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# A Limnological Analysis of Ten Mountain Lakes

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AN ABSTRACT OF THE THESIS OF GARY WAYNE BURNS for the Masters  
of Science in Biology presented June 3,1993.

Title: A Limnological Analysis of Ten Mountain Lakes.

APPROVED BY THE MEMBERS OF THE THESIS COMMITTEE:



Richard R. Petersen, Chair



Richard B. Forbes



Leonard Simpson



Daniel M. Johnson

Ten mountain lakes were analyzed in order that they be assigned a trophic status. The lakes which are located in the Mount Hood National Forest of Oregon are Anvil, Beaver Pond, Cripple Creek, Fish, Gifford, Monon, Ollalie, Rimrock, Round, and Sportsman. The purpose of this report is to determine the productivity of these waters.

Data were collected for analyses of temperature, dissolved oxygen concentration, Secchi depth, major ion

concentration, light intensity versus depth, alkalinity, phytoplankton species composition/total density, and zooplankton species composition/total density.

Samples were collected in Van Dorn sampling bottles and returned to the laboratory for chemical analyses and taxonomic identification of biological organisms. Field profiles were taken for light intensity, temperature, dissolved oxygen concentration, specific conductivity, and depth using portable electronic equipment. A Secchi disk was used in the field for obtaining light extinction data.

The lakes were assigned a trophic status according to Carlson's Trophic State Index (Carlson, 1977).

Beaver Pond Lake which is the most productive lake of the 10 surveyed had an average Secchi depth of 1.7 meters, an average soluble reactive phosphorous concentration of 59.8 ug/L, and an average chlorophyll-a concentration of 29.3 ug/L for the dates sampled. These values are consistent with lakes which are eutrophic.

Ollalie Lake had an average Secchi depth of 13.2 meters, an average soluble reactive phosphorous concentration of 1.64 ug/L, and an average chlorophyll-a concentration of 0.28 ug/L. This lake is ultraoligotrophic-to-oligotrophic according to the Carlson index. The other lakes of the study were assigned values for trophic state which are somewhere between those assigned to Beaver Pond and Ollalie lakes.

The 10 lakes studied for this report were compared to

lakes studied for the compilation of the Western Lake Survey (Landers, et. al. 1987). It was noted that Beaver Pond, Round, and Sportsman lakes are nutrient rich while Monon, Ollalie, and Gifford, are nutrient poor when compared to other lakes located in the Pacific Northwest. Anvil, Cripple Creek, Fish, and Rimrock lakes have profiles consistent with the majority of mountain lakes located in the area.

A LIMNOLOGICAL ANALYSIS OF TEN MOUNTAIN LAKES

by

GARY WAYNE BURNS

A thesis submitted in partial fulfillment of the  
requirements for the degree of

MASTER OF SCIENCE  
in  
BIOLOGY

Portland State University  
1993

TO THE OFFICE OF GRADUATE STUDIES:

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## DEDICATION

This thesis is dedicated to my wife.

## ACKNOWLEDGEMENTS

I would like to acknowledge the U.S. Forest Service for the research funding which made this project possible.

I would especially like to thank Robert Deibel for his assistance during the early stages of the project.

I would also like to thank my son Jonathan for his help in the field, Vic Menting for his help in the lab, and Allan Vogel, and Jim Sweet for their counsel.

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## INTRODUCTION

The ten lakes studied in this investigation are Anvil, Beaver Pond, Cripple Creek, Fish, Gifford, Monon, Ollalie, Rimrock, Round, and Sportsman. These lakes are located within the Cascade mountain range of northwestern Oregon, in the southern half of the Mount Hood National Forest (Figure 1). They are located within heavily forested watersheds and range in elevation from 600 m to over 1500 m (2000 f to 5000 f; TABLE 1).

The district ranger station for the lakes is Ripplebrook Ranger Station, located on Oregon State Highway 224 approximately 46.4 kilometers, (29 mi) southeast of Estacada, Clackamas County, Oregon (Figure 2). The ranger station is the reference point for the beginning of each access route. Refer to APPENDIX A for detailed directions into each lake.

The purpose of this thesis is twofold. First, it is to describe the physical, chemical, and biological conditions of the lakes and their drainage basins. Second, it is to define a trophic status to each lake according to the system developed by Carlson in 1977.

Six of the lakes surveyed for this thesis have not previously been studied. They are Anvil, Beaver Pond, Cripple Creek, Gifford, Rimrock, and Sportsman Lakes. This

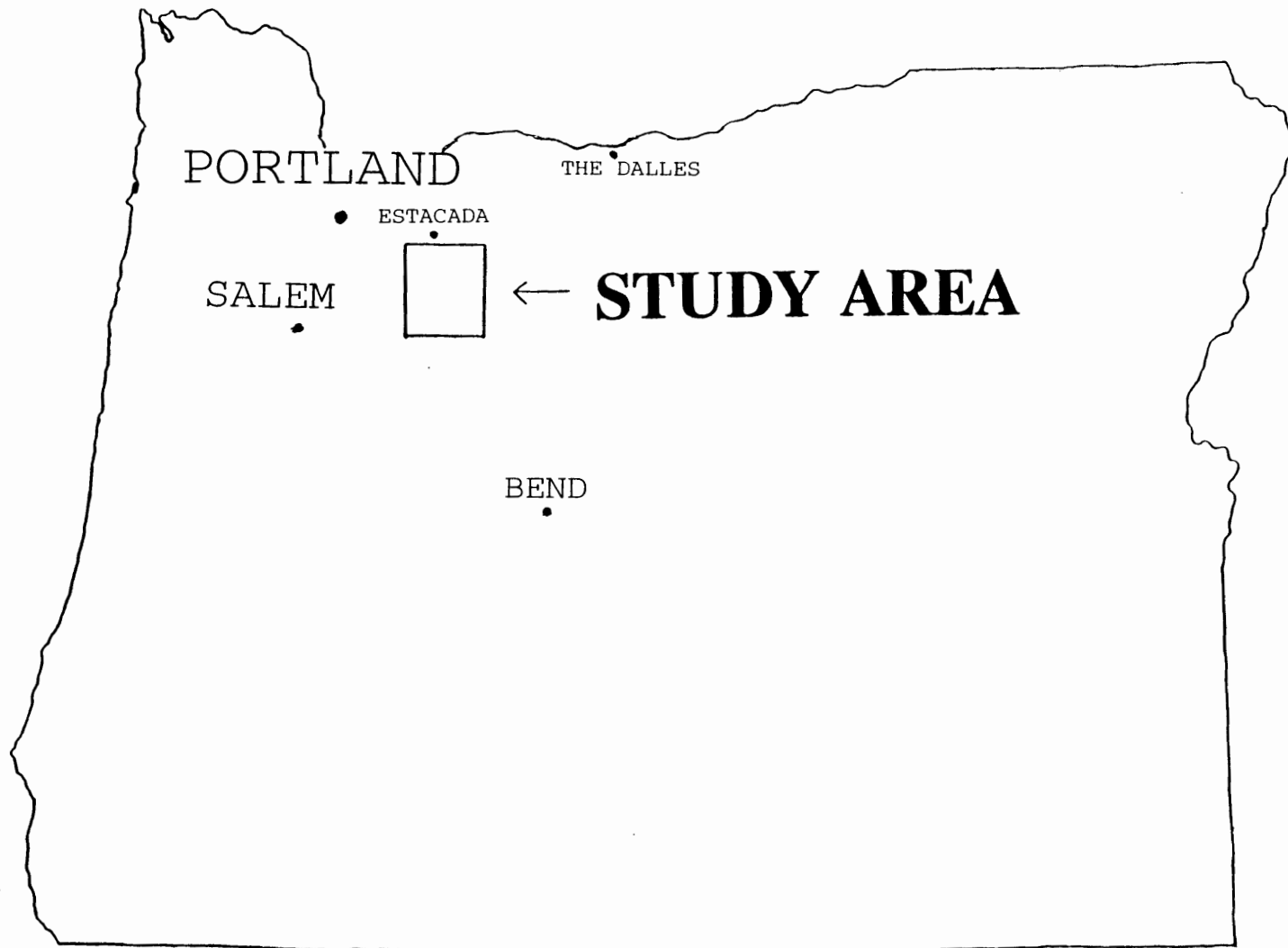
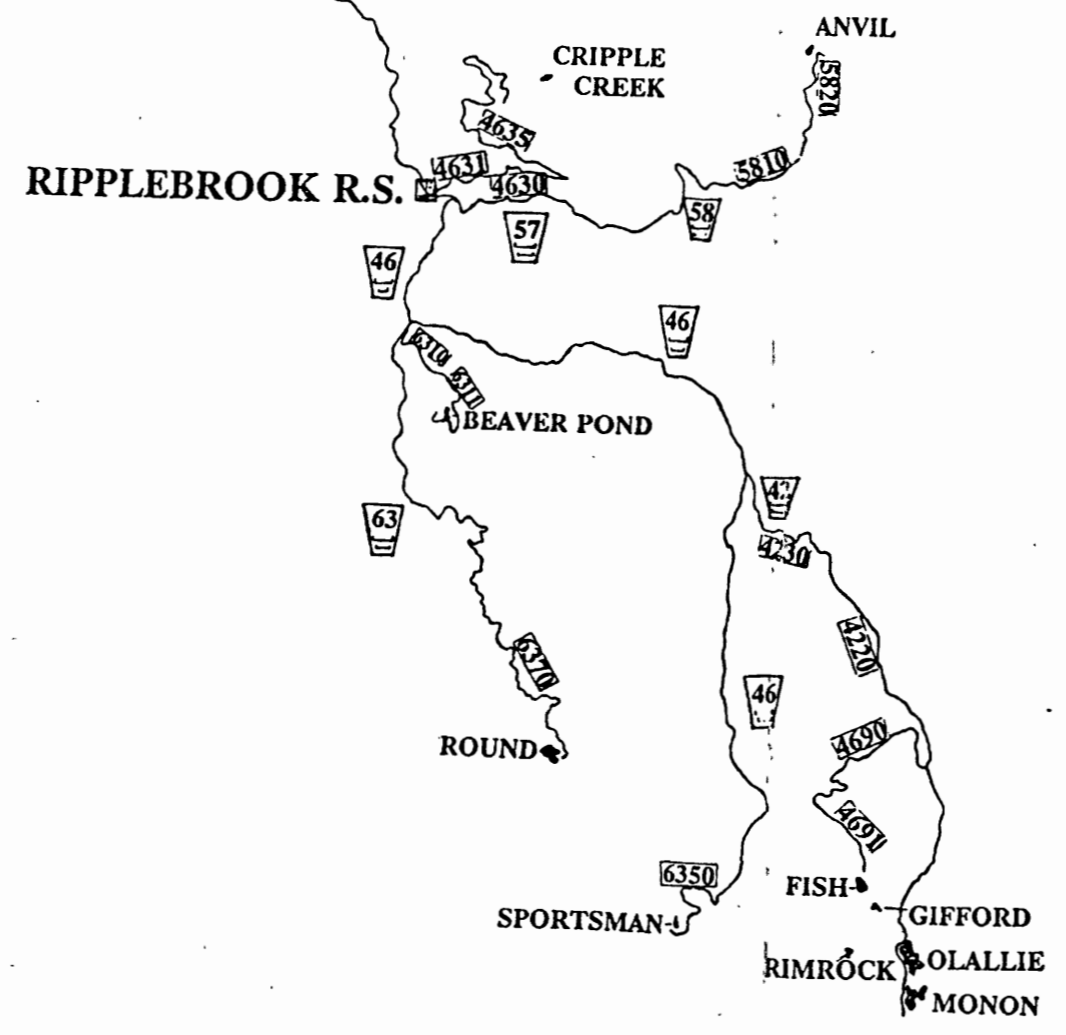


Figure 1. Study area.






ESTACADA

10 SUBALPINE LAKES



**MT. HOOD NATIONAL FOREST**  
(SOUTH HALF)  
OREGON

 OREGON STATE HIGHWAY  
 NATIONAL FOREST PRIMARY ROUTE  
 FOREST ROUTE


1 MILE 

Figure 2. Primary and secondary access routes.

TABLE I

## PHYSICAL PARAMETERS

LAKES	ELEV (m/f)	A (DB) (ha/A)	A (B) (ha/A)	DEPTH (m)	SL (km/mi)
ANVIL	1200/4000	158/391	0.70/1.7	1.50	0.37/0.23
BEAVER POND	703/2320	45/112	1.44/3.6	2.50	0.65/0.88
CRIPPLE CREEK	1303/4300	302/748	4.01/9.9	1.20	0.93/0.58
FISH	1300/4280	303/744	15.5/38.1	20.4	1.54/0.96
GIFFORD	1500/4950	155/383	1.65/2.6	18.0	0.32/0.20
MONON	1512/4959	337/832	39.7/98	12.7	4.2/2.6
OLLALIE	1504/4936	881/2176	76.1/188	13.6	6.3/3.9
RIMROCK	1561/5150	98/241	0.78/1.92	3.40	0.35/0.22
ROUND	1143/3750	114/282	3.7/9.1	8.0	0.75/0.47
SPORTSMAN	1220/4000	115/284	0.57/1.41	1.5	0.30/0.19

## CODES:

ELEV = Elevation

A(DB) = Area of the drainage basin

A(B) = Area of lake basin

SL = Shoreline length

accumulation of baseline data may be of value for future research and/or resource management.

Four of the lakes studied herein have previously been surveyed. They are Fish, Monon, Ollalie, and Round Lakes. The data collected for this study were compared to data obtained during the earlier investigations.

Of the four lakes previously studied, Ollalie has been the most often cited. The two most comprehensive studies of this lake were reported in the Atlas of Oregon Lakes (Johnson et. al., 1985) and in a United States Geological Survey open file report (Rinella, 1977). A comparison was made between the data taken during the earlier studies and the data collected for this report (DISCUSSION).

#### ANVIL LAKE

Anvil Lake, located approximately 27 km (17 mi) east from Ripplebrook Ranger Station, is shown on the Wolf Creek Oregon quadrangle topographic map at T5S, R8E, Sec. 17. Anvil Lake is located within a narrow band of trees and underbrush. There is only one open spot in which to gain lake access. To the south and west outside of the narrow band of vegetation are three clearcut areas. One of the three clearcuts is located just upstream from the lake on the western boundary of the watershed. Only one stream, Anvil Creek, flows into and out of Anvil Lake.

Other than the three clearcut areas and the single lake

access, there is only one obvious impact source within the watershed. USFS trail 724 parallels Anvil Creek to the northeast and at one point crosses a portion of the watershed. There are no campsites, buildings, or boat launches within the watershed (Figure 3), so it is probable that human impact from recreational uses is minimal.

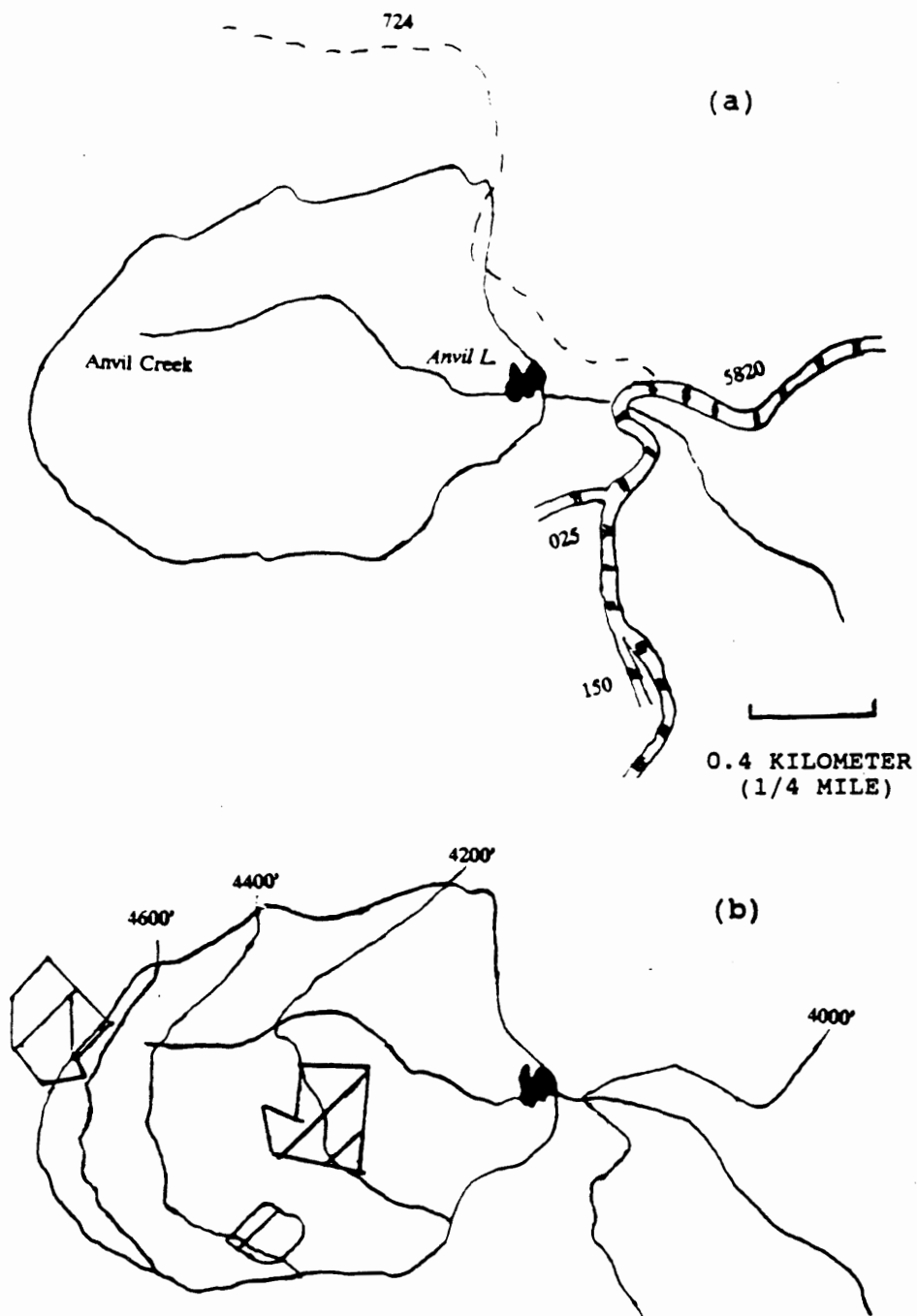
The lake is circular with a saucer-shaped basin. The bottom substrate is primarily silt. It has been heavily invaded by macrophytes (unidentified), and supports a large population of Rough-skinned Newts (Taricha granulosa). Unidentified fish were observed rising during the 1992 sampling. An unidentified waterbird species was also observed on one occasion. A sketch map of the lake bathymetry (Figure 4) was provided by the USGS.

#### BEAVER POND LAKE

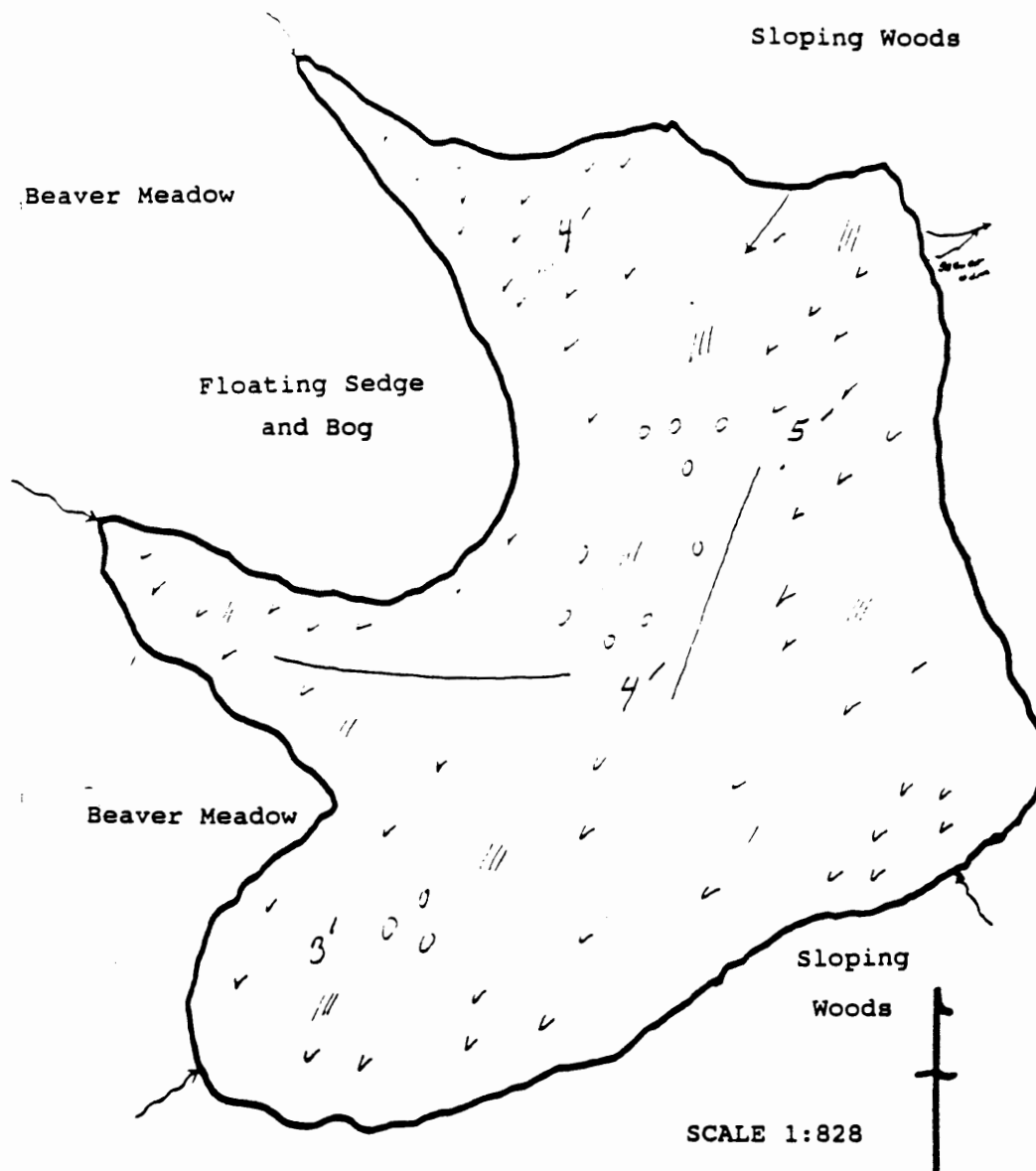
Beaver Pond Lake (referred to as Unnamed Lake by the USFS) is approximately 16 ki (10 mi) south of Ripplebrook Ranger Station. On the United States Geological Survey topographical quadrangle map (Bull of the Woods Quad), it is found at T7S, R6E, Sec. 2.

Beaver Pond Lake as the name implies is extremely small. It is surrounded on 3 sides by ridges and on a 4th side is a meadow. The meadow and lake are the remnants of what was once a moderate-size mountain lake.

The northeastern corner of the watershed is clearcut.



**Figure 3.** Road and trail system (a), and contours and clearcuts (b), for Anvil Lake. Clearcuts are designated by hatchlines.



**Figure 4.** Sketch map of bathymetry and benthic substrate for Anvil Lake. (Source, U.S.D.A. Division of Forest Service, Mount Hood National Forest).

Within the watershed are two well traveled roads. On the north end of the lake there is an area which is used by campers. This area is on a ridge approximately 91m (100y) above the lake (Figure 5).

The elongate basin is located between two small ridges. It supports a substantial growth of macrophytes (unidentified) and a number of standing snags. Unidentified waterbirds and amphibians were found along the shoreline.

The water appears dark. A number of downed trees extend into the water from the shoreline, as do a number of floating logs. The bottom substrate is deep mud which yielded a sulphurous odor when the boat anchor was hauled in.

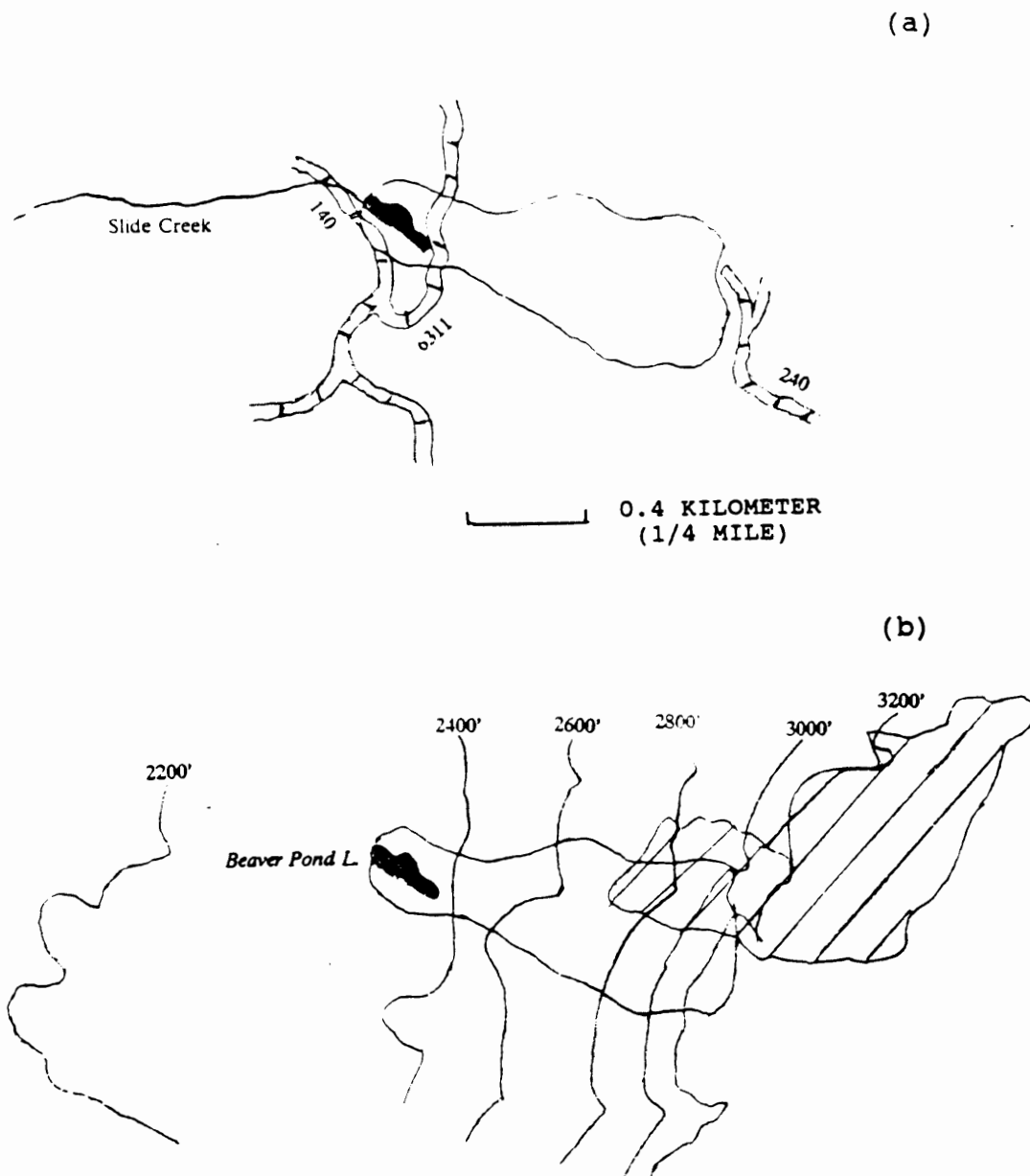
#### CRIPPLE CREEK LAKE

North and slightly east of Ripplebrook Ranger Station approximately 22 km (13.6 mi) is Cripple Creek Lake. It is found on the High Rock quadrangle (USGS) topographical map at T5S, R7E, Sec. 19.

Cripple Creek lake is not accessible by automobile. It requires a hike-in of approximately 50 minutes on USFS trail 702 (APPENDIX A). The trail is well used.

Cripple Creek Lake is a relatively long, finger-shaped lake set within a heavily forested perimeter. On the north side of the lake are a number of access points.

The relatively large watershed contains no clearcuts



**Figure 5.** Road and trail system (a), and contours and clearcuts (b), for Beaver Pond Lake. Clearcuts are designated by hatchlines.



but does contain two major trails (USFS trails 702 and 517). Cache Meadow lies in the center of the watershed. On the edge of the meadow is an abandoned cabin or shed.

The contour relief of the watershed is approximately 212 m (700 f). Most of the watershed consists of rolling forested hills. Two major stream tributaries join Cripple Creek before it drains into the lake. The watershed is covered with animal and hiking/horseback riding trails

On the north side of the lake is a large camping site. Near the site are a number of beached rafts which have been constructed from logs and poles cut from the site.

Cripple Creek Lake is finger shaped and its basin is shallow throughout. The maximum sampling depth is just over 1 m. Under the water column is a thick silt base. The lake has a macrophyte population more like that found in eutrophic systems, although the lake is oligotrophic according to most data. Salamanders (Taricha granulosa) were found in great numbers and fish risings were observed.

This lake and watershed is used for hunting, camping, fishing, and horseback riding (Figure 6; Figure 7). The wooded area along the north side of the lake contains a complex network of human and large animal trails.

#### FISH LAKE

Fish Lake is located in the Ollalie Butte area approximately 54 km (34 mi) southeast of Ripplebrook

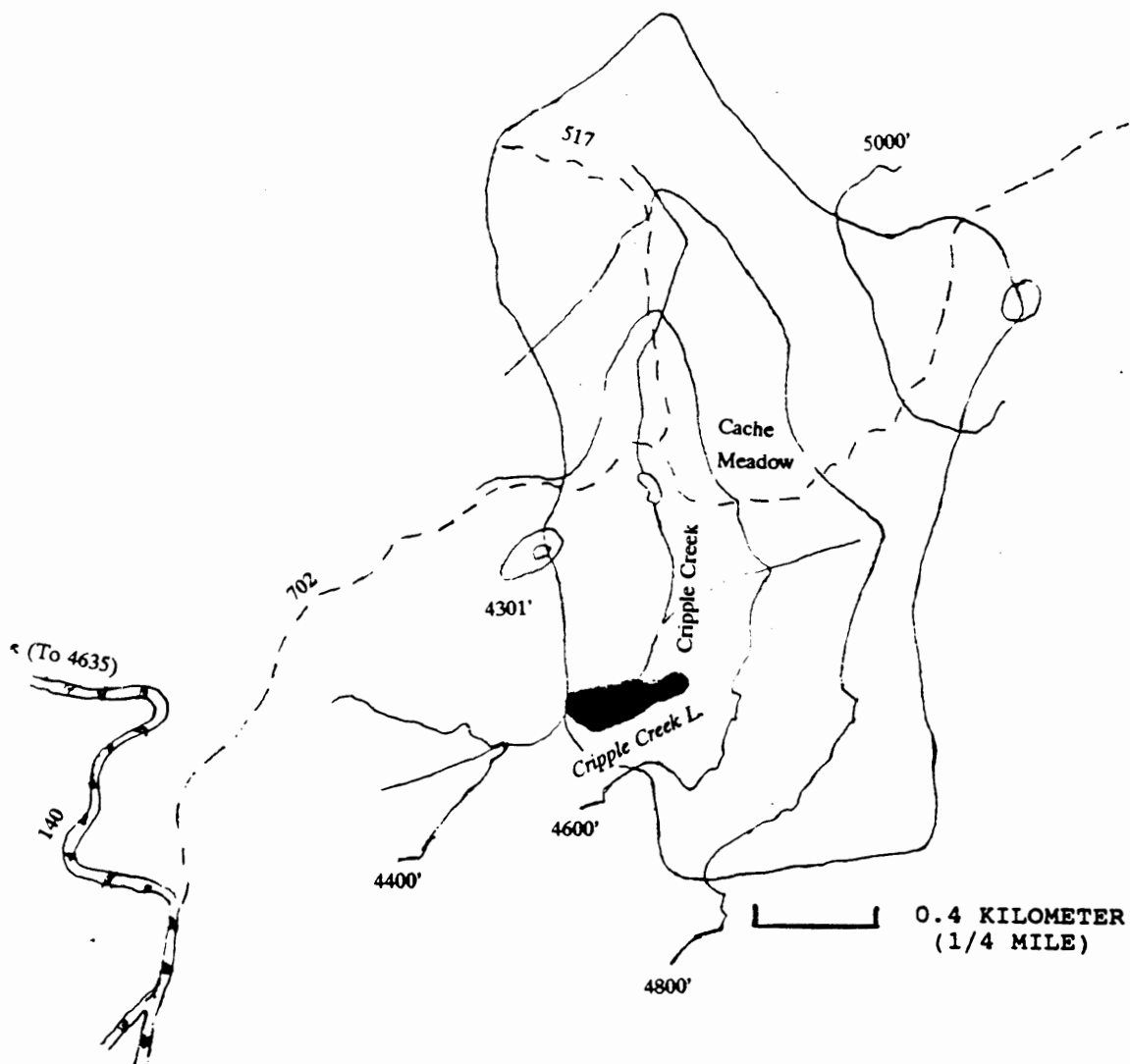
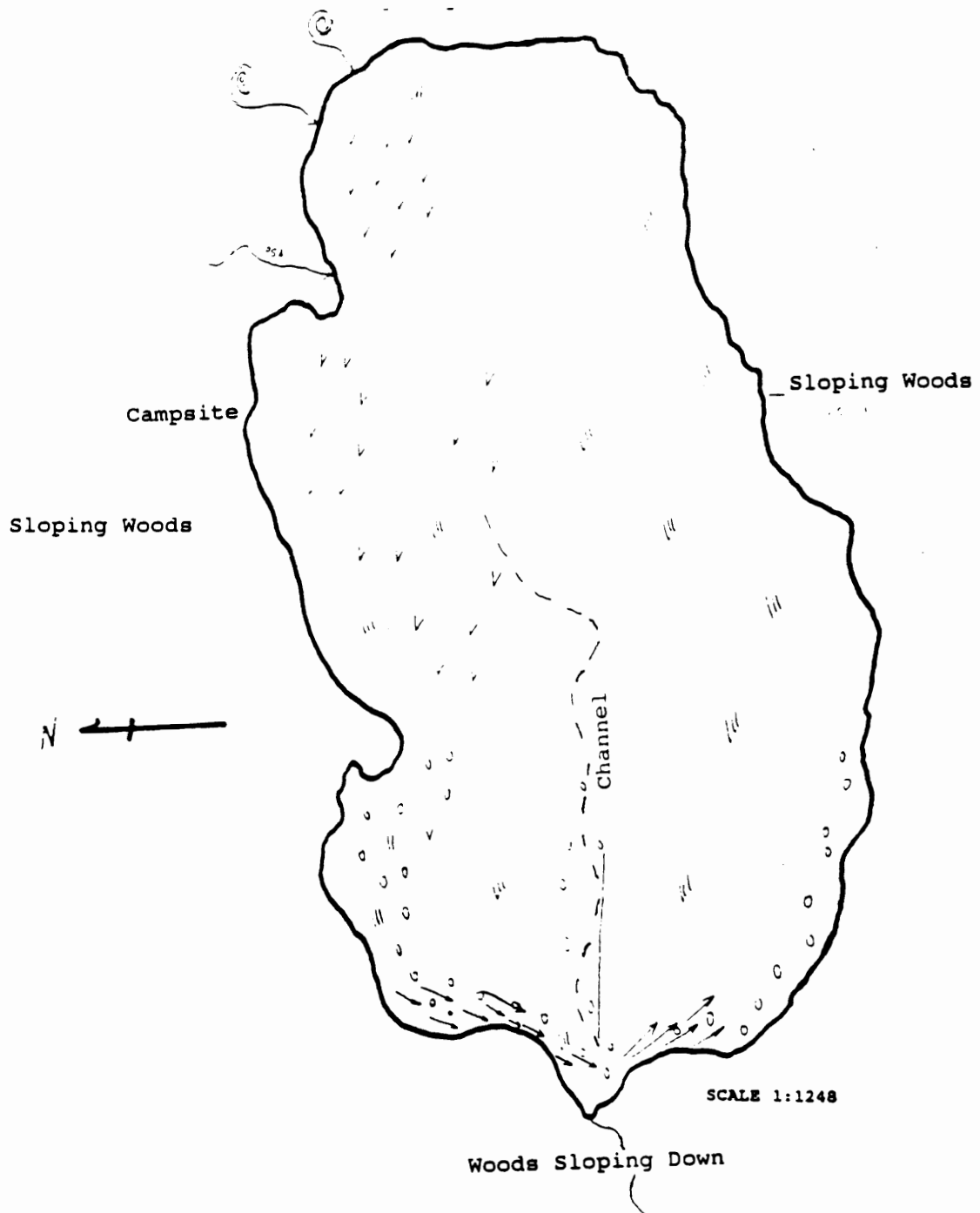


Figure 6. Roads, trails, and contours for the Cripple Creek Lake drainage basin.



**Figure 7.** Sketch map of bathymetry and benthic substrate for Cripple Creek Lake. (Source U.S.D.A. Division of Forest Service, Mount Hood National Forest).

Ranger Station. It is one of five lakes from this area which were sampled in this study. It can be found on the Ollalie Butte quadrangle (USGS) topographical map at T8S, R8E, Sec. 34.

Fish Lake is circular in shape. It has a distinctive rock-slide/clear area on the south end. The rest of the perimeter is forested.

The watershed has a contour relief of over 82 m (268.96 f). There are two popular hiking trails (USFS trails 706 and 717) within the drainage basin. At the northwestern-most corner of the watershed is Cornpatch Meadows.

The Fish lake basin is approximately bowl-shaped. It is the deepest lake of this study (TABLE I).

The northern portion of the basin has a silty bottom substrate. This side of the basin has a gradual contour relief. The south side of the lake has a rocky bottom and drops off sharply.

Fish lake supports macrophytes (unidentified), especially on the north and west sides. It also supports crayfish, salamanders (Taricha granulosa) and fish (unidentified).

The Fish Lake area is a very popular fishing, hiking, and camping spot. The northern campsite is located right on the immediate shoreline. There is a picnic table on the shore less than 30 m (approximately 33 y) from the waters edge.

USFS trail 717 parallels the lake on the west side. This trail connects with USFS trail 706 which eventually connects with the popular Pacific Crest Trail. This well traveled trail system along with forest route 4691 offers generous access to Fish lake (Figure 8; APPENDIX A).

#### GIFFORD LAKE

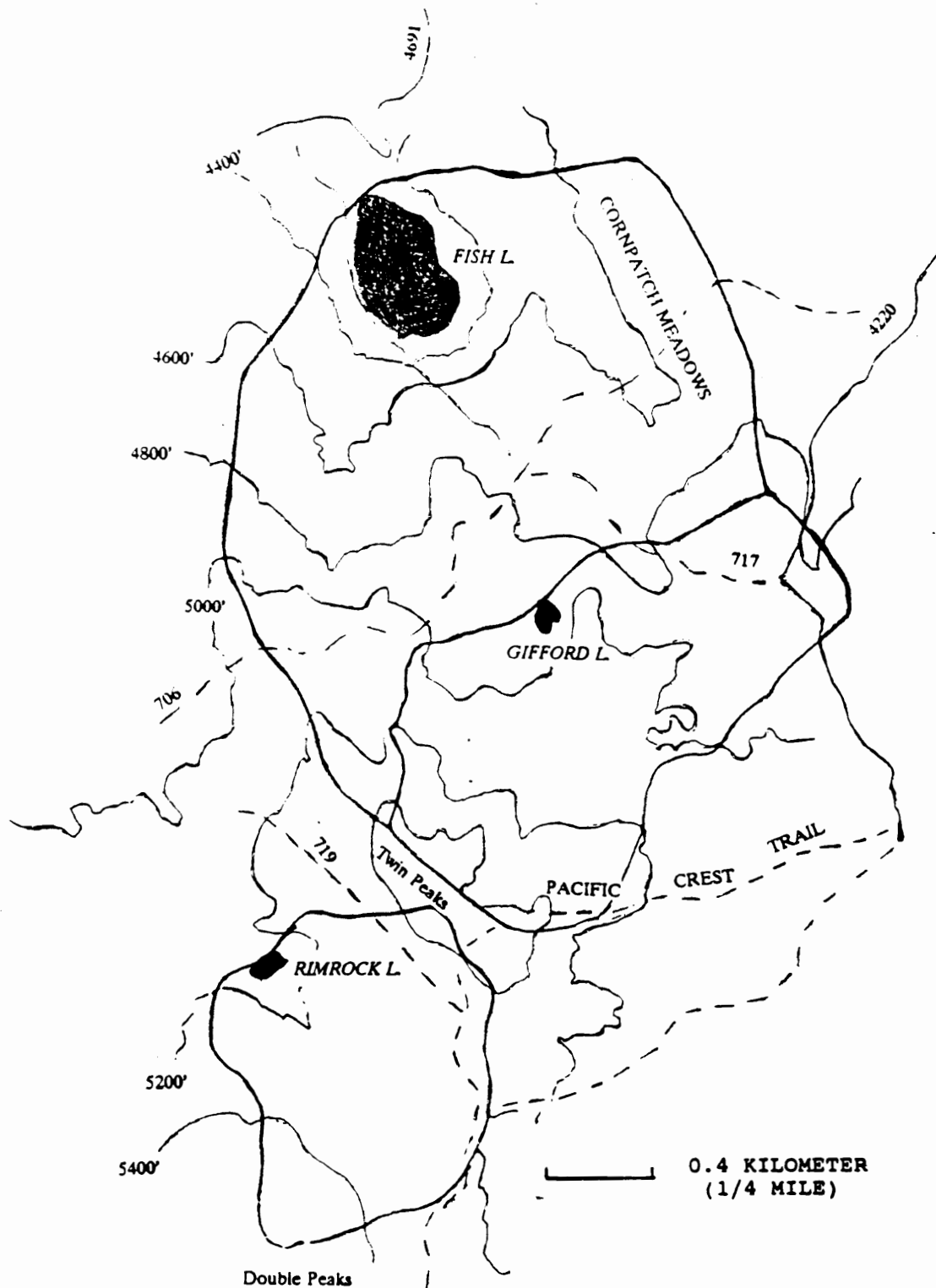
Gifford Lake is located approximately 50 km (31+ mi) southeast of Ripplebrook Ranger Station in the Ollalie Butte area. It can be located on the Ollalie Butte topographical map (USGS) at T9S, R8E, Sec. 3. (Figure 2).

Gifford Lake is approximately circular except for a peninsula extending from the north shore. The Gifford Lake Trail follows a ridge which becomes the peninsula.

Within the watershed are two popular hiking trails--the Pacific Crest Trail on the southern part of the watershed and USFS trail 717 on the north. The watershed is bordered by Twin Peaks [elevation 1575 meters (5200 feet)] to the southwest. The basin itself is generally steep and bowl-shaped although the slope on the northwest is gradual. The bottom substrate is predominantly rock.

Like Fish Lake, Gifford Lake has a rock slide area to the south. This slide is approximately 45 meters (50 yards) across. A pile of relatively large boulders extends into the basin.

Gifford Lake lacks the large macrophyte population



**Figure 8.** Road and trail systems, and contour relief for the Fish Lake, Gifford Lake, and Rimrock Lake drainage basins.

found in most of the other lakes of this report. However, the fish and salamander populations characteristic of most lakes in the area are present.

Gifford Lake Trail is difficult to find since the intersection of the trail off trail 706 is not marked. Therefore, there is only moderate human impact upon the system. However this lake has two features which make it vulnerable. The first is the location of the camping site on the narrow peninsula, and the second is the easy access available on the east side (an area only sparsely forested). Refer to the bathymetric map (Figure 9).

#### MONON LAKE

Monon Lake is located approximately 54.4 km (34 mi) southeast of Ripplebrook Ranger station, and 1.2 km (0.75 mi) south of Ollalie Lake. It is accessible by automobile on Forest Route 4220. On the Ollalie Butte topographical quadrangle map it is found at T9S, R8E, Sec. 13 (Figure 2).

Monon Lake has an irregular shape, consisting of a southern basin and a much smaller and deeper northern basin. The two basins are connected by a shallow channel. The area around the perimeter is sparsely-to-heavily wooded with a trail encircling the basin.

Monon Lake is one of many lakes within the popular Ollalie Lake recreational area. Within its watershed are numerous campsites, boat launches, and hiking trails.

↑  
Magnetic north

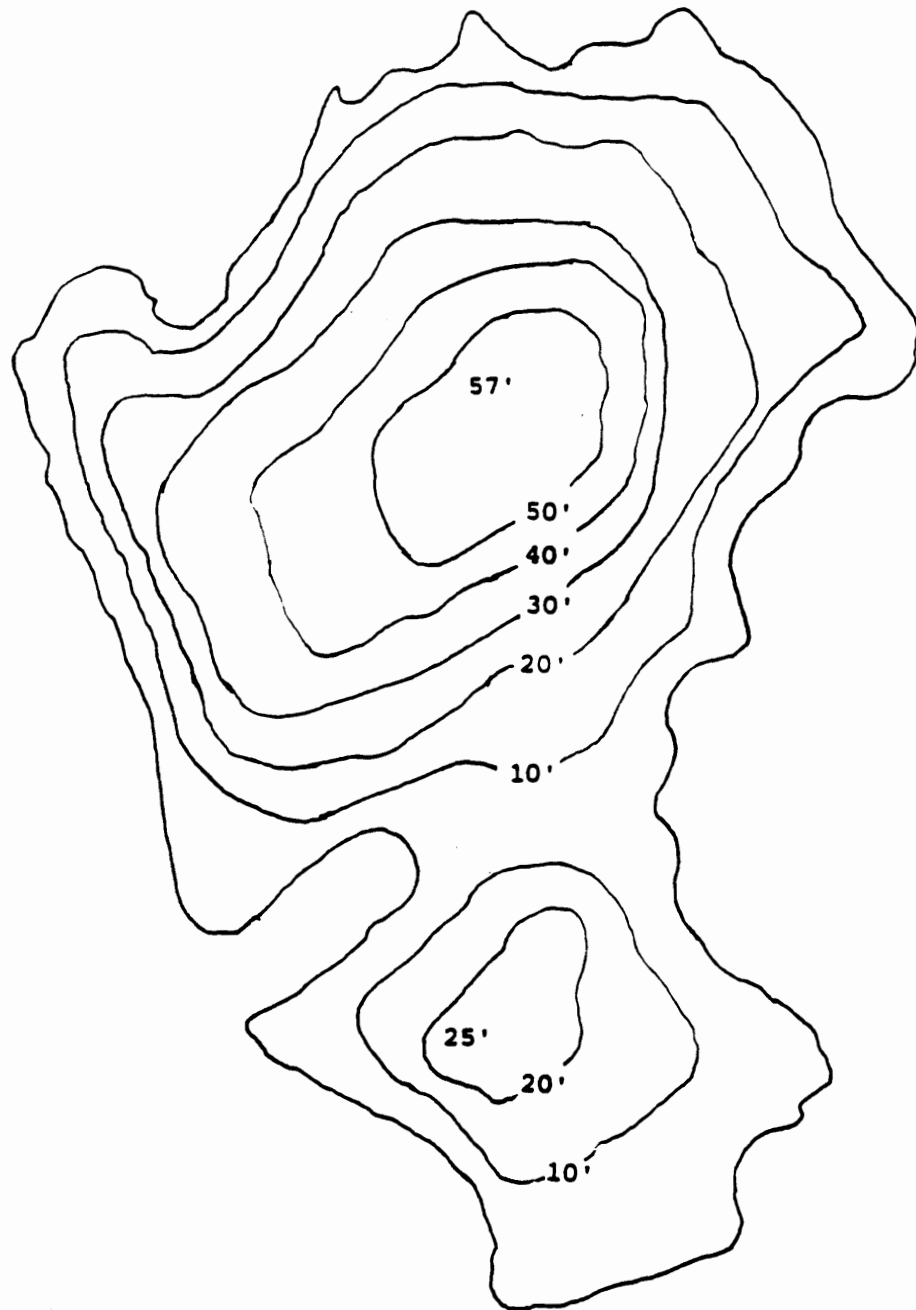


Figure 9. Sketch map of approximate bathymetry for Gifford Lake.



Both of the Monon basins are heavily fished although the northern basin is probably the more popular. The numerous boat access points and camping spots are found immediately off of forest route 4220. The trail circling Monon Lake is without significant relief and is often used by bicyclists as well as hikers.

#### OLLALIE LAKE

Ollalie Lake is the largest lake in the Ollalie Butte area. One of over 200 lakes and ponds in the area, it is located approximately 52.8 km (33 mi) southeast of Ripplebrook Ranger Station on Forest Route 4220. It can be found on the Ollalie Butte, Oregon topographical quadrangle map (USGS) at T9S, R8E, Sec. 12 (Figure 2).

The contour relief of the Ollalie Lake watershed is moderate. Throughout the area are stands of pine, fir, and hemlock trees.

On the west side of the lake is Forest Route 4220. On the east side, Forest Service Spur Road 170 extends 1/3 the length of the lake to the Paul Dennis Campground. USFS trail 731 begins at the end of the road and follows the northeast lake shore, circles the southeast tip, and connects with SR 180. Forest Service loop road 180 accesses the lakes southernmost camping area, the Peninsula Campground (APPENDIX A).

The Ollalie basin is elongate, with a peninsula

extending from its southeast shore. It is a very popular recreation site with 3 campgrounds and 2 boat ramps. A grocery store is located at the northern end of the lake. Cabins (which line the northeast corner of the lake), and boats can be rented at the store.

Ollalie Lake itself is a very popular recreational area, and in addition the campgrounds are used by people exploring Ollalie Butte, Twin Peaks, Double Peaks, Mount Jefferson, the Pacific Crest Trail, and any of the hundreds of lakes and ponds located within the Ollalie Butte Scenic Area.

#### RIMROCK LAKE

Rimrock Lake is located approximately 56 km (35 mi) southeast of Ripplebrook ranger station. It can be found on the Ollalie Butte, Oregon topographical quadrangle map at T9S, R8E, Sec. 10.

The Rimrock watershed has a contour relief of over 254.5 m (840 f). The watershed is bordered by Twin Peaks to the northeast and Double Peaks to the southwest. Two trails (Pacific Crest and Red Lake) cross its northeast corner. A number of lakes including Neknoberts, Cigar and Ring occupy the watershed (Figure 8).

Rimrock Lake consists of 2 basins. The main basin has a circular shape. To the southwest is a narrow channel leading into a shallow and elongate second basin. This

secondary basin lies beneath a steep rock cliff and slide area. The bottom substrate is predominantly rock. See bathymetric map (Figure 10).

There is a rocky point extending into the lake from the east side. The basin outflow is on the westside. The inflow location was not found. The heavily wooded area around the basin showed little sign of human activity.

#### ROUND LAKE

Round Lake is located approximately 0.4 km (0.25 mi) off of forest route 6370 about 40 km (25 mi) south of Ripplebrook Ranger Station. It can be found on the Mount Lowe topographical quadrangle map (USGS) at T8S, R7E, Sections 16 and 17. (Figure 2).

The Round Lake watershed has a contour relief of 320.1 m (1050 f). There are 3 roads within the watershed; Forest Roads 120 and 140 and Forest Route 6355. To the south of the lake is Cache Box Meadows. Also within the watershed are clearcut areas to the north, northeast, and south. The only recreational trail within the drainage basin is the Round Lake Trail which circles the lake and connects to Forest Route 6370.

As the name implies, the Round Lake basin is circular. The lake has two inflows, both on the east end, and one outflow thru a channel on the south side. On the east side of the lake, there is a bridge over one the inflowing

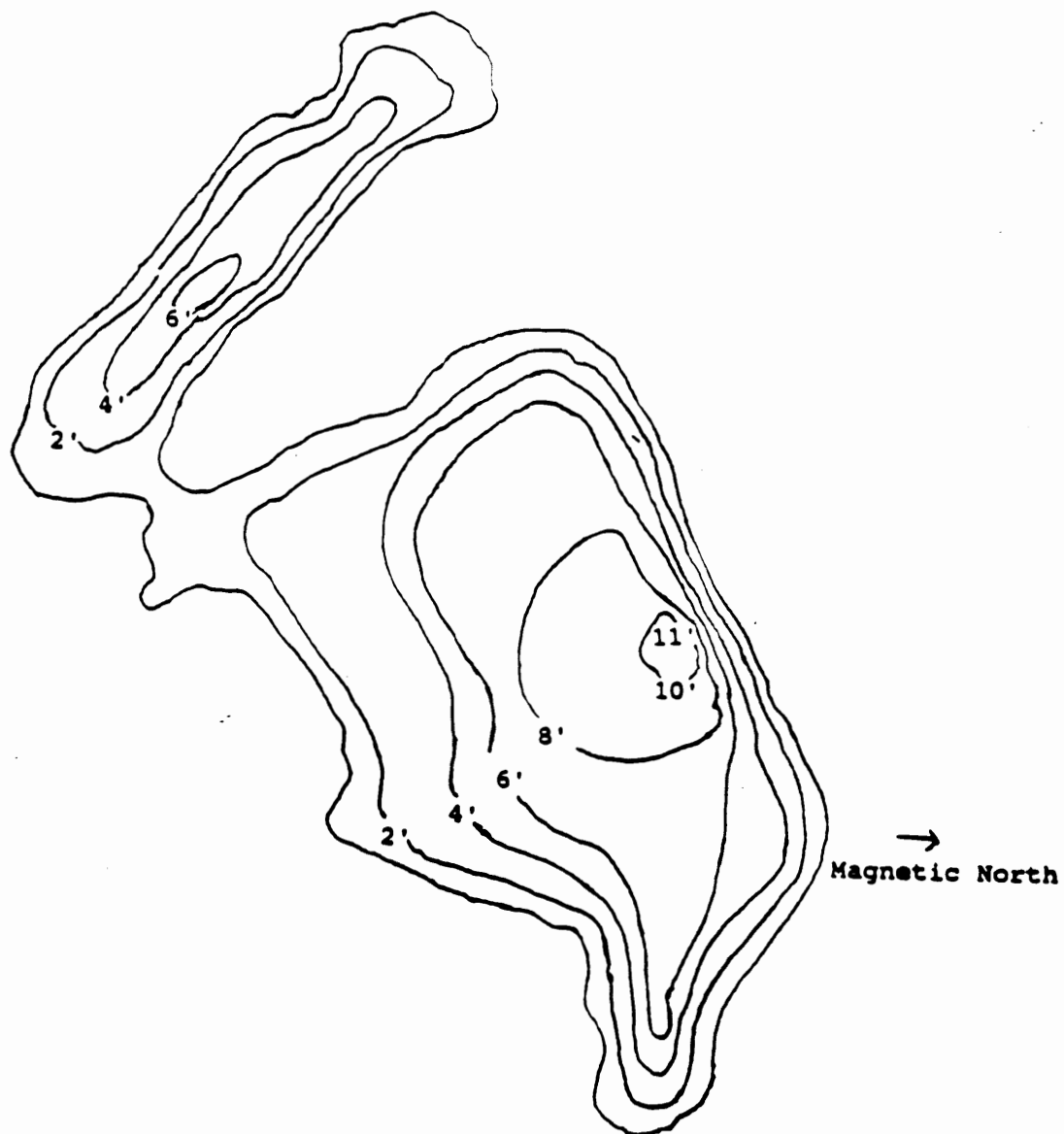


Figure 10. Sketch map of approximate bathymetry for Rimrock Lake.

streams. The bottom substrate is silt. Macrophytic vegetation was observed along the west end.

A distinctive characteristic of Round Lake is a shoreline growth of rhododendrons (unidentified) which rim the lake. These plant assemblages are so dense that they offer an impenetrable barrier to the water's edge along most of its shoreline.

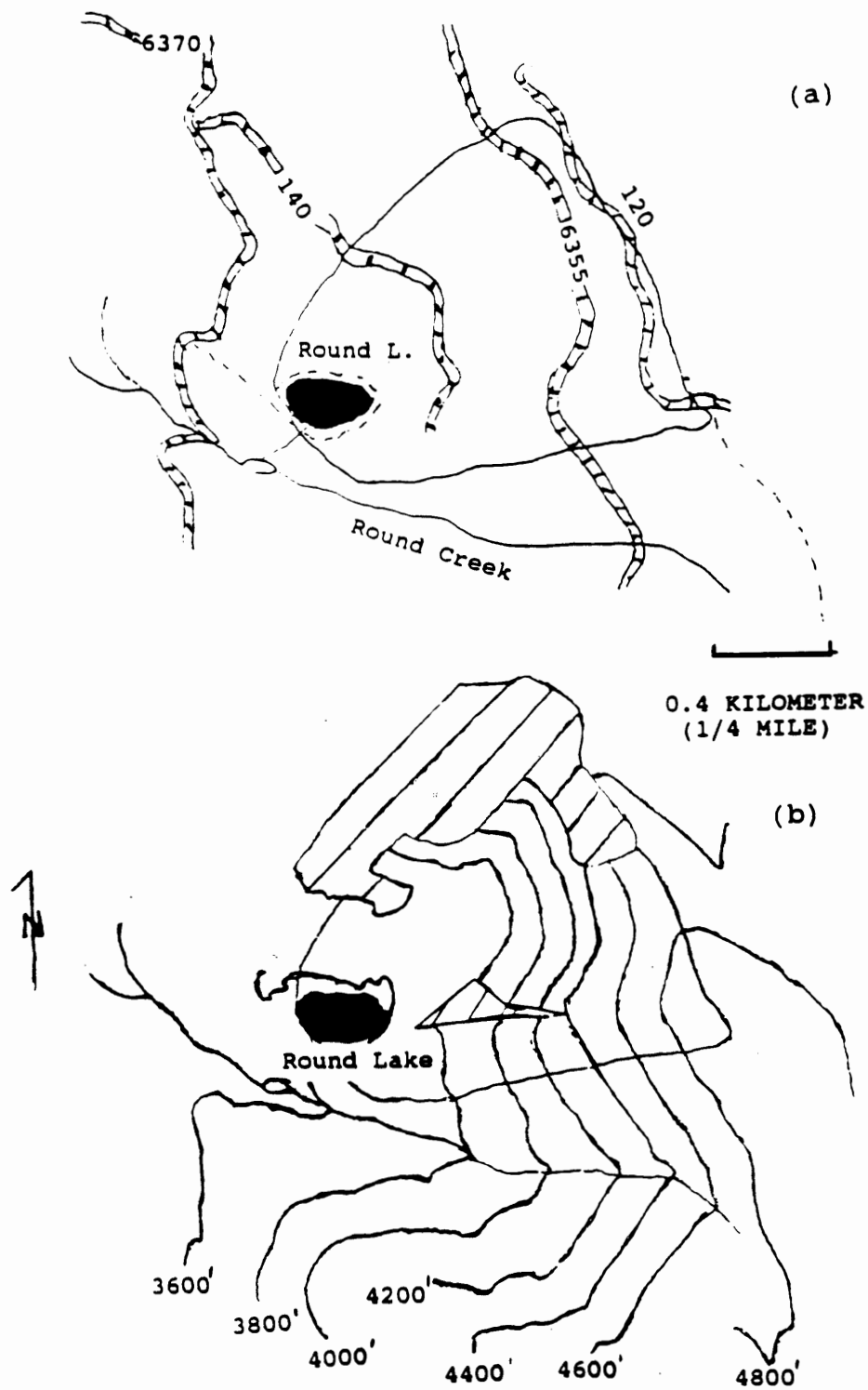
Round Lake is a popular recreational/fishing spot. Campsites are found on both sides of the lake. Fishing rafts constructed from logs cut from the nearby woods, can be found floating near the shoreline along the eastside (Figure 11).

#### SPORTSMAN LAKE

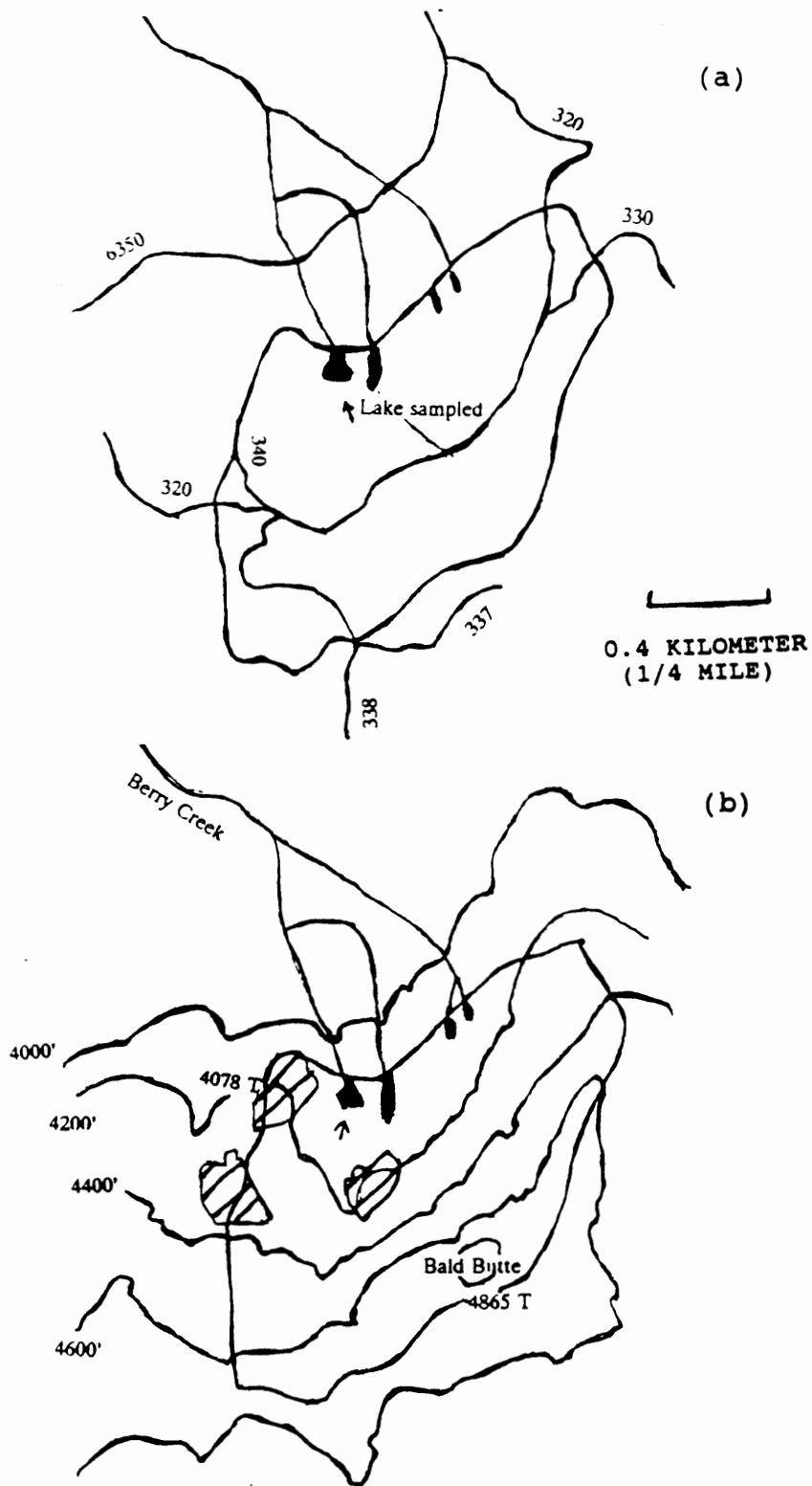
Sportsman Lake is located approximately 48 km (30 mi) south of Ripplebrook Ranger Station (Figure 2). It can be found on the Breitenbush Hot Springs topographical quadrangle map at T9S, R7E, Sec. 2.

The Sportsman Lake watershed has contour relief of approximately 251.1 m (825 f). The watershed is bordered by Bald Butte on the south and by two large clearcuts on the northwest. There is an extensive forest road system throughout the watershed (Figure 12).

Within the watershed are two basins. Collectively these basins are called Sportsman Lakes. The basin studied for this report is the westernmost one, which is located in



**Figure 11.** Road and trail systems (a), and contours and clearcuts (b), for the Round Lake drainage basin. Clearcuts are designated by hatchlines.



**Figure 12.** Road and trail systems (a), and contours and clearcuts (b), for the Sportsman Lake drainage basin. Clearcuts are designated by hatchlines.

section 2 of the U.S.G.S. topographical quadrangle map. The other basin is in section 1. There is a ridge between the 2 basins.

The western Sportsman Lake basin is shallow throughout. The maximum recorded depth was 1.5 m (4.9 f; TABLE I), but precise depth measurements were unobtainable because of the soft-mud bottom. The deepest part of the lake is on the north side. Emergent vegetation is found throughout. The lake supports a generous population of salamanders (Taricha granulosa). On one sampling occasion there appeared to be fish rising, but no fish were actually seen. There was a beaver observed swimming around its nest-site on the southwest side of the lake.

There has been a significant amount of timber cutting activity within the Sportsman Lake watershed but there was no evidence of significant recreational use.



## MATERIALS AND METHODS

### FIELD OBSERVATIONS

Upon arrival at the sampling site a photograph was taken, and a general description of the lake and surrounding landscape was recorded in a field notebook. The description included general information concerning topography and vegetative patterns of the shoreline. Other initial observations recorded included the locations of trails, roads, and campsites.

After the initial description was recorded, the boats were prepared and the on-lake sample and data collection initiated. Each lake was sampled at what appeared to be its deepest point as revealed by a Humminbird<sup>R</sup> LCR 400 depth sounder. Temperature and dissolved oxygen profiles were taken from at least five depths per lake unless the lake was shallower than 1.25 m. Only 4 depth intervals were profiled on Anvil and Cripple Creek Lakes' since they are barely over a meter deep.

All samples were collected in linear polyethylene (LPE) bottles. The bottles were acid washed and rinsed thoroughly in distilled/deionized water, prior to sample collection. A Scott Bottle (Scott Instruments, Seattle, Wa) was used for sampling specific depths in stratified lakes. In shallow

unstratified lakes an integrating sample bottle (homemade) was used.

#### TEMPERATURE AND DISSOLVED OXYGEN

Vertical profiles of temperature and dissolved oxygen were obtained using a YSI model 158 dissolved oxygen meter. First the temperature readings and then the readings for dissolved oxygen concentration were recorded at each successive depth interval. Readings were taken at a minimum of 5 depth intervals in lakes of sufficient depth. However, in most cases more than 5 depths (usually many more) were recorded. In the deeper lakes, readings were obtained at 1-meter depth intervals down to within 1-meter from the bottom. In the relatively shallow lakes, intervals of 0.25 m were taken. The probe was intentionally kept from contacting bottom sediments since stirring up bottom particulates could affect oxygen readings.

Oxygen concentration values were also determined using the Winkler titration method. This technique gives more accurate values for oxygen concentration than does the YSI meter but is more time-consuming. For this reason, the Winkler method was performed on water samples taken at depths of one meter and at the approximate depth of the upper one-third of the metalimnion.

## ALKALINITY AND CONDUCTIVITY

Samples were collected from each lake in LPE bottles for measuring alkalinity. The alkalinity samples were returned to the laboratory where they were titrated with .02 N H<sub>2</sub>SO<sub>4</sub> to a pH of 4.0 or less. An Orion Ionalyzer Specific Meter model 404 was used for the titrations. The alkalinity end points were determined by the Gran Plot method (Stumm and Morgan, 1981) from the range of values between pH 5 and pH 4.

A YSI (Yellow Springs Instrument Co.) model 33 SCT conductivity meter was used in the field to obtain a vertical profile of conductivity. Care was taken to assure that bottom sediments were not stirred up while performing the tests.

## LIGHT AND SECCHI DEPTH

When possible a light meter was taken into the field. Two different meters were used. The meters used were the Licor model LI 185-B and the Licor-1000 Data Logger. Both meters read light intensity in microEinsteins per meter squared second ( $\mu$ Einsteins/m<sup>2</sup> sec).

Light meter readings were taken at at least five depths except in extremely shallow lakes (1.5 meters or less). Extremely shallow lakes are easily 'muddied' by the stirring of bottom sediments by the light apparatus.

Water transparency was measured with a 20 centimeter

Secchi disk. The disk was lowered into the water until it disappeared, then raised through the column until it again became visible. That depth was also recorded. These two values were averaged for the final Secchi depth value.

#### MAJOR IONS

Samples were taken for major ion analysis. Major ion analysis was performed using a Perkin-Elmer model 305-B Atomic Absorption Spectrometer. Atomic absorption data were obtained for concentrations of calcium, magnesium, potassium, and sodium.

#### NUTRIENTS

Samples were taken from two depths for nutrient analyses, except in the extremely shallow lakes. Samples were collected at a depth of one meter and also at a depth of approximately the upper one-third of the metalimnion. The bottles were placed on ice as soon as possible.

The nutrient analyses were were performed in the laboratory. The concentrations of nitrate, ammonia, total phosphorus, soluble reactive phosphorous (SRP), and silica were determined using a Milton Roy model 401 spectrophotometer.

All laboratory nutrient analysis containers were prepared according to the following procedure. They were soap washed, tap water rinsed, rinsed six times in

distilled/deionized water, acid soaked (6 hours minimum), soaked in distilled/deionized water, and again rinsed six times in distilled/deionized water.

Nitrate-nitrogen analysis was performed via the reduction of cadmium method (Jones 1984). Soluble reactive phosphorus, total phosphorus, and silica analyses were performed as outlined by Wetzel and Likens (1979).

#### PHYTOPLANKTON

Waters samples were collected from the one meter depth and, if the lake was stratified, from the metalimnion. Each 250 ml bottle was treated with approximately 2.5 ml of Lugol's solution for preservation.

Phytoplankton were identified to at least genus and algal biomass values were obtained.

#### ZOOPLANKTON

One vertical tow for zooplankton was taken from each lake. The nets used were manufactured by Research Nets Incorporated (Seattle, Wa.). These nets have a mesh size of 73 microns. Two different nets were used. One had a diameter of 20 centimeters, the other a diameter of 36 centimeters.

The tows were made from just off the bottom to the surface. Approximately 150-200 ml of zooplankton sample were preserved with approximately 2.5 ml of formalin.

Butylated Hydroxy Toluene (BHT) was added to preserve color. Zooplankton were identified to species in most cases.

#### CHLOROPHYLL-A

At each lake, two 250 ml samples (one for each significant depth) were collected and filtered through a Whatman GF/F 47mm glass filter. Each filter was treated with  $MgCO_4$  and put on ice as soon as possible. Also, the filters were covered with tinfoil to eliminate the possibility of chlorophyll being degraded by ambient light.

The filters were brought back to the lab where they were immediately frozen. They were then ground with a tissue grinder after which the values for chlorophyll-a were obtained using a Turner Designs model 10 fluorometer.

## RESULTS

### TEMPERATURE AND DISSOLVED OXYGEN

Temperature and dissolved oxygen data were obtained twice in 1991 and once in 1992 (APPENDIX B).

In Anvil Lake the oxygen concentration was at saturation levels at all depths on all sampling dates. This is consistent with lakes that are relatively shallow and oligotrophic.

Anvil Lake is readily mixed throughout. Evidence of this is the near isothermal conditions throughout the water column. On July 8, 1991 the temperature was 19.1 degrees Celsius ( $^{\circ}\text{C}$ ) at the surface and 18.4 degrees on the bottom. On August 22, 1991 the surface temperature was 22.9  $^{\circ}\text{C}$  with a bottom temperature of 21.1. On July 4, 1992 the surface temperature was recorded at 18.0  $^{\circ}\text{C}$  with a bottom temperature of 17.1 degrees.

Beaver Pond Lake showed the greatest oxygen debt at depth. During the month of August 1991 the lake was well stratified with a thermocline at about 1.5 m. By October the lake was well mixed (according to the temperature profiles) and the whole water column was nearly anoxic (less than 2 mg/L  $\text{O}_2$ ). This is the result of bacterial respiration. It was also noted during the sampling that the

color (extremely dark) and odor (a musky sulphur smell) of the water suggested anoxia.

On June 24, 1991 the surface temperature of Beaver Pond Lake was recorded at 15.6 °C and the bottom temperature recorded was 11.9 degrees. The surface temperature of the lake reached a high of 22.2 degrees C. with a bottom temperature of 13.7 on August 23, 1991. On October 25, 1991 the surface temperature was 7.8 degrees with a bottom temperature of 7.7 (Figures 13 and 14).

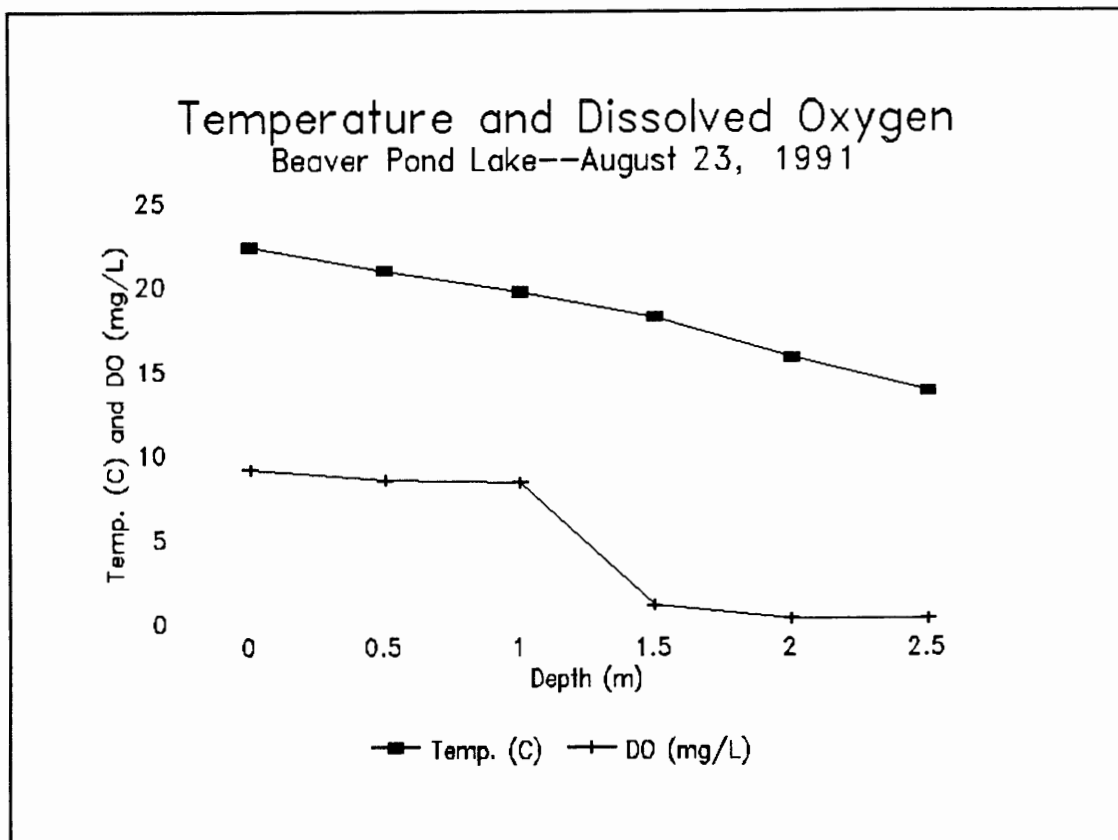
Cripple Creek Lake is relatively shallow and has a long fetch. Lakes with such morphometric characteristics are readily mixed. Data for Cripple Creek Lake showed only slight temperature variations with depth. Also, the oxygen concentration levels recorded were near saturation levels (APPENDIX B).

The temperature of Cripple Creek Lake reached a high of 19.4 °C at the surface and a low of 16.7 on the bottom on July 7, 1991. On August 21, 1991 a surface temperature of 22.0 °C was recorded with a bottom temperature of 22.4. And finally, on July 24, 1992 the recorded surface temperature was 17.6 degrees with a bottom temperature of 16.8.

Fish Lake is the deepest lake of the 10 studied. It is stratified during the summer with a thermocline at between 6 and 7 meters (depending upon the time of year). At that depth a significant dissolved oxygen peak was noted.

On July 1, 1991 the surface temperature recorded was





**Figure 13.** Temperature and dissolved oxygen profiles for Beaver Pond Lake for August 23, 1991 sampling.

16.5 °C. At the thermocline the temperature had decreased to 9.1 degrees. At the same time an orthograde dissolved oxygen profile was recorded. The temperature in the hypolimnion was 4.2 degrees. The same pattern was observed during the two successive samplings (Figure 15).

Gifford Lake is closely similar to Fish Lake in many respects. On its shoreline are distinct rock slides descending into the water. Its shape is similar to Fish Lake and it too is relatively deep, therefore it is not surprising that Gifford Lake showed a similar dissolved

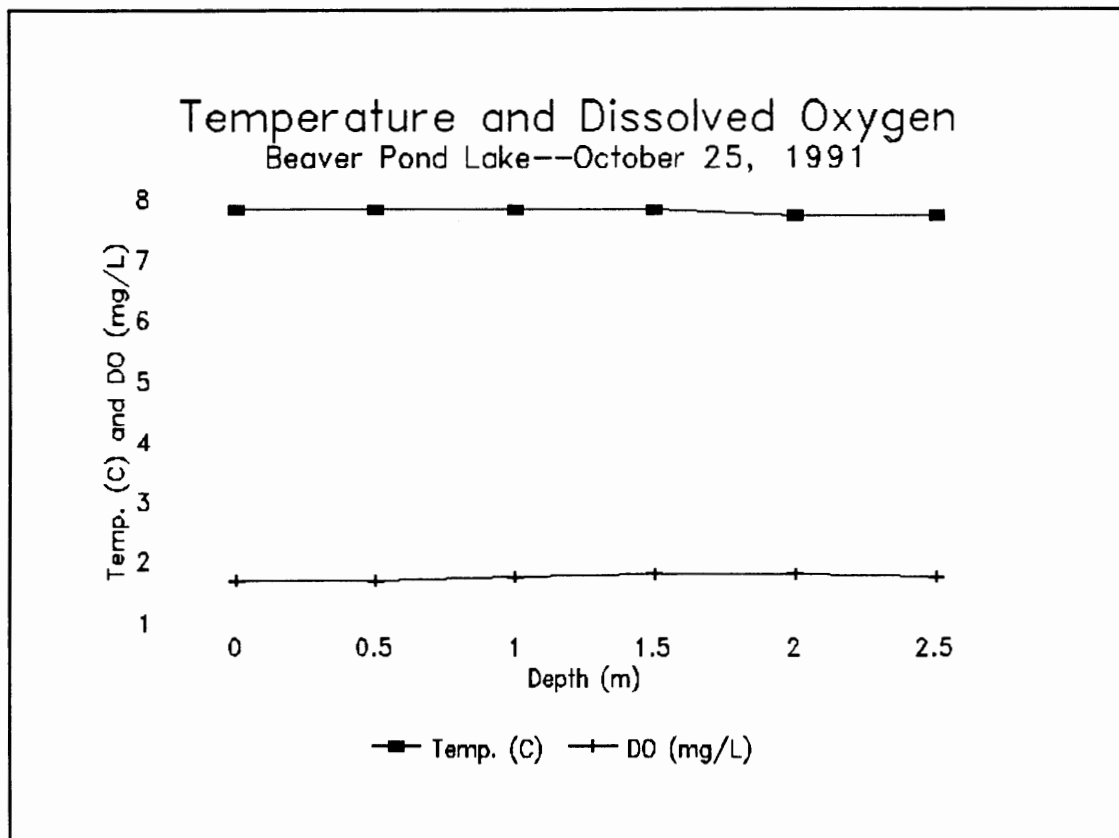


Figure 14. Temperature and dissolved oxygen profiles for Beaver Pond Lake for October 25, 1991 sampling.

oxygen profile with depth. However, stratification was not as well defined in Gifford as was the case in Fish Lake, and all depths showed oxygen concentrations at saturation.

The surface temperature of Gifford Lake was recorded at 16.4 °C on July 2, 1991 with a bottom temperature of 6.6 degrees. On August 29, 1991 the recorded surface temperature was 18.1 degrees with a bottom temperature of 12.4. And finally, on July 17, 1992 the surface temperature recorded was 21.4 degrees with a bottom temperature of 12.0.

Like Fish and Gifford lakes, Monon Lake is a relatively

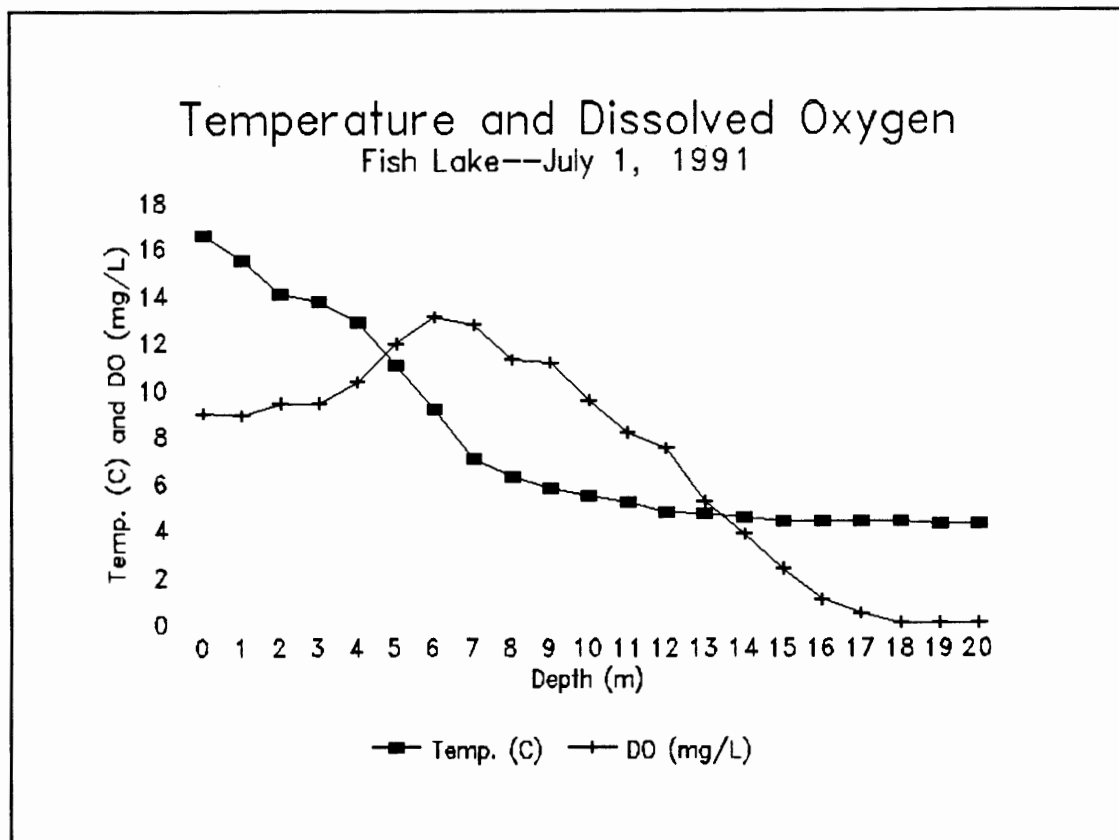


Figure 15. Temperature and dissolved oxygen profiles for Fish Lake for July 1, 1991 sampling.

large and deep system. The lake was saturated with oxygen on every sampling at every depth.

On June 29, 1991 Monon Lake had a surface temperature of 13.4 °C and a bottom temperature of 8.5. It showed an orthograde dissolved oxygen profile to the bottom.

On September 1, 1991 and on July 11, 1992, the lake was thoroughly mixed with very little temperature variability throughout the depth of the water column (APPENDIX B).

Ollalie Lake has the largest surface area of any of the of the lakes studied. Although it is relatively deep, it showed no sign of stratification during any of the sampling

dates. The lake is located within an open basin and has a relatively long fetch. For this reason the lake is well mixed throughout the summer months.

On June 30, 1991 the surface temperature reached 12.6 °C with a temperature of 11.3 at the 10 meter depth. On September 2, 1991 the temperature range from surface to bottom showed no significant variation from the surface reading of 17.3 degrees. On July 16, 1992 the surface temperature recorded was 18.0 degrees and the bottom temperature was 17.8. On all dates (and at all depths) Ollalie Lake showed saturation levels of dissolved oxygen.

Round Lake is stratified throughout the summer months. On July 8, 1991 the surface temperature recorded was 20.6 °C. The thermocline was at approximately 2 meters. The bottom temperature recorded was 9.6 degrees. On August 24, 1991 the surface temperature recorded was 20.2 °C. At the 3 meter depth (the upper metalimnion) the temperature had decreased to 17.5 degrees and the bottom temperature recorded was 12.5. Finally, on July 3, 1992 the surface temperature was 19.9 °C with a temperature of 16.5 at the 3 meter depth and a bottom temperature of 9.4.

The epilimnion of Round Lake was saturated with oxygen at all depths except at the 2-3 meter depth, where supersaturation was observed. This was probably the result of a metalimnetic algal bloom. Although the data collected on July 3, 1992 showed an inconsistent profile at 7-8 m

depth, this datum is believed to be erroneous due to having oxygen probe in the mud (Figure 16).

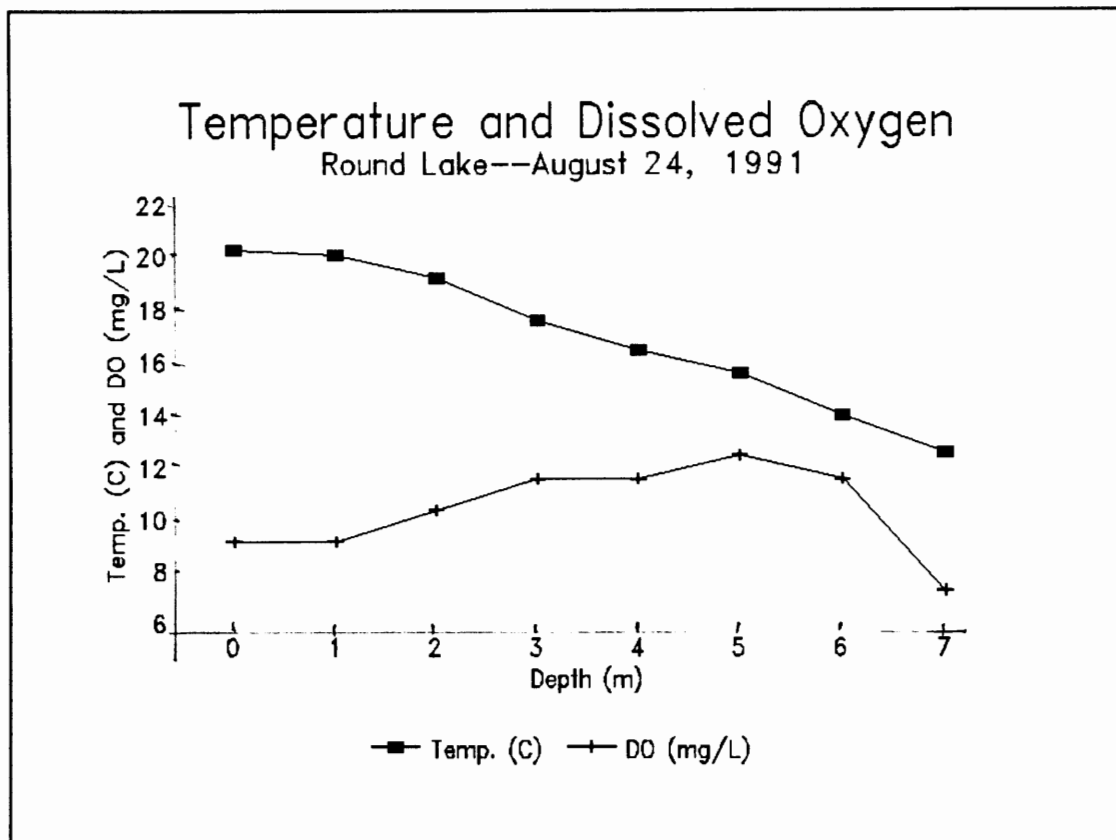


Figure 16. Temperature and dissolved oxygen profiles for Round Lake for August 24, 1991 sampling.

Rimrock Lake is relatively shallow like Anvil, Cripple Creek, and Sportsman Lakes. On July 3, 1991 it had a surface temperature of 18.8 °C and a bottom temperature of 15.7. On August 30, 1991 the temperature at the surface was 15.9 degrees and the bottom temperature was recorded to be 16.0. On July 16, 1992 the surface temperature was 20.5 °C with a bottom temperature of 19.5. On all sampling dates this thoroughly mixed lake was saturated throughout with

dissolved oxygen.

Sportsman Lake showed temperature and dissolved oxygen profiles consistent with the shallower lakes of this study. This lake was well mixed throughout the summer and the oxygen concentrations were always at saturation.

On July 4, 1991 the surface temperature was recorded at 21.5 °C and the bottom (1.25 meter depth) temperature was 18.5. On August 19, 1991 the surface temperature was 24.0 degrees with a bottom temperature of 21.6. On July 25, 1992 the surface temperature was 22.0 degrees with a bottom temperature of 18.6 (Appendix G).

#### WATER TRANSPARENCY: LIGHT INTENSITY AND SECCHI DEPTH

Figures 17 through 24 show the light extinction patterns through the water columns for all but Anvil and Round Lakes. These data are direct photometric measurements. A photometer was not available on the Anvil and Round lakes sampling dates. TABLE II contains the Secchi depth measurements for each lake that was deep enough to allow these tests. Also in TABLE II are two columns of light extinction coefficients. The second column contains the extinction coefficients calculated as a regression from the natural log of the light intensities versus depth. The third column presents the calculated coefficients. These extinction coefficients were calculated from the Secchi Disk measurements (TABLE II).

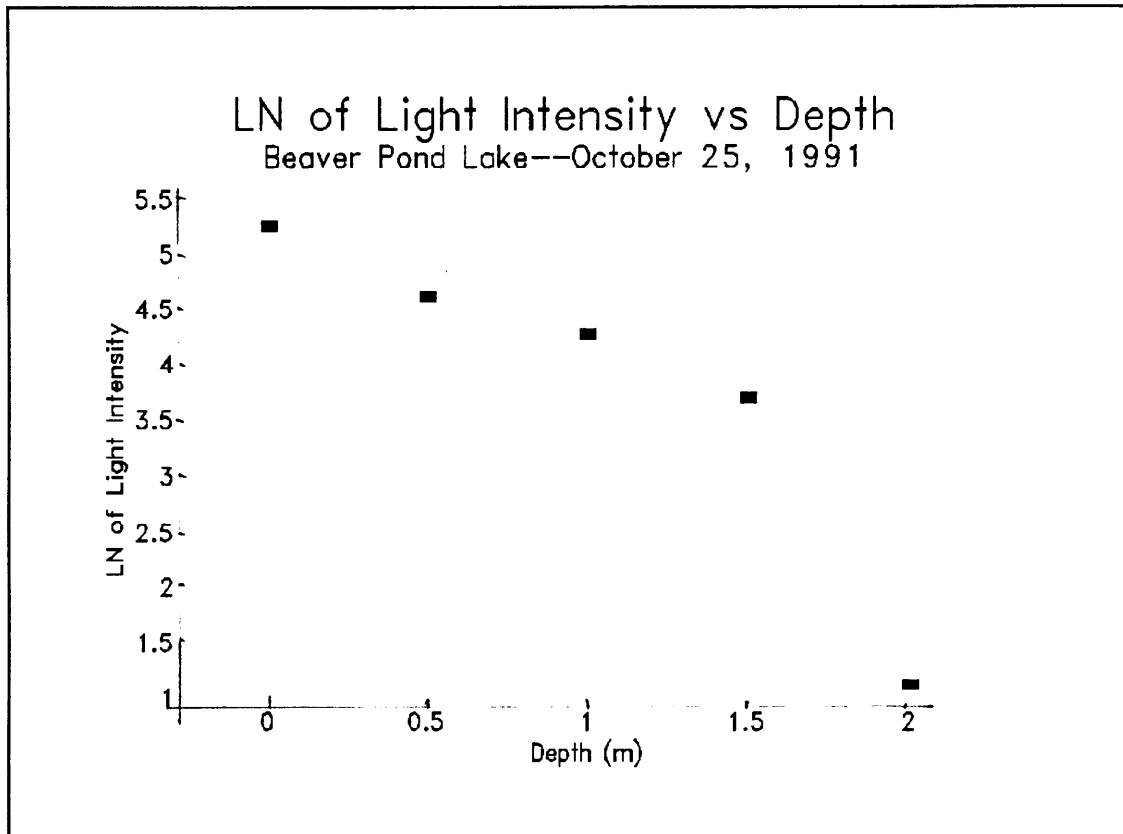


Figure 17. Light intensity versus depth for Beaver Pond Lake for October 25, 1991.

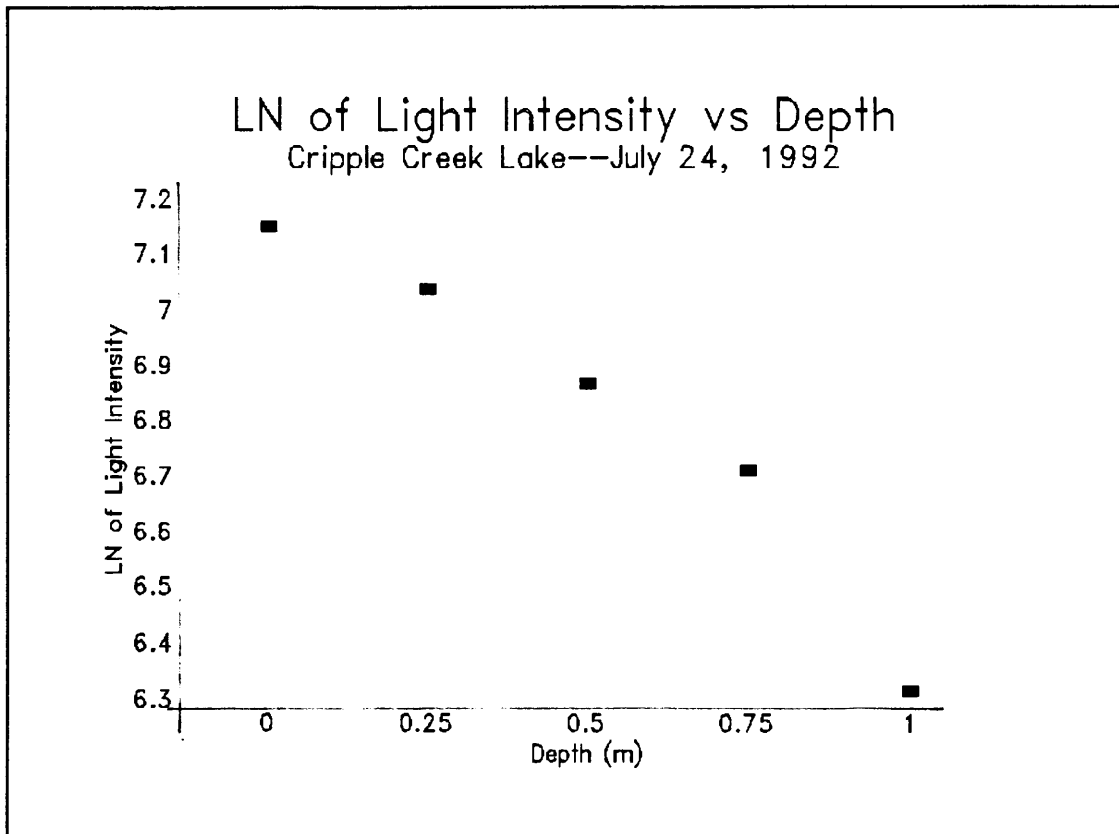


Figure 18. Light intensity versus depth for Cripple Creek Lake for July 24, 1992 sampling.



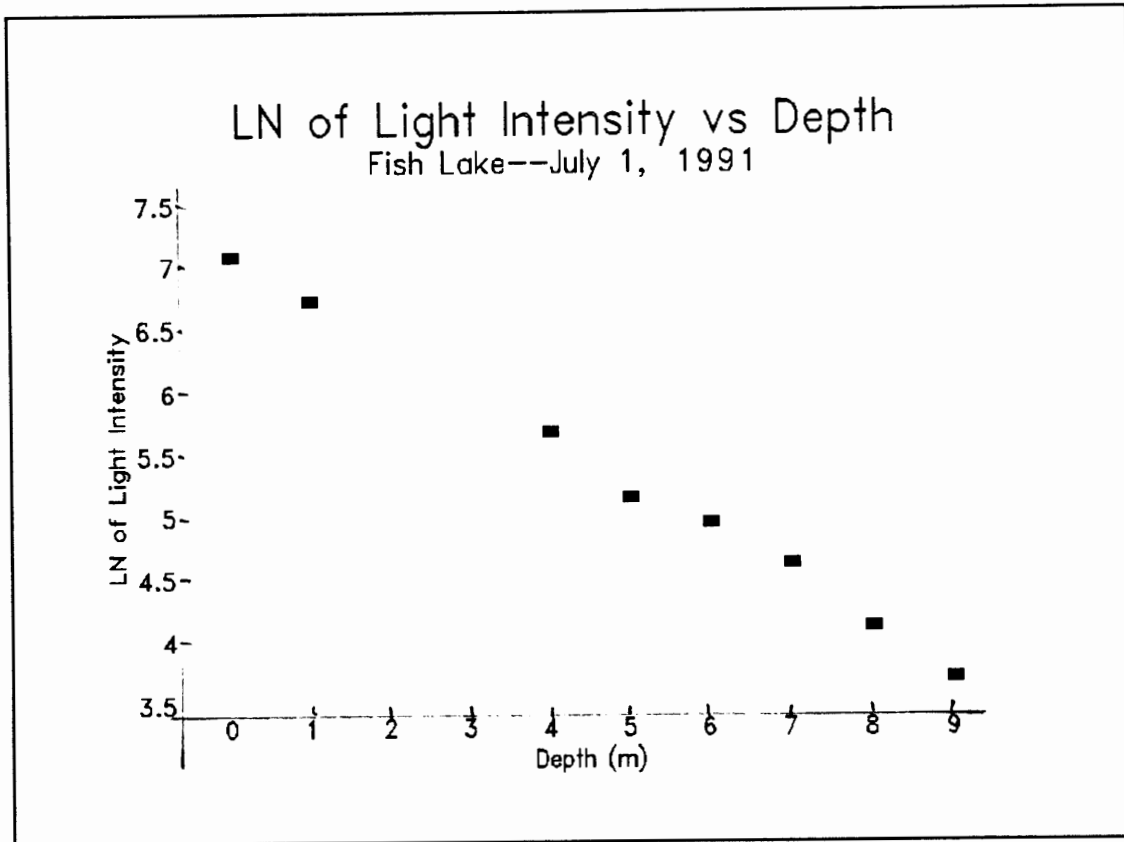


Figure 19. Light intensity versus depth for Fish Lake for July 1, 1991 sampling.

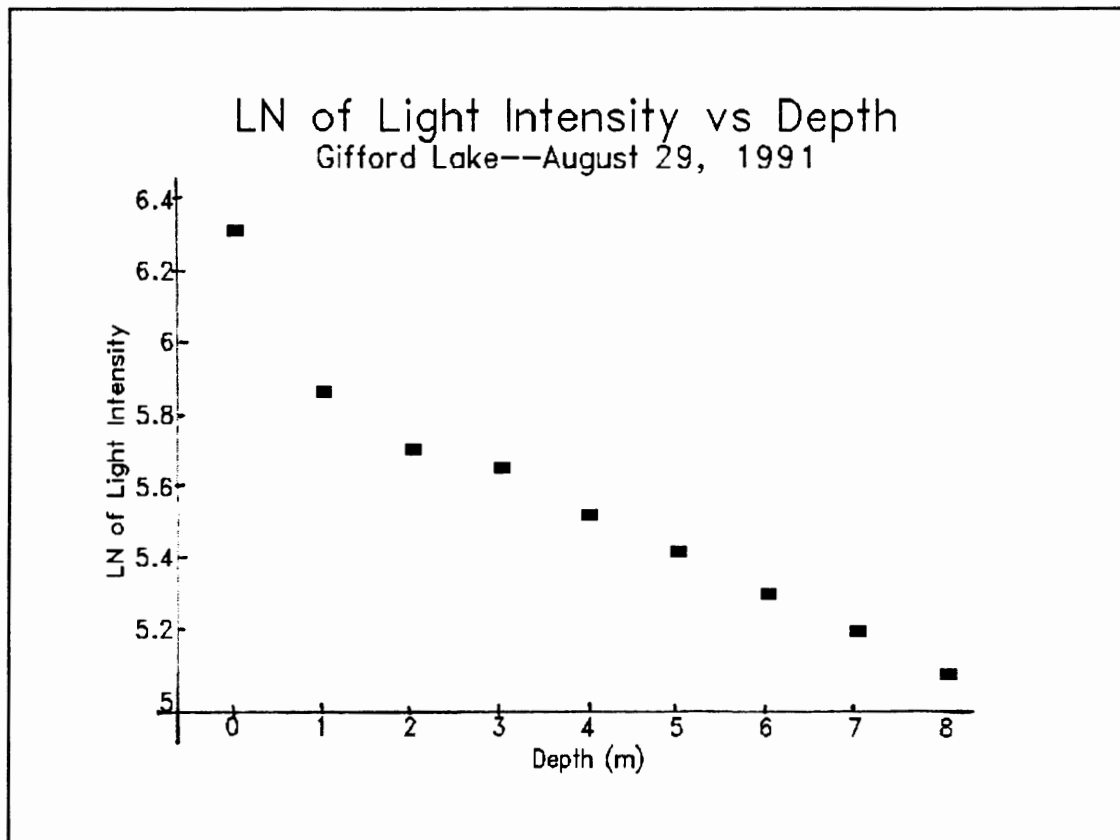


Figure 20. Light intensity versus depth for Gifford Lake for August 29, 1991 sampling.

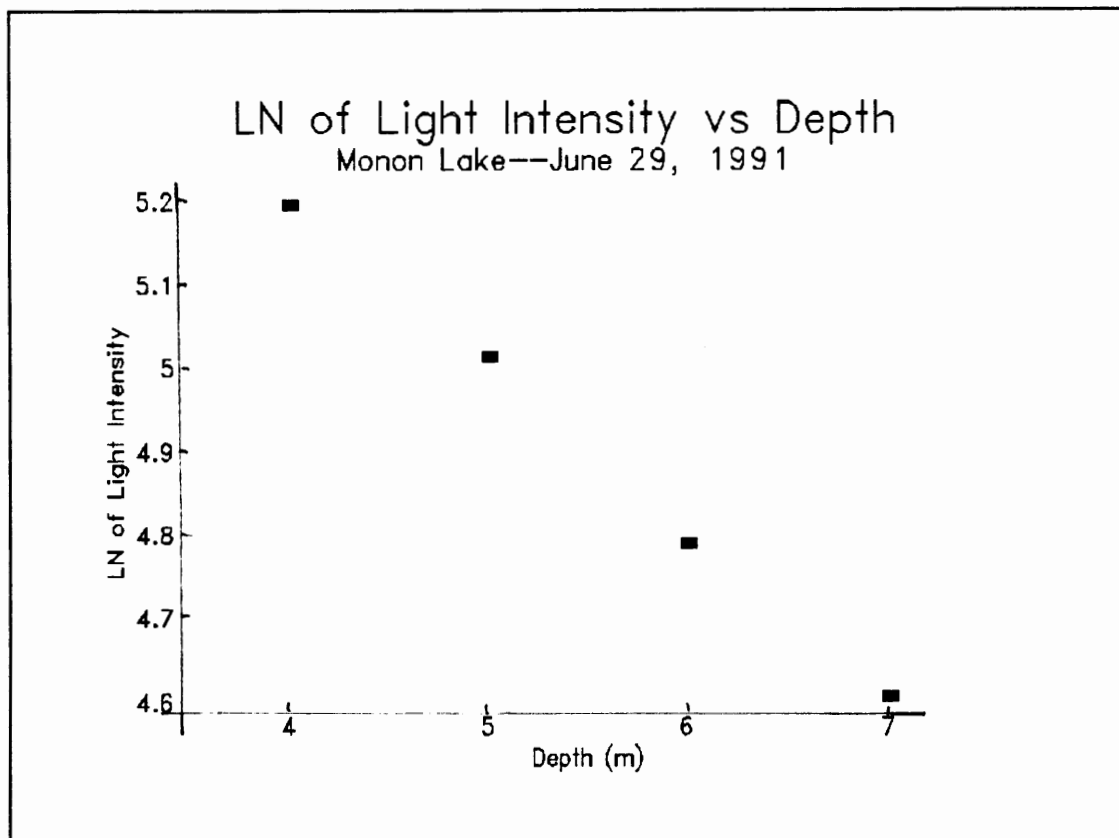


Figure 21. Light intensity versus depth for Monon Lake for June 29, 1991 sampling.

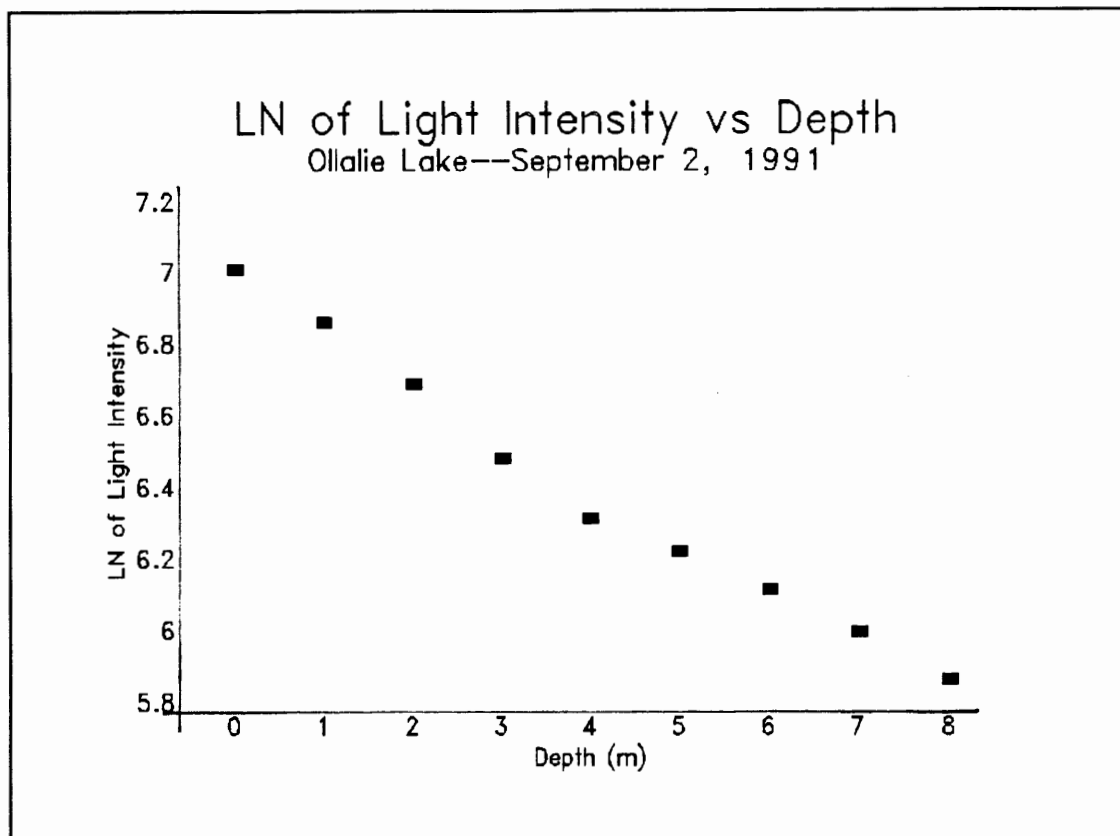


Figure 22. Light intensity versus depth for Ollalie Lake for September 2, 1991 sampling.

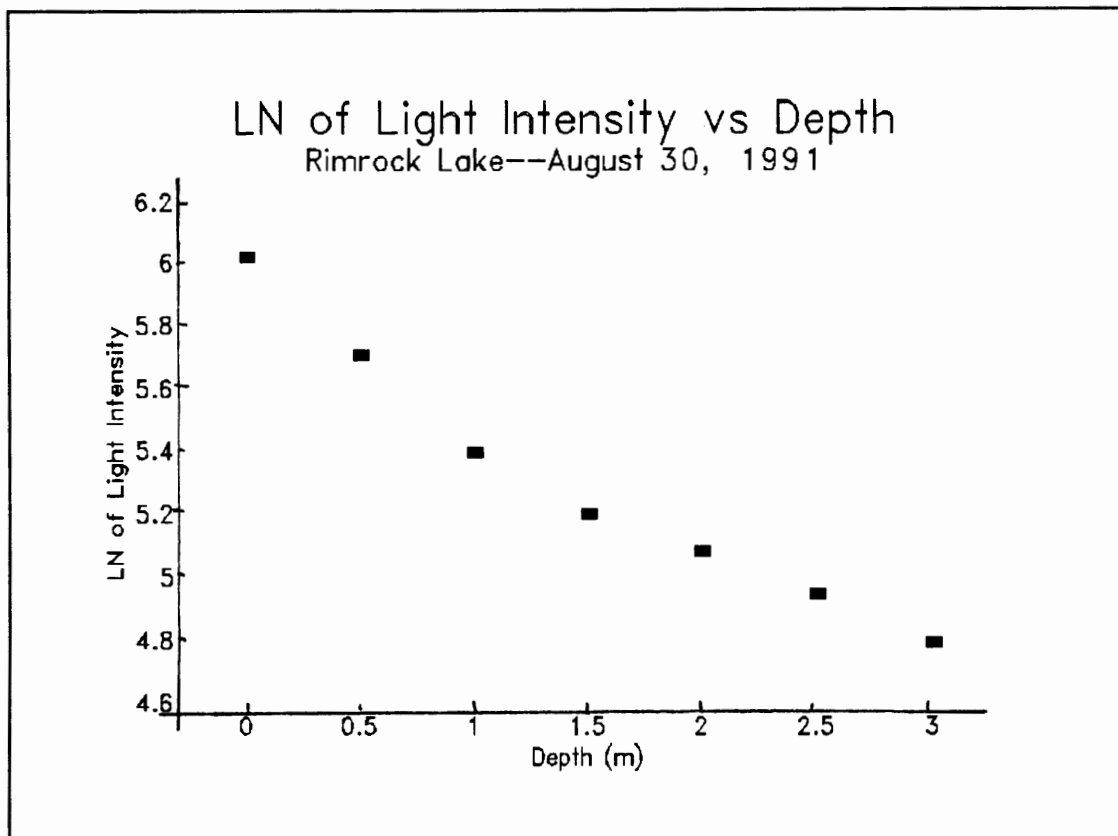


Figure 23. Light intensity versus depth for Rimrock Lake for August 30, 1991 sampling.

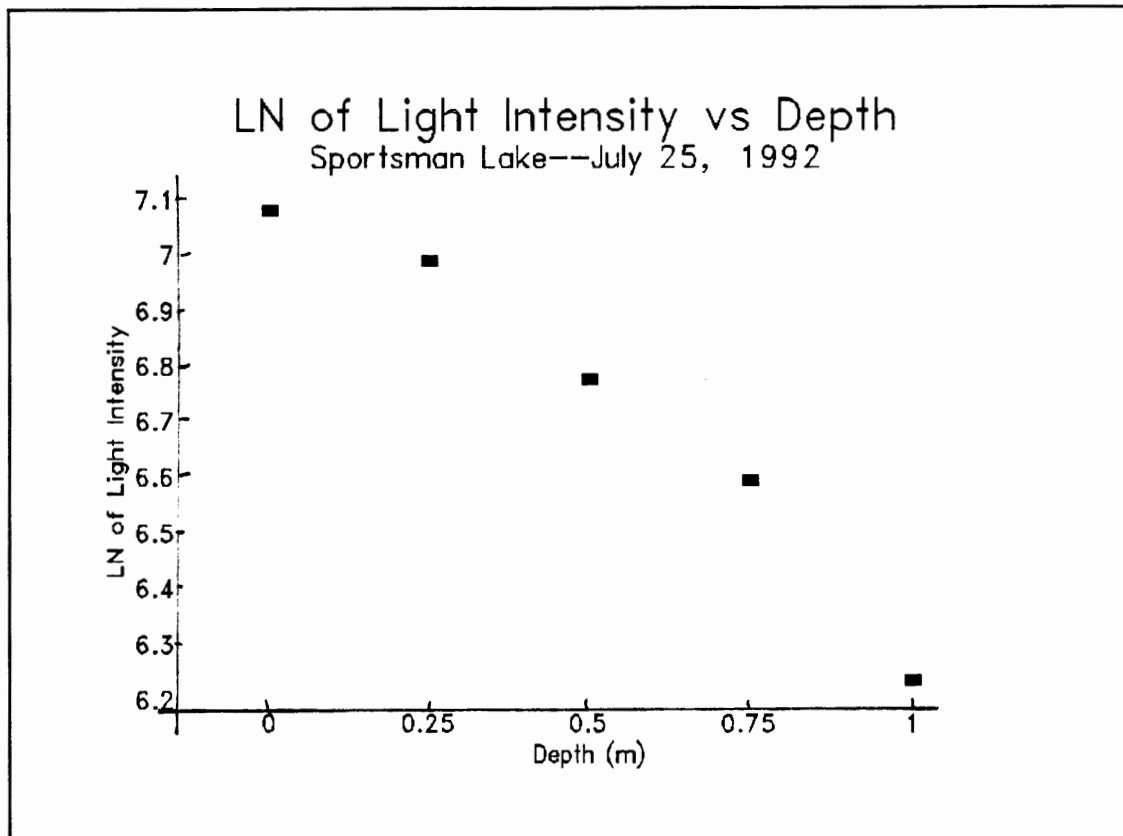


Figure 24. Light intensity versus depth for Sportsman Lake for July 25, 1992 sampling.

It is possible to compare the extinction coefficients which were calculated from photometric data ( $E_p$ ) with the extinction coefficients estimated from the Secchi depth data ( $E_{SD}$ ). Secchi depth is approximately 10% of the surface light intensity. The formula for determining the extinction coefficient using Secchi data is  $E = 1.7 z_{SD}$  (taken from empirical data) where  $z$  is the mean Secchi depth (Wetzel, 1983).

TABLE II  
WATER TRANSPARENCY DATA

	SD (m)	$E_{SD}$	$E_p$
Anvil	s.	-	n.d.
Beaver Pond	1.70	1.00	1.00
Cripple Creek	s.	-	0.59
Fish	4.96	0.34	0.38
Gifford	13.6	0.12	0.11
Monon	8.6	0.19	0.20
Ollalie	13.2	0.13	0.14
Rimrock	s.	-	0.39
Round	5.11	0.33	n.d.
Sportsman	s.	-	0.67

s. = too shallow for Secchi measurements

n.d. = no data

The euphotic zone is an estimation of the depth to which photosynthetic activity can be maintained as a function of light availability. It is commonly assumed that the euphotic zone extends to the depth at which light intensity has decreased to 1% of surface light intensity. The 1% light intensity can be calculated from the equation  $z = \ln (.01)/E$ , where  $z$  is the depth at the 1% intensity and  $E$

is the extinction coefficient. It was determined that all of the lakes except Fish Lake have sufficient light at the bottom of the water column for photosynthetic activity. In Fish Lake the light availability fell below the necessary 1% at just over 12 meters. The assumption that little photosynthesis is occurring below this depth is consistent with the dissolved oxygen data for this lake (Figure 15).

#### NUTRIENTS

Most chemical compounds found in fresh water systems are found in concentrations high enough to meet the demands of the phytoplankton and other aquatic flora. These compounds are the structural components of plant and algal cells and therefore limit population densities.

In freshwater lakes it is most commonly phosphorus (available only in the  $PO_4$  form) which is the limiting nutrient. Therefore any allochthonous source of phosphorus such as human or animal waste or dishwashing detergent, can significantly increase phytoplankton standing crop.

Lakes are sometimes deficient in fixed nitrogen. Often lakes which are low in nitrogen but which have sufficient phosphorus support relatively large populations of blue-green algae. These algae can fix atmospheric nitrogen, into a form which can be assimilated by the cells.

Silicon is a nutrient which is utilized by diatoms. It is a structural component of the frustule. Therefore silica



concentration data is valuable when doing a lake study.

TABLE III contains the data for the concentrations of nitrite-nitrogen, ammonium-nitrogen, phosphate-phosphorus, total-phosphorus, and silicate.

#### MAJOR IONS, CONDUCTIVITY, AND ALKALINITY

There are seven major inorganic ions present in fresh water lakes (TABLE IV). Major cations are calcium, magnesium, sodium, and potassium; major anions are carbonates (primarily bicarbonate), sulfate and chloride. These ions are responsible for 99% of the salinity in natural inland waters.

The major ion data offers information concerning the lake substrate, drainage basin rock sources, wet-dry deposition, evaporation/precipitation balance (Wetzel, 1979), alkalinity, and conductivity (TABLE V).

Conductivity measurements provide important information as to the total ionic composition of the lake. Relatively low conductivities often indicate oligotrophic conditions.

The alkalinity of lake water measures the ability of the water to resist acidification. These data are of value when making long term management decisions. The alkalinity, or acid neutralizing capacity is a description of the lakes' ability to withstand a significant allochthonous influx of acidic compounds (acidic precipitation, industrial wastes, etc.). Alkalinity data obtained from mountain lakes are

TABLE III

## NUTRIENT DATA

	NO <sub>3</sub> -N (ug/L)	NH <sub>4</sub> -N (ug/L)	PO <sub>4</sub> -P (ug/L)	P <sub>T</sub> (u/L)	SiO <sub>2</sub> (mg/L)
<b>Anvil</b>					
7/8/91	2.11	0.02	19.2	1.04*	10.6
8/22/91	2.15	0.04	9.75	13.1	12.9
DEPTH=.5m	1.63	0.05	11.2	19.8	12.9
7/4/92	7.85	0.06	3.14	4.57	1.20
<b>Beaver Pond</b>					
6/24/91	12.5	0.27	8.46	51.6	14.5
DEPTH=2.5m	5.97	0.27	2.75	92.7	16.0
8/23/91	2.30	0.03	47.6	219.0	11.3
DEPTH=2m	5.10	0.06	71.9	146.0	14.9
10/25/91	7.10	0.07	114.0	554.0	15.0
DEPTH=2m+	6.40	0.11	114.0	496.0	14.1
<b>Cripple Creek</b>					
7/7/91	2.10	0.04	23.2	36.4	13.9
8/21/91	1.70	0.05	11.2	18.3	16.1
REP.	1.81	0.06	10.5	17.6	16.2
7/24/92	1.03	0.05	9.34	43.4	10.9
<b>Fish</b>					
7/1/91	3.55	0.01	0.85	54.8	9.67
DEPTH=12m	3.95	0.01	1.49	72.8	10.7
8/30/91	3.95	0.01	1.49	72.8	10.7
DEPTH=7m	1.53	0.12	0.35	27.4	9.35
7/7/92	0.99	0.02	3.36	44.3	10.7
DEPTH=7m	1.45	0.13	3.36	93.0	9.45
<b>Gifford</b>					
7/2/91	3.49	0.06	0.27	24.0	1.28
DEPTH=11m	3.19	0.06	0.20	12.7	1.04
8/29/91	1.61	1.32	2.59	30.5	n.d.
DEPTH=11m	1.59	1.33	4.10	33.6	n.d.

TABLE III  
NUTRIENT DATA  
(continued)

Monon						
6/29/91	2.14	0.01	0.62	10.4	2.13	
DEPTH=10m+	1.74	0.01	0.72	11.4	1.44	
9/1/91	1.33	0.01	b.d.	5.70	2.56	
DEPTH=8m	1.59	0.02	1.87	22.0	2.53	
7/11/92	9.70	0.02	13.4	53.3	3.00	
Ollalie						
6/30/91	1.85	0.02	0.57	24.0	1.34	
9/2/91	1.45	0.00	b.d.	1.63	1.43	
DEPTH=10m	1.51	0.01	b.d.	7.05	1.52	
7/16/92	0.87	0.01	2.27	34.0	2.27	
DEPTH=10m	0.95	0.02	2.09	35.6	0.24	
Rimrock						
7/3/91	3.36	0.01	0.81	23.6	0.79	
DEPTH=1.5-3m	3.85	0.03	0.81	26.4	0.71	
8/30/91	2.04	1.34	3.35	25.9	n.d.	
DEPTH=1.5-3m	1.55	1.37	4.10	29.7	n.d.	
7/16/92	0.78	0.02	11.6	21.4	0.28	
Round						
7/8/91	2.09	0.02	32.5	7.16	22.4	
8/24/91	2.35	0.05	15.0	45.8	21.1	
DEPTH=6m	1.71	0.02	30.2	77.4	20.8	
7/3/92	7.60	0.02	3.07	9.32	2.01	
DEPTH=5m	7.81	0.06	2.99	11.1	2.39	
Sportsman						
7/4/91	2.17	0.02	1.22	56.9	10.5	
8/19/91 (.5m)	1.10	0.07	75.4	32.4	6.11	
DEPTH=1m+	0.87	0.07	77.6	33.1	6.05	
7/25/92	1.45	0.08	8.97	27.5	4.51	

n.d. = no data

b.d. = below detection

\* = outlier

TABLE IV

## MAJOR IONS

	Ca <sup>+2</sup>	Mg <sup>+2</sup>	K <sup>+</sup>	Na <sup>+</sup>	Cl <sup>-</sup>	SO <sub>4</sub>	HCO <sub>3</sub>
ANVIL							
7/8/91	2.73	1.32	0.15	1.37	n.d.	0063	170.0
8/22/91	3.99	2.45	0.11	1.91	0.50	0.66	327.2
BEAVER POND							
6/24/91	6.88	2.39	0.44	4.33	0.85	0.73	472.5
REP.	7.55	2.10	0.52	4.23	0.73	0.87	
8/23/91	9.06	2.25	0.28	4.36	0.90	0.53	594.4
10/25/91	13.5	3.97	0.92	5.91	1.56	2.51	675.0
CRIPPLE CREEK							
7/7/91	3.50	0.61	0.27	1.93	1.72	2.38	191.3
8/21/91	3.33	0.97	0.24	2.03	0.15	0.87	237.5
FISH							
7/1/91	2.60	0.45	0.48	1.38	0.02	0.62	103.5
8/30/91	2.09	0.54	0.48	1.42	b.d.	0.62	135.2
GIFFORD							
7/2/91	0.37	0.07	0.13	0.33	b.d.	5.60	1.22*
8/29/91	0.22	b.d.	0.12	0.33	b.d.	4.75	n.d.
MONON							
6/29/91	0.36	0.12	0.14	0.38	1.31	0.46	n.d.
9/1/91	0.22	0.04	0.14	0.41	b.d.	5.13	n.d.
OLLALIE							
6/30/91	0.29	0.07	0.12	0.33	b.d.	6.09	n.d.
9/29/91	0.16	0.02	0.11	0.31	b.d.	4.78	n.d.

TABLE IV

MAJOR IONS  
(continued)

	Ca <sup>+2</sup>	Mg <sup>+2</sup>	K <sup>+</sup>	Na <sup>+</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>-2</sup>	
RIMROCK							
7/3/91	0.24	0.03	0.14	0.29	1.17	1.06	n.d.
8/28/91	0.10	0.09	0.13	0.27	b.d.	3.49	n.d.
ROUND							
7/8/91	5.12	1.61	0.69	2.37	0.46	1.26	323.5
8/24/91	3.19	2.26	0.76	2.53	0.37	0.62	354.9
SPORTSMAN							
7/4/91	2.96	0.66	0.27	1.54	0.19	3.09	222.5
8/19/91	2.47	0.96	0.37	1.76	0.23	0.67	200.0

## Abbreviations:

b.d. = below detection  
n.d. = no data

\* = outliers

All ion data is in milligrams/liter.

TABLE V  
 CONDUCTIVITY AND ALKALINITY

	CONDUCTIVITY ( $\mu$ MHOS)	ALKALINITY (ueq)
ANVIL LAKE		
7/8/91	37	279.0
8/22/91	52	536.1
7/4/92	40	-
BEAVER POND		
6/24/91	90	774.3
REP.	92	-
8/23/91	101	974.0
10/25/91	112	1106.2
CRIPPLE CREEK		
7/7/91	40	313.5
8/21/91	48	389.3
7/24/92	-	-
FISH		
7/1/91	30	170.0
8/8/91	31	221.6
7/7/92	-	-
GIFFORD		
7/2/91	11	2.00
8/29/91	11	-
7/17/92	-	-
MONON		
6/29/91	11	57.7
9/1/91	11	2.34
7/11/92	-	-
OLLALIE		
6/30/91	10	21.2
9/2/91	10	47.2
7/16/92	-	-

TABLE V  
CONDUCTIVITY AND ALKALINITY  
(continued)

RIMROCK		
7/3/91	10	13.6
8/30/91	11	16.3
7/16/92	-	-
ROUND		
7/8/91	62	538.4
8/24/91	66	581.6
7/3/92	-	-
SPORTSMAN		
7/4/91	36	364.7
8/19/91	41	327.8
7/25/92	-	-

primarily a function of the concentration of bicarbonate and carbonate. TABLE IV contains the major ion data and TABLE V the data for conductivity, and alkalinity. Refer to TABLES IV and V.

#### PHYTOPLANKTON

The data for phytoplankton sample analysis are summarized in APPENDIX C. The analysis for species composition and identification of taxa were performed by Jim W. Sweet (Aquatic Analysts, Inc.). The species composition and population density values were used to characterize lake trophic status. Relatively high phytoplankton densities are often indicative of more nutrient-rich lakes. Also, there are algal species which are commonly found in lakes sharing the same trophic status.

In Anvil Lake, on July 8, 1991, the predominant alga was an Ochromonas-like phytoplankter. On that date the total density of phytoplankton (individuals/ml) was 543. On the next sampling of Anvil Lake (August 22, 1991), the dominant species was Rhodomonas minuta with 890 individuals/ml and the total phytoplankton density was 1424 individuals/ml.

In Beaver Pond Lake on June 24, 1991, the predominant alga was Rhodomonas minuta (2050 individuals/ml) and the total density of phytoplankton (all species present) was 2419 individuals /ml. On August 23, 1991 the lake had a



dominance of the phytoplankter Cryptomonas erosa with 884/ml and a total density of 2147 individuals/ml.

On July 7, 1991 in Cripple Creek Lake the dominant algal species was Rhodomonas minuta (791/ml) and the total density of phytoplankters was 2053 individuals/ml. On August 21, 1991 the dominant alga was also Rhodomonas minuta (341/ml) and the total density was 531 individuals/ml.

In Fish Lake on July 1, 1991 the predominant phytoplankter was Asterionella formosa with a density of 6013 individuals/ml, and the total phytoplankton density was 7547/ml. On August 8, 1991 the predominant species was Melosira distans (139/ml) and the total density was 356 individuals/ml.

In Gifford Lake on July 2, 1991 the predominant species was believed to be from the genus Glenodinium, but this was unsubstantiated. There were 21.9 individuals/ml present on this date. The total density was 31 individuals/ml. On August 8, 1991 the dominant phytoplankter was Chromulina spp. and the total density was 627/ml.

The dominant phytoplankter in Monon Lake on June 6, 1991 was an unidentified flagellate (102/ml). The total density on this date was 164/ml). On September 9, 1991, the dominant species was Chromulina spp. (553/ml) with a total density of 613/ml.

Ollalie Lake on September 2, 1991 had a dominance of Chromulina spp. with 987 individuals/ml and a total

phytoplankton density of 996/ml. On June 30, 1991 the same species was dominant with 48.5 individuals/ml and the total density was 81/ml.

In Rimrock Lake on July 2, 1991 the dominant phytoplankter was Chromulina spp. (329/ml) and the total density was 334 individuals/ml. On August 8, 1991 the same species was dominant (1933/ml) and the total phytoplankton density was 2019 individuals/milliliter.

In Round Lake on July 8, 1991 the predominant phytoplankter was Asterionella formosa (1353/ml) and the total density was 1995 individuals/ml. On August 8, 1991 the dominant species was Quadrigula lacustris and the total density was 1443/ml.

In Sportsman Lake on July 4, 1991 the predominant phytoplankter was Chromulina spp. (273/ml) and the total density was 547 individuals/ml. On August 19, 1991 the dominant species was Ankistrodesmus falcatus (467/ml) and the total density was 902 individuals/ml (APPENDIX C).

#### CHLOROPHYLL

Concentration values for chlorophyll are used as yet another indicator of productivity. These values are closely correlated with the values for phytoplankton density and biovolume.

Since the predominant active pigment molecule of photosynthesis is chlorophyll-a, primary productivity can be

determined from the relative concentrations of the molecule in a lake sample. The chlorophyll data are summarized in TABLE VI.

TABLE VI  
CHLOROPHYLL-A CONCENTRATION  
(ug/L)

ANVIL	
7-8-91	0.67
8-22-91	0.76
BEAVER POND	
6/24/91	1.02
8/23/91	47.3
10/25/92	39.7
CRIPPLE CREEK	
7/7/91	1.52
8/21/91	0.34
FISH LAKE	
7/1/91	n.d.
8/30/91	0.76
GIFFORD	
7/2/91	0.16
8/29/91	0.26
MONON	
6/29/91	n.d.
9/1/91	0.29
OLLALIE	
6/30/91	0.07
9/2/91	0.50
RIMROCK	
7/3/91	0.08
8/30/91	1.08
ROUND	
7/8/91	1.53
8/24/91	2.92
SPORTSMAN	
7/4/91	0.55
8/19/91	0.98

## ZOOPLANKTON

The data for zooplankton are summarized in APPENDIX D. The sample analysis was performed by Allan Vogel, ZP Taxonomic Services. Although there is insufficient evidence to conclude that zooplankton data are reliable trophic state indicators, they are commonly used as supporting evidence when making trophic state determinations (direct communication with Allan Vogel). These data were used in that context for this report (DISCUSSION and APPENDIX D).

In Anvil Lake the dominant zooplankter present on July 8, 1991 was Polyarthra dolichoptera (4043/cubic meter) and the total density of zooplankton (all species present), was 7289 individuals/m<sup>3</sup>. On August 22, 1991 Diaptomus kenai was dominant (5378/m<sup>3</sup>) and the total zooplankton density was 22871 individuals/cubic meter.

On June 24, 1991 in Beaver Pond Lake, the dominant zooplankter was a Diaptomus copepodite with a density of 20290 individuals/m<sup>3</sup> and the total phytoplankton density was 36180/m<sup>3</sup>. On August 23, 1991, a copepod nauplius was dominant (2053/m<sup>3</sup>) and the total phytoplankton density was 5250 individuals/m<sup>3</sup>).

In Cripple Creek on July 7, 1991 the dominant zooplankter was a Diaptomus copepodite (1019/m<sup>3</sup>) and the total zooplankton density was 3119 individuals/m<sup>3</sup>. On August 21, 1991 the dominant species was a copepod nauplii (2343/m<sup>3</sup>) and the total zooplankton density was 12249

individuals/m<sup>3</sup>.

In Fish Lake, the dominant zooplankter present on July 7, 1991 was a cyclopoid copepodite (1467/m<sup>3</sup>) and the total zooplankton density was 3282 individuals/m<sup>3</sup>. On August 8, 1991 the dominant species was also a cyclopoid copepodite (12060/m<sup>3</sup>) and the total zooplankton density was 18318/m<sup>3</sup>.

On July 2, 1991 in Gifford Lake the dominant zooplankter was a cyclopoid copepodite (1120/m<sup>3</sup>) and the total zooplankton density was 2540 individuals/m<sup>3</sup>. On August 19, 1991 the dominant species was Cyclops bicuspidatus thomasi (1508/m<sup>3</sup>) and the total zooplankton density was 5829 individuals/m<sup>3</sup>.

In Monon Lake on June 29, 1991 the dominant zooplankter present was a cyclopoid copepodite (1502/m<sup>3</sup>) and the total zooplankton density was 2928 individuals/m<sup>3</sup>. On September 1, 1991 the dominant species present was Daphnia galeata mendotae (7349/m<sup>3</sup>) and the total zooplankton density was 10984 individuals/m<sup>3</sup>.

On June 30, 1991 in Ollalie Lake the dominant zooplankter was a cyclopoid copepodite (2508/m<sup>3</sup>) and the total zooplankton density was 6277 individuals/m<sup>3</sup>. On September 2, 1991 the dominant zooplankter was Holopedium gibberum (1679/m<sup>3</sup>) and the total zooplankton density was 5383 individuals/m<sup>3</sup>.

On July 3, 1991 in Rimrock Lake the dominant zooplankter was Holopedium gibberum (7979/m<sup>3</sup>) and the total

zooplankton density was 9125 individuals/m<sup>3</sup>. On August 30, 1991 the dominant species present was Conochilus spp. (5967/m<sup>3</sup>) and the total zooplankton density was 13800 individuals/m<sup>3</sup>.

In Round Lake on July 8, 1991 the dominant zooplankter was Keratella quadrata (244/m<sup>3</sup>) and the total zooplankton density was 1427 individuals/m<sup>3</sup>. On August 24, 1991 the dominant species present was Daphnia pulex (5161/m<sup>3</sup>) and the total zooplankton density was 6262 individuals/m<sup>3</sup>.

In Sportsman Lake on July 4, 1991 the dominant zooplankter present was a copepod nauplii (3608/m<sup>3</sup>) and the total zooplankton density was 11735 individuals/m<sup>3</sup>. On August 19, 1991 the dominant species present was a Diaptomus copepodite (8855/m<sup>3</sup>) and the total zooplankton density was 28303 individuals/m<sup>3</sup>.

## DISCUSSION

### PHYSICAL CHARACTERISTICS AND MORPHOLOGY

The shape and size of a lake basin greatly influence the chemical, biological, and physical processes within the system. The shape, area, and depth of a lake taken together are powerful tools for predicting a lake's chemical and biological potential (Wetzel, 1983). Some limnologists have attempted to produce metabolic lake models using morphology as a primary consideration. Ryder (1965) used lake morphology (along with total dissolved solids) to generate his Morphoedaphic Index (MEI) which is an index used to predict nutrient status, algal biomass, and fish production. Even though recent works by Jackson (1990) and Chow-Fraser (1991) have found shortcomings with Ryder's index, lake morphology is still regarded as a primary consideration for limnological analysis (Ryder, 1974; Jackson, 1990; Chow-Fraser, 1991).

Gifford and Fish Lakes are relatively deep mountain lakes with depths of 18 and 20 meters respectively. Oligotrophic lakes are often comparatively deep (Wetzel 1983). In contrast, several of the lakes in this study (Anvil, Cripple Creek, and Sportsman Lakes) have maximum depths of approximately 1.5 meters, yet, they are also

relatively oligotrophic.

The area of the watershed is another factor which may influence trophic status. A lake which has a relatively high drainage basin area-to-surface area ratio is susceptible to eutrophication (Kelly 1992). A relatively large watershed can provide a source for high amounts of allochthonous organic material.

Anvil, Sportsman, and Gifford Lakes have relatively high ratios of watershed area to lake area. In the case of Anvil and Sportsman Lakes, which are extremely shallow (another indication of possible eutrophic conditions), the relatively large drainage basins are important considerations. However, the relatively great depth may offset the effect of the large drainage basin.

Monon and Ollalie Lakes have relatively small watershed-to-basin ratios. The low nutrient status of these lakes is consistent with predictions based on morphometric data.

The Cascade Mountains were the site of numerous volcanoes during the Cenozoic Period. During the Quaternary Period, glaciers cut deep into the mountains creating valleys and summit ice caps. Most, if not all of the lakes in this study are likely of glacial origin although Gifford and Fish Lakes could have been formed by landslide dams which blocked streams. Landslide lakes are common on lava-



based glaciated mountains (Wetzel, 1983; Carver 1973; Scott, 1990).

#### TEMPERATURE

The shallowest lakes-Anvil, Cripple Creek, and Sportsman-showed no sign of stratification on any of the three sampling dates. The temperature profiles for lakes which have extremely shallow basins are significantly affected by the ambient temperatures and wind. These lakes are readily mixed because the water density throughout the column is approximately equal.

Fish, Gifford, Monon, Beaver Pond, Rimrock, and Round Lakes showed the classic stratification patterns of dimictic mountain lakes (Petersen, 1992). Ollalie Lake was never stratified during the samplings. Ollalie Lake was probably sampled during the spring and fall turnover period, which is in the early and late summer (Johnson et. al, 1985). During these periods the temperatures from surface to bottom show little if any significant variation (Wetzel 1983).

#### DISSOLVED OXYGEN

The dissolved oxygen profile in a lake may be used as an indicator of primary production. Although dissolved oxygen profiles are not the most direct measure of primary productivity, the pattern of dissolved oxygen which develops in the water column over a period of stratification is an

indication of the primary productivity taking place. A metalimnetic oxygen maximum may develop in a lake if the overlying water is sufficiently transparent. The accumulated oxygen in the metalimnion may be used as a rough estimate of primary productivity in that layer. Similarly, a hypolimnetic deficit may be used to estimate the history of primary productivity in overlying layers (personal communication, Richard Petersen). It is important to note however that dissolved oxygen concentration data taken with data for phytoplankton and light is a valuable analytical tool (Kelly, 1992; Petersen, 1992; Cole, 1979).

The Fish, Gifford, Monon, Ollalie, and Round Lakes data produced positive heterograde oxygen profiles. The metalimnetic maximum was most pronounced in Fish, Gifford, and Round Lakes. This phenomenon was also observed but to a much lesser degree in Monon Lake on the June 29, 1991 sampling. Fish, Gifford, and Round Lakes had abrupt increases of dissolved oxygen in the metalimnion which is consistent with stratified dimictic lakes. Of these three, only Fish Lake showed signs of an oxygen depleted hypolimnion. This is likely because this lake is extremely deep with a very stable thermal stratification. Also, Fish Lake has a relatively small fetch to induce mixing. Therefore, it is possible that Fish Lake is not efficiently mixed during spring and fall, allowing an oxygen deficit to accumulate over several years.

Except for Beaver Pond Lake, the other lakes of the survey were consistently saturated with oxygen near the surface. Beaver Pond Lake is nearly anoxic throughout in the fall and was nearly anoxic in the bottom layers during the early and late summer samplings. This observation is interesting for two reasons. First, Beaver Pond Lake is relatively shallow and therefore should mix readily. Second, this lake is located in a valley which receives relatively heavy winds which might be expected to mix the water column.

During the Beaver Pond sampling probes or sampling nets retrieved from near the bottom, yielded a strong sulphurous odor. A number of anaerobic bacteria reduce sulfur as a means of meeting metabolic requirements. The accumulation of reduced sulfur is a consequence of the anoxia near the bottom.

Oxygen depletion from a lake is commonly the result of bacterial decomposition of phytoplankton and aquatic macrophytes. Oxygen may be depleted near the bottom by respiring organisms which consume the organic material produced by the phytoplankton and macrophytes during photosynthesis.

It is interesting to note that during the fall sampling, when oxygen depletion was most pronounced, there was only one macroscopic zooplankton species observed in the sample collected from Beaver Pond Lake. On all other occasions and at all other lakes, a diversity of fauna were

noted. The oxygen data and zooplankton observations from Beaver Pond Lake suggest that it is unlikely that this lake can support year round populations of aerobic organisms. Therefore, this lake is not a potential recreational fishing resource.

#### WATER TRANSPARENCY

The rank order of the lakes from lowest light transparency (greatest extinction) to highest is as follows: Beaver Pond, Sportsman, Cripple Creek, Rimrock, Fish, Round, Monon, Ollalie, and Gifford. No light data were obtained from Anvil Lake.

As a lake becomes more productive, water transparency decreases because light is absorbed by photosynthetic organisms. Therefore light attenuation with depth may be used to indicate abundance of phytoplankton within the water column. However, light is also absorbed by suspended inorganic and dissolved organic particles (Johnson et al., 1985), so reliable conclusions cannot be drawn using only water transparency data.

Another important consideration concerning the light data for these lakes is the bottom substrate. Sportsman and Cripple Creek Lakes are very shallow and have very silty bottoms. The bottom sediments were stirred up by the sampling activity (paddling of rafts, probes dragging along the bottom, etc.). Even though time was taken to allow the

silt to settle before light measurements were performed, conditions were far from optimal and may have affected measurements of water transparency. However, if these data are reliable, these lakes are classified as mesotrophic according to Carlson's Trophic Classification System (Carlson, 1977).

Beaver Pond Lake had the highest extinction coefficient of the lakes sampled. Secchi depth values indicate that Beaver Pond Lake is eutrophic. Compared with lakes surveyed for the compilation of the Western Lake Survey, Beaver Pond Lake has a very shallow Secchi Depth (Landers, 1987).

Fish, Rimrock, and Round Lakes, had similar extinction coefficients and Secchi depths. These light data are consistent with those from other lakes in the Cascade Mountains of the Pacific Northwest (Landers, 1987). According to Carlson's Trophic State Index, lakes with Secchi Depths of between 2 and 6 meters are mesotrophic (Carlson, 1987).

Gifford, Monon, and Ollalie Lakes had relatively low extinction coefficients and deep Secchi depths when compared with lakes of the Western Lakes Survey (Landers, 1987). These lakes fit the typical oligotrophic lake light profile (TABLE I).

During two of the three Monon Lake samplings, the Secchi Disk could be seen lying on the bottom at about 12 meters. It was only on the first sampling date (June 91)

that Secchi visibility was relatively poor. On that day a strong wind produced choppy surface water affecting visibility. Because of the water clarity on the other sampling dates, Monon Lake should probably not be considered less oligotrophic than Gifford or Ollalie Lakes.

## NUTRIENTS

### Nitrogen

Nitrate-nitrogen and ammonia-nitrogen are forms of fixed nitrogen that are readily assimilated by aquatic plants. The primary source of nitrate-nitrogen in mountain lakes is from the watershed.

The lakes in this study have nitrate concentrations which are consistent with other lakes studied in the Pacific Northwest (Landers, 1987). However, all of the lakes in this study except Ollalie have values greater than the median value (1.4 ug/L) given for 100 lakes studied in the Western Lake Survey. The Ollalie Lake value is exactly the median value 1.4 ug/L (Landers, 1987).

### Phosphorus

The values reported for total phosphorus on the 10 lakes are extremely high for Oregon Cascade Lakes. It appears that systematic errors were made on many samples analyzed during the same time period using the same methodology. For that reason the values reported for soluble-reactive-phosphate (SRP) were averaged and used to

rank order the lakes.

The SRP values for the 10 lakes were compared with the total phosphorus values that Carlson used to classify general lake productivity (Carlson, 1977). According to his system and using the SRP values, Beaver Pond Lake is eutrophic; Anvil, Cripple Creek, Round and Sportsman Lakes are meso-eutrophic; Monon and Rimrock are oligo-mesotrophic; and Fish, Gifford and Ollalie are ultra-oligotrophic (Carlson, 1979).

#### Nitrogen and Phosphorus Limitation

The concentrations of available nitrogen, phosphorus, and carbon affect the growth of algae and other aquatic plants more than any of the other elements. In most cases, nutrient loading of nitrogen or phosphorus is implicated as the primary cause of increased eutrophication (Wetzel, 1983).

By dry weight, algae require seven times more nitrogen than phosphorus. This 7:1 ratio was used to determine which nutrient would be most likely to limit productivity in the 10 lakes.

The phosphorus concentrations were plotted against the nitrogen concentrations (multiplied by 7 because of the 7:1 ratio) to determine the limiting nutrient, and a cluster analysis was performed for each lake. The purpose of this analysis was to determine whether the data were consistent from one sampling date to the next. Clustering occurred on

seven of the 10 lakes. The data points for Anvil, Round, and Sportsman did not cluster and therefore could not be used in the analysis.

It is likely that Gifford, Fish, Monon, Ollalie, and Rimrock are phosphorus-limited (typical for mountain lakes) while Beaver Pond and Cripple Creek appear to be limited by nitrogen and have an abundance of phosphorus. The relatively high concentration of phosphorus in Beaver Pond Lake is possibly due to its location. The lake is less than 30 m from of the main road and directly beneath a public access site.

Cripple Creek Lake has a number of campsites immediately on the lake. Also, the lake is encircled by trails and is a popular horseback riding area. Neither of these lakes have refuse containers or toilet facilities.

Besides having relatively high values for phosphorus concentration, Beaver Pond and Cripple Creek Lakes have high values for light extinction. From these data it appears that these lakes are relatively productive and nutrient rich.

### Silica

In many lakes diatoms play a major role in productivity. These organisms use large quantities of dissolved silica as a component of the cell wall (frustule). Therefore, the availability of this nutrient can significantly influence productivity in fresh water lakes



(Wetzel, 1979; Cole, 1983).

Half of the lakes of this study have dissolved silica values which are higher than the fourth quintile (80th percentile) of lakes represented in the Western Lake Survey.

Only 3 of the 10 lakes fell within the first to fourth quintile of the survey. These lakes are Monon, Ollalie, and Rimrock. Gifford Lake had a silica concentration value consistent with lakes within the 1st quintile (20 percentile) of the Western Lake Survey (Landers, 1987).

## CONDUCTIVITY

### Salinity

The specific conductivity of water is related to the concentration of the major ions present within a given volume of water (Cole, 1983).

Water conductivity values are closely correlated with values given for the concentrations of dissolved ions. Because testing for individual ions is rigorous and expensive, specific conductance profiles are often used as a substitute (Cole, 1983).

The conductivity values for the 10 lakes were compared to the values reported for the 100 lakes studied for the compilation of the Western Lake Survey.

Beaver Pond and Round Lakes have specific conductivities which are much higher than the fourth quintile (80th percentile) of lakes in the Western Lake Survey

report. Anvil, Cripple Creek and Sportsman Lakes have conductivities which are also relatively high, falling above the 80th percentile. The 10 lakes in this study more closely fit the profiles for lakes located in the northern Rocky Mountains (Landers, 1987).

The conductivity values representing Gifford, Monon, Ollalie, and Rimrock are relatively low for lakes in this study area but well within the expected limits for lakes located in the Pacific Northwest (Landers, 1987).

### Cations

Most lakes which have been formed from igneous rock have a cation ratio as follows: calcium > sodium > magnesium > potassium (Wetzel, 1983). The primary source of calcium carbonate is from igneous rocks. Although  $\text{CaCO}_3$  is abundant, only a small amount can be dissolved in pure water (Cole, 1983).

In six of the 10 lakes studied, calcium is the predominant cation. In the other 4, sodium is dominant.

Sodium is also an abundant weathering product of igneous rock (Hutchinson, 1957). Therefore it is not surprising that it is found in relatively high concentrations in these lakes which are of volcanic-glacial origin.

Because the total cation concentrations were low in the lakes dominated by Na, it is probably the lack of carbonates in the drainage basin which explains the low calcium/sodium

ratio.

Calcium concentrations sometimes vary as a function of biotic uptake. Calcium is an essential element of algae and other aquatic plants. Sodium, potassium, and magnesium are more conservative ions because they are commonly present in considerable excess of biologic demand (Wetzel, 1983).

### Anions

The anionic ratio for most lakes located in the western United States is as follows:  $\text{HCO}_3^- > \text{SO}_4^{2-} > \text{Cl}^-$ . However in lakes of the Pacific Northwest,  $\text{HCO}_3^-$  is dominant,  $\text{Cl}^-$  is next and  $\text{SO}_4^{2-}$  is least (Landers, 1987). The lakes in this study are not consistent with this pattern. Sulfate is the predominant anion in Anvil, Beaver Pond, Cripple Creek, Fish, Round, and Sportsman Lakes. Relatively high values for sulfate were recorded for the other four lakes.

There are two possible explanations for the dominance of sulfur in these lakes. First, sulfur is a weathering product of pyrite, a source of sulfide in lakes. This is just one of many weathering products of volcanic rock (direct communication with Vic Menting). Second, the concentrations of the other anions are extremely low.

### Carbonates and Bicarbonates

Inorganic carbon behaves dynamically in water. Bicarbonate enters the lake as the product of rock weathering processes. Carbonic acid percolation through soils and

over rocks causes dissolution of calcium carbonate (Wetzel, 1983).

Relative concentrations of carbonate species change with pH. Bicarbonate concentration does not vary significantly in hard water-eutrophic lakes (which contain high concentrations of carbonates) but mountain lakes have relatively low concentrations of inorganic carbon. Therefore, seasonal extremes in photosynthetic activity (or allochthonous sources of CO<sub>2</sub>) can have a dramatic effect on the availability of bicarbonate.

#### ALKALINITY

The values for alkalinity (acid neutralizing capacity, ANC) were compared with values reported in the literature (Western Lake Survey). The lakes were rank-ordered from greatest acid neutralizing capacity to least as follows: Beaver Pond, Round, Anvil, Sportsman/Cripple Creek (shared the same value), Fish, Ollalie, Monon, Rimrock, and Gifford.

In the Western Lake Survey, values were reported for both wilderness and non-wilderness mountain lakes. When compared to the literature values, Gifford, Ollalie, Monon, and Rimrock Lakes more closely fit the profiles for wilderness lakes (Landers, 1987).

The ANC values for Beaver Pond and Round Lakes are more consistent with non-wilderness lakes in the Southern Rocky Mountains than with lakes located in the Pacific Northwest

(Landers, 1987).

Because the total concentration of autochthonous inorganic carbon do not fluctuate significantly within the lake, the concentration of natural water buffers is relatively static. As is usually the case in mountain lakes, these buffering anions are in very low concentration. Therefore, any allochthonous source of strong acid such as sulphuric or nitric acid from industrial sources would be expected to drastically lower pH (Baker, 1991). However, due to the location of these lakes, it is unlikely that the chemistry of these waters will be altered by acid compounds entering from the atmosphere (acid rain).

#### PHYTOPLANKTON

Jim Sweet has developed a trophic state index, based on phytoplankton biovolume comparable to Carlson's Trophic State Index, based on total phosphorus, chlorophyll, and light extinction (Sweet, 1986; Carlson, 1977).

The 10 lakes were rank-ordered according to algal biovolume values (highest to lowest) as follows: Fish, Beaver Pond, Cripple Creek and Anvil (shared the same value), Sportsman, Round, Ollalie and Rimrock (shared the same value), Monon, and Gifford. According to these values, Fish and Beaver Pond Lakes are mesotrophic while the others are oligotrophic.

A comparison was made between the index generated

according to Sweet's biovolume index and the index developed by Carlson (based upon phosphorus, chlorophyll, and Secchi depth). Sweet's index agreed well with Carlson's indices (Carlson, 1977; Sweet, 1986; APPENDIX C).

It is interesting to note that Fish Lake has the highest trophic status of the 10 lakes according to phytoplankton data. It is doubtful that this lake is as productive as these data suggest, since other data indicate that Fish Lake is a more oligotrophic system. This discrepancy is apparently a consequence of a high metalimnetic population of phytoplankton.

When an algal bloom occurs within the metalimnion as was clearly the case in Fish Lake, surface profiles for Secchi depth, light intensity, nutrient concentration etc., are not affected. Although the algal biomass values may fall within in the range of what might be expected for a mesotrophic or eutrophic lake, the relatively low trophic state suggested by light and nutrient data may indicate a less productive system. It is probable that this is occurring in Fish Lake (personal communication with Jim Sweet).

### Indicator Species

The dominant phytoplankton species present in each lake is a useful indicator of trophic state. Therefore, another phytoplankton trophic state model (Jim Sweet, Aquatic Analysts, Inc.) has been developed based on indicator

species. Certain algae are commonly present in lakes of similar trophic classification. The 10 lakes of this study were classified using the Sweet model. This system assigns a trophic status value to a dominant algal species. These values were placed on a continuum from 1 (ultraoligotrophic) to 5 (hypereutrophic) (Sweet, 1986).

Anvil Lake had a dominance of Rhodomonas minuta on one sampling date. This alga is normally found in mesotrophic lakes. On another occasion, the dominant phytoplankton was an Ochromas-like alga which is not considered an indicator.

Beaver Pond Lake had a dominance of Cryptomonas erosa, a mesotrophic indicator species, on one sampling occasion and Rhodomonas minuta, an oligotrophic indicator species on another.

Cripple Creek had a dominance of Rhodomonas minuta on two sampling occasions.

Fish Lake had dominant algal species which have not yet been given trophic state classification.

Gifford Lake had a dominance of Chromulina spp. (an oligotrophic indicator) on one occasion. On another occasion the dominant species was Glenodinium spp. Glenodinium is not an indicator species.

Monon Lake on one occasion had a dominant indicator species, Chromulina spp. This alga is considered an oligotrophic lake phytoplankter.

On no sampling occasion did Round Lake have a dominant

indicator algal species.

Ollalie and Rimrock Lakes had a dominance of Chromulina spp. on two sampling occasions. As indicated previously, this is an oligotrophic lake indicator.

On one sampling trip Sportsman Lake contained a dominant indicator species, Chromulina spp. (APPENDIX C).

Assigning a lake to a trophic status using indicator species is far from an exact science since species composition is in constant flux. For instance, in the case of Beaver Pond Lake, an oligotrophic indicator was dominant on one occasion and a eutrophic indicator was dominant on another. An early summer sampling produced the oligotrophic species while a late summer sampling produced the eutrophic indicator.

Primary production and lake metabolism is constantly changing throughout the year. The presence or absence of particular organisms (phytoplankters or zooplankters) can be as much a function of seasonal variation as of trophic status.

#### CHLOROPHYLL-A

Another way of quantifying algal population densities is by determining the chlorophyll-a concentrations (Johnson et al., 1985). The lakes of this study were classified and ranked accordingly.

The average concentration of the chlorophyll-a in



Beaver Pond Lake for 1991 was 29.3 ug/L. This value falls well within the range of lakes considered eutrophic.

Round Lake had the next largest concentration with a value of 2.2 ug/l. According to these data this lake is mesotrophic.

Cripple Creek, Sportsman, Fish, Anvil, and Rimrock Lakes are solidly oligotrophic systems, according to chlorophyll data, while Monon and Ollalie are somewhere between ultra-oligotrophic and oligotrophic.

Gifford Lake is extremely unproductive with a chlorophyll-a a value of well below Carlson's 0.3 ug/l value given for ultraoligotrophic lakes (TABLE VI), (Carlson, 1977).

#### ZOOPLANKTON

Generalizations about lake metabolism can be made according to the densities (individuals/m<sup>3</sup>) and the species composition of the zooplankters. The dynamics of the lake ecosystem are exemplified by relationships between phytoplankters, zooplankters and fish. These interactions are extremely complex and are beyond the scope of this study. However, a basic understanding of the zooplankter assemblages within these lakes may provide valuable information for future analyses (APPENDIX D).

The two major zooplankton groups encountered in these lakes are the cladocerans and the copepods. Therefore in this analysis generalizations will be made according to the

presence of indicator species found in these zooplankter groups only.

Among the cladocerans, it is the members of the genus Daphnia which are considered as indicators. Daphnia rosea and D. galeata are indicative of oligotrophic-mestrophic lakes while Bosmina longirostris and Daphnia pulex are predominantly eutrophic lake indicators.

When focusing upon copepods, it is the ratio of Diaptomus to Cyclops which is used as the trophic indicator. The higher this ratio, the more oligotrophic the lake.

Another criterion using zooplankton as an indicator of trophic status is zooplankter population density. Lakes with densities of less than 5000 individuals/m<sup>3</sup> are considered ultraoligotrophic while those with densities of 15000 individuals are considered eutrophic (personal communication; Allan Vogel).

The cladocerans present in Anvil Lake were Daphnia rosea (an oligotrophic indicator) and Bosmina longirostris (a eutrophic indicator). The Daphnia slightly outnumbered the Bosmina.

The Diaptomus/Cyclops ratio was 1:9 which suggests an oligotrophic lake. Diaptomus are filter feeding herbivores which have specific food particle size requirements best met in oligotrophic systems. Cyclops are carnivorous and do well in systems which are nutrient-rich. Finally, Diaptomus are fed upon by the cyclopoid copepods (Wetzel, 1983; Cole,

1983; and personal communication with Allan Vogel).

The total density in Anvil Lake was 7289 individuals/m<sup>3</sup>. On the basis of these data, this lake has relatively little biological productivity. As was inferred previously, generalizations as to trophic status based solely upon zooplankton data are unreliable.

A large population of Daphnia pulex (a eutrophic indicator) appeared in Beaver Pond Lake.

Although Cripple Creek Lake has a relatively large Bosmina longirostris population (a eutrophic indicator), it also has a very high Diaptomus/Cyclops ratio, and the total density of phytoplankton is relatively low. Accordingly this lake is classified as oligo-mesotrophic.

Fish Lake has a relatively small Diaptomus/Cyclops ratio (indicative of eutrophic conditions) but because of its total density (10800 individuals/m<sup>3</sup>) may be classified as mesotrophic.

Gifford Lake has species of zooplankters which are inconsistent with the Allan Vogel model. The total density values suggest that these lakes are ultraoligotrophic yet the Diaptomus/Cyclops ratio is relatively low. However, this lake had been stocked with fish, and fish predation upon the Daphnia may have reduced the numbers of this oligotrophic indicator species.

Monon Lake has relatively high concentrations of Daphnia galeata mendotae and Eubosmina hagmanni which is

consistent with nutrient poor lakes. However, this lake has a relatively low Diaptomus/Cyclops ratio. Nevertheless, because of low total density of organisms, this lake is classified as oligotrophic. Values for total zooplankton density derived from mountain lake samples normally indicate that the system is nutrient poor. However, after a lake becomes extremely rich (highly eutrophic to hypereutrophic), the zooplankton density will decrease due to the nutrient overload, with its subsequent oxygen deficit (personal communication, Allan Vogel). After a lake has reached this trophic condition, blooms of algal species which are unpalatable to most zooplankters flourish. These are the gelatinous greens and blue-green algae (personal communication, Allan Vogel).

Ollalie Lake is nutrient-poor according to total zooplankton density values. Also, the presence of Daphnia rosea, Eubosmina hagmanni, and Daphnia galeata mendotae supports the assertion. Rimrock Lake has a relatively large population of planktonic herbivores (Diaptomus), no cyclopoid copepods and a moderate total density of individuals. Since there is no fish predation to interfere, it is likely that these data are representative of the lakes nutrient status.

Although Round Lake has relatively low total population density, it has a very low Diaptomus/Cyclops ratio. Also, due to the presence of a relatively large population of

Daphnia pulex (another eutrophic indicator) this lake is probably mesotrophic to eutrophic.

Sportsman Lake has the highest zooplankton population density of any of the lakes sampled but it also has a high Diaptomus/Cyclops ratio and there is a substantial population of Daphnia rosea. According to these data, this lake is likely an oligotrophic-mesotrophic system.

There is some evidence that lakes which are low in calcium have relatively large populations of the zooplankter Holopedium (Hutchinson, 1957; Cole 1983). A number of the lakes in this study have extremely low values for the cation.

In four of the lakes the concentrations of calcium (which is normally the predominant cation in mountain lakes) was lower than the concentration of sodium. Three of these lakes Gifford, Ollalie, and Rimrock Lakes have extremely large populations of Holopedium while the Monon has a modest population of the zooplanker.

Holopedium was also found in Fish Lake and Round Lake. These lakes are not calcium poor. However, the population densities of this animal in Fish Lake and Round Lake were significantly smaller than the population densities of Gifford, Ollalie, and Rimrock Lakes.

Because lake conditions change continually and rapidly over the summer season, it is difficult to glean appreciable meaning from zooplankton data. Phytoplanktonic assemblages

change continuously as do fish populations. Both variables affect zooplankton population size and species composition.

#### TROPHIC STATUS

It is a common convention to use trophic status for lake classification. In this study, the index published by Carlson in 1977, the phytoplankton index produced by Jim Sweet (based upon the Carlson index), and the Western Lake Survey data were the primary analytical tools (Wetzel, 1983; Landers, 1987; Sweet, 1986).

Each lake was classified to trophic state by each separate parameter. For example, Anvil Lake is eutrophic according to depth and watershed/surface area ratio, eutrophic according to nitrogen, phosphorus and silicate concentration, mesotrophic according to phytoplankton species composition, and oligotrophic according to phytoplankton density, chlorophyll concentration, and zooplankton density and species composition.

In this analysis, light extinction, nutrient concentration and chlorophyll concentrations were more heavily weighted since these parameters are considered the most reliable (Carlson, 1977).

The lakes have been rank-ordered from least to most productive and have been assigned a trophic status as follows: Ollalie Lake and Gifford Lake are ultra-oligotrophic-to-oligotrophic; Monon and Rimrock Lakes are

oligotrophic; Anvil, Cripple Creek, Fish, and Sportsman Lakes, are mesotrophic; Round Lake is mesotrophic-to-eutrophic; and Beaver Pond Lake is eutrophic.

Fish, Monon, Ollalie, and Round Lakes have been previously studied. A comparison was made between the data sets obtained from the previous surveys (performed by the United States Forest Service) and those presented in this report. The previous surveys produced only limited data sets with which to compare.

Since sampling techniques, laboratory techniques, and both sampling and laboratory equipment have become more sophisticated throughout the years, it can be difficult to draw reliable conclusions based upon comparisons over time. Also, without information related to the time of day that samples were taken and profiles performed, it is impossible to make direct comparisons. However, generalizations concerning the trends of the ecological processes over time are possible.

Fish Lake was surveyed in 1976 (Rinella, 1976). In 15 years the conductivity had increased approximately 26% while alkalinity had decreased 23%. The Secchi depth decreased approximately 15%. The lake produced a negative heterograde oxygen curve in 1976. In 1991 and 1992, this lake produced a supersaturated metalimnion (positive heterograde oxygen profile). This lake has undergone significant change over the past 15 years.

Monon Lake was surveyed in September of 1982 (Johnson, et al. 1985). These data were compared to the data obtained during the September 1991 sampling performed for this report. In 9 years the light extinction (versus depth) had increased 28%. The chlorophyll-a concentration increased from 0.2 ug./L to 0.3 ug/L. The conductivity values have nearly tripled.

In 1982, Ollalie Lake was surveyed (Johnson et al. 1985). It was sampled in September and therefore was compared with data obtained from the September 1991 sampling from this survey.

In 9 years the Secchi depth of Ollalie Lake decreased by 11% (approximately 1.4 meters). The concentration of chlorophyll-a increased from 0.3 ug/L to 0.5 ug/L. The conductivity of the lake increased from 4 micromhos to 10 micromhos (TABLE V).

Round Lake was sampled in August of 1976 (Rinella, 1977). A comparison was made between the light and alkalinity data taken from that survey and data taken for this report during the same month of 1991. Both the Secchi depth and acid neutralizing capacity (alkalinity) decreased by 15% in the 15 year period.

Six of the lakes of this study were never previously investigated. The lakes are Anvil, Beaver Pond, Cripple Creek, Gifford, Rimrock, and Sportsman. The data compiled for this report will serve as baseline information for



future lake monitoring.

Included in this report are clearcut maps of Anvil, Beaver Pond, Round, and Sportsman Lakes. Murphy (1981) and Carlson (1990) suggest that a significant change in stream macroinvertebrate species composition occurs as a result of clearcut logging (Murphy, 1981; Carlson, 1990). Since the streams feed the lake within the watershed, lake ecosystems could be affected.

However, Bormann (1979) suggests that as long as timber harvesting practices are performed in a responsible manner, no significant impact will occur.

Lake ecosystems evolve over the millenia. These changes are to be expected. Although changes which occur as the result of human use occur over a relatively short time span, with proper monitoring efforts, they can be remedied. Hopefully, the information in this report will be beneficial to that endeavor.

## CONCLUSION

Each lake surveyed was assigned a trophic status as follows: Ollalie and Gifford Lakes are ultraoligotrophic-to-oligotrophic, Monon and Rimrock Lakes are oligotrophic, Anvil, Cripple Creek, Fish, and Sportsman Lakes are mesotrophic, Round Lake is mesoeutrophic, and Beaver Pond Lake is eutrophic.

It appears that biological productivity of these lakes has increased over the past 10-15 years. These lakes should be carefully monitored in the future.

Beaver Pond, Round, and Sportsman Lakes are nutrient rich while Monon, Ollalie, and Gifford are nutrient poor when compared to other lakes located within the Pacific Northwest. The other four lakes of this survey, Anvil, Cripple Creek, Fish, and Rimrock, have profiles which are expected for lakes located within the study area.

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APPENDIX A

DETAILED DIRECTIONS INTO EACH LAKE

## SPECIFIC DIRECTIONS FROM RIPPLEBROOK RANGER STATION (RRS)

ANVIL LAKE

Anvil Lake is reached by traveling east on OSH 224 for approximately 1.6 km (1 mi) to National Forest Primary Route (NFPR) 57, and then east on NFPR 57 to NFPR 58. Route 58 is taken north for approximately 2.4 km (1.5 mi) to Forest Route (FR) 5810. One turns right on to FR 5810 which is taken for approximately 8 km (5 mi) to FR 5820. 5820 is taken north 5.6 km (3.5 mi) to Anvil Creek where there is an automobile pull-off. There is no maintained trail to the lake. Access requires a short hike [approx. 0.40 km (1/4 mi)] up Anvil Creek (Figure 2).

BEAVER POND

Beaver Pond Lake is reached by traveling from RRS. approximately 1.6 km (1 mi) to OSH 46. Oregon State Highway 46 is taken south approximately 7 km (4.4 miles) to Forest Route (FR) 6310. At FR 6310 one turns left and travels approximately 3.2 km (2 miles) to FR 6311 which is taken to the left. 6311 is taken for approximately 4 km (2.5 mi) to Spur Road 140. The spur is taken for a distance of approximately 0.32 km (0.2 mi) to the lake, which is approximately 9 m (30 y) off of the road to the right (Figure 2).

CRIPPLE CREEK

To reach Cripple Creek Lake, take FR 4631 east from RRS approximately 4.8 km (3 miles) to F.R. 4630. 4630 is

taken east for approx. 3.6 km (1 mile) to F.R. 4635. 4635 is taken to the left and travelled for approximately 17 km (11 mi) to SR 140. The trailhead is located where SR 140 crosses Cripple Creek. This is approximately 3.2 km (2 mi) off of FR 4635 on SR 140 (Figure 2).

#### FISH LAKE

Fish Lake may be reached by traveling from RRS approximately 1.6 km (1 mi) to OSH 46. One turns right on highway 46 which is travelled for approximately 24 km (15 mi) where OSH 42 branches off. Highway 42 is taken for approximately 1.6 km (1 mi) to FR 4230, the Ollalie Lake Junction (OLJ). 4230 is taken to the left and travelled for approximately 8 km (5 mi) to FR 4220. 4220 is then taken south for approximately 3.8 km (2.5 mi) to FR 4690. 4690 is taken west for approximately 6.4 km (4 mi) to FR 4691. 4691 is taken in a southeasterly direction approximately 4.8 km (3 mi), under a conspicuous set of electrical power lines, and finally, down a steep hill that curves to the right at the trail head.

Access to Fish Lake requires a hike of approximately a mile. The steep trail off of FR 4691 affords a quick descent to the lake. At the trails end (on the northside of the lake) is a campsite with a picnic table (see Figure 2).

#### GIFFORD LAKE

Gifford Lake may be reached by traveling from RRS southeast to FR 4220 via the same route as was outlined for

Fish Lake. 4220 is taken for approximately 12 km (7.5 mi) to the Lower Lake Campground which is approximately 3.2 km (2 mi) from Ollalie Lake. The trail to Gifford Lake begins at the west end of the campground.

Access to the lake requires a hike-in of just under an hour. USFS trail 717 (from the campground) is taken to USFS trail 706. 706 is taken west for approximately 800 m (0.50 mi). Off trail 706 is the Gifford Lake Trail which follows the ridgeline in a southeasterly direction. The Gifford Lake Trail is approximately 0.50 km (.31 mi) long (Figure 8).

#### MONON AND OLLALIE LAKES

Monon and Ollalie Lakes may be reached by traveling from RRS to Forest Route 4220 south past the Lower Lake Campground (as was previously described) for approximately 4.8 km (3 mi). The lake is immediately off of FR 4220 approximately 1.6 km (1 mi) south of Ollalie Lake which is also on FR 4220.

#### RIMROCK LAKE

Rimrock Lake is reached by first traveling to Ollalie Lake (directions previously described in the Monon Lake section of this paper). At the north end of Ollalie Lake, the Pacific Crest Trail can be accessed.

Rimrock Lake is difficult to find since there is no maintained trail to the lake. Access is via the Pacific Crest and Red Lake trails. The lake can be reached by



leaving the Red Lake Trail approximately 0.8 km (0.5 mi) northwest of the Pacific Crest Trail/Red Lake Trail junction, and traveling southeast (downhill) for approximately 0.4 to 0.8 km (0.25 to 0.5 mi). There are a few game trails through this heavily forested area. The total hiking time from the Pacific Crest Trail access point at Ollalie Lake to Rimrock Lake is approximately 1 hour and 15 minutes.

#### ROUND LAKE

Round Lake may be reached by driving east from RRS approximately 1.6 km (1 mi) to OSH 46. This highway is taken south for approximately 5.6 km (3.5 mi) to OSH 63. 63 is taken south for approximately 21.6 km (13.5 mi) to FR 6370. 6370 is taken south for approximately 11.2 km (7 mi) to the Round Lake trailhead where there is an automobile pulloff. The trail begins on the uphill (left) side of the road. The trailhead is well marked. The hike into the lake takes approximately 15 minutes.

#### SPORTSMAN LAKE

Sportsman Lake may be reached by taking Oregon State Highway 46 which as stated previously begins approximately 1.6 km (1 mi) east of RRS. Highway 46 is taken south for approximately 46.4 km (29.5 mi) to FR 6350 west. 6350 is taken for approximately 4.8 km (3 mi) to SR 320. 320 is taken southeast for approximately 3.2 km (2 mi) to SR 340. One turns right on SR 340 and it is followed until it

deadends at approximately 0.40 km (0.25 mi). Access to Sportsman Lake is difficult since there is no maintained trail. The easiest access requires a hike of approximately 0.8 km (0.5 mi) across a clearcut and burned area, located just off SR 340.

APPENDIX B

TEMPERATURE AND DISSOLVED OXYGEN DATA

## TEMPERATURE AND DISSOLVED OXYGEN

ANVIL LAKE  
JULY 8, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	19.1	8.68
0.25	19.0	7.23
0.50	18.9	6.78
0.75	18.7	7.13
1.00	18.4	6.84

ANVIL LAKE  
AUGUST 22, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	22.9	7.9
0.25	22.8	7.8
0.50	22.1	7.8
0.75	21.2	7.7
1.00	21.1	7.6
1.25	21.1	7.9

WINKLER OXYGEN TITRATION (WOT): 1-METER 8.20 mg/L  
REPLICA (REP) 9.20 mg/L

ANVIL LAKE  
JULY 4, 1992

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	18.0	8.07
0.25	18.0	8.00
0.50	18.0	7.95
0.75	18.0	8.96
1.00	17.5	7.60
1.25	17.1	7.60
1.50	17.0	8.05

WOT: 1-METER 6.80 mg/L

BEAVER POND LAKE  
JUNE 24, 1991

DEPTH	TEMPERATURE	DISSOLVED OXYGEN
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(m)	(C)	(mg/L)
0.00	15.6	6.50
0.50	15.0	6.30
1.00	15.0	5.30
1.50	14.4	5.40
2.00	14.0	5.50
2.50	12.5	2.24
3.00	11.9	1.10

BEAVER POND LAKE  
AUGUST 23, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	22.2	9.00
0.50	20.8	8.40
1.00	19.6	8.26
1.50	18.1	1.00
2.00	15.7	0.20
2.50	13.7	0.20

WOT: 1-METER 9.85, REPLICA (REP) -10.45  
2-METER 5.75, " - 6.10

BEAVER POND LAKE  
OCTOBER 25, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	7.8	1.66
0.50	7.8	1.67
1.00	7.8	1.73
1.50	7.8	1.78
2.00	7.7	1.78
2.50	7.7	1.73

WOT: DISSOLVED O2 VERIFIED, NO DATA (N.D.)

CRIPPLE CREEK LAKE  
JULY 7, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	19.4	7.94
0.25	19.4	7.81
0.50	19.3	7.80
0.75	18.7	7.59
1.00	16.7	9.00

CRIPPLE CREEK LAKE  
AUGUST 21, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	22.0	8.60
0.25	21.9	8.60
0.50	21.9	8.50
0.75	21.7	8.50
1.00	20.4	8.90

WOT: 0.00-0.75 METER 9.95 mg/L  
REP. 9.90 mg/L

CRIPPLE CREEK LAKE  
JULY 24, 1992

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	17.6	8.40
0.25	17.8	8.20
0.50	17.7	8.20
0.75	17.0	8.20
1.00	16.8	7.30

WOT: 1-METER 8.15 mg/L  
REP. 8.15 mg/L

FISH LAKE  
JULY 1, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	16.5	8.94
1.00	15.4	8.84
2.00	14.0	9.35
3.00	13.7	9.36
4.00	12.8	10.30
5.00	11.0	11.90
6.00	9.1	13.00
7.00	7.0	12.69
8.00	6.2	11.20
9.00	5.7	11.10
10.00	5.4	9.50
11.00	5.1	8.11
12.00	4.7	7.43
13.00	4.6	5.14
14.00	4.5	3.77
15.00	4.3	2.30

16.00	4.3	1.00
17.00	4.3	0.40
18.00	4.3	0.00
19.00	4.2	0.00
20.00	4.2	0.00

FISH LAKE  
AUGUST 8, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	19.6	8.89
1.00	19.4	8.80
2.00	19.1	8.78
3.00	18.8	8.80
4.00	18.6	8.77
5.00	18.5	8.75
6.00	17.5	12.60
7.00	12.7	14.45
8.00	10.7	14.30
9.00	7.9	12.00
10.00	7.0	11.30
11.00	6.2	9.30
12.00	5.6	7.10
13.00	5.2	4.00
14.00	4.9	0.50
15.00	4.8	0.30
16.00	4.7	0.10
17.00	4.5	0.10
18.00	4.5	0.09
19.00	4.5	0.09
20.00	4.5	0.08

WOT: 1-METER 2.40 mg/L      7-METER 10.10 mg/L  
 REP. 7.90 mg/L              REP. 10.75 mg/L

FISH LAKE  
JULY 7, 1992

DEPTH (ft)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	22.5	8.50
2.50	22.1	8.60
5.00	22.0	8.70
7.50	21.7	8.70
10.00	21.2	8.60
12.50	20.7	8.90
15.00	20.0	8.80
17.50	19.0	11.00
20.00	16.3	14.00

22.50	13.0	14.20
25.00	10.6	14.00
27.50	9.2	13.00
30.00	8.1	11.60
32.50	7.2	10.00
35.00	6.6	8.60
37.50	6.0	6.10
40.00	5.4	3.60
42.50	5.2	1.40
45.00	5.0	0.40
47.50	5.0	0.09
50.00	4.9	0.05

WOT: 1-METER 6.60 mg/L      7-METER 10.90 mg/L  
 REP. 7.45 mg/L              7-METER 10.90 mg/L

GIFFORD LAKE  
 JULY 2, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	16.4	8.60
1.00	14.3	8.99
2.00	13.2	8.88
3.00	12.7	9.00
4.00	12.2	8.90
5.00	11.3	9.07
10.00	7.4	9.33
15.00	6.6	9.37

GIFFORD LAKE  
 AUGUST 29, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	18.1	7.90
1.00	17.9	7.80
2.00	17.9	7.74
3.00	17.9	7.72
4.00	17.9	7.70
5.00	17.8	7.70
6.00	17.8	7.68
7.00	17.8	7.70
8.00	17.8	7.68
9.00	17.2	7.68
10.00	17.0	10.20
11.00	14.6	10.45
12.00	13.3	10.55
13.00	12.9	10.69
14.00	12.6	10.80



15.00	12.4	10.75
16.00	12.3	10.24
17.00	12.4	9.20
18.00	12.4	7.50

WOT: 1-METER 7.20 mg/L      11-METER 8.95 mg/L  
 REP. 7.50 mg/L              REP. 9.50 mg/L

GIFFORD LAKE  
 JULY 17, 1992

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	21.4	8.60
1.00	19.6	9.05
2.00	19.0	9.40
3.00	18.8	9.40
4.00	18.6	9.40
5.00	18.5	9.20
6.00	18.4	9.03
7.00	18.3	8.90
8.00	18.2	8.80
9.00	17.1	10.20
10.00	15.0	11.00
11.00	13.4	11.20
12.00	13.0	11.40
13.00	12.0	11.40
14.00	12.0	11.50
15.00	12.0	11.20
16.00	12.0	10.40
17.00	12.0	9.80
18.00	12.0	9.30

WOT: 1-METER 5.95 mg/L      11-METER 9.05mg/L

MONON LAKE  
 JUNE 29, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	13.4	8.70
5.00	12.1	9.00
10.00	8.5	10.50

MONON LAKE  
 SEPTEMBER 1, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVE OXYGEN (mg/L)
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0.00	17.4	8.00
1.00	17.4	7.88
2.00	17.3	7.84
3.00	17.3	7.81
4.00	17.3	7.81
5.00	17.2	7.79
6.00	17.1	7.67
7.00	17.0	7.70
8.00	16.9	7.73
9.00	16.9	7.71
10.00	16.9	7.63
11.00	16.9	7.63

WOT: 1-METER 7.30 mg/L  
 REP. 7.40 mg/L

8-METER 7.30 mg/L  
 REP. 6.70 mg/L

MONON LAKE  
 JULY 11, 1992

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	17.8	8.20
1.00	17.6	7.40
2.00	17.4	7.20
3.00	17.6	7.40
4.00	17.4	7.20
5.00	17.3	7.50
6.00	17.2	7.50
7.00	17.1	7.40
8.00	17.1	7.50
9.00	17.1	7.60
10.00	17.1	7.50
11.00	17.1	7.50

WOT: 1-METER 6.55 mg/L  
 REP. 6.90 mg/L

OLLALIE LAKE  
 JUNE 30, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	12.6	8.46
2.50	12.5	9.20
5.00	12.0	8.58
7.50	12.0	9.30
10.00	11.3	8.61

OLLALIE LAKE

SEPTEMBER 2, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	17.3	7.88
1.00	17.4	7.71
2.00	17.4	7.65
3.00	17.3	7.64
4.00	17.3	7.62
5.00	17.3	7.63
6.00	17.3	7.60
7.00	17.3	7.60
8.00	17.2	7.57
9.00	17.2	7.61
10.00	17.2	7.60
11.00	17.2	7.61
12.00	17.2	7.64
13.00	17.2	MUD
WOT: 1-METER	6.65 mg/L	11-METER 7.61 mg/L
	REP. 7.40 mg/L	REP. 8.00 mg/L

OLLALIE LAKE  
JULY 16, 1992

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	18.0	7.50
1.00	18.0	7.40
2.00	17.9	7.50
3.00	17.9	7.40
4.00	17.9	7.40
5.00	17.9	7.40
6.00	17.9	7.40
7.00	17.8	7.40
8.00	17.8	7.40
9.00	17.8	7.40
10.00	17.8	7.40
11.00	17.7	7.40
12.00	17.7	7.40
13.00	17.7	7.40
14.00	17.7	7.40
15.00	17.7	7.40
16.00	17.8	BOTTOM
WOT: SURFACE	6.82 mg/L	10-METER 6.90 mg/L
	REP. 6.80 mg/L	REP. 6.75 mg/L
(taken from 7/17/92 sampling)		

ROUND LAKE

JULY 8, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	20.6	8.57
1.00	18.2	9.31
2.00	14.8	10.62
3.00	12.9	10.92
4.00	11.5	11.00
5.00	10.5	11.04
6.00	9.6	11.50

ROUND LAKE  
AUGUST 24, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	20.2	9.10
1.00	20.0	9.10
2.00	19.1	10.30
3.00	17.5	11.50
4.00	16.4	11.50
5.00	15.5	12.40
6.00	13.9	11.50
7.00	12.5	7.20

WOT: 1-METER 11.65 mg/L      6-METER 12.20 mg/L  
 REP. 10.10 mg/L              REP. 11.60 mg/L

ROUND LAKE  
JULY 3, 1992

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	19.9	9.02
1.00	18.5	8.73
2.00	17.7	9.32
3.00	16.5	11.34
4.00	15.5	10.75
5.00	14.8	11.81
6.00	13.1	11.74
7.00	11.1	2.3-5?
8.00	9.4	0.30

WOT: 1-METER 8.85 mg/L      5-METER 9.90 mg/L  
 REP. 7.40 mg/L              REP. 10.40 mg/L

RIMROCK LAKE  
JULY 3, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	18.8	7.80
0.50	17.8	8.00
1.00	16.8	8.00
1.50	16.3	8.40
2.00	16.0	8.00
2.50	15.9	8.40
3.00	15.7	8.40

RIMROCK LAKE  
AUGUST 30, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	15.9	7.32
0.50	16.1	7.19
1.00	16.1	7.12
1.50	16.1	7.08
2.00	16.1	7.15
2.50	16.1	7.16
3.00	16.0	7.15

WOT: 1-METER 7.35 mg/L      2-METER 8.10 mg/L  
 REP. 7.60 mg/L              REP. 7.60 mg/L

RIMROCK LAKE  
JULY 16, 1992

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	20.5	7.50
0.50	20.3	7.60
1.00	19.8	7.60
1.50	19.6	7.60
2.00	19.5	7.50
2.50	19.6	7.50
3.00	19.5	7.60

WOT: 1-METER 5.95 mg/L  
 REP. 6.30 mg/L

SPORTSMAN LAKE  
JULY 4, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
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0.00	21.5	8.30
0.25	21.0	8.40
0.50	19.6	8.50
0.75	19.1	8.50
1.00	18.7	8.50
1.25	18.5	8.40

SPORTSMAN LAKE  
AUGUST 19, 1991

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	24.0	6.70
0.25	23.4	6.60
0.50	22.1	6.95
0.75	21.8	6.98
1.00	21.8	6.90
1.25	21.6	7.31
1.50	21.6	7.40

WOT: 1-METER 7.65 mg/L  
REP. 6.90 mg/L

SPORTSMAN LAKE  
JULY 25, 1992

DEPTH (m)	TEMPERATURE (C)	DISSOLVED OXYGEN (mg/L)
0.00	22.0	6.40
0.25	21.3	6.40
0.50	19.3	6.40
0.75	18.8	6.20
1.00	18.5	6.40
1.25	18.6	6.70

WOT: 1-METER 5.50 mg/L  
REP. 6.05 mg/L

APPENDIX C

PHYTOPLANKTON DATA

This phytoplankton analysis was performed by Jim  
Sweet, Aquatic Analysts Inc.

## APPENDIX C

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Cripple Creek Lake, 0-1 meter

SAMPLE DATE: 91-07-07

TOTAL DENSITY (#/ml): 2053

TOTAL BIOVOLUME (cu.um/ml): 488225

TROPIC STATE INDEX: 44.7

DIVERSITY INDEX: 2.78

SPECIES	DENSITY	PCT	BIOVOL	PCT
1 Rhodomonas minuta	791	38.5	15819	3.2
2 Fragilaria construens venter	623	30.3	84880	17.4
3 Melosira ambigua	135	6.6	178414	36.5
4 Fragilaria construens	84	4.1	35811	7.3
5 Fragilaria pinnata	67	3.3	12116	2.5
6 Melosira sp.	50	2.5	50485	10.3
7 Scenedesmus sp.	34	1.6	5049	1.0
8 Cymbella minuta	34	1.6	12453	2.6
9 Fragilaria capucina	17	0.8	17165	3.5
10 Scenedesmus denticulatus	17	0.8	3029	0.6
11 Epithemia sorex	17	0.8	19184	3.9
12 Selenastrum sp.	17	0.8	337	0.1
13 Achnanthes lanceolata	17	0.8	3029	0.6
14 Cyclotella stelligera	17	0.8	926	0.2
15 Cosmarium sp.	17	0.8	3534	0.7
16 Navicula minima	17	0.8	740	0.2
17 Melosira italica	17	0.8	31705	6.5
18 Navicula cryptocephala	17	0.8	3113	0.6
19 Unidentified flagellate	17	0.8	340	0.1
20 Nitzschia sp.	17	0.8	2019	0.4
21 Synedra radians	17	0.8	6058	1.2
22 Nitzschia sp.	17	0.8	2019	0.4

SAMPLE: Cripple Creek Lake, 0-.75 meters

SAMPLE DATE: 91-08-21

TOTAL DENSITY (#/ml): 531

TOTAL BIOVOLUME (cu.um/ml): 21129

TROPIC STATE INDEX: 22.3

DIVERSITY INDEX: 1.54

SPECIES	DENSITY	PCT	BIOVOL	PCT
1 Rhodomonas minuta	341	64.3	6822	32.3
2 Cyclotella stelligera	133	25.0	7296	34.5
3 Ankistrodesmus falcatus	14	2.7	355	1.7
4 Selenastrum minutum	14	2.7	284	1.3
5 Oocystis pusilla	9	1.8	2047	9.7
6 Chromulina sp.	5	0.9	95	0.4
7 Chlamydomonas sp.	5	0.9	1540	7.3
8 Cryptomonas erosa	5	0.9	2463	11.7
9 Achnanthes hauckiana	5	0.9	227	1.1



## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Anvil, 0-1

SAMPLE DATE: 91-07-08

TOTAL DENSITY (#/ml): 543

TOTAL BIOVOLUME (cu.um/ml): 56865

TROPIC STATE INDEX: 29.3

DIVERSITY INDEX: 1.75

SPECIES	DENSITY	PCT	BIOVOL	PCT
1 Ochromonas-like	388	71.4	17458	30.7
2 Mallomonas-like	58	10.7	5237	9.2
3 Mallomonas sp.	19	3.6	7371	13.0
4 Chromulina sp.	15	2.7	291	0.5
5 Unidentified flagellate	15	2.7	291	0.5
6 Chlamydomonas sp.	5	0.9	1576	2.8
7 Anabaena flos-aquae	5	0.9	4849	8.5
8 Cymbella microcephala	5	0.9	257	0.5
9 Tetraedron caudatum	5	0.9	194	0.3
10 Pediastrum tetras	5	0.9	145	0.3
11 Oocystis lacustris	5	0.9	1494	2.6
12 Achnanthes minutissima	5	0.9	242	0.4
13 Gymnodinium sp.	5	0.9	13094	23.0
14 Tetraedron minimum	5	0.9	873	1.5
15 Eunotia pectinalis	5	0.9	3492	6.1

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Anvil, 0.5-1

SAMPLE DATE: 91-08-22

TOTAL DENSITY (#/ml): 1424

TOTAL BIOVOLUME (cu.um/ml): 185991

TROPIC STATE INDEX: 37.7

DIVERSITY INDEX: 1.79

SPECIES	DENSITY	PCT	BIOVOL	PCT
1 Rhodomonas minuta	890	62.5	17803	9.6
2 Ankistrodesmus falcatus	320	22.5	13058	7.0
3 Ochromonas-like	36	2.5	1602	0.9
4 Chlamydomonas sp.	36	2.5	11572	6.2
5 Dinobryon sertularia	36	2.5	5683	3.1
6 Mallomonas sp.	24	1.7	9020	4.8
7 Sphaerocystis schroeteri	24	1.7	2908	1.6
8 Chryso-sphaerella sp.	12	0.8	5697	3.1
9 Ceratium hirundinella	12	0.8	116311	62.5
10 Crucigenia quadrata	12	0.8	1009	0.5
11 Tetraedron sp.	12	0.8	320	0.2
12 Crucigenia crucifera	12	0.8	1009	0.5

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Beaver Pond, 1.25-2.5

SAMPLE DATE: 91-06-24

TOTAL DENSITY (#/ml): 2419

TOTAL BIOVOLUME (cu.um/ml): 113283

TROPIC STATE INDEX: 34.2

DIVERSITY INDEX: 1.03

SPECIES	DENSITY	PCT	BIOVOL	PCT
1 Rhodomonas minuta	2050	84.7	41000	36.2
2 Chromulina sp.	123	5.1	2460	2.2
3 Ankistrodesmus falcatus	62	2.5	1538	1.4
4 Kephyrion sp.	41	1.7	2583	2.3
5 Cryptomonas erosa	41	1.7	21320	18.8
6 Chrysococcus rufescens	41	1.7	3485	3.1
7 Trachelomonas volvocina	21	0.8	38643	34.1
8 Unidentified flagellate	21	0.8	410	0.4
9 Mallomonas-like	21	0.8	1845	1.6

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Beaver Pond, 2 meters

SAMPLE DATE: 91-08-23

TOTAL DENSITY (#/ml): 2147

TOTAL BIOVOLUME (cu.um/ml): 847609

TROPIC STATE INDEX: 48.7

DIVERSITY INDEX: 2.70

SPECIES	DENSITY	PCT	BIOVOL	PCT
1 Cryptomonas erosa	884	41.2	459659	54.2
2 Ankistrodesmus falcatus	451	21.0	11275	1.3
3 Rhodomonas minuta	235	10.9	4690	0.6
4 Phacus sp.	198	9.2	69454	8.2
5 Chlamydomonas sp.	72	3.4	23452	2.8
6 Sphaerocystis schroeteri	72	3.4	12628	1.5
7 Gymnodinium sp.	36	1.7	97416	11.5
8 Ochromonas sp.	36	1.7	3067	0.4
9 Chroomonas sp.	36	1.7	2345	0.3
10 Trachelomonas sp.	18	0.8	36080	4.3
11 Coccoconeis placentula	18	0.8	8298	1.0
12 Peridinium cinctum	18	0.8	75768	8.9
13 Nitzschia acicularis	18	0.8	5051	0.6
14 Dictyosphaerium ehrenbergianum	18	0.8	2165	0.3
15 Trachelomonas volvocina	18	0.8	34005	4.0
16 Dinobryon sp.	18	0.8	2255	0.3

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Gifford Lake, 11 meters

SAMPLE DATE: 91-07-02

TOTAL DENSITY (#/ml): 31

TOTAL BIOVOLUME (cu.µm/ml): 16730

TROPIC STATE INDEX: 20.7

DIVERSITY INDEX: 1.41

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Glenodinium ?	21.9	71.1	15331	91.6
2	Unident. desmid	4.9	15.8	803	4.8
3	Unidentified flagellate	1.6	5.3	32	0.2
4	Chlamydomonas-like	0.8	2.6	264	1.6
5	Asterionella formosa	0.8	2.6	178	1.1
6	Navicula sp.	0.8	2.6	122	0.7

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Gifford Lake, 11 meters

SAMPLE DATE: 91-08-29

TOTAL DENSITY (#/ml): 627

TOTAL BIOVOLUME (cu.µm/ml): 20143

TROPIC STATE INDEX: 22

DIVERSITY INDEX: 0.43

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Chromulina sp.	588	93.8	11765	58.4
2	Oocystis pusilla	25	3.9	4235	21.0
3	Mallomonas sp.	5	0.8	1863	9.2
4	Chlamydomonas-like	5	0.8	1593	7.9
5	Sphaerocystis Schroeteri	5	0.8	686	3.4

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Monon, 10 meters

SAMPLE DATE: 91-06-29

TOTAL DENSITY (#/ml): 164

TOTAL BIOVOLUME (cu.um/ml): 8445

TROPIC STATE INDEX: 16.2

DIVERSITY INDEX: 1.65

SPECIES	DENSITY	PCT	BIOVOL	PCT
1 Unidentified flagellate	102	62.2	2038	24.1
2 Chromulina sp.	38	23.5	768	9.1
3 Chlamydomonas sp.	10	6.1	3257	38.6
4 Cyclotella atomus	5	3.1	100	1.2
5 Tetraedron minimum	2	1.0	301	3.6
6 Oocystis pusilla	2	1.0	361	4.3
7 Cryptomonas erosa	2	1.0	869	10.3
8 Anacystis sp.	2	1.0	501	5.9
9 Navicula sp.	2	1.0	251	3.0

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Monon, 8 meters

SAMPLE DATE: 91-09-01

TOTAL DENSITY (#/ml): 613

TOTAL BIOVOLUME (cu.um/ml): 42037

TROPIC STATE INDEX: 27.1

DIVERSITY INDEX: 0.46

SPECIES	DENSITY	PCT	BIOVOL	PCT
1 Chromulina sp.	553	90.3	11062	26.3
2 Cryptomonas erosa	60	9.7	30974	73.7

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Olallie, 10 meters

SAMPLE DATE: 91-09-02

TOTAL DENSITY (#/ml): 996

TOTAL BIOVOLUME (cu.µM/ml): 21765

TROPIC STATE INDEX: 22.5

DIVERSITY INDEX: 0.09

SPECIES	DENSITY	PCT	BIOVOL	PCT
1 Chromulina sp.	987	99.1	19731	90.7
2 Oocystis pusilla	5	0.5	507	2.3
3 Chlamydomonas sp.	5	0.5	1527	7.0

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Olallie, 0-12

SAMPLE DATE: 91-06-30

TOTAL DENSITY (#/ml): 81

TOTAL BIOVOLUME (cu.µM/ml): 26025

TROPIC STATE INDEX: 23.8

DIVERSITY INDEX: 1.97

SPECIES	DENSITY	PCT	BIOVOL	PCT
1 Chromulina sp.	48.5	60.2	971	3.7
2 Oocystis pusilla	11.0	13.6	2622	10.1
3 Chlamydomonas sp.	7.0	8.7	2290	8.8
4 Gymnodinium sp.	7.0	8.7	19027	73.1
5 Sphaerocystis schroeteri	1.6	1.9	329	1.3
6 Tetraedron sp.	1.6	1.9	42	0.2
7 Unidentified flagellate	1.6	1.9	31	0.1
8 Achnanthes minutissima	0.8	1.0	39	0.2
9 Crucigenia quadrata	0.8	1.0	266	1.0
10 Cryptomonas erosa	0.8	1.0	407	1.6

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Fish, 12 meters

SAMPLE DATE: 91-07-01

TOTAL DENSITY (#/ml): 7547

TOTAL BIOVOLUME (cu.uM/ml): 2731256

TROPIC STATE INDEX: 57.1

DIVERSITY INDEX: 1.17

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Asterionella formosa	6013	79.7	2645867	96.9
2	Chrysochromulina sp.	872	11.6	17439	0.6
3	Cyclotella stelligera	180	2.4	9922	0.4
4	Selenastrum minutum	120	1.6	2405	0.1
5	Rhodomonas minuta	120	1.6	2405	0.1
6	Chlamydomonas sp.	90	1.2	29315	1.1
7	Unidentified flagellate	60	0.8	1203	0.0
8	Crucigenia quadrata	30	0.4	2556	0.1
9	Achnanthes clevei	30	0.4	4510	0.2
10	Cryptomonas erosa	30	0.4	15635	0.6

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Fish, 7 meters

SAMPLE DATE: 91-08-30

TOTAL DENSITY (#/ml): 356

TOTAL BIOVOLUME (cu.uM/ml): 80722

TROPIC STATE INDEX: 31.8

DIVERSITY INDEX: 2.43

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Melosira distans	139	39.0	50556	62.6
2	Chromulina sp.	100	28.0	1995	2.5
3	Oocystis pusilla	30	8.5	7967	9.9
4	Crucigenia quadrata	26	7.3	2212	2.7
5	Botryococcus braunii	22	6.1	12489	15.5
6	Rhodomonas minuta	22	6.1	434	0.5
7	Asterionella formosa	4	1.2	954	1.2
8	Ankistrodesmus falcatus	4	1.2	108	0.1
9	Sphaerocystis schroeteri	4	1.2	607	0.8
10	Fragilaria construens	4	1.2	3400	4.2

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Rimrock, 1.5 - 3

SAMPLE DATE: 91-08-28

TOTAL DENSITY (#/ml): 2019

TOTAL BIOVOLUME (cu.µM/ml): 52670

TROPIC STATE INDEX: 28.7

DIVERSITY INDEX: 0.28

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Chromulina sp.	1933	95.7	38657	73.4
2	Sphaerocystis schroeteri	75	3.7	10523	20.0
3	Chlamydomonas sp.	11	0.5	3490	6.6

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Rimrock, 1.5 - 3

SAMPLE DATE: 91-07-02

TOTAL DENSITY (#/ml): 334

TOTAL BIOVOLUME (cu.µM/ml): 8562

TROPIC STATE INDEX: 16.3

DIVERSITY INDEX: 0.12

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Chromulina sp.	329	98.6	6577	76.8
2	Cryptomonas erosa	2	0.7	1221	14.3
3	Chlamydomonas sp.	2	0.7	763	8.9

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Round, 0-6 meters

SAMPLE DATE: 91-07-08

TOTAL DENSITY (#/ml): 1995

TOTAL BIOVOLUME (cu.µm/ml): 912300

TROPIC STATE INDEX: 49.2

DIVERSITY INDEX: 1.56

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Asterionella formosa	1353	67.8	634016	69.5
2	Chlamydomonas sp.	382	19.1	124025	13.6
3	Rhodomonas minuta	104	5.2	2082	0.2
4	Chromulina sp.	35	1.7	694	0.1
5	Unidentified flagellate	35	1.7	694	0.1
6	Cocconeis placentula	17	0.9	7979	0.9
7	Ochromonas sp.	17	0.9	1474	0.2
8	Melosira italica	17	0.9	65360	7.2
9	Peridinium cinctum	17	0.9	72854	8.0
10	Gomphonema angustatum	17	0.9	3122	0.3

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Round, 6 meters

SAMPLE DATE: 91-08-24

TOTAL DENSITY (#/ml): 1443

TOTAL BIOVOLUME (cu.µm/ml): 247629

TROPIC STATE INDEX: 39.8

DIVERSITY INDEX: 1.62

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Quadrigula lacustris	812	56.2	100095	40.4
2	Asterionella formosa	438	30.4	99277	40.1
3	Rhodomonas minuta	90	6.2	1804	0.7
4	Cryptomonas erosa	64	4.5	33503	13.5
5	Chlamydomonas sp.	13	0.9	4188	1.7
6	Staurastrum gracile	13	0.9	6958	2.8
7	Sphaerocystis Schroeteri	13	0.9	1804	0.7



## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Sportsman, 0-1.5

SAMPLE DATE: 91-07-04

TOTAL DENSITY (#/ml): 547

TOTAL BIOVOLUME (cu.µM/ml): 35747

TROPIC STATE INDEX: 26

DIVERSITY INDEX: 2.07

SPECIES	DENSITY	PCT	BIOVOL	PCT
1 Chromulina sp.	273	50.0	5467	15.3
2 Unidentified flagellate	178	32.5	3553	9.9
3 Chlamydomonas sp.	14	2.5	4442	12.4
4 Cocystis pusilla	14	2.5	2214	6.2
5 Mallomonas-like	9	1.7	820	2.3
6 Synedra cyclopum	9	1.7	7699	21.5
7 Ankistrodesmus falcatus	9	1.7	228	0.6
8 Sphaerocystis Schroeteri	9	1.7	6378	17.8
9 Rhodomonas minuta	9	1.7	182	0.5
10 Nitzschia paleacea	5	0.8	446	1.2
11 Tetraedron minimum	5	0.8	820	2.3
12 Gomphonema sp.	5	0.8	911	2.5
13 Cryptomonas erosa	5	0.8	2369	6.6
14 Fragilaria construens venter	5	0.8	219	0.6

## PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Sportsman, 1 meter

SAMPLE DATE: 91-08-19

TOTAL DENSITY (#/ml): 902

TOTAL BIOVOLUME (cu.µM/ml): 54612

TROPIC STATE INDEX: 29

DIVERSITY INDEX: 1.80

SPECIES	DENSITY	PCT	BIOVOL	PCT
1 Ankistrodesmus falcatus	467	51.8	11685	21.4
2 Chromulina sp.	287	31.8	5740	10.5
3 Cryptomonas erosa	57	6.4	29848	54.7
4 Rhodomonas minuta	41	4.5	820	1.5
5 Mallomonas-like	25	2.7	2214	4.1
6 Unidentified flagellate	8	0.9	164	0.3
7 Gomphonema angustatum	8	0.9	1476	2.7
8 Chlamydomonas sp.	8	0.9	2665	4.9

APPENDIX D

ZOOPLANKTON DATA

This zooplankton analysis was performed by Allan  
Vogel, ZP Taxonomic Services.

## ZOOPLANKTON DATA

ANVIL LAKE--7/8/91

<u>SPECIES</u>	
<u>DENSITY</u> (Individuals/m <sup>3</sup> )	
<u>Daphnia rosea</u>	191
<u>Ceriodaphnia reticulata</u>	64
<u>Bosmina longirostris</u>	159
<u>Chydorus sphaericus</u>	32
<u>Diaptomus novamexicanus</u>	350
<u>Diaptomus kenai</u>	191
<u>Diaptomus copepodite</u>	223
<u>Cyclops vernalis</u>	127
Cyclopoid copepodites	32
Copepod nauplii	1019
<u>Epiphanes spp.</u>	32
<u>Kellicattia longispina</u>	255
<u>Keratella cochlearis</u>	414
<u>Polyarthra dolichoptera</u>	4043
<u>P. vulgaris</u>	95
Water mite	64
TOTAL DENSITY	7289

ANVIL LAKE--8/22/91

<u>SPECIES</u>	<u>DENSITY</u> (Individuals/m <sup>3</sup> )
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<u>Daphnia rosea</u>	272
<u>Ceriodaphnia reticulata</u>	8964
<u>Diaphanosoma brach.</u>	598
<u>Bosmina longirostris</u>	217
<u>Chydorus sphaericus</u>	109
<u>A. guttata</u>	54
<u>Diaptomus novamexicanus</u>	2553
<u>D. kenai</u>	5378
<u>D. copepodite</u>	2716
<u>Cyclops vernalis</u>	217
Cyclopoid copepodites	109
Copepod nauplii	1358
<u>Cypridopsis vidue</u>	54
<u>Polyartha dolichoptera</u>	272
TOTAL DENSITY	22871

## BEAVER POND LAKE--6/24/91

SPECIESDENSITY(Individuals/m<sup>3</sup>)

<u>Daphnia pulex</u>	2037
<u>Diaptomus kenai</u>	5949
<u>D. copepodite</u>	20290
<u>Copepod naulii</u>	7823
<u>Keratella quadrata</u>	81
TOTAL DENSITY	36180

## BEAVER POND LAKE--8/23/91

<u>Daphnia pulex</u>	782
<u>Ceriodaphnia pulchella</u>	16
<u>Diaptomus kenai</u>	1010
<u>D. copepodite</u>	839
<u>Cyclops vernalis</u>	8
Cyclopoid copepodites	16
<u>Copepod nauplii</u>	2053
<u>Cypridopsis vidua</u>	41
<u>Polyartha dolichoptera</u>	8
<u>Chaoborus</u>	440
Water mite	16
TOTAL DENSITY	5240

## CRIPPLE CREEK LAKE--7/7/91

<u>SPECIES</u>	
<u>DENSITY</u> (Individual/m <sup>3</sup> )	
<u>Daphnia rosea</u>	95
<u>Bosmina longirostris</u>	509
<u>Chydorus sphaericus</u>	64
<u>Alona quadrangularis</u>	32
<u>Diaptomus tyrrelli</u>	223
<u>D. kenai</u>	509
<u>D. copepodite</u>	1019
<u>Cyclops vernalis</u>	64
Cyclopoid copepodites	64

Copepod nauplii	414
<u>Keratella cochlearis</u>	64
<u>Polyartha dolichoptera</u>	64
TOTAL DENSITY	3119

## CRIPPLE CREEK LAKE--8/21/91

<u>SPECIES</u>	
<u>DENSITY</u> (Individual/m <sup>3</sup> )	
<u>Daphnia rosea</u>	102
<u>Ceriodaphnia pulchella</u>	25
<u>Diaphanosoma brach.</u>	25
<u>Bosmina longirostris</u>	102
<u>Alona quadrangularis</u>	25
<u>Diaptomus tyrrelli</u>	1401
<u>D. kenai</u>	1044
<u>D. copepodite</u>	5297
<u>Epischura nevadensis</u>	25
<u>E. nevadensis</u> copepodites	51
Copepod nauplii	2343
<u>Conochilus spp.</u>	1375
<u>Filinia terminalis</u>	76
<u>Kellicottia longispina</u>	127
<u>Keratella cochlearis</u>	153
<u>K. quadrata</u>	51
Chironomid larvae	25
TOTAL DENSITY	12249

## FISH LAKE--7/7/91

<u>Daphnia rosea</u>	16
<u>Eubosmina hagmanni</u>	166
<u>Holopedium gibberum</u>	420
<u>Diaptomus tyrrelli</u>	83
<u>D. kenai</u>	3
<u>D. copepodite</u>	89
<u>Epischura nevadensis</u>	54
<u>E. nevadensis copepodites</u>	16
<u>Cyclops bicuspidatus thomasi</u>	172
Cyclopoid copepodites	1467
Copepod nauplii	83
<u>Conochilus spp.</u>	691
<u>Kellicottia longispina</u>	22
TOTAL DENSITY	3282

## FISH LAKE--8/8/91

<u>Daphnia rosea</u>	98
<u>Eubosmina hagmanni</u>	33
<u>Holopedium gibberum</u>	456
<u>Diaptomus tyrrelli</u>	228
<u>Diaptomus kenai</u>	130
<u>D. copepodite</u>	196
<u>Cyclops bicuspidatus thomasi</u>	3390
Cyclopoid copepodites	12060

Copepod nauplii	65
<u>Conochilus</u> spp.	65
<u>Kellicottia longispina</u>	1597
TOTAL DENSITY	18318

GIFFORD LAKE--7/2/91

SPECIES

DENSITY(Individuals/m<sup>3</sup>)

<u>Daphnia rosea</u>	13
<u>Eubosmina hagmanni</u>	407
<u>Holopedium gibberum</u>	363
<u>Diaptomus</u> copepodite	6
<u>Epischura nevadensis</u>	38
<u>E. nevadensis</u> copepodites	64
<u>Cyclops bicuspidatus thomasi</u>	210
<u>Cyclopoid</u> copepodites	1120
Copepod nauplii	45
<u>Conochilus</u> spp.	115
<u>Kellicottia longispina</u>	153
<u>Keratella cochlearis</u>	6
TOTAL DENSITY	2540

GIFFORD LAKE--8/19/91

<u>Daphnia rosea</u>	64
<u>Eubosmanni hagmanni</u>	665
<u>Holopedium gibberum</u>	933



<u>Eubosmanni hagmanni</u>	665
<u>Holopedium gibberum</u>	933
<u>Diaptomus signicauda</u>	26
<u>Diaptomus</u> copepodite	141
<u>Epischura nevadensis</u>	77
<u>E. nevadensis</u> copepodites	882
<u>Cyclops bicuspidatus thomasi</u>	1508
Cyclopoid copepodites	1163
Copepod nauplii	64
<u>Conochilus</u> spp.	64
<u>Keratella cochlearis</u>	205
<u>Polyartha dolichoptera</u>	38
TOTAL DENSITY	5829

## MONON LAKE--6/29/91

<u>Daphnia galeata mendotae</u>	64
<u>Eubosmina hagmanni</u>	484
<u>Holopedium gibberum</u>	166
<u>Diaptomus</u> copepodite	51
<u>Epischura nevadensis</u>	76
<u>E. nevadensis</u> copepodites	38
<u>Cyclops bicuspidatus thomasi</u>	388
Cyclopoid copepodites	1502
Copepod nauplii	95
<u>Polyartha dolichoptera</u>	64

## MONON LAKE--9/1/91

<u>Daphnia galeata mendotae</u>	7349
<u>D. rosea</u>	731
<u>Eubosmina hagmanni</u>	138
<u>Holopedium gibberum</u>	494
<u>Diaptomus signicauda</u>	119
<u>D. copepodite</u>	20
<u>Epistura nevadensis</u>	217
<u>E. nevadensis</u> copepodites	336
<u>Cyclops bicuspidatus thomasi</u>	99
Cyclopoid copepodites	948
<u>Brachionus</u> spp.	20
<u>Kellicottia longispina</u>	59
<u>Polyartha dolichoptera</u>	454
TOTAL DENSITY	10984

## OLLALIE LAKE--6/30/91

<u>Daphnia rosea</u>	13
<u>Eubosmina hagmanni</u>	1019
<u>Holopedium gibberum</u>	1642
<u>Diaptomus kenai</u>	382
<u>Epischura nevadensis</u>	38
<u>E. nevadensis</u> copepodites	191
<u>Cyclops bicuspidatus thomasi</u>	407
Cyclopoid copepodites	2508

Copepod nauplii	64
<u>Kellicottia bostonensis</u>	13
TOTAL DENSITY	6277

## OLLALIE LAKE--9/2/91

<u>Daphnia geleata mendotae</u>	1047
<u>D. rosea</u>	109
<u>Eubosmina hagmanni</u>	1531
<u>Holopedium gibberum</u>	1679
<u>Diaptomus kenai</u>	89
<u>Epischura nevadensis</u>	49
<u>E. nevadensis</u> copepodites	533
Cyclopoid copepodites	30
Copepod nauplii	49
<u>Kellicottia bostonensis</u>	10
<u>Polyartha dolichoptera</u>	247
<u>Synchaeta</u> spp.	10
TOTAL DENSITY	5383

## RIMROCK LAKE--7/3/91

<u>Eubosmina hagmanni</u>	21
<u>Holopedium gibberum</u>	7979
<u>Diaptomus kenai</u>	637
<u>Diaptomus</u> copepodite	42
Copepod nauplii	403

<u>Asplanchna priodonta</u>	42
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TOTAL DENSITY	9125
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## RIMROCK LAKE--8/30/91

<u>Eubosmina hagmanni</u>	158
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<u>Holopedium gibberum</u>	5546
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<u>Chydorus sphaericus</u>	26
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<u>Alona guttata</u>	26
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<u>Diaptomus signicauda</u>	631
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<u>D. copepodite</u>	53
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<u>Epischura nevadensis</u>	499
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<u>E. nevadensis</u> copepodites	841
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Copepod nauplii	26
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<u>Conochilus</u> spp.	5967
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<u>Keratella cochlearis</u>	26
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TOTAL DENSITY	13800
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## ROUND LAKE--7/8/91

<u>Daphnia rosea</u>	196
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<u>Daphnia pulex</u>	64
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<u>Bosmina longirostris</u>	85
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<u>Holopedium gibberum</u>	74
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<u>Diaptomus</u> copepodite	5
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<u>Epischura nevadensis</u>	5
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<u>E. nevadensis</u> copepodites	149
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<u>Cyclops bicuspidatus thomasi</u>	223
Cyclopoid copepodites	133
Copepod nauplii	122
<u>Conochilus</u> spp.	11
<u>Kellicottia longispina</u>	5
<u>Keratella cochlearis</u>	101
<u>K. quadrata</u>	244
<u>Polyartha dolichoptera</u>	5
Unidentified spp.	5
TOTAL DENSITY	1427

## ROUND LAKE--8/24/91

<u>Daphnia pulex</u>	5161
<u>Bosmina longirostris</u>	14
<u>Holopedium gibberum</u>	27
<u>Diaptomus kenai</u>	14
<u>Cyclops bicuspidatus thomasi</u>	475
Cyclopoid copepodites	177
Copepod nauplii	367
<u>Kellicottia longispina</u>	14
Nematode	14
TOTAL DENSITY	6261

## SPORTSMAN--7/4/91

<u>Daphnia rosea</u>	2292
<u>Chydorus sphaericus</u>	85

<u>Diaptomus signicauda</u>	127
<u>D. kenai</u>	870
<u>D. copepodite</u>	3565
<u>Cyclops vernalis</u>	21
Copepod nauplii	3608
<u>Keratella cochlearis</u>	1167
TOTAL DENSITY	11735

## SPORTSMAN--8/19/91

<u>Daphnia rosea</u>	1467
<u>Daphnia reticulata</u>	163
<u>Diaphanasoma brach.</u>	2879
<u>Eubosmina hagmanni</u>	109
<u>Chydorus sphaericus</u>	163
<u>Alona affinis</u>	217
<u>Pleuroxus denticulatus</u>	163
<u>Sida crystallina</u>	109
<u>Diaptomus signicauda</u>	9453
<u>D. kenai</u>	1467
<u>D. copepodite</u>	8855
<u>Cyclops vernalis</u>	869
Cyclopoid copepodites	380
Copepod nauplii	435
<u>Cypridopsis vidua</u>	54
<u>Keratella cochlearis</u>	1412
Oligochaete	54

Hydra

54

TOTAL DENSITY

28303