PREFERRED AND OBSERVED CONDITIONS FOR SOCKEYE SALMON IN OZETTE LAKE AND ITS TRIBUTARIES, CLALLAM COUNTY, WASHINGTON



U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 78-64

Open-File Report

Prepared in Cooperation With the
Makah Indian Tribe

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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1979

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

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Open-File Report

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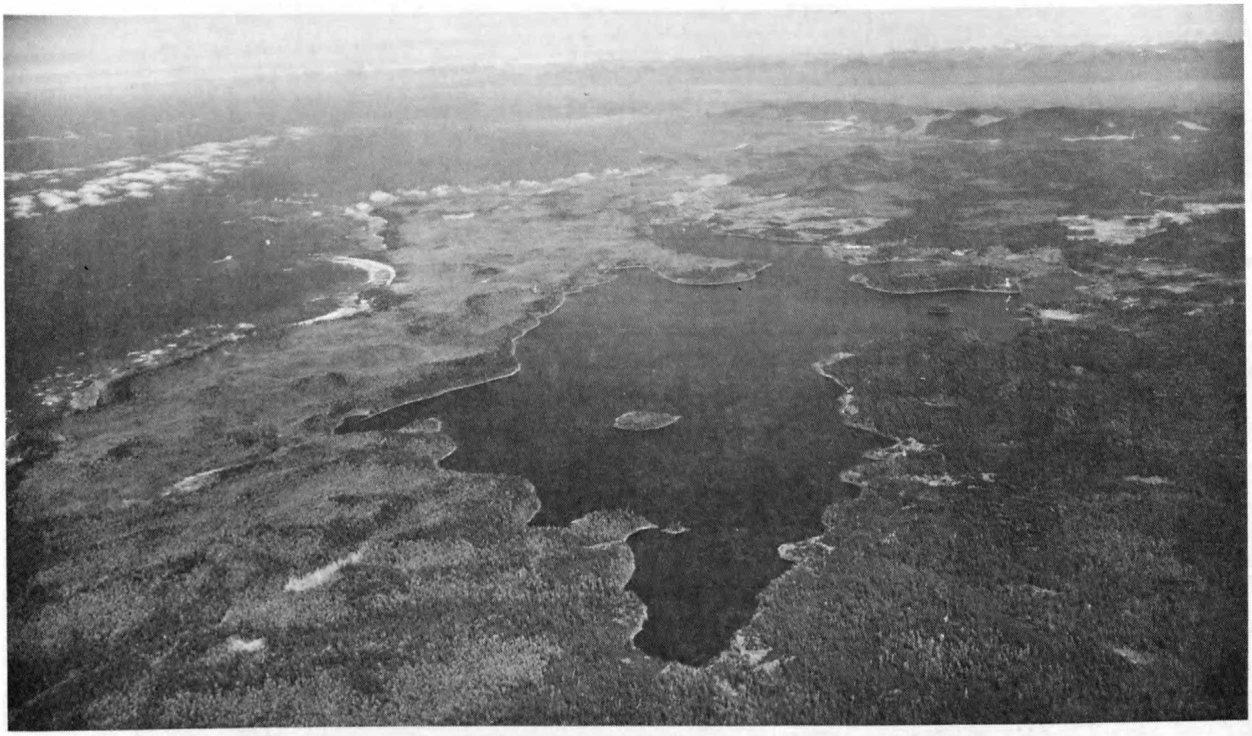

View northward, with Pacific Ocean on left
and Vancouver Island at top.

View southward, with Pacific Ocean on right.

FRONTISPIECE

Aerial views of Ozette Lake,
by Northwest Air Photos.

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METRIC CONVERSIONS

Multiply	By	To obtain
acre	4,047	square meter (m^2)
cubic foot per second (ft^3/s)	.02832	cubic meter per second (m^3/s)
foot (ft)	.3048	meter (m)
foot per second (ft/s)	.3048	meter per second (m/s)
foot per mile (ft/mi)	.1894	meter per kilometer (m/km)
inch	.02540	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
square yard (yd^2)	.8361	square meter (m^2)
degree Fharenheit (°F)	Subtract 32 multiply remainder by 0.5556	degree Celsius (°C)

PREFERRED AND OBSERVED CONDITIONS FOR SOCKEYE SALMON IN OZETTE LAKE AND ITS TRIBUTARIES, CLALLAM COUNTY, WASHINGTON

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ABSTRACT

Ozette River and Ozette Lake and its tributaries have many of the qualities that are generally supportive of good sockeye salmon production, even though the run of sockeye has decreased drastically over the past 25 years. The annual number of sockeye taken by Makah Indians from the Ozette River near its mouth has decreased from over 17,000 in 1949 to 0 in 1974 and 1975.

The Ozette River discharge in 1976 was sufficient to allow the downstream migration of smolts from Ozette Lake to the sea in spring, and the upstream migration of adults to the lake in early summer. During the 1976-77 spawning season (October-March) the discharge of Big River, the largest tributary of Ozette Lake, was within the range preferred by sockeye for spawning during the period of late November-late February; the discharge of Umbrella Creek was within the preferred range from mid-December to mid-January and for about 5 weeks from mid-February to late March.

In Big River and Umbrella Creek the streambed areas with gravels suitable for spawning were calculated to be about 39,000 and 31,000 square yards, respectively. If those areas were completely utilized they would accommodate about 13,000 and 10,000 spawning sockeye females, respectively.

Water temperatures in the range preferred for spawning (51-54 degrees Fahrenheit) were observed in the major tributaries of Ozette Lake from mid- to late October 1976.

Ozette Lake is a large, deep lake and historically has been a natural rearing area for young sockeye. In summer 1976 temperatures preferred for the growth of young sockeye (45-68 degrees Fahrenheit) occurred between about 200 feet of depth and the water surface, or generally in the zone of steep temperature gradient. Dissolved-oxygen concentrations in excess of 8 milligrams per liter at all depths throughout the year provided an adequate supply of oxygen for sockeye production.

Chlorophyll a concentrations indicate the lake is low to moderate in algal production. Concentrations of total zooplankton ranged from 7.0 to 11.0 organisms per liter during the period May-November 1976. In comparison with eight other sockeye-producing lakes in Washington and Alaska, the concentrations of zooplankton in Ozette Lake appear adequate to support the rearing of sockeye salmon.

INTRODUCTION

Ozette Lake is a large, deep lake drained by the Ozette River, which flows through the Makah Indian Reservation before emptying into the Pacific Ocean. The lake was formerly a good producer of sockeye salmon, and the Makah Indian Tribe long depended in part on the fish for income and food. However, the decreasing run of sockeye salmon to Ozette Lake and its tributaries in recent years has become a matter of prime concern. This study, conducted in cooperation with the Makah Indian Tribe, was made to determine the existing migrating, spawning, and rearing environments of the streams and lake, and to compare those observed conditions with known preferred conditions.

In comparing existing and preferred environmental conditions for sockeye propagation, it is recognized that the concept of preferred ranges is not rigid. That is, preferred ranges are based on observed conditions in a number of different Pacific Coastal streams, but any given water may have conditions outside the preferred range but to which indigenous fish are well adapted (Foerster, 1968, p. 190).

Description of Study Area

The study area encompasses the entire Ozette River drainage basin in the northwestern corner of the Olympic Peninsula in Washington State (fig. 1).

The climate of the area is of the marine type, with cool summers and mild winters. Climatological records at Forks, about 15 miles southeast of the basin, indicate a mean annual temperature of 49.1°F (degrees Fahrenheit). January has the lowest mean monthly temperature, 38.5°F, and July the highest, 60.0°F (fig. 2). Prevailing onshore winds carry warm, moist air into the region from the Pacific Ocean. The mean annual precipitation at Forks is 117 inches, of which about 77 percent falls as rain during the period October to March.

The area is of generally low relief; well-rounded hills and ridges rise approximately 400 to 600 feet above the adjacent valley floors (fig. 3). The maximum altitude in the basin is approximately 1,900 feet above mean sea level.

Ozette Lake, which is the third largest natural lake is Washington, has a surface area of 7,300 acres and a drainage of 77 square miles. The lake is approximately 29 feet above mean sea level; because the lake is more than 320 feet deep (fig. 9), the bottom of the lake extends below sea level.

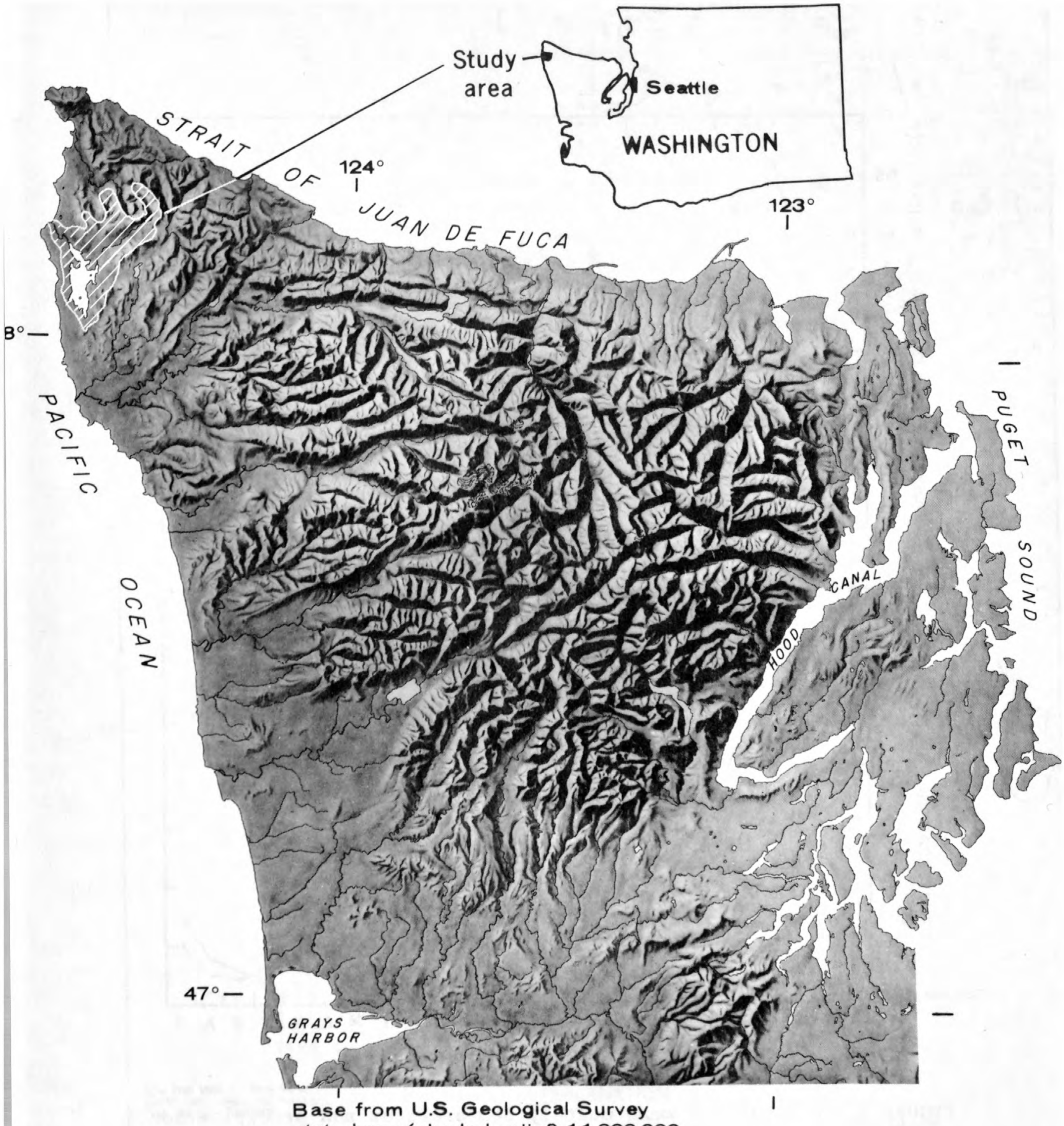

FIGURE 1.--Location of Ozette River and Ozette Lake drainage basin, northwestern Olympic Peninsula.

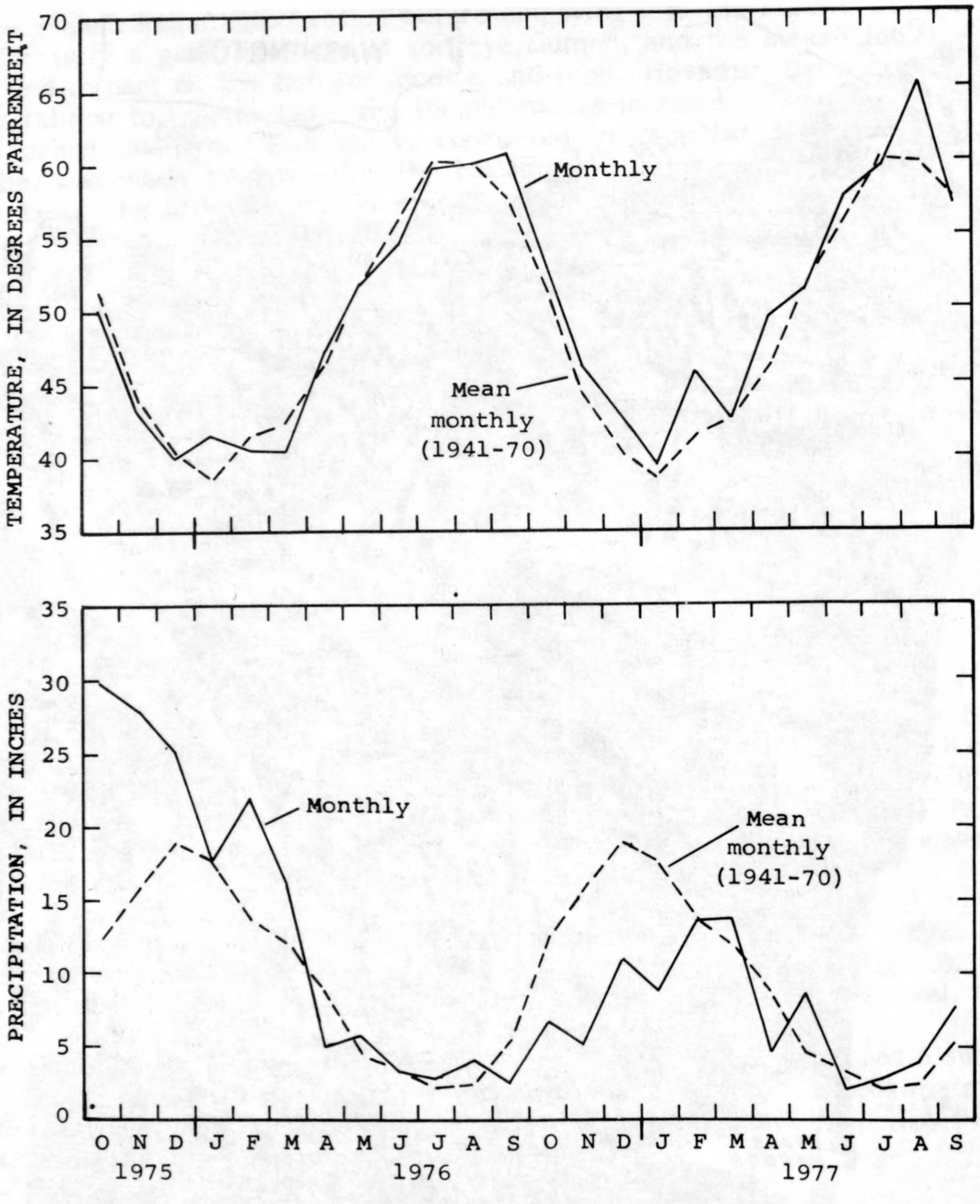

FIGURE 2.--Monthly and mean monthly temperatures and precipitation at Forks, Wash.

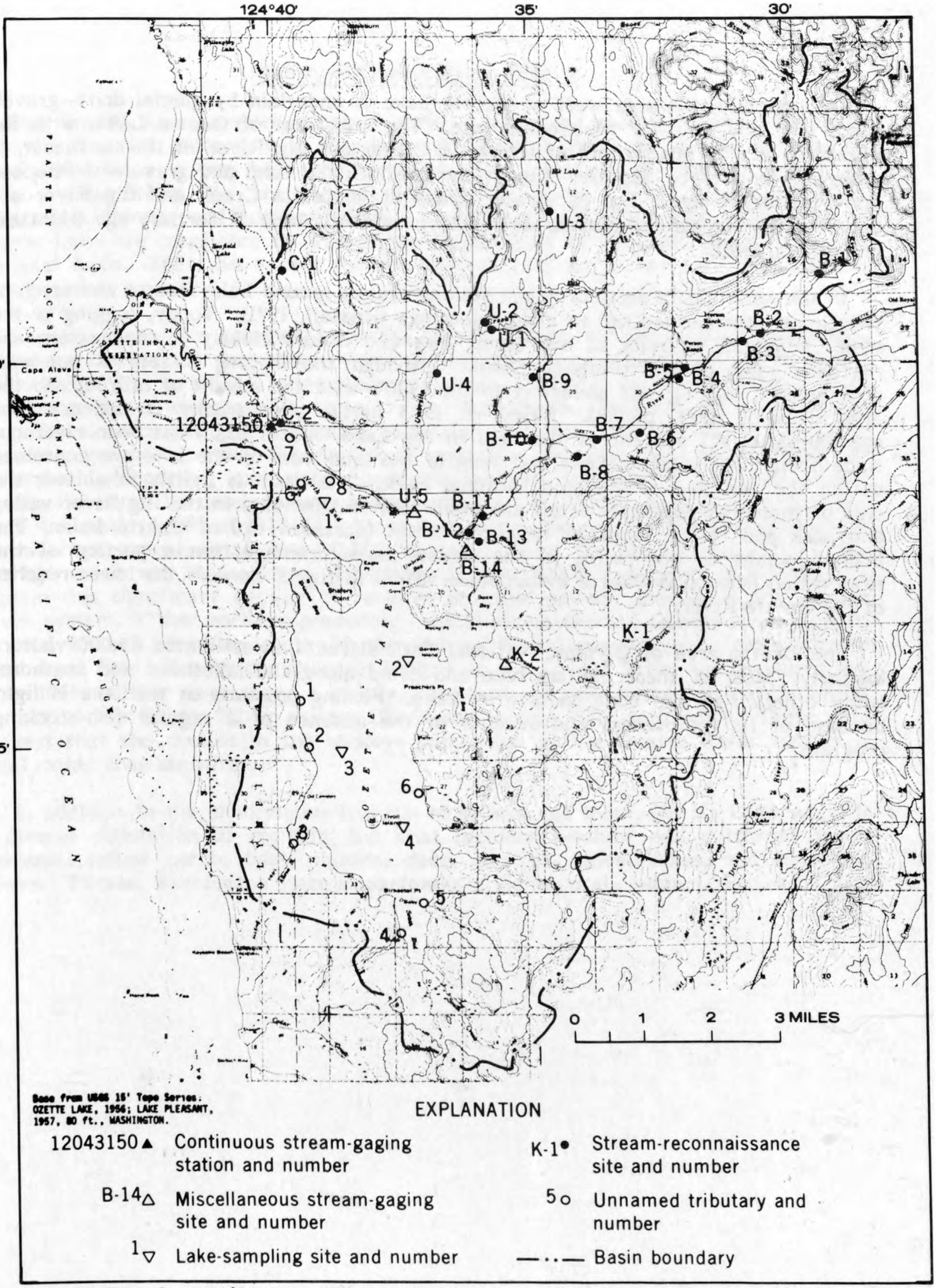

FIGURE 3.--Tributary streams and data-collection sites in the Ozette River drainage basin.

Geologically, the area west of Ozette Lake is underlain by glacial drift--gravel, sand, silt, and clay--of Pleistocene age. The area east of Ozette Lake, with the exception of the headwaters of Umbrella Creek and Big River in the northeast, is underlain by terrace deposits--fluvial and glaciofluvial sand and gravel--of Pliocene and Pleistocene age. The headwater areas of Umbrella Creek and Big River are underlain by marine and nonmarine sandstone and siltstone of Tertiary age (Huntting and others, 1961).

In the early 1880's settlers began staking claims around Lake Ozette and much of the timber was burned off to make clearings (Russell, 1971). Today, logging is the major economic activity of the study area and occurs chiefly in the eastern and northern parts of the drainage basin. Although the logging history is not well documented, logging was underway in the 1930's with the advent of railroads to the area (Russell, 1971, p. 88). Based on 1973 aerial photography it appears that approximately 25 percent of the land in the Lake Ozette basin has been clear-cut since about 1940. Ozette Lake and most of the land west of the lake are contained within the confines of Olympic National Park. The basin is lightly inhabited; the only permanently populated areas are small farm settlements in the Big River valley and park and resort facilities near the outlet (northern tip) of Ozette Lake. The Makah Indians do not reside in the Ozette Lake drainage, but a portion of the reservation (shown as Ozette Indian Reservation in fig. 3) borders the lower reaches of the Ozette River.

The Ozette area of Olympic National Park attracts an estimated 65,000 visitors annually. Most of these visitors hike and camp along the lakeshore and seashore, while others fish and boat on Ozette Lake. Fishing pressure on the lake is light because of its remoteness and because of the absence of a regular fish-stocking program.

History of Ozette River Fishery

The Ozette River system supports runs of sockeye, chinook, coho, and chum salmon. However, according to Phinney and Bucknell (1975), all spawning areas in the Ozette River system have not been identified. Sockeye salmon are known to occur in Big River and are thought to occur in some of the other accessible tributaries (Phinney and Bucknell, 1975). Spawning-ground surveys of tributaries to Ozette Lake are conducted by Washington Department of Fisheries personnel on an irregular basis. The most recent surveys (1975-76) indicated that only coho salmon were present.

Records of salmon catches from the Ozette River, as reported by fishermen, have been maintained since 1948 by the Washington Department of Fisheries (Ward and others, 1976, p. 108). The numbers of salmon taken by the Makah Indians from the Ozette River are shown in table 1. The data shown represent the approximate commercial catch and give a relative indication of numbers of fish migrating to the spawning grounds in the Ozette River system. Despite the inconsistency of fishermen in reporting such data, these are the only information available on the Ozette fishery. The catch records indicate that all species of salmon have declined since the peak period of 1948-52. According to the records for the period 1948-52, the average annual catch was 10,800 sockeye, while for the period 1971-76 the average catch was 144 sockeye. However, no documented evidence is available to explain this significant decline of sockeye or other salmon species in the Ozette River system. Other sockeye-producing coastal rivers are the Queets and Quinault, located 45 and 60 miles south of the Ozette River, respectively. Although the number of fish taken by the Quinault Indians on the Queets River has remained low since 1964, neither river shows a steady, long-term decline in sockeye catch similar to that of the Ozette River system (Ward and others, 1976, p. 109-110). These data suggest that the decline in the sockeye population in the Ozette River system is local rather than areawide.

In addition to the anadromous fish run of salmon and trout, Ozette Lake supports a diverse population of resident fish that includes rainbow and cutthroat trout, kokanee, yellow perch, bass, shiners, dace, suckers, mudminnows, and squawfish (Robert Watson, Washington State Department of Game, oral commun., Feb. 4, 1977).

TABLE 1.--Numbers of salmon taken by Makah Indians from Ozette River near mouth, 1948-75

Salmon species

[Numbers of fish taken by set nets or drag seines, as reported to State of Washington Department of Fisheries by Makah Indians (Ward and others, 1976, p. 108.)]

Year	Chinook	Chum	Coho	Sockeye	Totals	Percent sockeye
1948	491	1,063	1,991	3,850	7,395	52
1949	1,876	1,339	1,572	17,638	22,525	78
1950	1,629	1,226	2,407	14,556	19,818	73
1951	1,213	1,021	1,103	15,074	18,411	82
1952	396	682	3,697	3,047	7,822	39
1953	431	431	906	2,380	4,148	57
1954	823	907	862	2,110	4,702	45
1955	404	806	1,031	1,107	3,348	33
1956	241	0	1,149	1,396	2,786	50
1957	428	0	1,119	512	2,059	25
1958	147	0	721	395	1,263	31
1959	0	0	0	682	682	100
1960	0	0	0	1,851	1,851	100
1961	3	0	281	1,054	1,338	79
1962	0	0	385	1,645	2,030	81
1963	1	1	263	1,551	1,816	85
1964	1	0	350	448	799	56
1965	1	0	407	257	665	39
1966	0	0	504	405	909	45
1967	0	0	272	313	585	54
1968	0	0	385	468	853	55
1969	0	0	189	295	484	61
1970	1	0	296	432	729	59
1971	0	0	244	328	576	57
1972	0	0	325	346	671	52
1973	0	0	0	49	49	100
1974	0	0	0	0	0	--
1975	33	0	0	0	33	0

Sockeye Salmon Life Cycle

Sockeye salmon (Oncorhynchus nerka) is an anadromous fish--it spends most of its life in the ocean but, when approaching maturity, it returns to fresh water to spawn (fig. 4). The sockeye usually selects those coastal streams or tributaries of major river systems which originate in or pass through lakes. Spawning takes place in either (1) the small streams flowing into the lake(s), (2) the shallow-water, gravel areas along the lakeshore where subsurface springs occur, or (3) the upper reaches of the lake outlet stream, usually in that order of preference (Foerster, 1968, p. 99). Sockeye salmon in the coastal region of Washington spawn from October to March (Fay Conroy, State of Washington Department of Fisheries, written commun., Dec. 4, 1975). The eggs are deposited in nests (redds) which have been excavated by the female fish in selected parts of the stream or lake bed. The eggs are then fertilized by the accompanying male fish and subsequently covered over by the female. Both the male and female die shortly after spawning. The period of egg incubation depends primarily on the temperature of the water flowing through the redd; under normal conditions the incubation period may range from 80 to 140 days, with warmer temperature producing the shorter periods.

The fully formed and free-swimming fry emerge from the gravel in spring. The young salmon reside in the adjacent lake for a period of 1, 2, or, more rarely, 3 years before setting out on their seaward migration sometime during April-June.

Sockeye remain in the ocean feeding areas from 1 to 4 years and, with the onset of maturity, return again to coastal waters and to their natal stream. The fish are harvested commercially as they move to the spawning grounds.

For a more detailed description of the sockeye's life cycle the reader is referred to the paper by Foerster (1968).

Acknowledgments

The authors appreciate the assistance of the Makah Indian Tribe in designing the framework of this study and for assisting with field measurements of lake stage. The assistance of William Lester, Olympic National Park ranger at Ozette Lake, is gratefully acknowledged for the use of equipment and facilities and for volunteering to read gage heights to determine lake levels. Appreciation is also expressed to William Wood of the Washington Department of Fisheries for providing information on spawning-ground surveys and the physical descriptions of streams tributary to Ozette Lake.

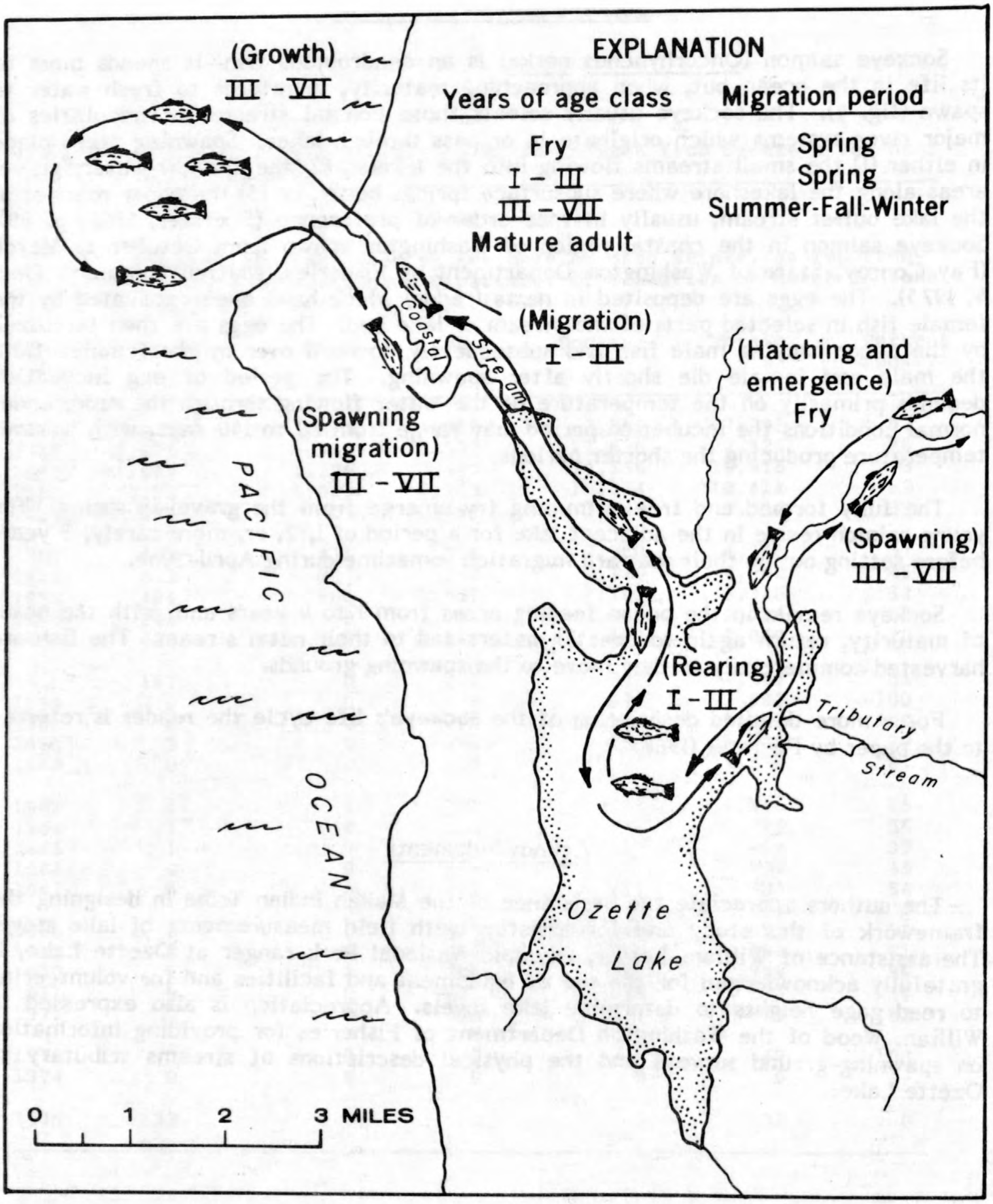

FIGURE 4.--Generalized diagram showing migration cycle of sockeye salmon in study area.

APPROACH AND METHODS

The production of young sockeye salmon depends directly on the amount of zooplankton as food in the resident lake. Because the production of zooplankton depends on the abundance of phytoplankton and this, in turn, depends on the qualitities of the essential inorganic substances and on favorable conditions for photosynthesis, a study of the important elements of the food chain was of paramount importance.

In 1976 chemical and biological data were collected from Ozette Lake on a monthly basis at four sites (fig. 3). In order to determine year-to-year variations in selected parameters at sites 2 and 3, measurements also were made in 1977--in February, May, July, and September.

Measurements of temperature and dissolved oxygen were made at the sites indicated. Composite water samples for mineral, nutrient, pH, and color analyses were collected from the upper, middle, and lower depths in the lake. Measurements of pH and color, and filtration of nutrient samples were performed in the field, with the nutrient samples being cooled to between 32°-40°F immediately after collection to avoid decomposition prior to analysis. Samples collected for chlorophyll a analyses from different levels of the upper lighted zone of the lake were composited, and the samples (0.5-2.0 liters) were filtered immediately in the field, using 0.45 micrometer Millipore[1] filter. The filters containing the pigment were stored immediately in a dessicator, iced in the field, and later stored in a dessicator at -4°F. Analyses were performed on the samples 1 to 20 days after collection. Samples collected for analysis of algal-growth potential were composited from the entire water column and were filtered in the field through 0.45 and 0.22 micrometer Gelman filters. The samples were stored on ice until analysis. Phytoplankton samples were collected with a 75-micrometer net towed horizontally 2-5 feet below the water surface. The samples were preserved with Lugols solution. Zooplankton samples were collected by hauling vertically with a 153-micrometer net from a depth of 90 feet to the surface and preserved with formalin.

The mineral and nutrient analyses were performed by U.S. Geological Survey laboratories using procedures outlined by Brown, Skougstad, and Fishman (1970). Phytoplankton and zooplankton identification was performed by lake-project personnel with quality control by U.S. Geological Survey central laboratories.

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[1]The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

MIGRATION CONDITIONS

Two factors having a major influence on the upstream ascent of sockeye salmon are (1) the physical condition of the fish, and (2) the environmental rigors and hazards to be faced and overcome. Sockeye do not feed after entering fresh water and therefore must rely on energy reserves for the several months they take to return to their natal spawning area and reproduce. Sockeye salmon migrate up the Ozette River to Ozette Lake primarily in the months of June and early July, and reside in the lake until spawning begins in autumn (Lloyd Phinney, Washington Department of Fisheries, written commun., March 1, 1977).

Preferred Migration Conditions

Sockeye salmon need adequate streamflow for passage to a lake during their spawning migration and a stream corridor free of natural and manmade barriers. Obstacles to a speedy and easy ascent to the lake and up lake tributaries may result in delay and extra exertion of energy. High water temperatures of rivers in which sockeye are migrating, and in water in which they spawn, may at times cause appreciable mortality of unspawned individuals (Foerster, 1968, p. 90; Bell, 1973, chap. 7, p. 4). The preferred temperature range for migrating adult sockeye is given as 45^{o} to $60^{o}F$ by Bell (1973, chap. 11, p. 4).

Observed Migration Conditions

The Ozette River is free of impediments such as slides, cave-ins, and waterfalls, but it does contain logjams. During the summer of 1976 three logjams were present near the middle of the 4.7-mile-long Ozette River, but these did not appear to restrict water movement or to prevent fish passage. Logjams were removed from the Ozette River in 1956 and 1964 to facilitate the passage of fish (Patrick Bucknell, State of Washington Department of Fisheries, oral commun., February 21, 1977).

The total length of perennial tributaries to Ozette Lake, as measured on topographic maps, is about 79 miles. However, fish passage is not possible for this entire length. Impassable falls are located at mile 4.6 on North Fork Crooked Creek and at mile 11.0 on Big River. The total length that is passable by fish is approximately 70 miles. This estimate does not take into consideration other possible impediments to fish passage, such as inadequate water depths and debris jams.

The discharge of Ozette River during the period January 1976-September 1977 (fig. 5A), at a point about 250 feet downstream from the lake, was 400 to 1,000 ft^3/s during the winter months, and 63 to 235 ft^3/s during the summer months. Although the data required to determine the average long-term discharge of Ozette River are not available, streamflow appears to be adequate during the migration of adult fish to the lake in June or July and during the migration of young salmon from the lake to the sea during April or May. The flows in the summer of 1977 were in a drought year and the discharge of Ozette River in August 1977 was at least 45 ft^3/s (not shown in fig. 5A).

As shown in figure 6, water temperatures in the Ozette River during June 1976 were within the temperature range (45°-60°F) preferred for migration. Yet, in June and July of 1977, the water temperatures were generally warmer than preferred. However, the preferred ranges, as previously mentioned, should not be viewed as rigid requirements for sockeye. It has been noted by Foerster (1968, p. 190) that different races of sockeye native to areas with different climatic conditions may be acclimated to different water temperatures.

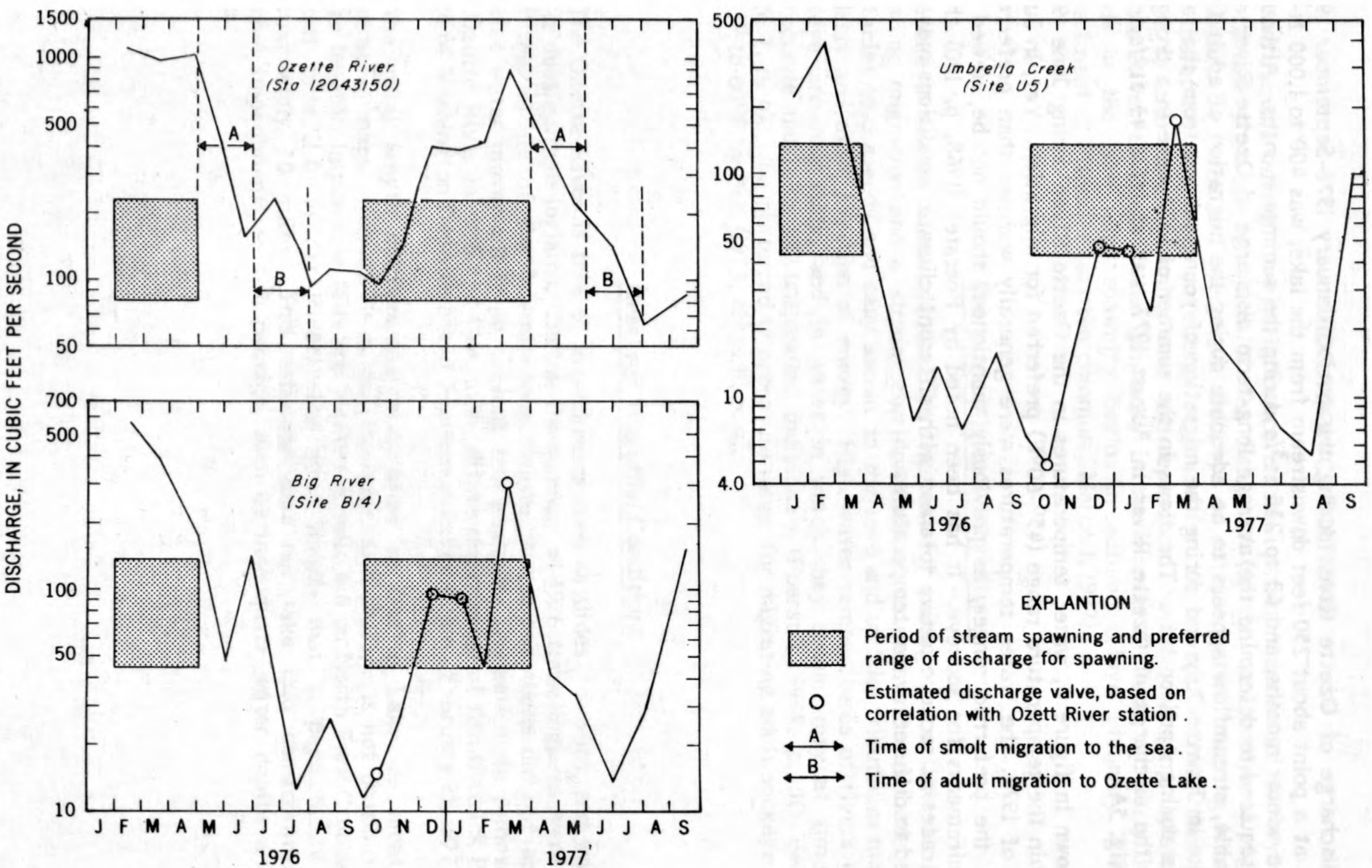


FIGURE 5.--Hydrographs showing discharges of Ozette River and selected tributaries of Ozette Lake.

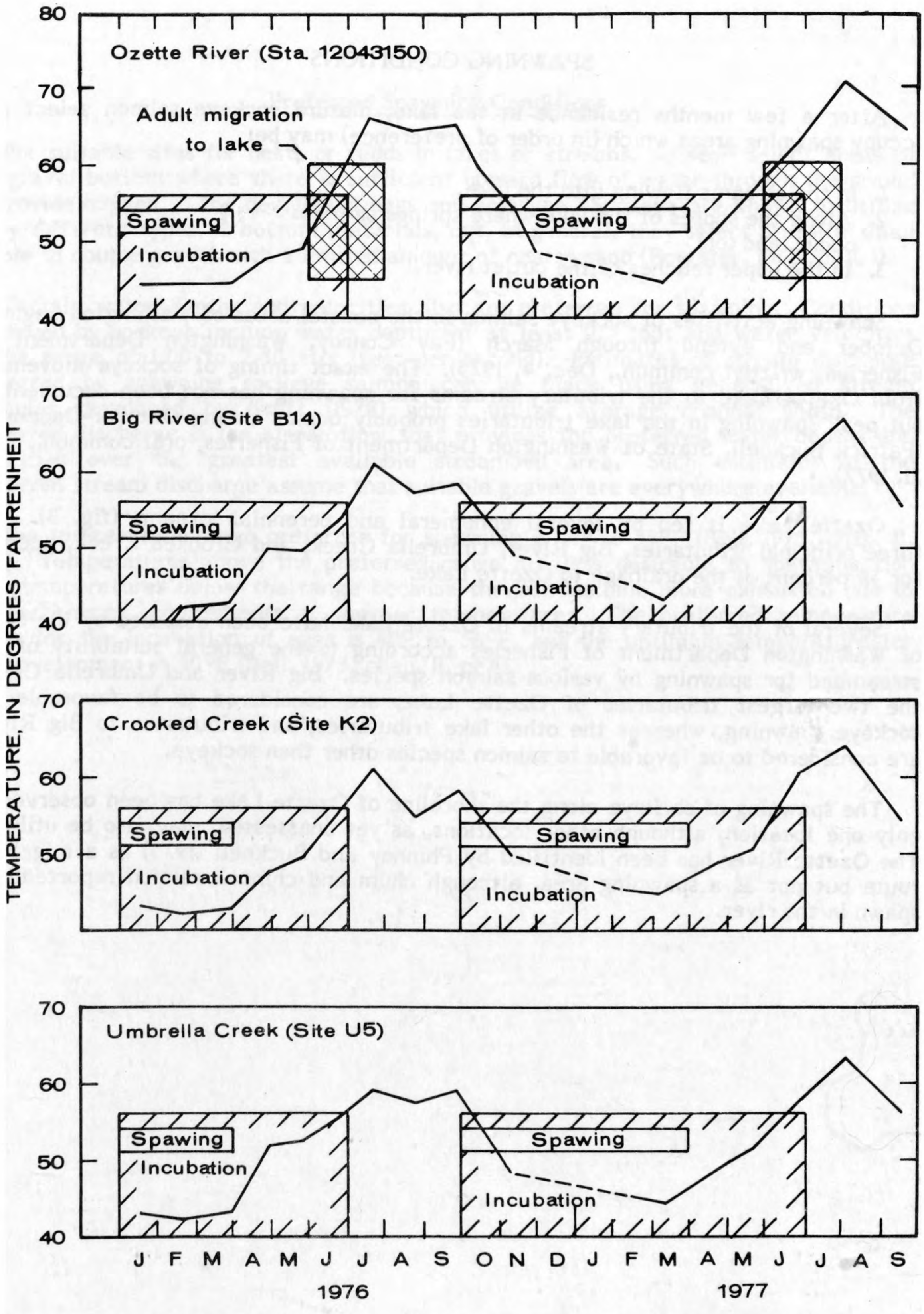


FIGURE 6.--Water temperatures in Ozette River and selected tributaries of Ozette Lake.

SPAWNING CONDITIONS

After a few months residence in the lake, mature sockeye salmon select and occupy spawning areas which (in order of preference) may be:

1. In the streams flowing into the lake,
2. Along the shores of the lake where springs or seeps occur, and (or)
3. In the upper reaches of the outlet river.

Spawning activities of sockeye salmon in the coastal areas of Washington begin in October and extend through March (Fay Conroy, Washington Department of Fisheries, written commun., Dec. 4, 1975). The exact timing of sockeye movement from Ozette Lake to the tributary streams for spawning has not been documented, but peak spawning in the lake tributaries probably occurs during October-December (Patrick Bucknell, State of Washington Department of Fisheries, oral commun., Feb. 21, 1977).

Ozette Lake is fed by several ephemeral and perennial streams (fig. 3). The three principal tributaries, Big River, Umbrella Creek, and Crooked Creek, account for 58 percent of the drainage to Ozette Lake.

Several of the tributary streams to Ozette Lake have been assessed by the State of Washington Department of Fisheries according to the general suitability of the streambed for spawning by various salmon species. Big River and Umbrella Creek, the two largest tributaries of Ozette Lake, are considered to be favorable for sockeye spawning, whereas the other lake tributaries, and tributaries to Big River, are considered to be favorable to salmon species other than sockeye.

The spawning of sockeye along the shoreline of Ozette Lake has been observed at only one location, although other locations, as yet unassessed, may also be utilized. The Ozette River has been identified by Phinney and Bucknell (1975) as a migration route but not as a spawning area, although chum and chinook salmon reportedly do spawn in the river.

Preferred Spawning Conditions

For suitable sites for nests or redds in lakes or streams, sockeye select areas of the gravel bottom where there is sufficient upward flow of water through the gravel to provide oxygen to the developing eggs and embryos. Sockeye are known to utilize many different types of bottom materials, but, in general, they select areas of small cobble to course gravel with a limited amount of coarse sand (Foerster, 1968, p. 103).

Certain water depths and velocities also are preferred for spawning. Conditions preferred by sockeye include water depths of at least 0.5 foot and water velocities in the range of 1.00 to 2.50 ft/s (feet per second). Estimates of stream discharge preferred by spawning sockeye salmon can be made using generalized stream formulas developed by Swift (1978) which utilize average channel width. The preferred discharge is the streamflow that provides the preferred water depths and velocities over the greatest available streambed area. Such estimates of the preferred stream discharge assume that suitable gravels are everywhere available.

The temperature range preferred for spawning is 51° to 54°F (Bell, 1973, chap. 11, p. 4). Temperatures above the preferred range are less desirable to spawning fish than temperatures below the range because the fish become more exhausted due to greater energy requirements at warmer temperatures. The preferred temperature range for the incubation of eggs is 40° to 56°F, but the optimum temperature for egg development is 50°F (Bell, 1973, chap. 11, p. 4).

Observed Spawning Conditions

Physical Characteristics of Selected Tributaries and of Ozette Lake Shore

Most of the larger streams that enter Ozette Lake are sluggish in their lower reaches. The main stems of Crooked Creek and Big River have low to moderate gradients of 15 to 16 ft/mile. The tributaries and headwaters of these streams, however, have steep gradients, commonly 75 to 200 ft/mile. The smaller streams that enter Lake Ozette, such as Siwash, Elk, and South Creeks, also have steep gradients. The gradient profiles of Ozette River and of the prinicipal streams that drain to Ozette Lake, as obtained from topographic maps, are shown in figure 7. Photographs of typical lower-reach streambank vegetation and channel characteristics are shown in figure 8 for two sites, one on Big River and one on Umbrella Creek. The locations of the photograph sites are shown in figure 9.

Tributary reaches with low to moderate gradients would be expected to have streambeds of relatively fine materials—gravel and sand; conversely, tributary reaches with high gradients would be expected to have streambeds of coarser materials—boulders and cobbles. Measurements of streambed materials in the Ozette Lake tributaries tend to substantiate these assumptions. As shown in figure 7, the low-gradient lower reaches of the principal tributaries contain higher percentages of fine-grained materials than the high-gradient upper reaches. Therefore, based on the composition of the streambed, the middle reaches and parts of the lower reaches of the principal tributaries can be considered usable by sockeye for spawning.

The selection of a spawning site, however, is based on hydraulic conditions as well as streambed composition. Sockeye select riffles for spawning, as opposed to pools and rapids, probably to insure oxygenation of their eggs. Although the lower reaches of Big River and Umbrella Creek have about 6 and 4 miles, respectively, of streambed materials suitable for spawning, riffles exist only at certain locations within these reaches. Data on the occurrence of riffles in tributaries to Ozette Lake (see below) were provided by the State of Washington Department of Fisheries (William Wood, written commun., Jan. 18, 1977).

Tributary	Reach of suitable streambed (river miles)	Riffles (percent)	Approximate length of suitable spawning reach (miles)
Big River-------	3.0-4.0	10	0.1
	4.0-8.0	30	1.2
	8.0-9.0	60	.6
Umbrella Creek--	0.0-4.0	40	1.6

Based on the data above, suitable spawning reaches for sockeye in Big River and Umbrella Creek total 1.9 and 1.6 miles, respectively.

Shoreside spawning in Ozette Lake by sockeye has been documented, but the extent to which this occurs is not known. Spawning grounds along the lakeshore vary greatly in suitability; lakebed materials and water conditions in some areas are excellent for the deposition and incubation of eggs while others are only marginal. A shore survey of Ozette Lake was completed on August 25, 1976, to assess the suitability of nearshore lakebed materials in the shallows for spawning. Because the lake stage had receded considerably toward the summer minimum by that time, a large area of beach was exposed. In general, the beach sediment along the 31 miles of shore is highly variable in size, ranging from silt to boulders.

The beach and lakebed material observed most frequently was a mixture of silt, sand, gravel, and cobbles. Figure 9 shows the part of the Ozette Lake shore that appears to have the most suitable materials for sockeye salmon spawning--uniform coarse gravel to small cobble with a limited amount of coarse sand. The shore areas that have the most uniform gravels (0.5 to 2.5 inches) are at the head of Ericsons Bay and on the southwest shore of the lake. Typical beach conditions at the head of Ericsons Bay are shown in figure 10. The most uniform small cobbles (2.5 to 5 inches) are at the southeastern shore of the lake. Much of the remaining shore is heterogeneous and composed of a mixture of materials ranging in size from silt to boulders. The beaches in the peninsula areas of Shafers Point and Rocky Point, which separate the main body of the lake from North End Bay (fig. 9), were composed of boulders.

Much of the beach is exposed during the summer, allowing the growth of grasses, shrubs, and other vegetation. Typical of the condition are the beaches on the west shore, near Eagle Point, and on the east side of Ericsons Bay (fig. 11). The beach vegetation is dominated by a woody shrub, sweetgale (Myrica Gale). This ubiquitous shrub dominates much of the Ozette Lake shoreline throughout the year and, because of its density, probably reduces the area available for spawning salmon. Other aquatic plants found along the shoreline include horsetail, sedges, yellow lily, pondweed, smartweed, bur reed, watershield, and grasses. As sweetgale is a common, native plant of the coastal region, it probably was present at a time before the decline in sockeye run and thus was not a contributing factor in the loss of spawning habitat.

As in tributary spawning sites, spawning sites in the shallows along the lakeshore also reflect a combination of suitable lakebed materials and hydraulic conditions. Lake-spawning sockeye usually select areas where ground water discharges upward through the gravel (as lake-bottom springs), probably to ensure an adequate supply of oxygen for their eggs. However, the locations of springs or seeps vary with respect to the shoreline, according to lake stage. In summer, when the lake stage is usually at its lowest level, springs may occur above the lake level, but in autumn and winter, when spawning occurs, the springs are probably submerged.

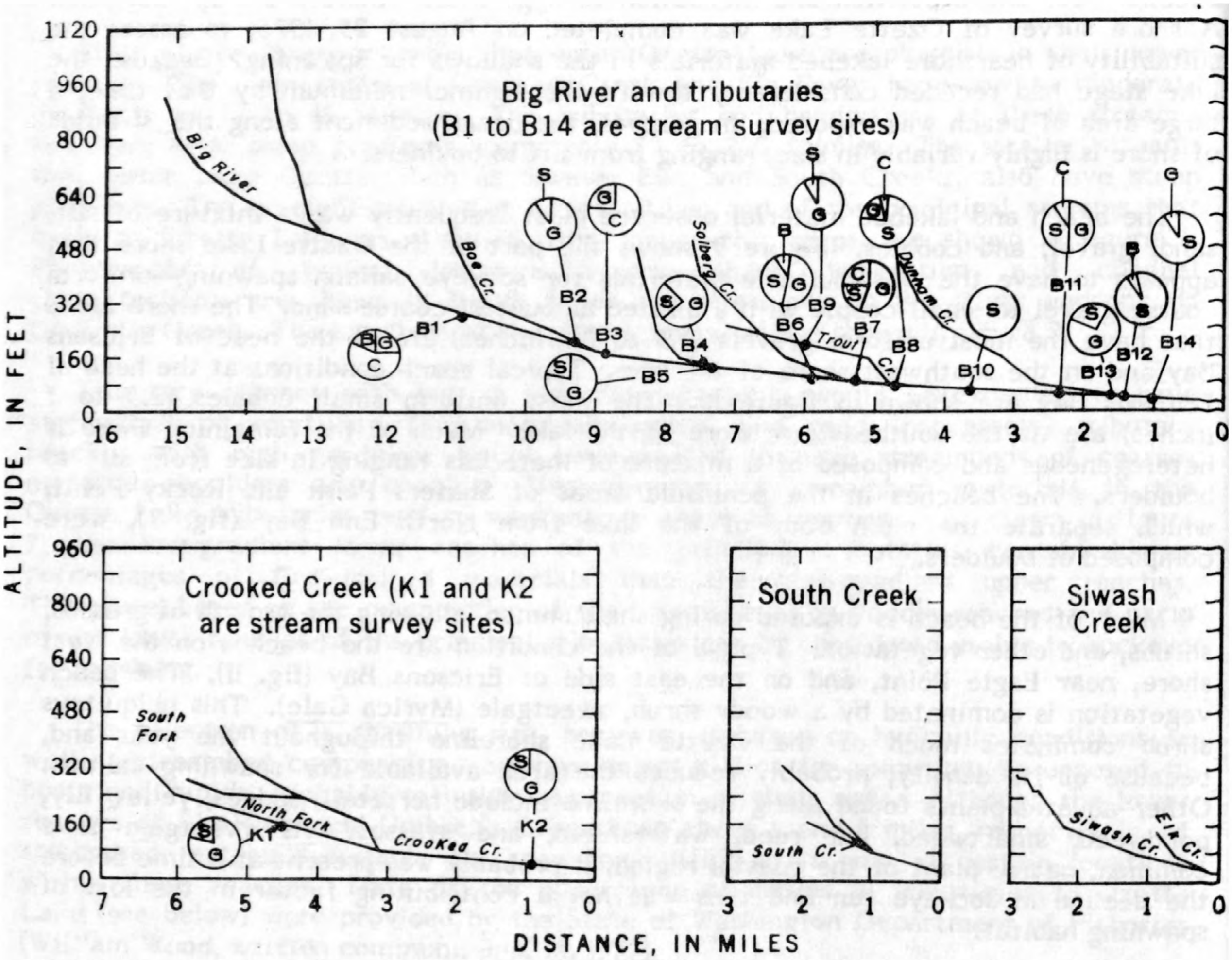
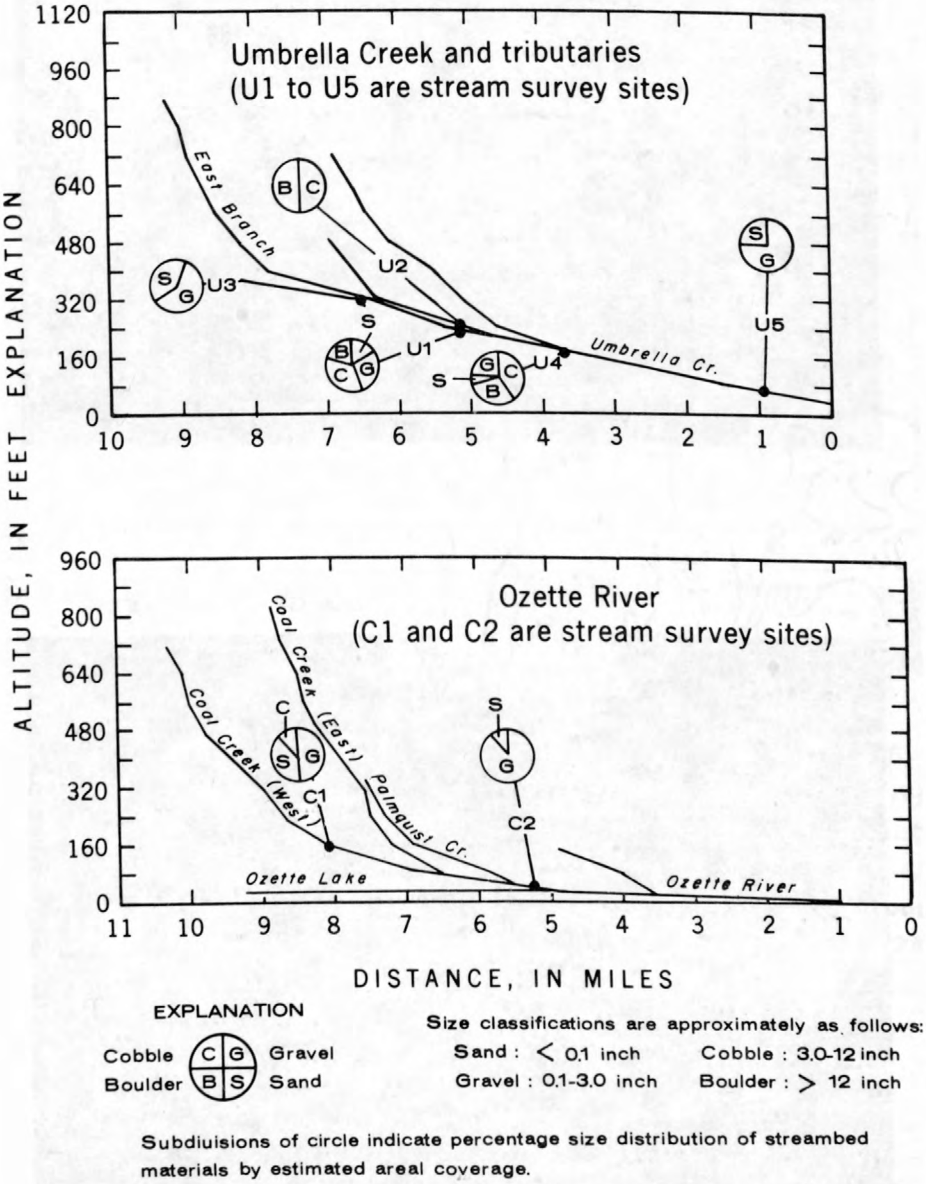


FIGURE 7.--Gradient, stream length, and streambed composition of Ozette River and selected tributaries of Ozette Lake.


Umbrella Creek and tributaries
(U1 to U5 are stream survey sites)
East Branch
Umbrella Cr.
U1
U2
U3
U4
U5
Ozette River
(C1 and C2 are stream survey sites)
Coal Creek (West)
Coal Creek (East)
Palmquist Cr.
Ozette Lake
Ozette River
C1
C2
ALTITUDE, IN FEET EXPLANATION
DISTANCE, IN MILES
EXPLANATION
Cobble
Boulder
Gravel
Sand
Size classifications are approximately as follows:
Sand : < 0.1 inch
Gravel : 0.1-3.0 inch
Cobble : 3.0-12 inch
Boulder : > 12 inch
Subdiuisions of circle indicate percentage size distribution of streambed materials by estimated areal coverage.

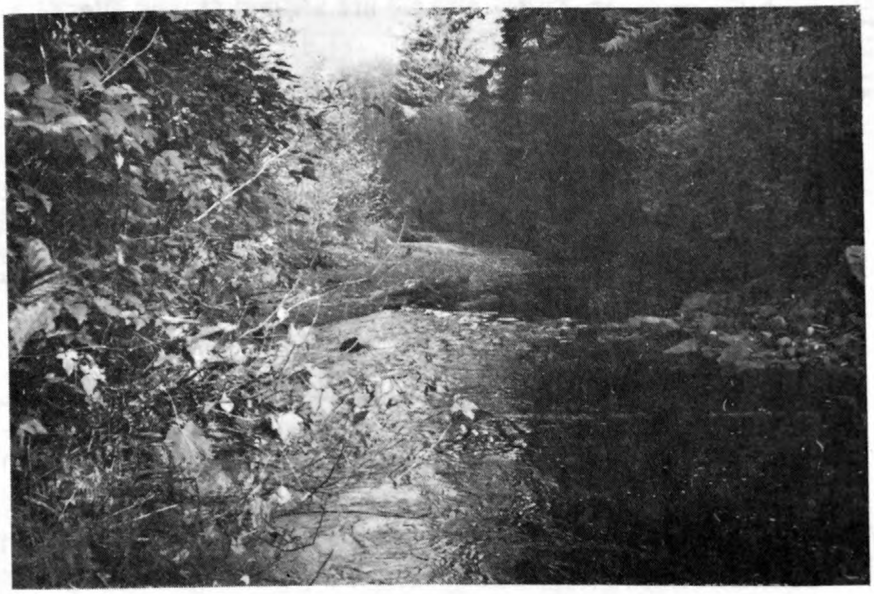


FIGURE 8.-- Typical channel conditions on lower reaches of Big River (upper, site B 12) and Umbrella Creek (lower site U 5). Photographs by G.C. Bortleson, November 10, 1976.

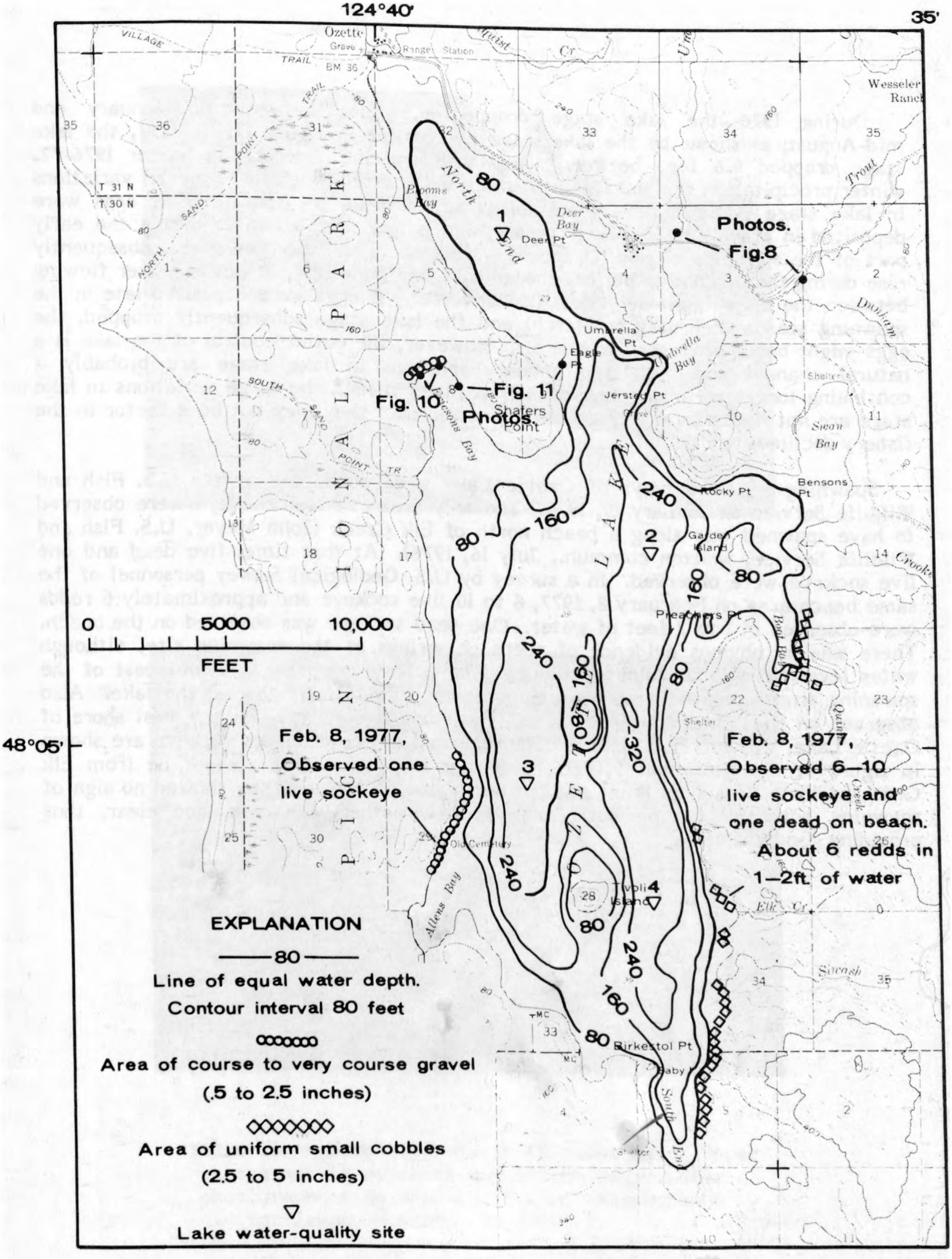


FIGURE 9.--Bottom contours of Ozette Lake and locations of nearshore lakebed gravels suitable for spawning by sockeye salmon.

During 1976 the lake stage dropped 6.5 feet between mid-January and mid-August, as shown by the lake-stage hydrograph in figure 12. In 1977, the lake stage dropped 4.6 feet between mid-March and mid-August. In winter 1976-77, winter precipitation was much less than normal (fig. 2). Such large annual variations in lake stage could limit the suitability of the lake for spawning. If eggs were deposited in gravels near springs or seeps in a few feet of water during the early part of the spawning season (October or November) and the lake stage subsequently rose during the incubation period, the amount and beneficial effect of water flowing between the eggs might be reduced. Conversely, if eggs were deposited late in the spawning season (February or March) and the lake stage subsequently dropped, the eggs might become exposed to the air. However, the outlet control of the lake is a natural channel and the large annual variations in lake stage are probably a continuing long-term characteristic. Thus, even though the large variations in lake stage are not necessarily a desirable characteristic, they may not be a factor in the fishery decline since 1950.

Spawning-ground surveys of Ozette Lake were conducted by the U.S. Fish and Wildlife Service on January 10, 1974. The only area in which sockeye were observed to have spawned was along a beach north of Elk Creek (John Meyer, U.S. Fish and Wildlife Service, written commun., July 16, 1976). At that time, five dead and one live sockeye were observed. In a survey by U.S. Geological Survey personnel of the same beach area on February 8, 1977, 6 to 10 live sockeye and approximately 6 redds were observed in 1 to 2 feet of water. One dead sockeye was observed on the beach. There was no obvious evidence of seeps or springs at the spawning site, although water levels in two piezometers, located on private property 250 feet east of the spawning site, indicated a water-table gradient of 0.15 ft/ft toward the lake. Also observed on the same date (Feb. 8, 1977) was one live sockeye on the west shore of Ozette Lake, west of Tivoli Island. The locations of the observed sockeye are shown in figure 9. On November 9, 1976, a similar inspection of the shoreline from Elk Creek north to Preachers Point and the north side of Ericsons Bay showed no sign of spawning activity. During both surveys the weather was calm and clear, thus providing good visibility.

FIGURE 10.-- Beach gravels in Ericsons Bay. Upper photograph is at north end of the bay; Lower photograph is on northeast side. Photographs by G.C.Bartleson, November 10,1976

FIGURE 11.-- Vegetation along Ozette Lake shoreling at low lake stage in summer. Upper photograph is **shore** shore near Eagle Point. Lower photograph is shore on east side of Ericsons Bay. Photographs by G.C. Bartleson, November 10, 1976.

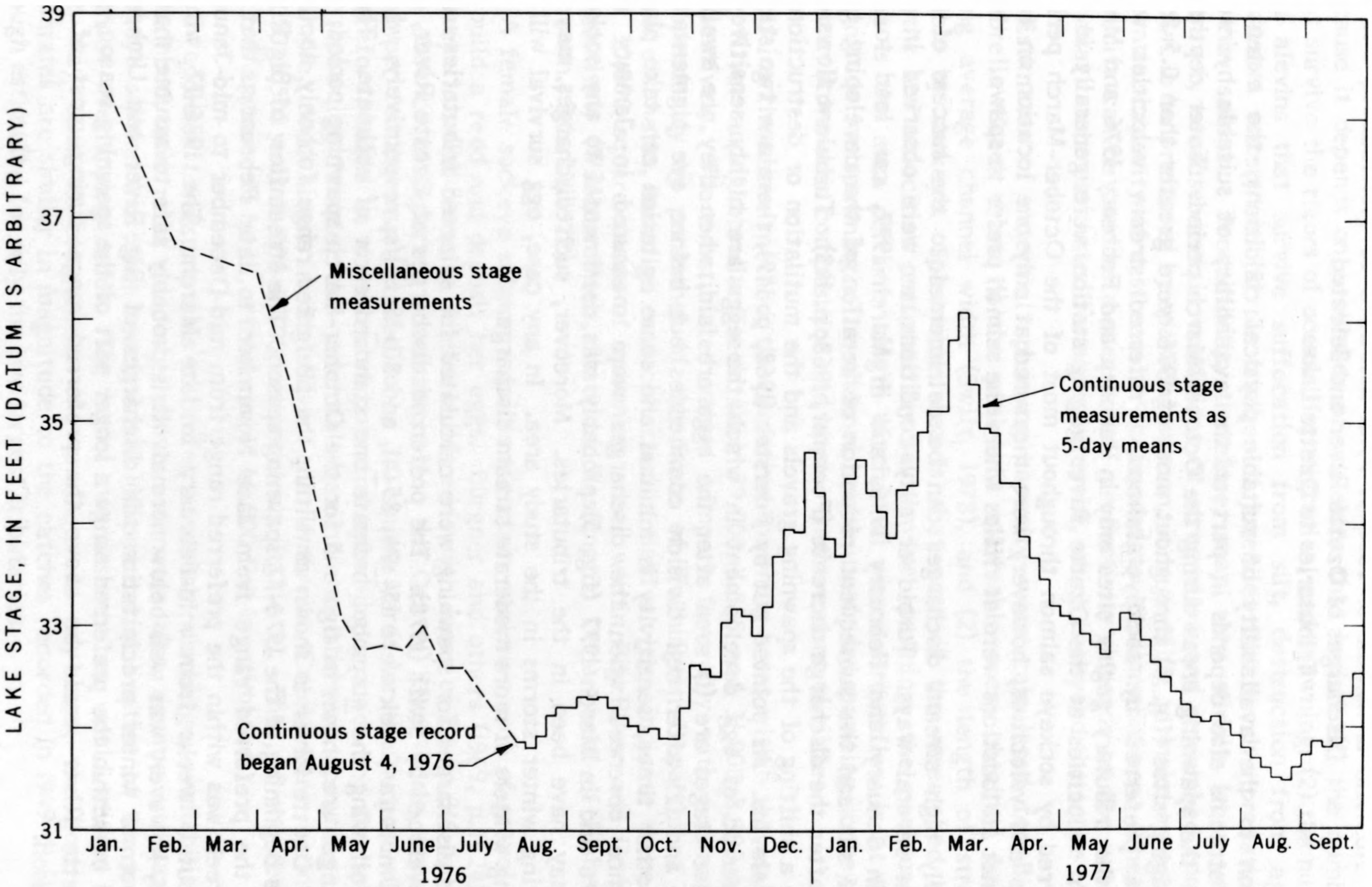


FIGURE 12.--Hydrograph of Ozette Lake stage at the lake outlet (Ozette River, station 12043150).

Discharges of Ozette River and Selected Tributaries to Ozette Lake

In addition to the availability of suitable physical conditions, the extent of spawning in streams also depends in part on the availability of suitable hydraulic conditions in the spawning areas during the October-March period. Water depths at all stream-gaging sites (fig. 3) throughout most of 1976 were greater than 0.5 foot, those depths preferred by sockeye salmon. Preferred stream velocities were observed at the tributary gaging sites only in January and February 1976 and March 1977. Stream velocities at the Ozette River gaging station were generally in the range preferred by sockeye salmon throughout most of the October-March period. These depths and velocities, however, were measured at only one location on each stream, and not all locations were at riffles where the salmon prefer to spawn.

Excessively high stream discharges can be detrimental to the success of egg incubation in several ways. Turbid or silty conditions, as were observed in the tributaries in January and February 1976, and in March 1977, can lead to the deposition of silt and the subsequent reduction of aeration of the developing eggs and alevins after the discharge decrease (Foerster, 1968, p. 143). Turbulent flows can also produce a shifting of the spawning gravels and the mutilation or destruction of the eggs or alevins. As pointed out by Foerster (1968, p. 149), there are two stages within the period of egg development in which the eggs are highly sensitive to jarring. These stages are (1) soon after the eggs are laid, when they are swelling with water, and (2) after cell division commences but before eye pigmentation begins. At other times, sensitivity is minimal and some agitation can take place. The turbulence observed when the discharges were measured in January and February 1976 and in March 1977 (fig. 5) probably was detrimental to any sockeye eggs that may have been in the tributaries. Moreover, such discharges may be common during winter storms in the study area. In any case, egg survival will be greater during winters of more moderate stream discharge.

Preferred discharges for spawning were calculated for selected tributaries using a method developed by Swift (1978). The preferred discharges of Ozette River, Big River, and Umbrella Creek were 154 ± 74, 85 ± 41, and 80 ± 38 ft^3/s, respectively, where the values following the $\pm$ symbol indicate one standard error of estimate. These discharge ranges are shown in figure 5 for the October-March spawning period; the discharge of Ozette River is shown as within the preferred range for only about 7 weeks at the beginning of the 1976-77 spawning season. The streamflow of Big River was within the preferred range from late November to late February; that of Umbrella Creek was within the preferred range from mid-December to mid-January and for about 5 weeks from mid-February to late March. The 1976-77 winter precipitation, however, was well below normal. It is probably safe to assume that in a year of normal winter precipitation the discharges of Big River and Umbrella Creek would be within the preferred range a longer part of the spawning season, and that of Ozette River would be above the preferred range during most of the spawning season.

The productivity of a stream with respect to salmon is difficult to determine because it depends on a number of variables that include (1) the number of adults that survive the rigors of ocean life, migration, and spawning; (2) the number of eggs and alevins that survive suffocation from silt, destruction from agitation, and too-warm water; and (3) the number of juveniles that survive predation to become sea-run salmon. Productivity, therefore, may vary widely from year to year. However, because certain conditions of streamflow and streambed composition are known to be preferred by spawning salmon, it is possible to make an estimate of the potential capacity of a stream to accommodate spawning salmon. Whether potential capacity can be used as a measure of productivity depends on the extent to which survival can be estimated for any given year, which is beyond the scope of this study.

Estimates of potential spawning capacity were calculated for Big River and Umbrella Creek from (1) the peak-unit spawnable area, obtained from equations using average channel width (Swift, 1978), and (2) the length of stream channel usable by sockeye. Spawnable area is that part of the streambed having water depths and velocities preferred by salmon for spawning; the peak-unit spawnable area is the area per unit length of channel where streamflow is at the preferred magnitude for spawning. The channel length usable by spawning sockeye is based in part on streambed composition and in part on the extent of riffles.

Using the above method, the preferred spawning areas within the usable length of Big River and Umbrella Creek were 39,000±11,000 and 31,000±8,300 square yards, respectively. These estimated values compare favorably with estimates compiled independently by personnel of the State of Washington Department of Fisheries. Their estimates, based on data collected in field surveys, indicate there were 39,000 and 30,000 square yards of spawning areas within Big River and Umbrella Creek, respectively (William Wood, State of Washington Department of Fisheries, written commun., Jan. 12, 1977).

A female sockeye salmon requires a certain minimum area of gravel bed in which to build a redd and deposit her eggs. Burgner and others (1969, p. 424) report that sockeye in small rivers in Alaska build redds with areas of 2.4 to 3.6 square yards. In the absence of reported observations for the Ozette River basin, an average redd area per female was assumed to be 3.0 square yards for the purpose of this report. Therefore, based on the area of potential spawning grounds and the space required per spawning female, the potential maximum numbers of spawning females (for example, redd sites) in Big River and Umbrella Creek were estimated to be 13,000±3,500 and 10,000±2,800, respectively (table 2). Thus, if the female-to-male ratio is assumed to be 1:1, a total run of 46,000 fish is estimated.

In addition to assumptions of preferred stream discharge, availability of suitable streambed, and redd size, the above estimates also assume utilization only by sockeye salmon (no other species) and 100-percent utilization of the preferred area without overlapping redds. The latter two assumptions would seldom be achieved, but may tend to compensate one another. In any case, the potential-capacity estimates are similar in magnitude to the catches recorded in 1949-51 (table 1), even though estimated for only the two largest tributaries.

TABLE 2.--Estimated salmon-spawning potential of Big River and Umbrella Creek

Potential capacity	Big River	Umbrella Creek
River-mile use, by sockeye[1] ----------	3.0-9.0	0.0-4.0
Area of spawning gravel at preferred flow (square yards)[2]-----	39,000 ± 11,000	31,000 ± 8,300
Area of spawning gravel as determined by Washington Department of Fisheries[1] (square yards) --------	39,000	30,000
Number of redd sites at preferred flow[3]------------------------------	13,000 ± 3,700	10,000 ± 2,800

[1]From William Wood, State of Washington Department of Fisheries, written commun., Jan. 12, 1977.

[2]Based on unit-spawnable-area equations by Swift (1978).

[3]Assumes 3.0 square yards per sockeye redd and 100-percent potential area utilized (without overlap) by sockeye.

Stream Temperatures

The water temperatures observed in 1976 and 1977 in Ozette River, Big River, Crooked Creek, and Umbrella Creek are presented in figure 6, as well as the temperatures reported as preferred by migrating and spawning sockeye salmon (Bell, 1973) and the optimum temperatures for incubation of the eggs. For spawning, preferred temperatures of the streams tributary to Ozette Lake were observed during mid-October - late October, which is about the time that stream discharges were increasing toward preferred values (fig. 5). Stream temperatures were within the preferred incubation range throughout most of the total incubation period.

REARING CONDITIONS

After emergence from the redd areas the young sockeye quickly migrate into the adjacent lake--the natural rearing area for sockeye salmon. Even though streamflow during the migration period is not usually a problem, streamflow measurements and estimates in 1976 were made at selected sites (fig. 3) on the Ozette Lake tributaries in August, a month when low-flow conditions can be expected. The data, presented in table 3, show that discharges exceeded 1 ft^3/s at all sites on the major tributaries, and that discharges of the smaller, unnamed tributaries ranged from 0.3 to 2.0 ft^3/s. The estimated flows were probably above normal seasonal low flows because of the above-normal precipitation that occurred in August 1976 (fig. 2).

Juvenile salmon spend 1 year--sometimes 2 years or more--in the lake before migrating to the sea. Beyond surviving predators and disease, the well-being and growth of juvenile sockeye depend primarily on (1) the abundance of food organisms on which they subsist, and (2) the numbers of young sockeye and other species of fish in the lake which compete for food. This report will focus on the abundance of food organisms available to the fish and the overall capacity of Ozette Lake to produce a crop of food for the rearing of sockeye.

Preferred Rearing Conditions

Preferred rearing conditions for young sockeye in a lake are difficult to establish, but lake characteristics such as temperature, dissolved oxygen, lake transparency, nutrient concentrations, and phytoplankton-zooplankton abundance are directly related to the growth and development of young sockeye. In most instances, however, quantitative values of the lake characteristics preferred by sockeye for rearing are unknown and only qualitative estimates can be made.

Water temperature affects the production of plankton, and the mobility, feeding, and growth of fish and other aquatic animals. According to Foerster (1968, p. 191), the favorable temperature range for the growth of young sockeye is 45° to 68°F, and the optimum temperature range is 48° to 56°F. At temperatures below 40°F and above 70°F, sockeye lose weight (Foerster, 1968, p. 191-192). For example, temperatures colder than about 45°F not only reduce the mobility of the fish, thereby reducing its ability to catch food, but also reduce the rate of metabolizing of food that is caught.

Dissolved-oxygen concentration in a lake varies with time of year and is a function of many factors, including the water temperature and atmospheric pressure. Oxygen concentration in water is continually being altered by life processes, such as photosynthesis and respiration, and by complex chemical reactions. The organisms in the lighted upper layers of water consume oxygen in metabolizing food, and produce organic waste matter which settles to the bottom of the lake. There, bacteria consume oxygen to degrade the organic materials, often reducing the oxygen concentration in that zone. A dissolved-oxygen concentration of less than 4.0 mg/L (milligrams per liter) is generally considered unfavorable to several fish species (National Academy of Sciences and National Academy of Engineering, 1973, p. 132). Although dissolved-oxygen standards for the good growth and general health of fishes are not easily defined, a minimum of 5 mg/L for warm-water fish species and 6 or 7 mg/L for cold-water species (including salmon) have been recommended and widely accepted (Bennett, 1970, p. 73).

TABLE 3.--Discharge, temperature, and selected chemical characteristics of tributaries to Ozette Lake during a low-flow period

Stream and site		River mile above Lake Ozette	Date (1976)	Discharge[1] (ft^3/s)	Temperature (°F)	Specific conductance (micromho/cm at 25°C)	Color (Pt-Co units)
Big River	B1	11.0	August 25	8-10	53.2	60	35
	B3	8.9	do	10	54.7	52	45
	B5	7.4	do	10-12	54.7	58	45
	B7	5.3	do	12-15	55.2	60	50
	B12	1.5	do	20	56.8	54	80
	B14	1.0	do	26.2m	57.2	57	85
Boe Creek	B2	9.4	do	1-2	51.8	40	60
Trout Creek	B9	6.1	do	2-3	55.0	41	110
	B10	3.6	do	2-3	59.9	38	220
	B11	2.0	do	3-4	57.9	41	170
Dunham Creek	B13	1.6	do	1-2	55.8	80	90
Crooked Creek	K1	4.6	do	2-3	53.6	42	120
	K2	.9	do	12.1m	55.4	38	80
Umbrella Creek	U1	5.2	do	3-4	55.0	48	50
	U2	5.2	do	1-2	55.0	44	130
	U3	8.2	do	1-2	57.6	38	40
	U5	.9	do	15.2m	56.8	68	120
Coal Creek	C2	.2	August 27	2-3	55.4	76	110
Siwash Creek		(2)	August 25	2	55.4	63	60
South Creek		(2)	do	4	57.2	67	110
Unnamed	2	(2)	do	1-2	53.6	68	320
tributaries	3	(2)	do	stagnant	--	44	75
to Ozette	4	(2)	do	0.6	53.6	45	45
Lake.	5	(2)	do	1	53.6	60	45
	6	(2)	do	0.4	54.5	90	40
	7	(2)	August 27	1-2	53.6	44	120
	8	(2)	do	0.5	52.7	44	85
	9	(2)	do	0.3	52.7	48	150

[1] Estimated, unless noted by "m" (for measured).

[2] At mouth of stream at Ozette Lake.

No criteria for lake transparency have been established for rearing sockeye, and clear water may have both beneficial and detrimental effects. Assuming that the young sockeye actively seek out zooplankton on which to feed, the greater the water transparency the better the feeding conditions (Foerster, 1968, p. 194). On the other hand, according to Foerster, the clearer the water the more vulnerable the young sockeye will be to their predators. In general, the transparency of the lake water will determine, in part, the depth at which young sockeye will be found during the active feeding period. Studies have shown that in heavily silted lakes plankton production is confined to the lighted, near-surface layers and that the young sockeye will, in all probability, be concentrated there also. In more transparent lakes the plankton production zone will be appreciably deeper and the concentration of sockeye likewise (Foerster, 1968, p. 194). Thus, in general, clarity is preferred because it allows deeper light penetration and hence a greater volume of water for food production.

Many elements and compounds serve as food supply (or "nutrients") for aquatic plants and algae. Nitrogen and phosphorus usually are considered the nutrients most important in determining the capacity of a lake to produce a crop of algae (Wetzel, 1975, p. 196-217). Algae are simple plants, often microscopic in size, which are consumed by zooplankton which, in turn, are eaten by fish. Although optimum concentrations of nutrients and algae are not known for lake rearing, higher nutrient and algal concentrations are known to promote a greater abundance of zooplankton, thus favoring the growth of young sockeye.

The most important food constituent in sockeye-rearing areas is zooplankton. After feeding for about a month in the nearshore zone (Foerster, 1968, p. 161), the young sockeye then move to the main body of the lake, where they remain until they are ready to begin the migration to the sea. While in the main body of the lake, the sockeye feed on the larger crustacean zooplankton, chiefly the cladocerans and copepods (Foerster, 1968, p. 214). The concentrations of zooplankton preferred for lake-rearing conditions are not known, but comparisons of the Ozette Lake zooplankton populations with populations in other successful sockeye-producing lakes can be made to gain some insight into the probable range of desirable concentrations.

Observed Rearing Conditions

Physical, chemical, and biological data were collected from four sites (fig. 9) in Ozette Lake in an effort to assess the suitability of the lake for the rearing of juvenile sockeye salmon. As shown in figure 9, lake-sampling sites 2, 3, and 4 are in the main body of the lake in about 250 feet of water, whereas site 1 in North End is in about 90 feet of water.

The data collected at these sites are presented in figures 14-17 at the end of the report. The nutrient data are summarized in table 4 and more detailed zooplankton data are presented in table 5, both in this section of the report. Additional water-quality data for the 1976 water year are presented in the water-data report by the U.S. Geological Survey (1977).

Lake Temperature

From mid-February to early April 1976, the temperature of the lake was 41° to 43°F and nearly uniform from top to bottom (figs. 14-17). In late April the lake showed a slight temperature stratification as warmer air temperatures and increased day length brought about a rise in the temperature of the surface water of the lake to about 48°F, the lower end of the optimum range. A zone of steep temperature gradient began to develop in late May, separating the warmer, upper water from the colder water below; by summer a zone of steep temperature gradient existed between about 30 and 75 feet below the water surface. By early November the vertical mixing of the lake had begun in response to cooler air temperatures and shorter days, and the temperature of the upper water had decreased to within a few degrees of that of the bottom water. In winter the water column was once again uniform in temperature from top to bottom.

The 1976 summer (June-September) water temperatures of Ozette Lake, which represent the period of greatest algal and zooplankton production, are presented below, as an average of the four stations.

Depth of water (ft)	Temperature (°F)	
(Surface)	62.8	Average of four sites
10	62.8	
20	62.6	
30	61.7	
40	58.3	
50	53.2	
60	50.2	
70	48.4	
80	47.5	
90	46.8	
100	46.5	Average of three sites
120	46.2	
200	44.6	

The table shows that in the summer the water column above 200 feet was within a favorable range (45°-68°F) for the growth of young sockeye, and the water from about 44 to 70 feet below the water surface was within the optimum range (48°-56°F) for the growth of young sockeye. The warmest water at the surface (62.8°F) was well below the critical level of 70°F.

Dissolved Oxygen

Dissolved-oxygen concentrations observed in Ozette Lake at the four sites in 1976 and two sites in 1977 are shown in figures 14-17. Concentrations of dissolved oxygen remained at 11-12 mg/L (near saturation) at all depths in the lake from late fall to early spring. During summer the dissolved-oxygen concentrations remained above 8.0 mg/L at all depths in the lake. Concentrations of dissolved oxygen above 8.0 mg/L at all depths throughout the year indicate that an adequate supply of oxygen for sockeye production is present in the lake.

Transparency of Lake Water

Water transparency, or clarity, is measured with a Secchi-disc and is the depth beneath the water surface at which a black and white, 8-inch diameter disc disappears from view. In 1976, the Secchi-disc visibility in Ozette Lake ranged from 7.0 to 12.5 feet (figs. 14-17), with greater visibility generally occurring in summer and autumn. The average Secchi-disc reading of 9.0 feet for the lake is slightly greater than the me- dium value of 8.5 feet obtained during an investigation of 617 lakes throughout the State (Bortleson and Dion, 1978).

As an incidental observation, the water in Ozette Lake is a slight tea color; this usually results from an accumulation of natural organic matter carried by streams draining to the lake. Several of these streams have color values several times greater than that of the lake water (table 3 and figs. 14-17). Such coloration, however, is generally harmless to fish.

Nutrients and Algae

Data on the concentrations of inorganic nitrogen, organic nitrogen, total phosphorus, and orthophosphate at the four sites in Ozette Lake in 1976 are given in figures 14-17, and average values are shown in table 4. The average concentrations of these nutrients in the upper, middle, and lower layers of the lake are given for the winter-spring and summer-fall periods. The nutrient concentrations during winter and spring are probably maximum values because the water is completely mixed (or nearly so) and nutrient consumption by algae is low. In general, the nutrient concentrations during all seasons and for all depths within the lake were low in comparison with many of the other lakes in Washington (Bortleson and Dion, 1978). Total-phosphorus concentrations were 0.007 to 0.008 mg/L throughout the year at all depths. Inorganic nitrogen (nitrite + nitrate + ammonia) concentrations in the upper water decreased from 0.15 mg/L during winter-spring to 0.06 mg/L by summer-fall. In summer, nutrient consumption by plants is often pronounced and the nutrient concentration in the water is consequently reduced. Based on the relatively low phosphorus and nitrogen concentrations in the water, the algal production in Ozette Lake is also expected to be relatively low.

The amount of algae in the water is usually estimated as a function of the amount of chlorophyll a in the water sample. Chlorophyll a concentrations in Ozette Lake are given in figures 14-17 and monthly averages are shown in figure 13 (top graph). Generally, concentrations were lowest in winter and highest in summer. In July 1976 the chlorophyll a concentration (average of data from four sites) was 5.0 µg/L (micrograms per liter). The average concentration of chlorophyll a during the summer (June-September 1976) was 3.5 µg/L. For comparison, these concentrations are somewhat higher than those of many sockeye-producing lakes in southeastern Alaska studied by Burgner and others (1969, p. 417). The mean and median chlorophyll a concentrations for 23 of those lakes were 1.7 and 0.8 µg/L, respectively.

Algal bioassay tests provide another estimate of the capacity of lake water to sustain algal production. Algal growth potential is the amount of algal material that can be produced in a natural water sample under standardized laboratory conditions. The results of tests of Ozette Lake water (average of data from all four sites) are shown below.

Month (1976)	Algal growth potential (milligrams of dry weight per liter)
February	0.6
March	.3
April	.4
June	.3
August	.3
November	.3

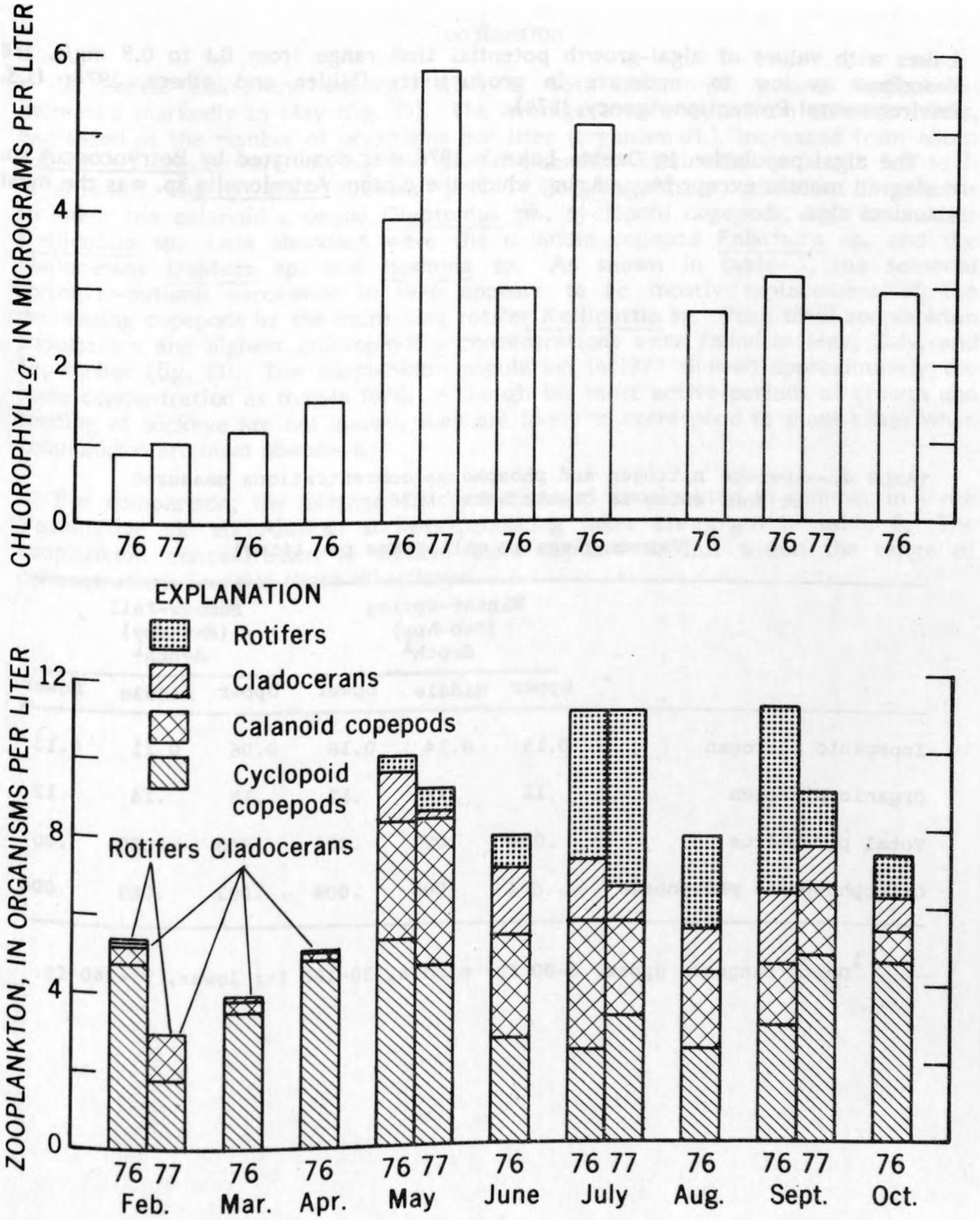


FIGURE 13.--Chlorophyll a and total zooplankton concentrations in Ozette Lake. Average of four sampling sites in 1976 and two sampling sites in 1977.

Lakes with values of algal-growth potential that range from 0.1 to 0.9 mg/L are described as low to moderate in productivity (Miller and others, 1974; U.S. Environmental Protection Agency, 1974).

The algal population in Ozette Lake in 1976 was dominated by Botryococcus sp. during all months except May, during which the diatom Asterionella sp. was the most abundant alga.

TABLE 4.--Average nitrogen and phosphorus concentrations measured at four sites in Ozette Lake, 1976

[Values given in milligrams per liter]

	Winter-Spring (Feb-Apr) depth[1]			Summer-Fall (May-Nov) depth[1]		
	Upper	Middle	Lower	Upper	Middle	Lower
Inorganic nitrogen	0.15	0.14	0.16	0.06	0.11	0.13
Organic nitrogen	.11	.11	.12	.13	.14	.12
Total phosphorus	.008	.007	.008	.008	.008	.007
Orthophosphate phosphorus	.004	.003	.004	.003	.003	.004

[1]Depth ranges: upper, 0-80 ft; middle, 30-160 ft; lower, 75-260 ft.

Zooplankton

In Ozette Lake, the concentrations of both chlorophyll a and zooplankton increased markedly in May (fig. 13). The average total zooplankton concentrations, expressed as the number of organisms per liter (organisms/L), increased from about 4.0 to 5.5 organisms/L during the period February-April 1976 to about 7.0 to 11 organisms/L during the following period May-November. Abundant organisms included the calanoid copepod Diaptomus sp., cyclopoid copepods, and the rotifer Kellicottia sp. Less abundant were the calanoid copepod Epischura sp. and the cladocerans Daphnia sp. and Bosmina sp. As shown in table 5, the seasonal spring-to-autumn succession in 1976 appears to be mostly replacement of the decreasing copepods by the increasing rotifer Kellicottia sp. Peak total zooplankton populations and highest chlorophyll a concentrations were found in May, July, and September (fig. 13). The zooplankton population in 1977 showed approximately the same concentration as that in 1976. Although the most active periods of growth and feeding of sockeye are not known, they are likely to correspond to those times when zooplankton are most abundant.

For comparison, the average concentrations of zooplankton in summer in three Washington and six Alaskan sockeye-producing lakes are given in table 6. The zooplankton concentration in Ozette Lake appears to fall within the range of concentrations found in those other lakes.

TABLE 5.--Monthly distribution of the principal zooplankton in Ozette Lake

	Percentage of total zooplankton												
	1976[1]									1977[2]			
Zooplankton	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov	Feb	May	July	Sept
Rotifers													
<u>Kellicottia</u> <u>sp</u>.	0.3	0.2	0.4	3.6	11	35	31	43	19	1.0	4.5	41	15
Cladocerans													
<u>Daphnia</u> <u>sp</u>.	.8	2.2	1.8	6.0	5.3	4.9	6.3	8.2	6.8	1.0	1.0	5.0	8.2
<u>Bosmina</u> <u>sp</u>.	2.3	.6	1.2	5.5	16	9.0	7.6	7.5	3.8	0	.2	3.0	2.5
Calanoid copepods													
<u>Diaptomus</u> <u>sp</u>.	5.8	5.5	1.5	23	24	21	21	13	8.6	34	19	21	16
<u>Epischura</u> <u>sp</u>.	.8	.5	1.1	8.9	8.7	9.1	4.1	2.3	.8	4.0	9.3	1.0	4.3
Cyclopoid copepods (undifferentiated)	90	91	94	53	35	21	30	26	61	60	66	29	54

[1]Average of four sites.

[2]Average of two sites.

TABLE 6.--Average concentrations of zooplankton in Ozette Lake and other sockeye-producing lakes in Washington, Alaska, and Canada

Lakes	Zooplankton concentration (organisms per liter)	Reference
Cultus (Canada)	16.4	Foerster (1968, p. 225),
Karluck (Alaska)	15.0	Do.
Danlee (Alaska)	13.4	Do.
Osoyoos (Wash.)	10.2	Allen and Meekin (1972, p. 24),
Ozette (Wash.)	9.9	--
Lakelse (Canada)	5.7	Foerster (1968, p. 325).
Blizhnee (Alaska)	5.5	Do.
Wenatchee (Wash.)	.88	Allen and Meekin (1972, p. 24),
Port John (Alaska)	.67	Foerster (1968, p. 225)

SUMMARY AND CONCLUSIONS

This report describes preferred and observed conditions for the migration, spawning, and rearing of sockeye salmon in the Ozette River system. The observed conditions are generally supportive of potentially good sockeye production in Ozette Lake and its tributaries, even though annual sockeye catches in the river system have declined greatly over the past 25 years.

The Ozette River discharge in 1976 was sufficient to allow the migration of young salmon to the sea in spring and the upstream migration of adults to Ozette Lake in early summer. Summer discharges at all measuring sites on principal Ozette Lake tributaries were greater than 1 ft^3/s, which is probably adequate for the migration of young, newly hatched salmon to Ozette Lake for rearing.

In general, the lower and middle reaches of the main tributaries to Ozette Lake (about 10 miles for the combined reaches of Big River and Umbrella Creek) appear to contain gravels more suitable for spawning sockeye than do the shore areas of Ozette Lake. Only small parts of the shore areas have gravels or small cobbles that are 0.5-5 inches in size with a limited amount of coarse sand--the most suitable substrate for sockeye spawning. Most of the nearshore lakebed is composed of a mixture of bottom materials ranging from silt to boulders, and many of these areas are submerged in winter and exposed as beach during the summer, allowing the growth of shrubs and other vegetation. During 1976 the lake stage fluctuated 6.5 feet, and such a large variation could expose shallow spawning areas as the lake stage receded in the spring. However, during 1977 the lake stage fluctuated only 4.6 feet.

During the spawning seasons within the period of this study (January-March 1976 and October 1976-March 1977), the discharges of Big River and Umbrella Creek were generally above that preferred for spawning during the period January-March 1976, but somewhat below those preferred during the first two months of the period October 1976-March 1977. However, the 1976-77 winter precipitation was well below normal; a period of normal precipitation would probably have given discharges within the preferred range a longer part of the spawning season. In years when streamflows are excessive, however, siltation and turbulence could be detrimental to eggs and alevins in the spawning areas.

The areas of gravels suitable for sockeye spawning in the streambeds of Big River and Umbrella Creek were estimated to be about 39,000 and 31,000 square yards, respectively. If those areas were utilized completely, they would accommodate approximately 13,000 and 10,000 spawning females, respectively. If the female-to-male ratio is assumed to be 1:1, a total run of 46,000 fish is estimated.

Preferred spawning temperatures (51°-54°F) were observed from mid-to-late October in the major streams tributary to Ozette Lake. Stream temperatures were within the preferred incubation range (40°-56°F) most of the total incubation period (October-June).

Ozette Lake is a large, deep lake and is a natural rearing area for young sockeye. The maximum depth is approximately 320 feet. In summer, favorable temperatures (45^{o}-$68^{o}F$) for the growth of young sockeye occurred between about 200 feet of depth and the water surface. Concentrations of dissolved oxygen in excess of 8.0 mg/L at all depths throughout the year indicate an adequate supply of oxygen for sockeye production.

Ozette Lake appears to be low to moderate in algal production, based on chlorophyll a concentrations. In comparison with eight other sockeye-producing lakes in Washington and Alaska, the quantity of zooplankton in Ozette Lake appears to be adequate. The zooplankton concentration begins to increase in May and remains high during the summer months, when young sockeye feed most actively. The concentrations of total zooplankton ranged from about 7.0 to 11.0 organisms/L during the period May-November 1976.

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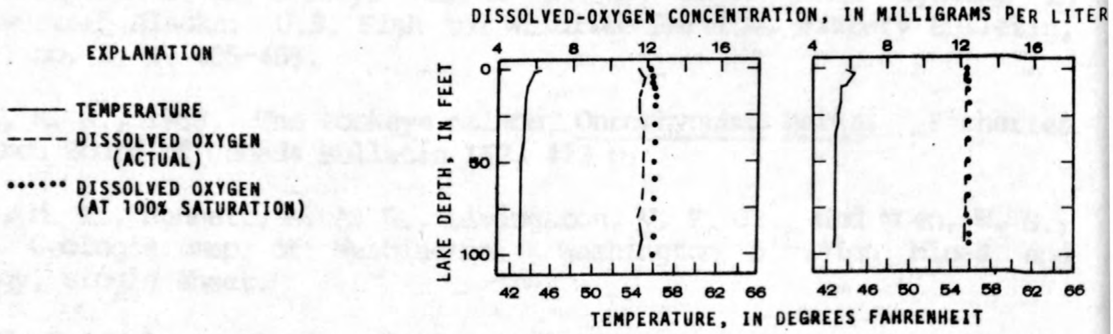
FIGURE 14.--Water-quality data from site 1, Ozette Lake.

[Milligrams per liter unless otherwise indicated]

Date of collection	February 19, 1976			April 1, 1976		
Approximate composite water depth (ft)	30	60	90	30	60	90
Total nitrate nitrogen (as N)	0.10	0.09	0.10	0.08	0.07	0.16
Total nitrite nitrogen (as N)	.002	.004	.004	.002	.006	.004
Total ammonia nitrogen (as N)	.06	.05	.05	.04	.06	.06
Total organic nitrogen (as N)	.14	.13	.12	.10	.08	.12
Total phosphorus (as P)	.010	.010	.008	.006	.006	.007
Total orthophosphate (as P)	.004	.004	.004	.004	.004	.003
Specific conductance (µmho/cm at 25°C)	39	39	39	37	--	39
pH (pH units)	7.1	--	7.1	7.4	--	7.2
Water temperature (°F)	43.3	43.2	43.2	43.3	43.2	43.2
Color (Pt-Co scale)	25	--	30	20	--	20
Dissolved oxygen	11.7	11.8	11.7	12.3	12.3	12.2
Secchi disc (ft)	----	9.0	----	----	7.5	----
Chlorophyll a in photic zone (µg/L)	----	.9	----	----	1.2	----
Algal growth potential (composite of all depths)	----	.6	----	----	.3	----
Total zooplankton (organisms/L)	----	4.9	----	----	3.2	----



April 27, 1976			May 27, 1976			June 22, 1976		
30	60	90	40	70	90	15	57	88
0.06	0.06	0.07	0.05	0.08	0.09	0.03	0.06	0.09
.001	.001	.002	.002	.004	.002	.00	.00	.00
.06	.06	.06	.04	.03	.04	.03	.03	.03
.13	.09	.08	.12	.19	.14	.18	.18	.14
.007	.007	.007	.005	.006	.006	.010	.010	.010
.003	.002	.004	.003	.003	.003	.000	.000	.010
39	--	38	36	--	39	36	--	36
7.0	--	7.1	7.1	--	6.7	6.6	6.6	6.6
46.4	45.5	44.4	54.7	46.0	44.8	59.0	48.2	46.4
25	--	25	30	--	30	30	--	30
11.3	11.2	11.1	9.8	9.8	9.9	10.0	10.1	10.2
----	10	----	----	8.5	----	----	9.0	----
----	1.6	----	----	4.1	----	----	2.7	----
----	.4	----		--		----	.3	----
----	2.6	----	----	10	----	----	4.2	----

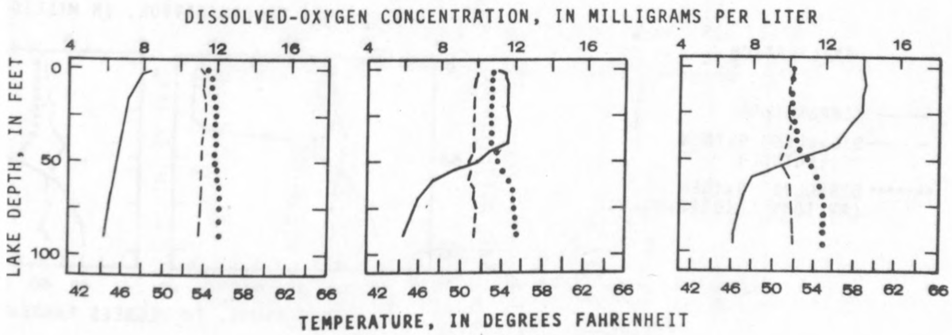
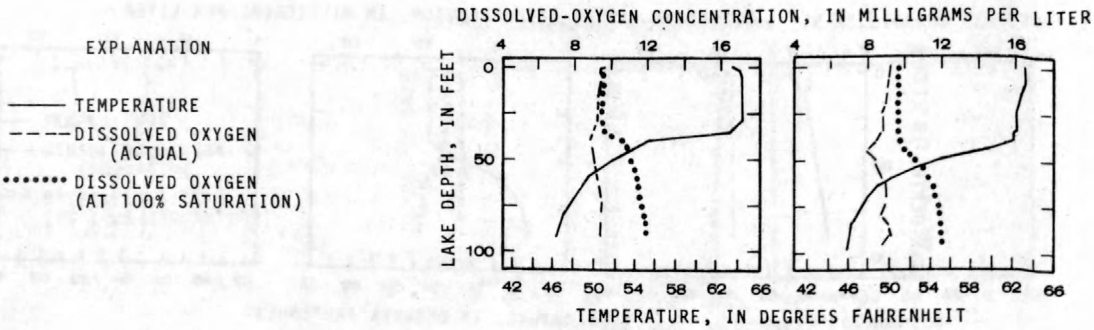


FIGURE 14.--Water-quality data from site 1, Ozette Lake--Continued

[Milligrams per liter unless otherwise indicated]

Date of collection	July 21, 1976			August 26, 1976		
Approximate composite water depth (ft)	25	50	90	20	60	85
Total nitrate nitrogen (as N)	0.00	0.04	0.09	0.00	0.06	0.10
Total nitrite nitrogen (as N)	.002	.002	.002	.004	.003	.004
Total ammonia nitrogen (as N)	.05	.05	.04	.03	.04	.04
Total organic nitrogen (as N)	.11	.11	.10	.14	.15	.16
Total phosphorus (as P)	.010	.007	.004	.022	.007	.008
Total orthophosphate (as P)	.001	.005	.004	.002	.003	.003
Specific conductance (μmho/cm at 25°C)	36	--	38	34	--	--
pH (pH units)	7.4	--	6.7	5.9	--	--
Water temperature (°F)	64.6	51.8	46.6	63.0	50.5	46.4
Color (Pt-Co scale)	35	--	35	35	--	--
Dissolved oxygen	9.3	9.1	9.4	9.1	8.8	9.1
Secchi disc (ft)	----	7.0	----	----	9.5	----
Chlorophyll a in photic zone (μg/L)	----	5.0	----	----	2.6	----
Algal growth potential (composite of all depths)		--			--	
Total zooplankton (organisms/L)	----	13	----	----	8.1	----



September 28, 1976			November 9, 1976		
24	60	90	17	57	82
0.00	0.05	0.05	0.02	0.02	0.08
.001	.003	.003	.004	.004	.003
.06	.06	.05	.04	.04	.03
.09	.07	.09	.08	.07	.15
.006	.007	.008	.005	.005	.007
.003	.004	.004	.002	.002	.003
37	--	39	40	34	30
--	--	--	--	--	--
63.5	50.2	46.2	53.6	53.6	48.4
--	--	--	--	--	--
9.3	8.3	8.6	9.4	9.3	8.1
----	9.4	----	----	8.0	----
----	3.6	----	----	2.2	----
	--			--	
----	11	----	----	8.2	----

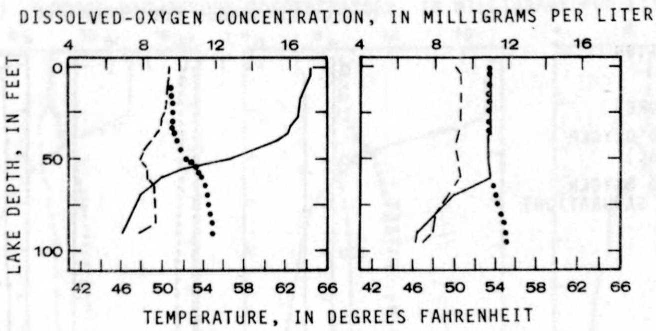
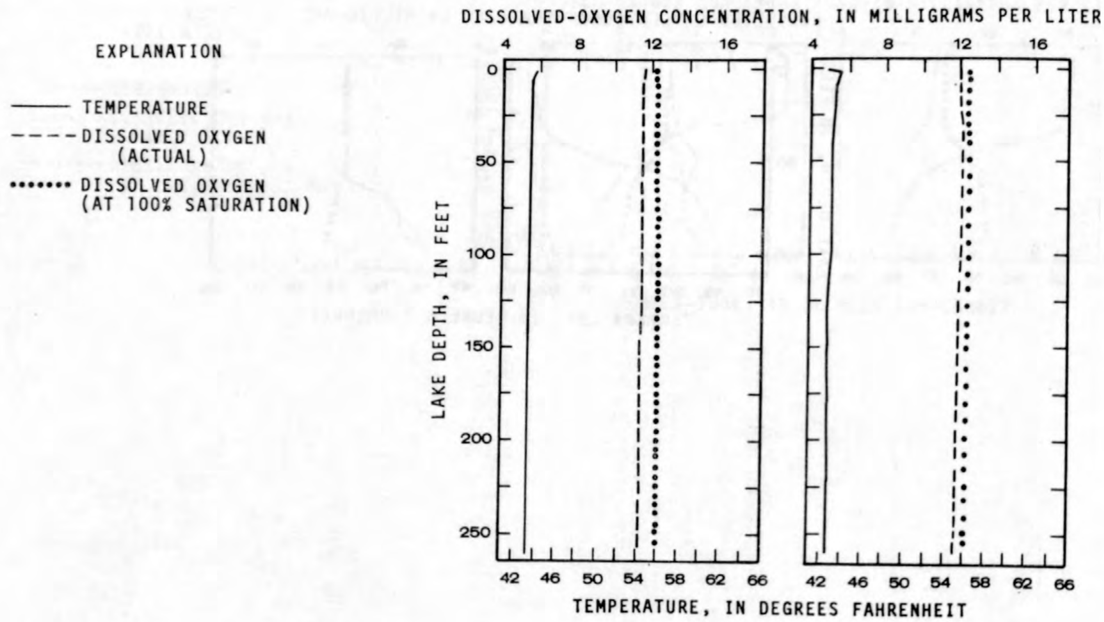


FIGURE 15.--Water-quality data from site 2, Ozette Lake.

[Milligrams per liter unless otherwise indicated]

Date of collection	February 20, 1976			April 1, 1976		
Approximate composite water depth (ft)	80	160	260	80	160	260
Total nitrate nitrogen (as N)	0.10	0.10	0.11	0.08	0.09	0.09
Total nitrite nitrogen (as N)	.002	.002	.004	.008	.003	.003
Total ammonia nitrogen (as N)	.04	.05	.05	.05	.04	.05
Total organic nitrogen (as N)	.11	.15	.12	.09	.10	.15
Total phosphorus (as P)	.010	.008	.010	.006	.007	.007
Total orthophosphate (as P)	.005	.003	.003	.003	.003	.003
Specific conductance (μmho/cm at 25°C)	40	40	40	37	--	38
pH (pH units)	6.4	--	6.6	6.8	--	6.8
Water temperature (°F)	43.7	43.5	43.5	43.0	42.8	42.8
Color (Pt-Co scale)	30	--	30	20	--	20
Dissolved oxygen	11.6	11.5	11.5	12.1	12.0	11.9
Secchi disc (ft)	---- 7.5 ----			---- 7.5 ----		
Chlorophyll a in photic zone (μg/L)	---- 1.2 ----			---- .8 ----		
Algal growth potential (composite of all depths)	---- .6 ----			---- .3 ----		
Total zooplankton (organisms/L)	---- 4.9 ----			---- 3.3 ----		



June 22, 1976			July 21, 1976			August 26, 1976		
15	57	170	25	80	240	20	60	190
0.03	0.07	0.10	0.00	0.05	0.08	0.01	0.07	0.08
.000	.000	.000	.002	.002	.002	.003	.004	.006
.03	.03	.03	.06	.05	.04	.04	.04	.03
.19	.14	.16	.10	.18	.13	.13	.11	.07
.010	.010	.010	.007	.006	.006	.008	.009	.007
.000	.000	.000	.002	.002	.003	.003	.004	.004
36	--	35	37	--	39	34	--	--
6.7	--	6.6	7.4	--	6.8	5.9	--	--
59.5	50.0	45.0	64.4	47.7	44.2	62.6	49.6	44.6
30	--	30	35	--	35	35	--	--
10.0	9.6	10.4	9.1	9.5	9.7	9.0	9.0	9.7
----	8.0	----	----	7.0	----	----	11	----
----	2.9	----	----	4.9	----	----	2.6	----
----	.3	----		--			--	
----	9.5	----	----	13	----	----	7.0	----

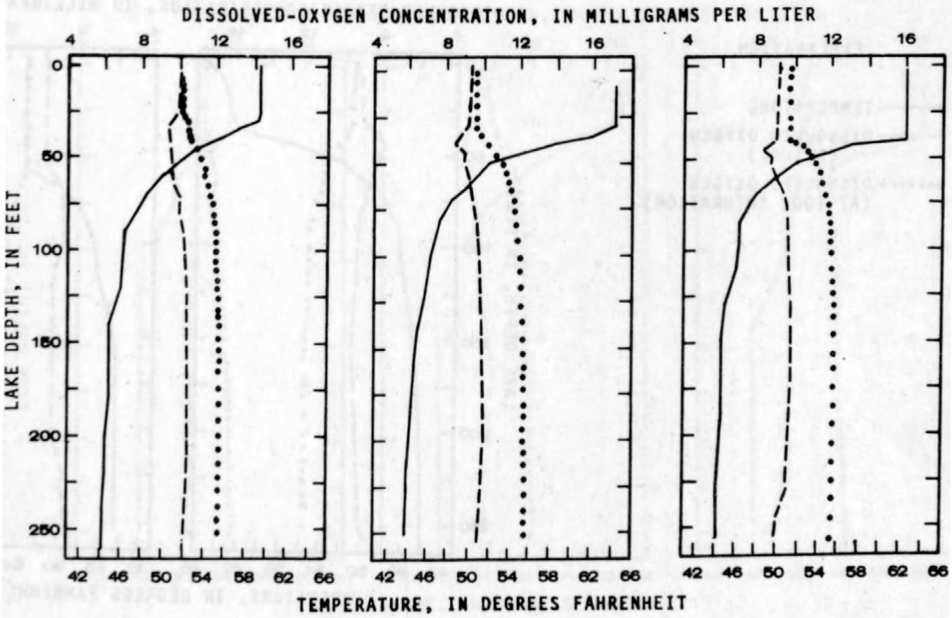
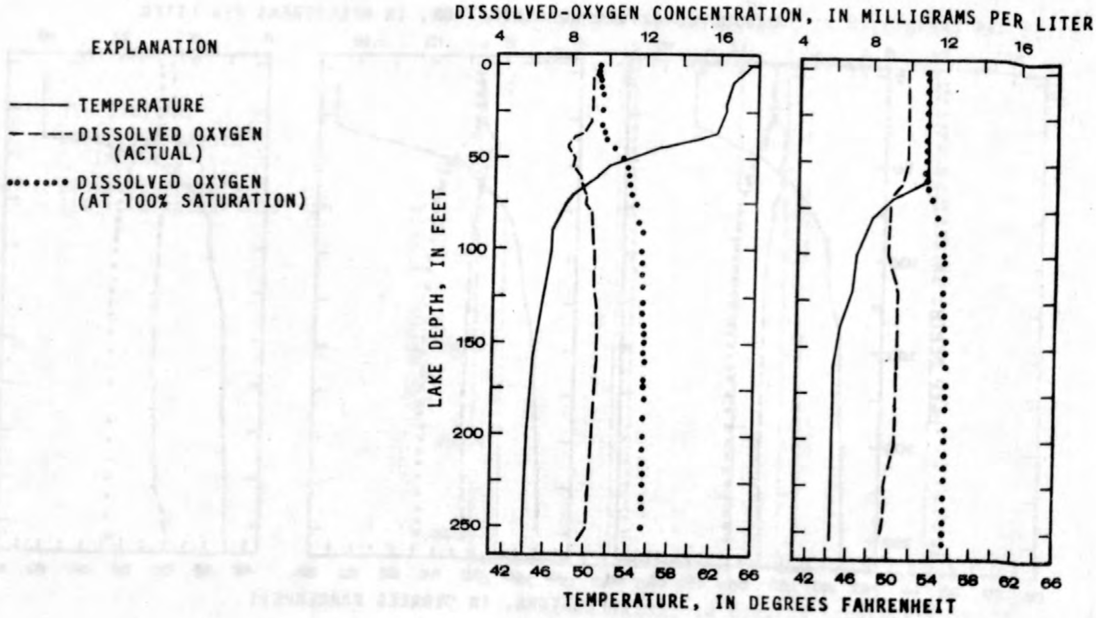


FIGURE 15.--Water-quality data from site 2, Ozette Lake--Continued

[Milligrams per liter unless otherwise indicated]

Date of collection	September 28, 1976			November 9, 1976		
Approximate composite water depth (ft)	28	100	250	17	80	200
Total nitrate nitrogen (as N)	0.00	0.04	0.05	0.02	0.06	0.08
Total nitrite nitrogen (as N)	.001	.003	.003	.003	.003	.003
Total ammonia nitrogen (as N)	.08	.03	.06	.04	.03	.04
Total organic nitrogen (as N)	.04	.09	.05	.12	.11	.08
Total phosphorus (as P)	.005	.005	.007	.005	.005	.007
Total orthophosphate (as P)	.005	.004	.005	.002	.003	.004
Specific conductance (µmho/cm at 25°C)	38	--	40	30	35	35
pH (pH units)	--	--	--	--	--	--
Water temperature (°F)	63.1	46.6	42.8	53.6	48.2	44.6
Color (Pt-Co scale)	--	--	--	--	--	--
Dissolved oxygen	9.2	9.4	9.2	9.8	8.9	9.4
Secchi disc (ft)	----	9.5	----	----	12.5	----
Chlorophyll *a* in photic zone (µg/L)	----	3.2	----	----	2.5	----
Algal growth potential (composite of all depths)		--		----	.3	----
Total zooplankton (organisms/L)	----	14	----	----	8.1	----



May 16, 1977			July 12, 1977			September 20, 1977		
25	70	220	20	70	225	20	75	220
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
54.7	50.0	46.0	64.6	51.3	46.2	61.9	49.8	46.0
--	--	--	--	--	--	--	--	--
10.0	9.8	10.0	9.1	8.8	9.4	8.9	8.6	8.9
----	10	----	----	9.0	----	----	10	----
----	5.5	----		--		----	2.8	----
	--			--			--	
----	9.1	----	----	11	----	----	8.6	----

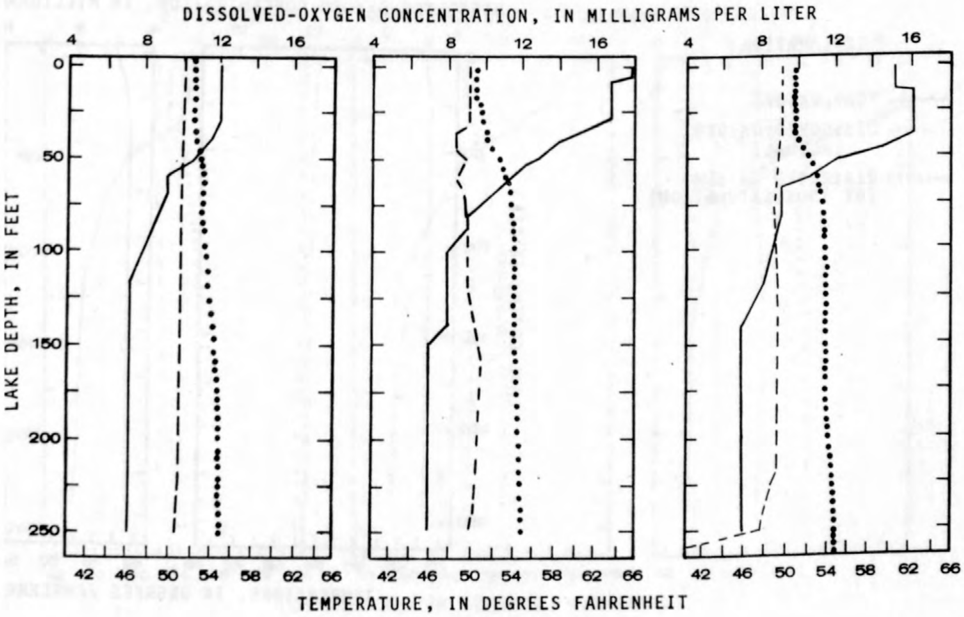
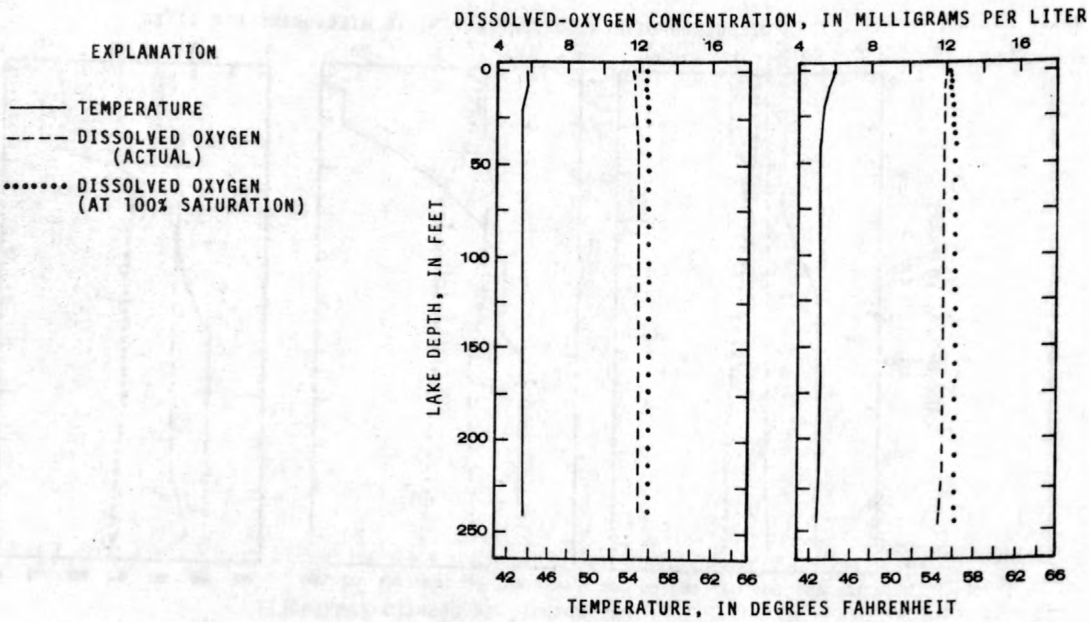


FIGURE 16.--Water-quality data from site 3, Ozette Lake.

[Milligrams per liter unless otherwise indicated]

Date of collection	February 19, 1976			March 31, 1976		
Approximate composite water depth (ft)	60	140	220	60	140	220
Total nitrate nitrogen (as N)	0.10	0.10	0.11	0.09	0.08	--
Total nitrite nitrogen (as N)	.004	.002	.002	.003	.005	--
Total ammonia nitrogen (as N)	.04	.05	.06	.06	.06	--
Total organic nitrogen (as N)	.16	.12	.14	.06	.11	--
Total phosphorus (as P)	.007	.007	.007	.006	.007	--
Total orthophosphate (as P)	.003	.003	.004	.004	.003	--
Specific conductance (µmho/cm at 25°C)	39	39	39	37	--	--
pH (pH units)	6.8	--	6.8	6.4	--	--
Water temperature (°F)	43.7	43.7	43.7	43.0	43.0	43.0
Color (Pt-Co scale)	30	--	30	20	--	--
Dissolved oxygen	11.8	11.8	11.8	11.8	11.8	11.8
Secchi disc (ft)		9.7			7.5	
Chlorophyll a in photic zone (µg/L)		.8			1.0	
Algal growth potential (composite of all depths)		.7			.4	
Total zooplankton (organisms/L)		4.2			4.0	



May 25, 1976			June 22, 1976			July 20, 1976		
30	100	220	15	57	180	16	70	240
0.05	0.19	0.09	0.03	0.07	0.10	0.00	0.05	0.07
.002	.002	.004	.000	.000	.000	.002	.002	.002
.04	.06	.04	.04	.04	.04	.05	.07	.04
.14	.08	.13	.21	.30	.17	.14	.13	.19
.006	.006	.008	.010	.010	.010	.011	.008	.007
.002	.002	.004	.000	.000	.000	.002	.002	.003
37	--	38	36	--	36	36	--	39
6.9	--	6.6	6.7	--	6.6	7.2	--	--
54.1	45.5	43.9	60.4	50.5	45.1	65.3	49.1	44.2
25	--	25	35	--	30	25	--	35
9.9	10.2	10.1	10.1	9.9	10.4	9.2	9.4	9.6
----	8.0	----	----	10	----	----	7.5	----
----	3.5	----	----	2.7	----	----	5.4	----
	--		----	.3	----		--	
----	10	----	----	8.7	----	----	11	----

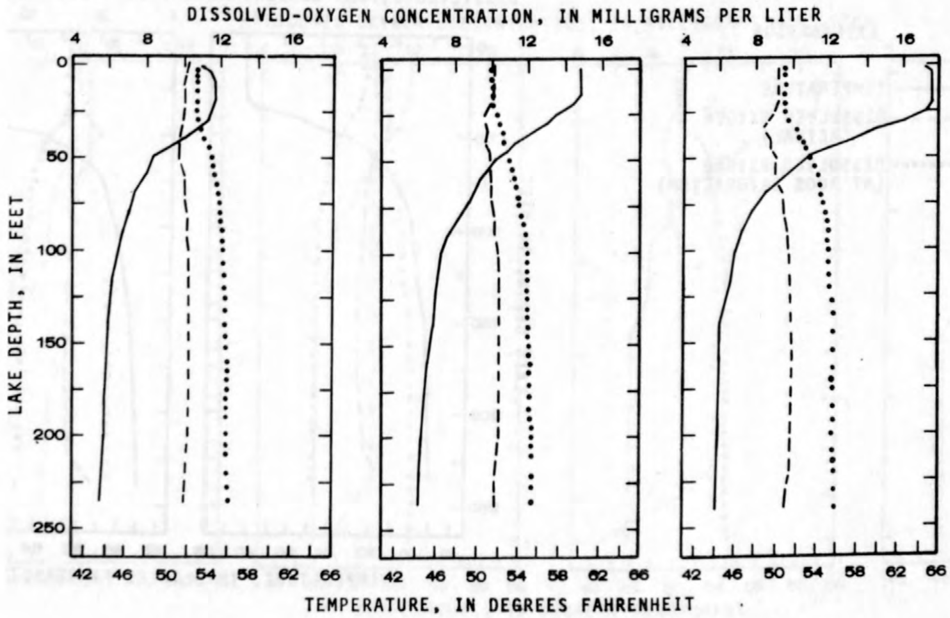
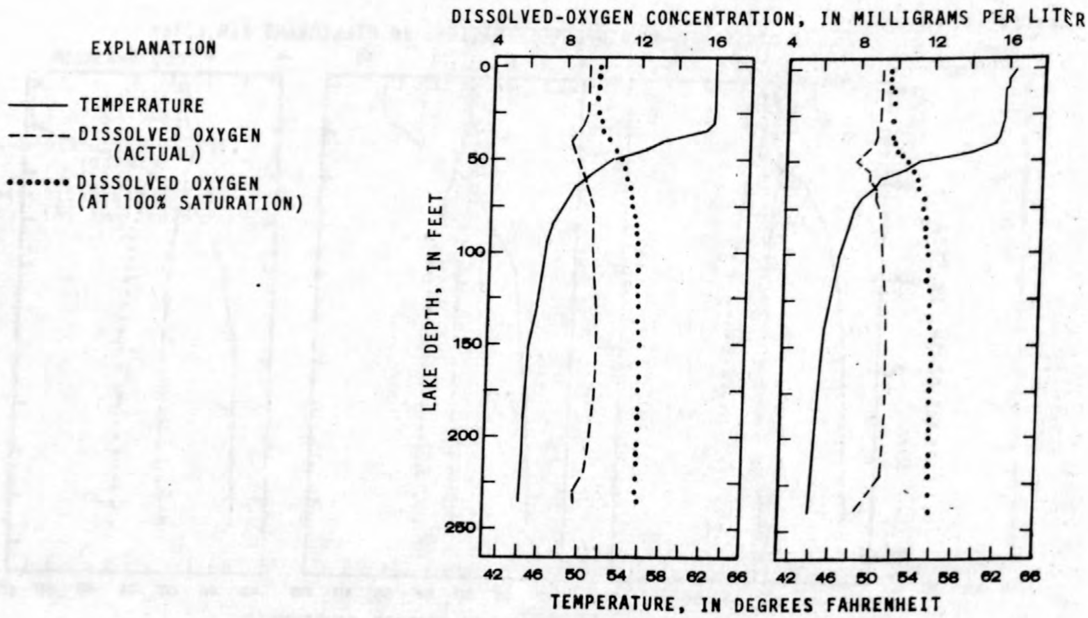


FIGURE 16.--Water-quality data from site 3, Ozette Lake--Continued

[Milligrams per liter unless otherwise indicated]

Date of collection	August 26, 1976			September 28, 1976		
Approximate composite water depth (ft)	20	60	185	36	100	240
Total nitrate nitrogen (as N)	0.00	0.07	0.10	0.00	0.04	0.05
Total nitrite nitrogen (as N)	.006	.006	.004	.001	.003	.003
Total ammonia nitrogen (as N)	.04	.04	.04	.07	.06	.07
Total organic nitrogen (as N)	.13	.16	.14	.09	.06	.09
Total phosphorus (as P)	.007	.023	.004	.005	.011	.010
Total orthophosphate (as P)	.003	.004	.004	.002	.005	.007
Specific conductance (μmho/cm at 25°C)	36	--	--	39	--	41
pH (pH units)	5.9	--	--	--	--	--
Water temperature (°F)	62.6	50.0	44.6	62.1	46.6	44.2
Color (Pt-Co scale)	35	--	--	--	--	--
Dissolved oxygen	9.1	9.0	9.7	9.0	9.4	8.2
Secchi disc (ft)	---- 10.5 ----			---- 9.5 ----		
Chlorophyll a in photic zone (μg/L)	---- 2.3 ----			---- 2.2 ----		
Algal growth potential (composite of all depths)	---- .3 ----			--		
Total zooplankton (organisms/L)	---- 7.1 ----			---- 8.1 ----		



November 10, 1976			May 16, 1977			July 12, 1977			September 20, 1977		
17	80	190	20	60	220	20	70	225	20	70	220
0.02	0.07	0.08	--	--	--	--	--	--	--	--	--
.002	.004	.006	--	--	--	--	--	--	--	--	--
.04	.03	.06	--	--	--	--	--	--	--	--	--
.11	.10	.07	--	--	--	--	--	--	--	--	--
.005	.005	.007	--	--	--	--	--	--	--	--	--
.003	.003	.004	--	--	--	--	--	--	--	--	--
38	36	36	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
53.6	48.2	44.6	54.3	49.6	45.7	64.2	50.0	45.7	61.7	50.5	46.0
25	25	35	--	--	--	--	--	--	--	--	--
9.8	8.8	9.0	10.2	9.8	9.8	9.1	9.1	9.2	9.1	8.8	9.1
----	11	----	----	10	----	----	9.0	----	----	10	----
----	3.5	----	----	5.9	----		--		----	2.5	----
----	.3	----		--						--	
----	7.7	----	----	9.4	----	----	11	----	----	9.3	----

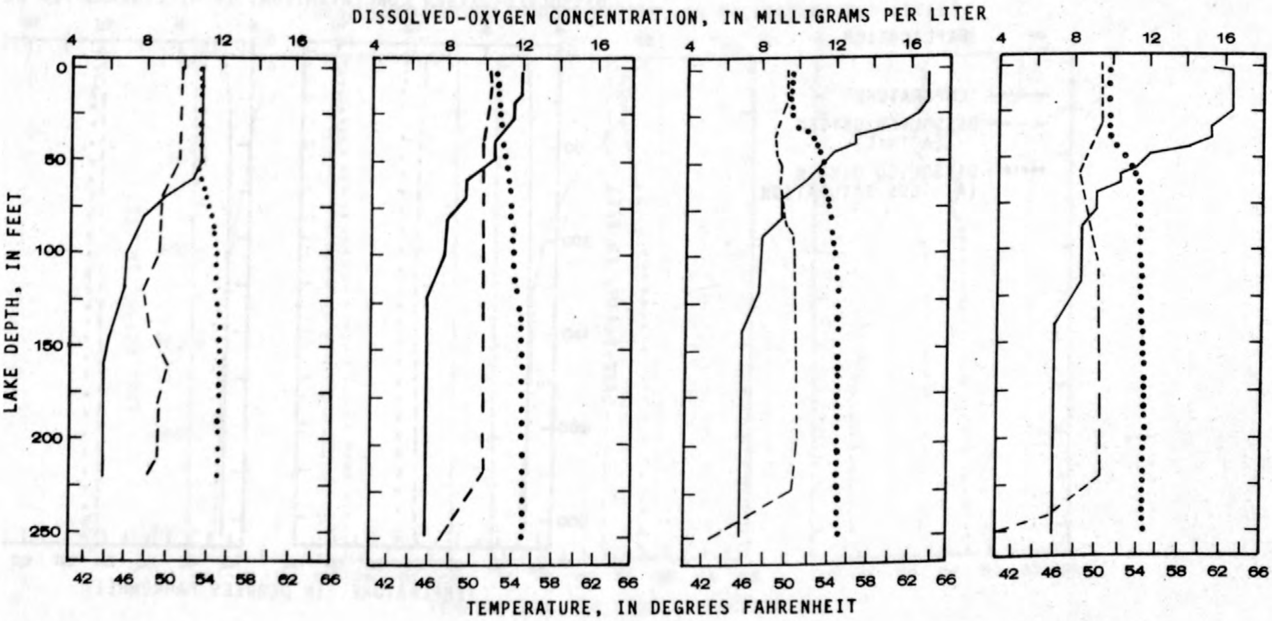
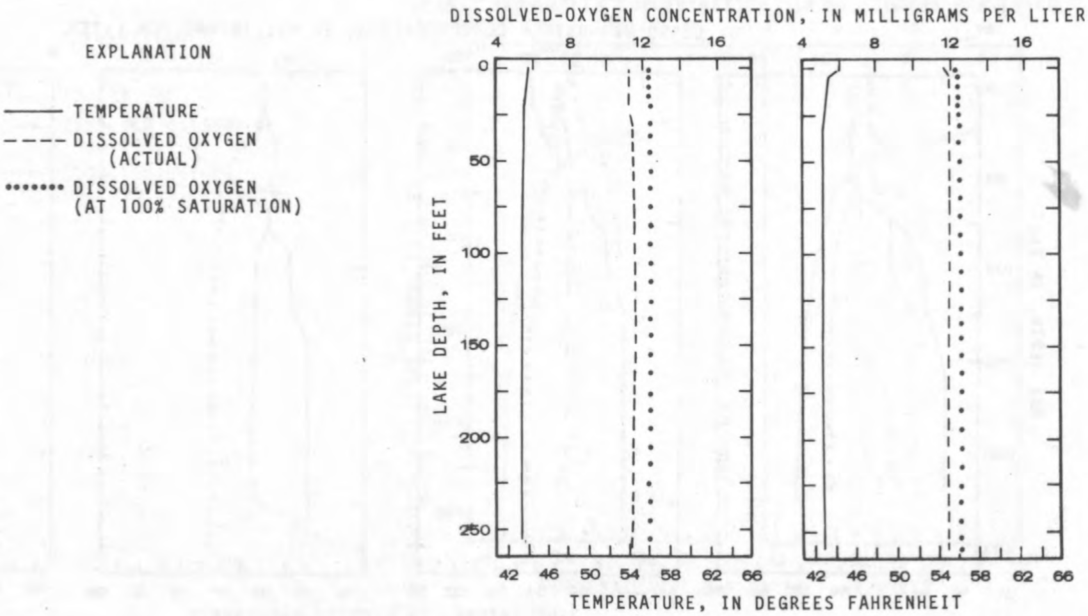


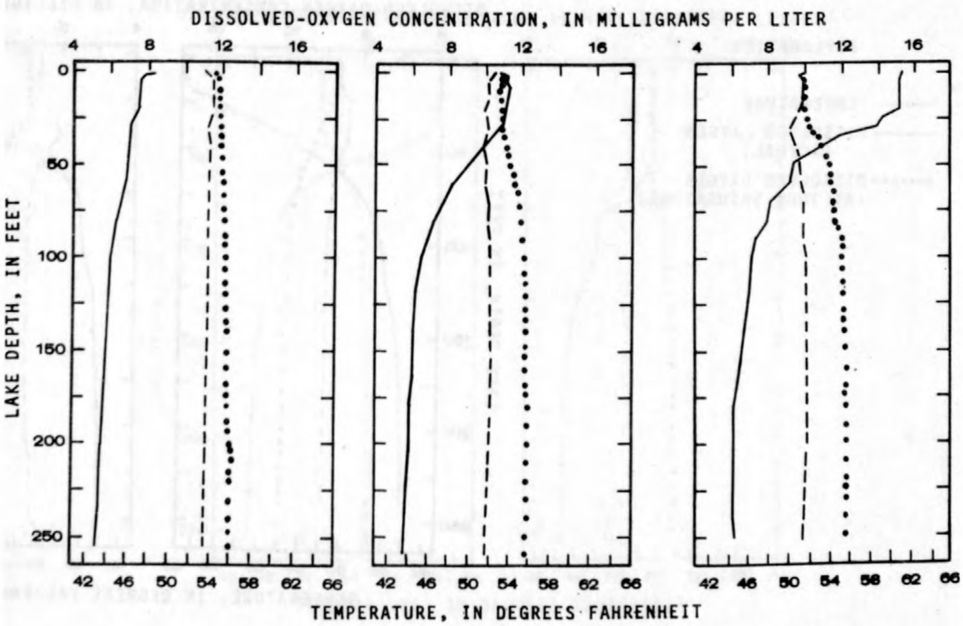
FIGURE 17.--Water-quality data from site 4, Ozette Lake.

[Milligrams per liter unless otherwise indicated]

Date of collection	February 20, 1976			March 31, 1976		
Approximate composite water depth (ft)	80	160	260	80	160	260
Total nitrate nitrogen (as N)	0.20	0.10	0.11	0.08	0.08	0.09
Total nitrite nitrogen (as N)	.004	.002	.002	.005	.005	.004
Total ammonia nitrogen (as N)	.05	.05	.06	.06	.06	.05
Total organic nitrogen (as N)	.15	.14	.13	.08	.06	.09
Total phosphorus (as P)	.010	.008	.012	.006	.005	.005
Total orthophosphate (as P)	.004	.003	.003	.004	.003	.003
Specific conductance (µmho/cm at 25°C)	40	40	40	39	--	38
pH (pH units)	7.2	--	6.8	6.8	--	6.8
Water temperature (°F)	43.5	43.5	43.5	43.0	42.8	42.8
Color (Pt-Co scale)	30	--	30	20	--	20
Dissolved oxygen	11.5	11.6	11.4	11.9	11.8	11.8
Secchi disc (ft)		7.3			7.5	
Chlorophyll a in photic zone (µg/L)		.5			1.2	
Algal growth potential (composite of all depths)		.7			.3	
Total zooplankton (organisms/L)		7.0			4.5	

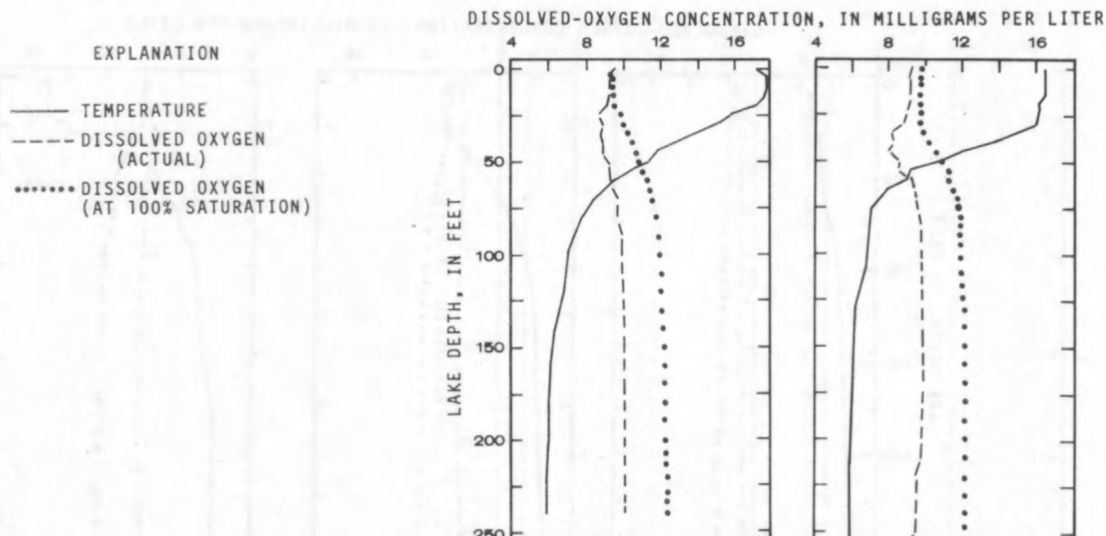


April 27, 1976			May 25, 1976			June 22, 1976		
80	160	250	30	100	260	15	57	200
0.06	0.07	0.07	0.06	0.08	0.10	0.03	0.07	0.10
.001	.001	.001	.004	.004	.002	.000	.000	.000
.08	.05	.06	.04	.04	.03	.03	.04	.03
.06	.13	.11	.20	.30	.20	.17	.13	.16
.007	.007	.007	.016	.006	.006	.010	.010	.010
.004	.003	.005	.003	.003	.003	.010	.000	.000
39	--	38	37	--	37	36	--	37
7.1	--	7.1	6.8	--	6.6	6.7	--	6.7
45.1	44.1	43.3	53.2	45.5	43.9	61.0	50.2	44.6
20	--	20	30	--	30	30	--	35
11.2	11.1	11.0	10.0	10.2	10.1	9.8	9.7	10.0
----	10	----	----	7.5	----	----	9.0	----
----	1.4	----	----	3.8	----	----	3.6	----
----	.4	----		--		----	.3	----
----	7.5	----	----	9.8	----	----	8.9	----



[Milligrams per liter unless otherwise indicated]

Date of collection	July 20, 1976			August 26, 1976		
Approximate composite water depth (ft)	16	70	240	20	60	185
Total nitrate nitrogen (as N)	0.00	0.06	0.09	0.00	0.07	0.10
Total nitrite nitrogen (as N)	.002	.003	.002	.006	.006	.004
Total ammonia nitrogen (as N)	.06	.07	.05	.04	.04	.04
Total organic nitrogen (as N)	.19	.17	.14	.13	.11	.12
Total phosphorus (as P)	.006	.006	.004	.005	.008	.008
Total orthophosphate (as P)	.002	.004	.003	.002	.003	.005
Specific conductance (μmho/cm at 25°C)	36	--	38	36	--	--
pH (pH units)	7.2	--	6.7	5.9	--	--
Water temperature (°F)	65.5	48.9	44.2	63.0	50.0	44.6
Color (Pt-Co scale)	25	--	35	35	--	--
Dissolved oxygen	9.2	9.6	10.0	9.1	9.2	9.8
Secchi disc (ft)	---- 7.0 ----			----10.5 ----		
Chlorophyll _a_ in photic zone (μg/L)	---- 4.8 ----			---- 3.0 ----		
Algal growth potential (composite of all depths)	--			---- .3 ----		
Total zooplankton (organisms/L)	---- 8.6 ----			---- 9.2 ----		



September 28, 1976			November 10, 1976		
12	100	250	17	80	205
0.00	0.04	0.04	0.02	0.06	0.09
.001	.003	.005	.004	.004	.003
.08	.07	.10	.05	.05	.05
.08	.15	.06	.10	.13	.13
.005	.005	.008	.002	.003	.004
.005	.005	.006	.007	.005	.007
38	--	40	37	37	36
--	--	--	--	--	--
63.0	46.4	44.2	53.6	47.8	44.6
--	--	--	25	35	30
9.2	9.3	9.0	9.7	9.2	9.3
---- 9.6 ----			---- 11.5 ----		
---- 3.4 ----			---- 3.5 ----		
--			---- .4 ----		
---- 11 ----			---- 6.2 ----