5	7.5	65.0	7.8		7.5	65.8	7.8
50	58.5	7.5	64.4	7.8		7.5	65.3	7.6
60	-	-	-	-		7.5	-	-
67	-	-	-	-		7.5	-	-
70	-	-	-	-		7.5	-	-
75	58.5	7.5	64.2	7.6		7.5	64.0	7.6
80	58.5	-	-	-		-	-	-
100	58.5	7.5	63.5	7.6		7.5	63.0	7.6
122	-	-	-	-		-	-	-
150	58.0	7.5	63.0	7.6		7.5	61.2	7.6
200	57.5	7.5	61.5	7.5		7.5	60.1	7.6
240	-	-	59.5	7.2		-	-	-
250	57.5	7.5	-	-		-	59.4	7.6
260	-	-	-	-		7.5	-	-
285	-	-	-	-		-	59.2	8.2
300	57.0	7.5	-	-		-	-	-
352	56.5	7.5	-	-		-	-	-

Depth in Feet	Hall Creek 7/13 Temp. F.	pH	Colville River 7/12 Temp. F.	pH	Kettle River 7/9 Temp. F.	pH	Kettle River 8/19 Temp. F.	pH	Flat Creek 7/10 Temp. F.	pH
0	66.0	7.6	60.0	7.5	59.5	7.5	63.7	8.0	60.0	7.5
10	63.0	7.5	1/	7.6	58.5	7.5	63.5	7.2	1/	7.5
20	1/	7.5		7.6	58.5	7.5	63.0	7.2		7.5
30		7.5		7.6	58.0	7.5	63.0	7.4		7.5
40		7.5		7.6	58.0	7.5	63.0	7.4		7.5
50		7.5		7.6	58.0	7.5	63.0	7.6		7.5
60		-		-	58.0	7.5	63.0	7.6		7.5
67		-		-	-	-	-	-		7.6
70		-		-	58.0	7.5	63.0	7.6		
75		7.5		7.6	-	-				
80		-		-	58.0	7.5				
100		7.5		7.6						
122		7.6								

1/ No temperatures at this level or below, due to failure of thermometer.

Alkalinity

The property of buffering in a lake may be important to prevent sudden shifts to extreme acid or alkaline condition. Therefore, acidity and total alkalinity were determined because of their capacity to neutralize many types of wastes. The method used for determining these alkalinities involved the use of two indicators; phenolphthalein and methyl orange. Titration was done with .02 normal sulfuric acid. Since the alkalinity is generally the result of carbonates, calcium carbonate in particular, three types of alkalinity were evaluated (Table 3) -- namely, hydroxide (OH), normal carbonate (CO_3), and bicarbonate (HCO_3) -- the three summed as total alkalinity expressed as calcium carbonate.

With the range of carbonates and bicarbonates as calcium carbonate extending between 35 and 62 P.P.M., Roosevelt Lake lies well within the bounds (0 to 350 P.P.M.) established for natural unpolluted waters supporting good fish fauna. The expected values for most lakes are between 45 and 200 P.P.M. No evidence of hydroxides, which are added through pollutants or chemical wastes and may cause great damage to the fauna, was found in any of the samples taken.

Carbon Dioxide and Acidity

Free Carbon dioxide and total acidity as calcium carbonate were determined by titration with N/44 sodium hydroxide solution using phenolphthalein as the indicator. As in the majority of natural waters containing good fish fauna, Roosevelt Lake has very little free carbon dioxide (Table 4). The scarcity of free carbon dioxide is due to its reaction with other compounds in solution plus constant aeration. Small quantities are important, however, to bacterial growth and photosynthetic activities of chlorophyll bearing plants.

The importance of acidity in the water lies in its capacity to neutralize alkaline pollutants and other types of wastes. Its presence in natural waters is usually due to the presence of carbon dioxide and other organic acids. Carbonates and bicarbonates in the quantities found have little immediate effect on fish, but do influence the living habits of the fish indirectly. Bicarbonates are necessary for the process of photosynthesis which completes the food chain upon which fish depend. Even though in some samples only small traces of carbonate were found, and the amounts in others were undetectable, these minute quantities are valuable for phytoplankton and other aquatic plants.

TABLE 3. Hydroxide alkalinity in P.P.M., calcium carbonate normal carbonate as P.P.M., calcium carbonate bicarbonate in P.P.M. of calcium carbonate and total alkalinity, Roosevelt Lake, 1948.

Depth in Feet	SAN POIL RIVER 7/8 (OH)	(CO_3)	(HCO_3)	Tot.	8/17 (OH)	(CO_3)	(HCO_3)	Tot.
0	0	0	57.0	57.0	0	1.0	53.0	54.0
10	0	0	58.0	58.0	0	1.0	58.0	59.0
20	0	0	59.0	59.0	0	1.0	58.0	59.0
30	0	0	59.0	59.0	0	1.0	58.0	59.0
40	0	0	59.0	59.0	0	1.0	58.0	59.0
50	0	0	59.0	59.0	0	1.0	58.0	59.0
60	-	-	-	-	-	-	-	-
67	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-
75	0	0	59.0	59.0	0	0	59.0	59.0
80	-	-	-	-	-	-	-	-
100	0	0	59.0	59.0	0	0	59.0	59.0
122	-	-	-	-	-	-	-	-
150	0	0	59.0	59.0	0	0	59.0	59.0
200	0	0	59.0	59.0	0	0	59.0	59.0
240	-	-	-	-	0	0	62.0	62.0
250	0	0	59.0	59.0				
260	-	-	-	-				
285	-	-	-	-				
300	0	0	60.0	60.0				
352	0	0	60.0	60.0				

TABLE 3 (Cont'd)

Depth in Feet	SPOKANE RIVER 7/15 (OH)	(CO_3)	(HCO_3)	Tot.	8/18 (OH)	(CO_3)	(HCO_3)	Tot.
0	0	1.0	35.0	36.0	0	2.0	47.0	49.0
10	0	1.0	46.0	47.0	0	2.0	55.0	57.0
20	0	1.0	58.0	59.0	0	2.0	55.0	57.0
30	0	1.0	58.0	59.0	0	1.0	56.0	57.0
40	0	1.0	58.0	59.0	0	1.0	56.0	57.0
50	0	1.0	58.0	59.0	0	0	57.0	57.0
60	-	-	-	-	-	-	-	-
67	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-
75	0	0	0	59.0	0	0	57.0	57.0
80	-	-	-	-	-	-	-	-
100	0	0	0	59.0	0	0	57.0	57.0
122	-	-	-	-	-	-	-	-
150	0	0	0	59.0	0	0	57.0	57.0
200	0	0	0	59.0	0	0	57.0	57.0
240	-	-	-	-	-	-	-	-
250	-	-	-	-	0	0	57.0	57.0
260	0	0	0	35.0	-	-	-	-
285					0	3.0	56.0	59.0
300								
352								

TABLE 3. (Cont'd)

Depth in Feet	HALL CREEK 7/13 (OH)	(CO_3)	(HCO_3)	Tot.	COLVILLE RIVER 7/12 (OH)	(CO_3)	(HCO_3)	Tot.
0	0	0	56.0	56.0	0	0	59.0	59.0
10	0	0	59.0	59.0	0	0	59.0	59.0
20	0	0	59.0	59.0	0	0	59.0	59.0
30	0	0	59.0	59.0	0	0	59.0	59.0
40	0	0	59.0	59.0	0	0	59.0	59.0
50	0	0	59.0	59.0	0	0	59.0	59.0
60	-	-	-	-	-	-	-	-
67	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-
75	0	0	61.0	61.0	0	0	59.0	59.0
80	-	-	-	-	-	-	-	-
100	0	0	63.0	63.0	0	0	59.0	59.0
122	0	0	63.0	63.0				

TABLE 3. (Cont'd)

Depth in Feet	KETTLE RIVER 7/9 (OH)	(CO_3)	(HCO_3)	Tot.	KETTLE RIVER 8/19 (OH)	(CO_3)	(HCO_3)	Tot.	FLAT CREEK 7/10 (OH)	(CO_3)	(HCO_3)	Tot.
0	0	0	61.0	61.0	0	3.0	51.0	54.0	0	0	59.0	59.0
10	0	0	61.0	61.0	0	0	54.0	54.0	0	0	59.0	59.0
20	0	0	61.0	61.0	0	0	54.0	54.0	0	0	59.0	59.0
30	0	0	61.0	61.0	0	0	54.0	54.0	0	0	59.0	59.0
40	0	0	61.0	61.0	0	0	54.0	54.0	0	0	59.0	59.0
50	0	0	61.0	61.0	0	0	54.0	54.0	0	0	59.0	59.0
60	0	0	61.0	61.0	0	0	54.0	54.0	0	0	59.0	59.0
67	-	-	-	-	-	-	-	-	0	0	59.0	59.0
70	0	0	61.0	61.0	0	0	56.0	56.0				
75												
80												
100												

TABLE 4. Free carbon dioxide in P.P.M. and acidity as calcium carbonate in P.P.M., Roosevelt Lake, 1948.

Depth	San Poil River				Spokane River				Hall Cr.		Colville R.	
in	7/8		8/17		7/15		8/18		7/13		7/12	
Feet	CO_2	Acid.	CO_2	Acid.	CO_2	Acid.	CO_2	Acid.	CO_2	Acid.	CO_2	Acid.
0	0.5	1.1	-	-	-	-	-	-	0.5	1.1	0.5	1.1
10	0.5	1.1	-	-	-	-	-	-	0.5	1.1	0.5	1.1
20	0.5	1.1	-	-	-	-	-	-	0.5	1.1	0.5	1.1
30	0.5	1.1	-	-	-	-	-	-	0.5	1.1	0.5	1.1
40	0.5	1.1	-	-	-	-	-	-	0.5	1.1	0.5	1.1
50	0.5	1.1	-	-	-	-	0.5	1.1	0.5	1.1	0.5	1.1
60	-	-	-	-	-	-	-	-	-	-	-	-
67	-	-	-	-	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-	-	-	-	-
75	0.5	1.1	0.5	1.1	0.5	1.1	0.5	1.1	0.5	1.1	0.5	1.1
80	-	-	-	-	-	-	-	-	-	-	-	-
100	0.5	1.1	0.5	1.1	0.5	1.1	0.5	1.1	0.5	1.1	0.5	1.1
122	-	-	-	-	-	-	-	-	0.5	1.1	-	-
150	0.5	1.1	0.5	1.1	0.5	1.1	0.5	1.1	-	-	-	-
200	0.5	1.1	4.0	9.1	0.5	1.1	1.0	2.3	-	-	-	-
240	-	-	-	-	-	-	-	-	-	-	-	-
250	0.5	1.1	-	-	-	-	0.5	1.1	-	-	-	-
260	-	-	1.0	2.3	1.0	2.3	-	-	-	-	-	-
285	-	-	-	-	-	-	-	-	-	-	-	-
300	0.5	1.1	-	-	-	-	-	-	-	-	-	-
352	1.0	2.3	-	-	-	-	-	-	-	-	-	-

Depth	Kettle River				Flat Cr.	
in	7/9		8/19		7/10	
Feet	CO_2	Acid.	CO_2	Acid.	CO_2	Acid.
0	0.5	1.1	-	-	0.5	1.1
10	0.5	1.1	0.5	1.1	0.5	1.1
20	0.5	1.1	0.5	1.1	0.5	1.1
30	0.5	1.1	0.5	1.1	0.5	1.1
40	0.5	1.1	0.5	1.1	0.5	1.1
50	0.5	1.1	0.5	1.1	0.5	1.1
60	0.5	1.1	0.5	1.1	0.5	1.1
67	-	-	-	-	0.5	1.1
70	0.5	1.1	4.5	10.2	-	-
75	-	-	-	-	-	-
80	0.5	1.1	-	-	-	-
100						

Dissolved oxygen

A complete series of dissolved oxygen determinations was made at the various stations using the basic Winkler method as described in Ellis, Westfall and Ellis (1946). Table 5 is a complete tabulation of the findings in parts per million of dissolved oxygen at the various stations on the lake. The oxygen readings are accompanied by temperatures because of the comparative importance of the latter in the respiration of aquatic organisms. Oxygen demand, for example, is almost doubled by a rise of 10°C, and oxygen has twice the supply value at 5° as at 15°C, (Ruttner, 1926). Considering that water containing 5 P.P.M. dissolved oxygen free from pollutants is generally regarded as favorable for fresh water fishes, it can be seen from Table 5 that sufficient oxygen for fish exists in the reservoir. It is interesting to note that slightly less oxygen was found in the Spokane River area than at other points. This may possibly be a result of oxidation of raw sewage and industrial pollutants which are poured from the City of Spokane sewer system into the river at the present time. No dangerously low oxygen concentrations were found, however.

Table 6 contains the values in percentages of saturation of oxygen in accordance with temperatures and normal surface barometric pressure at an elevation of 1,000 feet. From the Table it can be seen that practically all readings were at or near the saturation point.

Transparency of the Water

A secchi disk was used to measure transparency of the lake water. It consisted of a round metallic plate weighted with lead having black and white quadrants painted on its surface; it was lowered by a rope marked at half meter intervals. The depth at which the disk disappeared from view was recorded, and it was then lifted until it reappeared. The average of these two readings was listed as the limit of visibility. These Secchi disk readings furnished a useful, rough index for purposes of comparison.

Table 7 is a summary of transparency readings taken in 1948. From them, two phenomena are apparent: a gradual diminution of the silt load near the surface at stations successively farther downstream in the reservoir; and a clarification of the water throughout the reservoir as flows subsided from the record spring runoff in 1948.

TABLE 5. Dissolved oxygen content at stations in Roosevelt Lake in parts per million, 1948, with accompanying temperatures.

Depth in Feet	San Poil River 7/8 °F.	San Poil River 7/8 O_2	San Poil River 8/17 °F.	San Poil River 8/17 O_2	Spokane River 7/15 °F.	Spokane River 7/15 O_2	Spokane River 8/18 °F.	Spokane River 8/18 O_2
0	59.5	10.2	66.0	8.8	66.0	8.8	68.7	8.8
10	59.0	10.2	66.0	9.2	64.0	9.2	68.7	8.8
20	59.0	10.4	65.4	10.2	1/	9.2	66.9	8.8
30	58.5	10.4	65.0	10.2		9.2	66.2	8.8
40	58.5	10.4	65.0	10.2		9.2	65.8	8.8
50	58.5	10.6	64.4	10.2		9.2	65.3	8.8
60	-	-	-	-		-	-	-
67	-	-	-	-		-	-	-
70	-	-	-	-		-	-	-
75	58.5	10.6	64.2	9.0		9.2	64.0	8.8
80	58.5	-	-	-		-	-	-
100	58.5	10.4	63.5	8.6		9.2	63.0	8.8
122	-	-	-	-		-	-	-
150	58.0	10.4	63.0	8.2		9.2	61.2	8.6
200	57.5	10.4	61.5	8.8		9.0	60.1	8.6
240	-	-	59.5	8.2		-	-	-
250	57.5	10.4				-	59.4	8.6
260	-	-				8.8	-	-
285	-	-					59.2	8.6
300	57.0	10.4						
352	56.5	9.6						

Depth in Feet	Hall Creek 7/13 °F.	Hall Creek 7/13 O_2	Colville R. 7/12 °F.	Colville R. 7/12 O_2	Kettle River 7/9 °F.	Kettle River 7/9 O_2	Kettle River 8/19 °F.	Kettle River 8/19 O_2	Flat Creek 7/10 °F.	Flat Creek 7/10 O_2
0	66.0	10.6	60.0°	10.4	59.5	10.4	63.7	9.2	60.0°	10.6
10	63.0	10.6	1/	10.6	58.5	10.6	63.5	9.2	1/	10.6
20		10.4		10.6	58.5	10.6	63.0	9.2		10.6
30		10.4		10.6	58.0	10.6	63.0	9.2		10.6
40		10.4		10.6	58.0	10.6	63.0	9.2		10.6
50		10.4		10.6	58.0	10.6	63.0	9.2		10.6
60		-		-	58.0	10.6	63.0	9.2		10.6
67		-		-	-	-	-	-		
70		-		-	58.0	10.6	63.0	9.2		
75		10.4		10.6		-				
80		-		-	58.0	10.6				
100		10.4		10.6						
122		10.4		-						

1/ No temperatures at this level or below, due to failure of thermometer.

TABLE 6. Dissolved oxygen given in percentages of saturation at stations in Roosevelt Lake, 1948, at 1000 foot normal atmospheric pressure.

Depth in Feet	San Poil R.		Spokane R.		Hall Cr.	Colville R.	Kettle R.		Flat Cr.
	7/8	8/17	7/15	8/18	7/13	7/12	7/9	8/19	7/10
0	105	98	98	101	118	108	107	99	110
10	104	102	100	101	115		108	99	
20	106	112		99			108	99	
30	106	112		98			108	99	
40	106	112		97			108	99	
50	108	112		97			108	99	
60	-	-		-			108	99	
67	-	-		-			-	-	
70	-	-		-			108	99	
75	108	98		96			-		
80	-	-		-			108		
100	106	92		95					
122	-	-		-					
150	105	88		91					
200	105	93		90					
240	-	85		-					
250	105			89					
260	-			-					
285	-			88					
300	105								
352	104								

The heavy silt load in July could be detrimental to the productivity of the lake by reducing the penetration of the sunlight which is required for growth of phytoplankton. Similar observations should be continued in the future to determine whether 1948 was an abnormal year due to its record spring runoff.

PLANKTON

Plankton samples were taken whenever water analysis was made at the various stations located on the reservoir. Plankton material was secured by means of a standard type plankton net with a 3-3/4 inch orifice, a brass collection bucket, and covered with number 20 silk bolting cloth. The procedure used was to lower the net 10 meters and slowly raise it to the surface. By standardizing this procedure a rough quantitative comparison among various stations located on the lake was made possible; it was accomplished by inspection of uniform diameter vials containing the preserved plankton. Rather meager hauls at stations upstream as compared to good takes below indicated greater productivity in the downstream portion of the reservoir. This undoubtedly is due to the stream-like nature of the upper section of the reservoir as compared with the deeper, slower-moving section below.

TABLE 7. 1948 Secchi Disk readings Roosevelt Lake, measured in Feet.

Date of Surveys	San Poil River	Spokane River	Hall Creek	Colville River	Kettle River	Flat Creek
July 6-16	8.0	5.0	6.0	6.0	5.0	5.0
Aug. 16-20	16.0	15.0			10.0	
Sept. 7-9	26.0	18.0			13.0	

FISH POPULATIONS

Gill Net Sampling

Fish sampling was carried out by means of gill nets at six different locations along the reservoir (Figure 4). Three nets were used; they were 125 feet long by 6 feet deep, and had mesh graded from

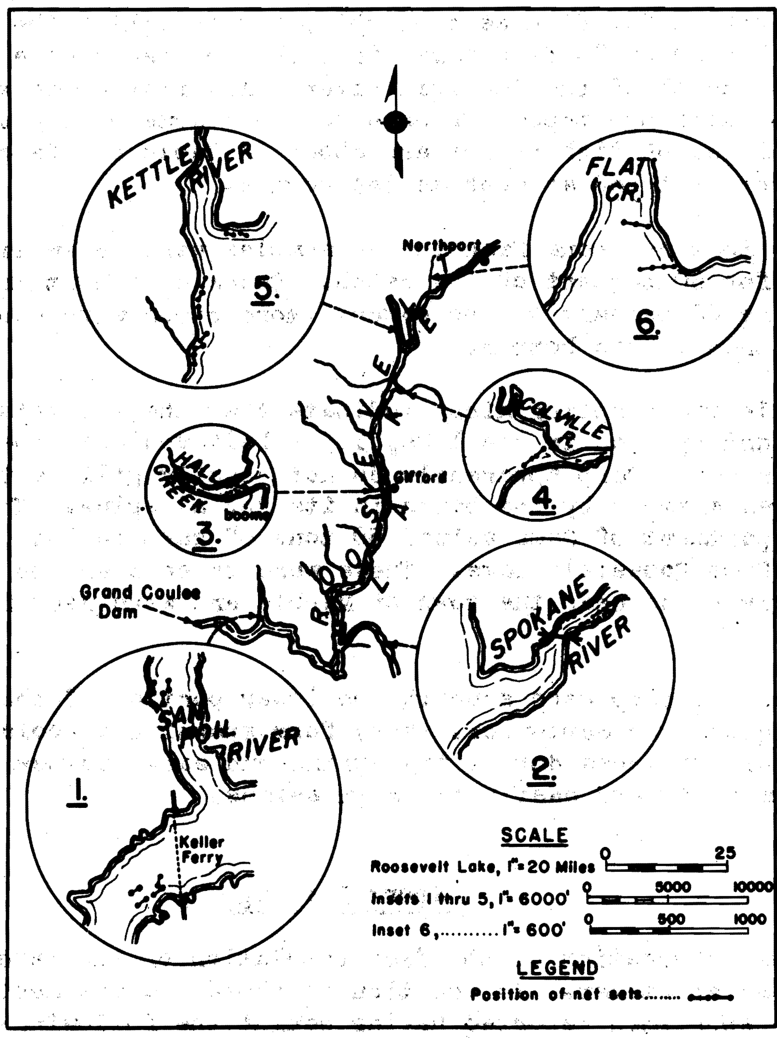

Figure 4. -- Locations at which gill nets were set, Roosevelt Lake, 1948.

1 to 4 inches stretched measure. Sets were made overnight and the nets were hauled in each morning. The fish were measured, and a sample of each species was saved for purposes of identification.

Table 8 shows the results of fishing both at the surface and at the bottom. In 21 net-nights of fishing on the bottom, there was an average catch of 7.4 fish per net-night, and in 9 net nights of fishing at the surface 7.3 fish were caught per net-night. The largest single haul consisted of 28 fish taken in 6 feet of water at a point one mile above the mouth of the San Poil River. All fish appeared in good condition although tapeworms were found in some of the squawfish and chubs. Sizes of fish caught are shown in Table 9. Larger squawfish and suckers weighed as much as two pounds.

The most numerous fish in the samples were squawfish, which accounted for 60 percent of the catch. Chubs were next in abundance, comprising 22 percent of the catch. More chubs were caught near the surface than at the bottom.

While the sampling might indicate that the squawfish was the predominant species in the lake, it is believed that the carp is more abundant. Carp apparently do not readily gill as the only carp caught was snagged by the barbs in its dorsal spine. The Washington State Department of Game seined 50 tons of carp in 1947 and 100 tons in 1948 from Roosevelt Lake. These were taken near the mouth of the Kettle River and near the town of Marble and were used for hatchery food.

Numerous carp were seen in the lower portion of the Kettle River during August and September. They form spawning schools in the shallow slough areas during the spring and early summer months, at which time they are easily taken in seines.

Sport Fishing

Some information on the fish population of the lake was obtained from local sportsmen. In addition to those species mentioned in Table 9, sportsmen reported having caught the following:

1. Rainbow trout, *Salmo gairdnerii*
2. Brook trout, *Salvelinus fontinalis*
3. Whitefish, *Prosopium coulteri*, *Prosopium williamsoni*, *Prosopium oregonium*
4. Kokanee (landlocked sockeye salmon), *Oncorhynchus nerka kennerlyi*
5. Kamloops trout, *Salmo gairdnerii kamloops*

TABLE 8. Data on gill net catches of fish in Roosevelt Lake, 1948. Each line of the table represents the set of one net.

Area fished	Date	Number of hours fished	Depth fished feet	Fish caught	Fish per net hour
		Bottom Haul			
San Poil R.	July 7	14.5	45	6	0.41
San Poil R.	July 7	15.5	6	28	1.81
San Poil R.	July 7	15.0	100	4	0.27
Spokane R.	July 14	11.0	10-20	3	9.27
Spokane R.	July 14	12.0	20-30	4	0.33
Hall Creek	July 13	14.0	70	2	0.14
Hall Creek	July 13	14.5	80	-	0.00
Colville R.	July 11	16.0	90	4	0.25
Colville R.	July 11	16.0	7-20	2	0.12
Kettle R.	July 9	16.0	6	8	0.50
Kettle R.	July 9	14.0	11	11	0.78
Flat Creek	July 10	13.0	10	3	0.23
Flat Creek	July 10	13.0	10	4	0.31
San Poil R.	Aug. 17	17.0	30	11	0.65
Spokane R.	Aug. 18	15.0	30	4	0.27
Spokane R.	Aug. 18	15.0	45	5	0.33
Kettle R.	Aug. 19	16.0	25	17	1.06
Kettle R.	Aug. 19	16.0	20	20	1.25
San Poil R.	Sept. 7	16.5	28	8	0.48
Spokane R.	Sept. 8	15.5	30-40	7	0.45
Kettle R.	Sept. 9	17.0	40	5	0.29
Total		312.5		156	0.50
		Surface Haul			
San Poil R.	Aug. 17	17.0		7	0.41
Spokane R.	Aug. 18	15.0		13	0.87
Kettle R.	Aug. 19	16.0		5	0.31
San Poil R.	Sept. 7	17.0		4	0.24
San Poil R.	Sept. 7	17.0		4	0.24
Spokane R.	Sept. 8	16.0		13	0.81
Spokane R.	Sept. 8	16.0		12	0.75
Kettle R.	Sept. 9	16.0		6	0.38
Kettle R.	Sept. 9	18.5		2	0.11
Total		148.5		66	0.44

TABLE 9. Species composition, size range, and average size of fish caught by gill nets, Roosevelt Lake surveys, 1948.

Species	Bottom Haul No.	Bottom Haul %	Surface Haul No.	Surface Haul %	All Hauls No.	All Hauls %	Size Range, Inches	Average Size, Inches
Squawfish, *Ptychocheilus oregonensis*	102	65	31	47	133	59.9	4.3-15.0	9.5
Chub, *Mylocheilus caurinus*	22	14	28	42	50	22.5	5.5-11.0	8.5
Sucker, *Catastomus* species	15	10	1	2	16	7.2	6.7-16.2	10.9
Shiner, *Richardsonius balteatus*	6	4	6	9	12	5.4	4.7-5.9	5.3
Perch, *Perca flavescens*	5	3	-	-	5	2.2	3.9-9.1	6.8
Tench, *Tinca tinca*	2	1	-	-	2	0.9	7.9	7.9
Sunfish, *Lepomis gibbosus*	2	1	-	-	2	0.9	3.9-4.5	4.2
Sculpin, *Cottus* species	1	1	-	-	1	0.5	5.9	5.9
Carp, *Cyprinus carpio*	1	1	-	-	1	0.5	17.7	17.7
Total	156	100	66	100	222	100	3.9-17.7	--

6. Cutthroat trout, *Salmo clarkii*
7. Char or Dolly Varden trout, *Salvelinus malma*
8. Bass, largemouth black, *Micropterus salmoides*
9. Bass, smallmouth black, *Micropterus dolomieu*

One sportsman was observed fishing for cray fish near the Colville River.

Tom Rouston of Northport, Washington, who has fished the Columbia River and tributaries in the area for about 40 years, stated that large catches of prize fish were caught when few people lived in the area but that fishing became progressively poorer as more fishermen came to the area. Occasionally Mr. Rouston catches rainbow, brook, and Dolly Varden trout; but shiners, whitefish, squawfish, carp, and suckers are more common, however.

Harvey Broderious, also of Northport, complained that whitefish seemed to have almost disappeared since the impoundment was established.

According to another old time local sportsman, Frank Hines of Keller's Ferry, Washington, bass and occasionally kokanee are caught in the San Poil River, but catches of fish other than scrapfish have been small. He also reports that a run of kokanee ascends the San Poil River to spawn every fall. A large specimen was caught by him in a stunned condition this spring, and he saved the head, which was seen by the writers. Judging from the head size the fish must have weighed between three and four pounds or as much as a Columbia River sea-run blueback. There is poor fishing in the slackwater of the San Poil River, but in the upper portions of the stream there is fair fishing for trout and the stream is still heavily fished, Hines reports.

A large number of kokanee were observed spawning in the San Poil River in 1948, by Clifford J. Burner of the Fish and Wildlife Service. He reports spawning land-locked salmon from the first riffle above slack water to fifty miles upstream.

Every year numerous kokanee are found below Grand Coulee Dam, of which many are dead and others are injured. What causes the land-locked blueback salmon to migrate from Roosevelt Lake is not known. Specimens found below the dam apparently had not been starved.

Interviews were made with sportsmen who had fished the following areas: San Poil River, Gifford, Colville River, Sheep Creek, and Northport. Undoubtedly other areas are fished, although not as extensively. As nearly as could be determined by the surveys, very little fishing is carried on in the reservoir at the present time. Only a few fishermen were observed during the survey in July, when nearly the entire length of the reservoir was visited by us over a period of 10 days.

Generally speaking the consensus of opinion of sportsmen interviewed was that: (1) sport fishing has been on the decline during the last ten years (2) Grand Coulee Dam has contributed to this decline, and (3) scrap fish have become a nuisance.

Relative Size of Fish Populations

Gill net fishing has been done at Cultus Lake in British Columbia to reduce the number of predaceous fish (Foerster and Ricker, 1942), and information on the fish population obtained there is of interest for comparison with the Roosevelt Lake data. Because the squawfish was the most abundant species gill netted in both lakes, a comparison of the catches of that species was made; results are given in Table 10.

It is seen from Table 10 that in 1935 Cultus Lake nets yielded 11.2 squawfish per net night as compared with 4.9 for Roosevelt Lake in 1948 (1935 data are used for comparison because the abundance of squawfish was presumably reduced after that year as a result of the predator control program). Since the nets at Cultus Lake were 1.2 times longer than the Roosevelt Lake nets, the Cultus nets can be expected to have 1.2 times better opportunity of catching fish. The catch at Cultus was 2.3 times as great as that at Roosevelt Lake, but if the larger net size at Cultus Lake is taken into consideration the catch of squawfish actually was only 1.9 times greater for Cultus Lake.

The predator control work in Cultus Lake was carried on especially for the purpose of reducing the number of squawfish, which are extremely predaceous on young salmon. Squawfish were taken in largest numbers during the months of April, May, June and early July, in nets set near shore. During this period the fish were spawning on the gravel beaches where the nets were set. During most of July, August, and early September, poor catches were made, by all types of gear. After mid-September, fish were caught in fair numbers in nets set on the bottom off shore, and as the season progressed they were taken in greater numbers in the deeper waters of the lake.

Fishing at Roosevelt Lake, on the other hand, was not done specifically to catch squawfish but to get a representative sample of the fish population. The nets were set at various depths and locations but usually not near the shore where the squawfish were more likely to be numerous. Also, the time fished was not during the spring spawning as at Cultus Lake, but during the summer. When all of the above factors are considered it seems probable that the

TABLE 10. Comparison of squawfish catch, Roosevelt and Cultus Lakes, gill net fishing.

Roosevelt Lake 1948 season

	Catch	No. net nights	Catch per net night
Bottom sets	102	21	4.9
Surface sets	31	9	3.4
Total	133	30	4.4

Nets used - 125 feet long, 6 feet deep, graded mesh 1"-4"

Cultus Lake 1/ 1935 season

	Catch	Net nights	Catch per net night
1935 Shore set 6 feet deep	649	58	11.2
1936 shore 6 feet	395	351	1.12
1936 floating nets 9-12 feet	762	590	1.29
1937 and shore nets 6 feet	224	376	0.60
Total	2030	1375	1.48

Nets used - 150 feet long, 6 feet deep, mesh 2" - 4 1/2"

1/ Data from Foerster and Ricker, 1942.

population of squawfish in Roosevelt Lake is equivalent to the maximum population of squawfish in Cultus Lake. Apparently, however, there is a much greater population of chubs in Roosevelt Lake than in Cultus Lake, since only 27 chubs were reported caught in 7 years of fishing at Cultus Lake whereas 50 chubs were caught in the one season's fishing at Roosevelt Lake.

SUMMARY

1. Roosevelt Lake, situated in northeastern Washington, is the storage reservoir behind Grand Coulee Dam.

2. The surrounding shoreline has been established as a National Park for the recreational benefit of the public and is easily accessible by good roads.

3. The greater part of the reservoir lies in a rain belt which supports evergreen forests.

4. Various physical and biological aspects of the lake were investigated including temperatures, oxygen, carbon dioxide, hydroxides, carbonates and bicarbonates, pH, turbidity, plankton, and fish populations.

5. The most surprising discovery was the almost complete lack of thermal gradient, a very unusual condition for a lake of this depth.

6. All physical factors of the water appeared favorable to fish with the exception of extreme turbidity of the water.

7. Plankton hauls revealed fair-to-good abundance in the lower reservoir as compared to rather sparse concentrations in the upper stretches.

8. Further study should be made of the turbidity of the lake and of the meager plankton output of the upper region in order to determine whether or not the 1948 season was made unusual by the heavy spring flood.

9. Fish sampling at Roosevelt Lake in 1948 consisted of 30 gill net-nights of fishing. An average of 7.4 fish were caught per net-night.

10. Slightly larger catches were made fishing at the bottom than at the surface.

11. Species caught were squawfish, chubs, suckers, shiners, perch, tench, sunfish, sculpin, and carp.

12. In addition to the above species sport fishermen claim to have caught the following: Rainbow, brook, cutthroat, dolly varden and kamloops trout; kokanee or landlocked blueback salmon; whitefish; largemouth and smallmouth bass.

13. A comparison of the Roosevelt Lake gill net catches with those made at Cultus Lake reveals that the concentration of squawfish in Roosevelt Lake in 1948 was at least as great as that in Cultus lake, in 1935.

DISCUSSION AND CONCLUSIONS

Roosevelt Lake is surrounded by attractive country which is well suited for recreational and sightseeing purposes because of its mountainous terrain, virgin park like forests, and scenic drives; it has not yet, however, been utilized extensively. Since the lake had produced rather poor fishing the National Park Service was of the opinion that improved sport fishing might be influential in attracting more people to take advantage of recreational facilities of the lake. The Park Service, therefore, was instrumental in inaugurating the surveys made by the Fish and Wildlife Service in 1948.

The results of the investigation were in general found to be favorable:

1. pH's, carbonates, bicarbonates, carbon dioxide, oxygen were present in proportions favorable to bacterial growth, photosynthetic activities of chlorophyll bearing plants, and fauna.
2. Low free carbon dioxide content, complete absence of hydroxides, and good dissolved oxygen content were indicative of freedom from pollution.
3. Plankton hauls were fair to good in the downstream portion of the reservoir, comparing favorably to fish producing bodies of water such as Karluk Lake, Alaska; Tieton Reservoir, Washington; and Arrowrock Reservoir, Idaho.
4. From the fish sampling work, Roosevelt Lake appears to compare favorably with Cultus Lake, B. C. in production of rough fish.

There were, however, some unfavorable factors:

1. Absence of a cold water layer may prove incompatible to the well being of certain fishes.
2. The extreme turbidity existing in July is not regarded as favorable to production of phytoplankton (this may have been an abnormal condition as a result of the unprecedented floods of 1948).
3. Meager plankton hauls in the upper reservoir were not indicative of good productivity in that portion of the lake (this condition also may have been aggravated by the spring flood in 1948).
4. No salmonoids were caught in the experimental fishing with gill nets, indicating scarcity of these game fishes.
5. Fish sampling indicated that large populations of undesirable rough fish exist, such as squawfish, chubs, suckers, and carp.

Although more complete determinations are necessary to secure all information which may be needed, it appears advisable to consider, at least, a stocking program for Roosevelt Lake. It should be made clear at this point that the lake is too extensive to make an overall stocking program successful. Therefore, if an attempt to stock the lake is made an area should be selected which most closely resembles the natural habitat of the fish introduced. Then if a local population is built up sufficiently to support a sport fishery in that particular area the program can be gradually expanded to other locations.

Careful consideration of the type of fish best suited for Roosevelt Lake should be made. At the present time stocking of Kokanee (landlocked blueback salmon) has been carried on by the Washington State Game Department in Roosevelt Lake. These fish have been observed spawning in the San Poil River and are occasionally taken by local fishermen. They have not proven satisfactory, however, because of their migratory habit which carries many of them to death over Grand Coulee Dam each spring.

Rainbow trout are known to inhabit the lake in the winter, but migrate into various tributary streams in the summer, providing excellent stream fishing for sportsmen, but no lake fishing for family groups. An important factor then, in introducing a stock into the lake, is to introduce a fish which would remain in the lake to provide fishing in the summer.

Before a stocking program is formulated, however, more detailed study of existing problems should be made taking careful account of the above points. The turbidity of the water found in July and scarcity of plankton material in the upper reservoir should be examined in a normal year, as the condition found in the summer of 1948 might merely be a temporary result of the unprecedented floods of 1948. It is also recommended that more widespread experimental fishing with various types of gear be carried out at various times of the year. This should be done especially in early spring, as more reliable information on the fish populations in that season is needed.

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