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MEASUREMENT OF LAKE ROOSEVELT BIOTA IN RELATION TO RESERVOIR OPERATIONS

DRAFT REPORT
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1.0 INTRODUCTION

The purpose of this research project is to collect data to model resident fish requirements for Lake Roosevelt as part of the Bonneville Power Administration (BPA), Bureau of Reclamation (BoR), and U.S. Army Corps of Engineer's (ACE) System Operation Review. The System Operation Review (SOR) is a tri-agency team functioning to review the use and partitioning of Columbia Basin waters. User groups of the Columbia have been defined as power, irrigation, flood control, anadromous fish, resident fish, wildlife, recreation, water quality, navigation, and cultural resources.

Once completed the model will predict biological responses to different reservoir operation strategies. The model being developed for resident fish is based on Montana Department of Fish, Wildlife, and Parks model for resident fish requirements within Hungry Horse and Libby Reservoirs. While the Montana model predicts fish growth based on the impacts of reservoir operation and flow conditions on primary and secondary production levels, the Lake Roosevelt model will also factor in the affects of water retention time on zooplankton production levels and fish entrainment. Major components of the Lake Roosevelt model include: 1) quantification of impacts to zooplankton, benthic invertebrates, and fish caused by reservoir drawdowns and low water retention times; 2) quantification of number, distribution, and use of fish food organisms in the reservoir by season; 3) determination of seasonal growth of fish species as related to reservoir operations, prey abundance and utilization; and 4) quantification of entrainment levels of fish as related to reservoir operations and water retention times.

In July 1991, BPA entered into a contract with the Spokane Tribe of Indians to initiate the System Operation Review process with continued research through 1995. The SOR project is a modification of the Lake Roosevelt Monitoring Project contract with Bonneville that studies the affects of kokanee reintroduction into Lake Roosevelt. This report contains the results of the resident fish system operation review program for Lake Roosevelt from January through December 1992.

1.1 DESCRIPTION OF STUDY AREA

Lake Roosevelt is a mainstem Columbia River impoundment formed by the construction of Grand Coulee Dam in 1939 (Figure 1.1.1). Filled in 1941, the reservoir inundated 33,490 hectares at a full pool elevation of 393 m above mean sea level. It has a maximum width of 3.4 km and a maximum depth of 122 m (Stober *et al.* 1981). Grand Coulee Dam is a Bureau of Reclamation storage project operated primarily for power, flood control, and irrigation with secondary operations for recreation, fish, and wildlife.

1.2 STUDY OBJECTIVES - 1992

The objectives of the project were to determine how reservoir operations affect reservoir biology:

#1. Development of surface area vs. elevation and volume vs elevation tables to calculate wetted bottom at each elevation;

#2. Determination of reservoir hydrology, downstream flow constraints and how these affect reservoir operations:

#3. Collection of temperature profile data to develop a longitudinal thermal structure in the forebay of Lake Roosevelt;

#4. Collection of light penetration data at four sites to describe annual shifts in euphotic zone depth and light availability for photosynthetic use at depth intervals;

#5. Determination of carbon fixation levels of phytoplankton using a C^{14} liquid scintillation technique at Gifford (site 2), Porcupine Bay (site 4), Seven Bays (site 6), and Spring Canyon (site 9). Concurrently collect solar input data using a recording light meter;

#6. Determine zooplankton biomass, density, vertical distribution, and entrainment;

#7. Determine benthic macroinvertebrate production levels and densities at differing reservoir strata;

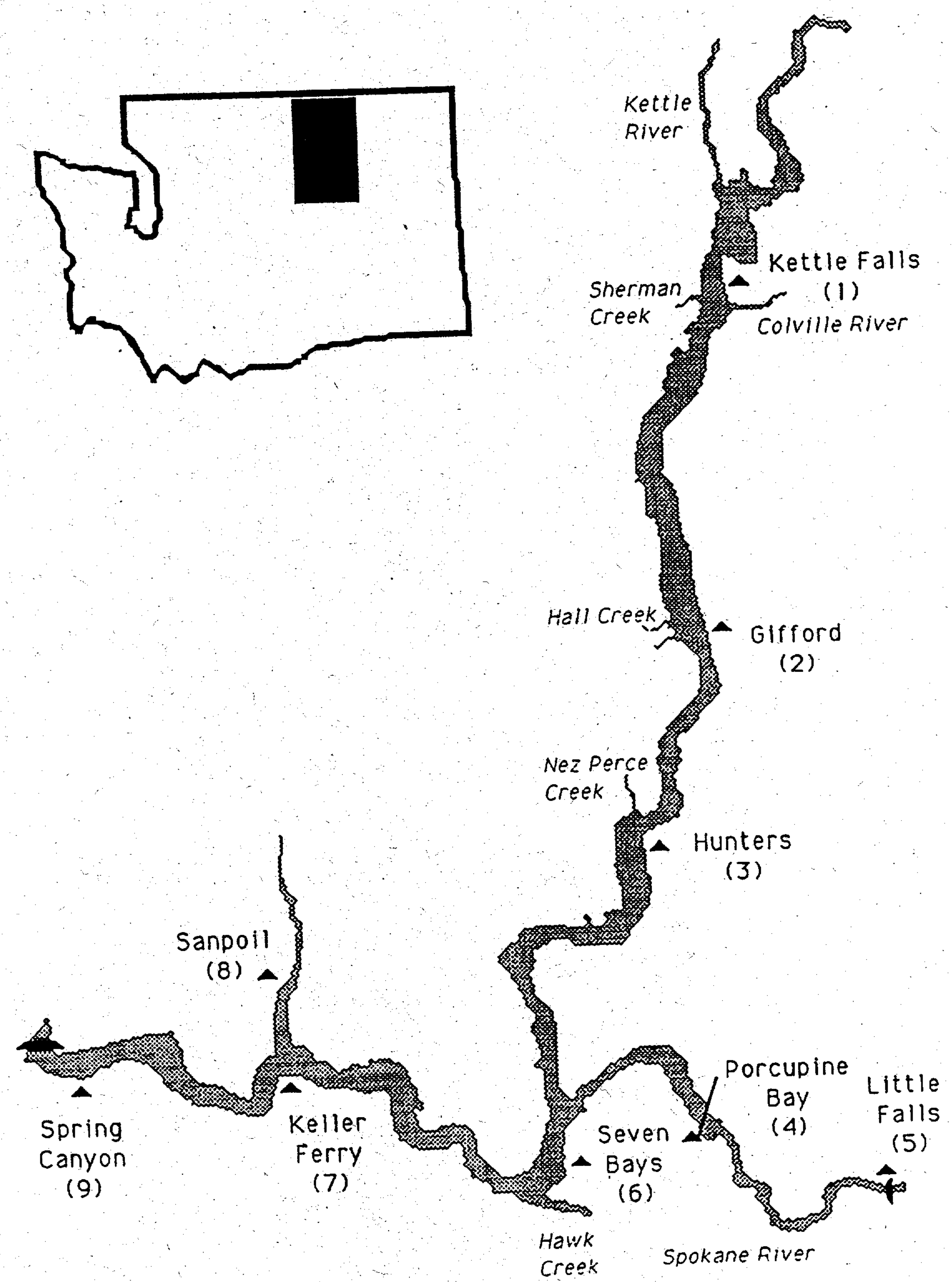

Figure 1.1.1 Lake Roosevelt, Washington and the nine sampling stations used for data collection.

#8. Determine benthic insect emergence levels at differing reservoir strata;

#9. Determine terrestrial insect deposition levels at differing reservoir strata;

#10. Determination of target species seasonal feeding habits, and utilization of zooplankton, benthic macroinvertebrates, terrestrial insects and other fish in relation to prey abundance in reservoir;

#11. Determination of target species growth based upon backcalculations as related to seasonal food habits, seasonal food availability and seasonal temperatures;

#12. Determination of entrainment levels via placement of coded wire and floy tags in target species, and a reservoir wide creel survey of Rufus Woods Reservoir to determine entrainment levels of rainbow and kokanee salmon from Lake Roosevelt.

2.0 MATERIALS AND METHODS

2.1 RESERVOIR ELEVATION AND WATER RETENTION

Reservoir elevation and water retention time were calculated by obtaining daily midnight reservoir elevation (ft) and total outflow (kcfs) from daily summary reports for Grand Coulee Dam prepared monthly in 1992 by the U.S. Army Corps of Engineers, Reservoir Control Center in Portland, OR. Reservoir elevation (ft) was converted to volume of water stored (kcfsd) using a U.S. Army Corps of Engineers (1981) reservoir water storage table. Water retention time was calculated using the formula:

$$\text{Water retention time (days)} = \frac{\text{Reservoir volume (kcfsd)}}{\text{Outflow (kcfs)}}$$

Mean reservoir elevation and water retention time for the month were calculated by adding the daily values for each category and dividing by the number of days in each month.

2.2 ZOOPLANKTON SURVEYS

Zooplankton samples were collected mid-channel at Location 2 (Gifford), Location 4 (Porcupine Bay), Location 6 (Seven Bays), and Location 9 (Spring Canyon) monthly and at each index station in May, August, and October in 1992 (Figure 2.2.1). Samples were taken using a Wisconsin vertical tow plankton net with an 80 µm silk net and bucket. Duplicate tows were made from 25-33 m to the surface at each location. Organisms were washed into a 253 ml bottle containing 10 ml of 37% formaldehyde and 0.5 g sugar (Rigler 1978). Organisms were stained with 1.0 ml of five percent Lugol's solution and 1.0 ml of saturated eosin-y ethanol stain.

In the lab, zooplankton were identified to species using taxonomic keys of Brandlova *et al.* (1972), Brooks (1957), Edmondson (1959), Pennak (1978;1989), Ruttner-Kolisko (1974), and Stemberger (1979). A Nikon SMZ-10 dissecting microscope with a ring illuminator system and Nikon Optiphot phase contrast microscope were used for identification. Three sub-samples were counted using a modified counting chamber (Ward 1955) until 100 organisms or 25 ml of sample had been counted (Edmondson and Winberg 1971, Downing and Rigler 1984). Volume of sub-sample was dependant upon organism density in the sample.

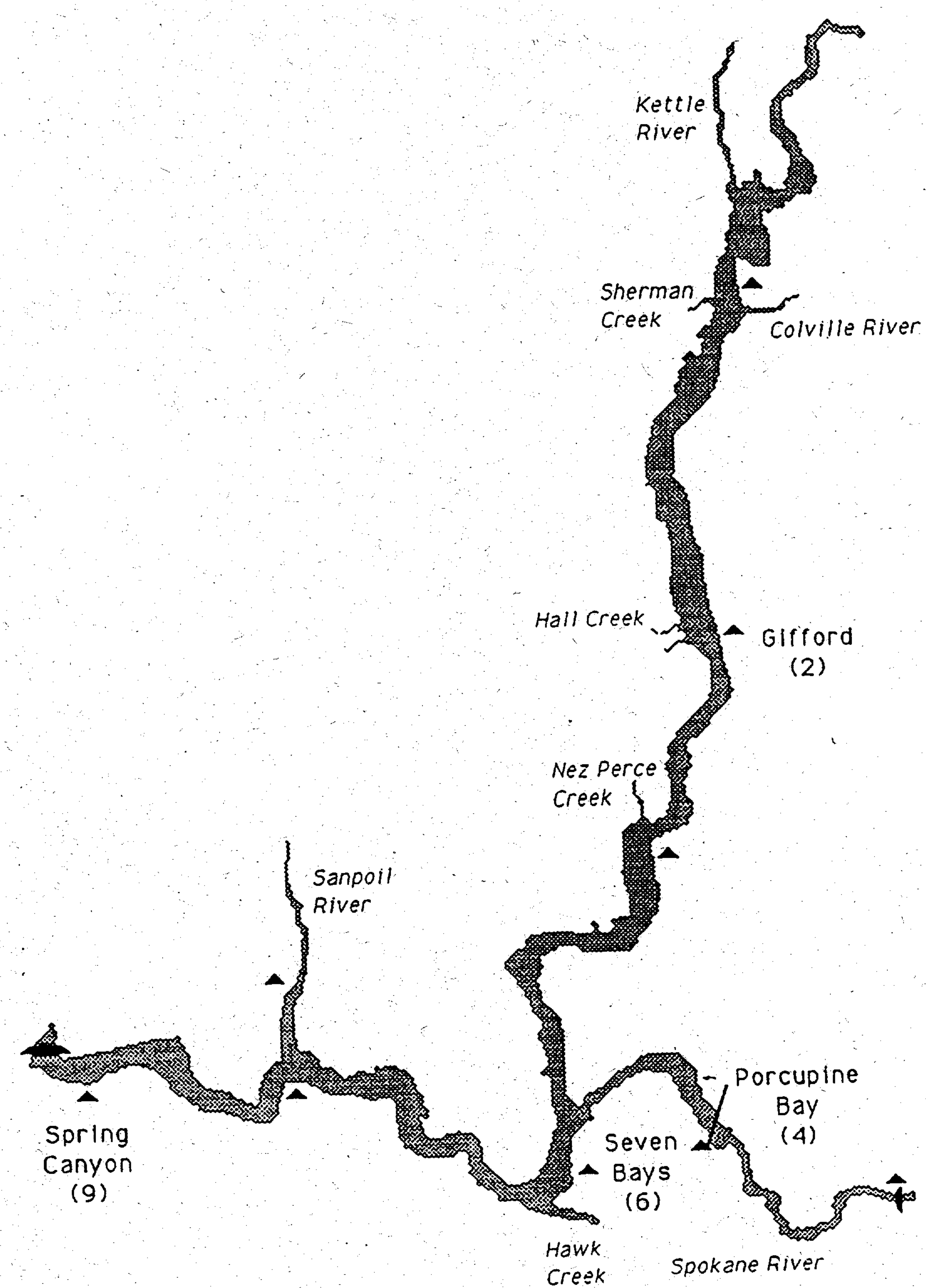

Figure 2.2.1 Lake Roosevelt, WA indicating location of four index stations used for zooplankton.

Species counts in each sub-sample were recorded with a Microsoft Excel spreadsheet program. Density (# organisms/m^3) was calculated in the program using the following sets of equations. Volume of the sample collected by the Wisconsin plankton sampler was calculated using the following formula:

$$V = \Pi r^2 h$$

where:

V = volume of the sample;
Π = pi (3.414);
r^2 = radius of sampler; and
h = depth of sample.

Microcrustacean zooplankton density (# organisms/m^3) was calculated using the following calculation:

$$D = \frac{\left(\frac{Tc}{Sn} x \frac{SV}{SSV}\right)}{V} DF{*}1000$$

where:
D = density (# organisms/m^3);
Sn = number of sub-samples;
SV = sample volume;
SSV = sub-sample volume;
V = volume of entire sample;
DF = dilution factor; and
Tc = total number counted of each species of organisms.

Predominant cladocerans were randomly chosen and measured from the top of the head to the base of the carapace, excluding the spine. Cladocera biomass was determined using length-weight regression equations summarized by Downing and Rigler (1984). The formula used to calculate dry weight estimate was:

$$ln\ w = ln\ a + (b)(ln\ L)$$

where:
$ln\ w$ = natural log of the dry weight estimate (μg) for the Cladocera species;

ln a = natural log of the intercept for the Cladocera species;

b = slope value for the Cladocera species; and

ln L = natural log of the mean length value of the Cladocera species.

The following slope (b) and intercept (*ln* a) values were used with the dry weight estimate calculation:

Cladocera Species	*ln* a	b
Daphnia ambigua	1.54	2.29
Daphnia galeata mendotae	1.51	2.56
Daphnia retrocurva	1.4322	3.129
Daphnia schødleri	2.30	3.10
Daphnia thorata	2.64	2.54
Leptodora kindti	-0.822	2.670

Cladocera biomass was calculated using the formula:

$$B = (ln\ w)(D)$$

where:

B = biomass ($\mu g/m^3$);

ln w = log of the dry weight estimate for the Cladocera species (μg); and

D = density (# organisms/m^3).

2.3 BENTHIC MACROINVERTEBRATE SURVEYS

2.3.1 Benthic Macroinvertebrate

Quantitative samples of benthic macroinvertebrates were collected using a Ponar dredge with an opening of 0.053 m. Benthos were collected from March through October at index stations 2 (Gifford), 4 (Porcupine Bay), 6 (Seven Bays), and 9 (Spring Canyon) (see Figure 2.2.1). Three replicate samples were taken from each of the following reservoir elevations at each station: Area 1 below elevation 1210 ft, Area 2 1240 to 1211 ft, and Area 3 1290 ft (full pool) to 1241 ft.

Benthic samples were sub-sampled by stirring the grab mixture, allowing it to settle, then pouring off top water sample through a series of U.S. Standard sieves measuring 4 mm, 2 mm, and 0.5 mm. Material remaining on the final screen was retained and preserved in 10% formalin solution, labeled "top water" and later transferred to 70% alcohol. The remaining grab was weighed. If weight of the remaining sample was less than 1 kg the entire sample was filtered through the sieves and preserved, if the sample was greater than 1 kg three sub-samples of 10% by weight were taken. Each sub-sample was filtered through the series of sieves, labeled accordingly and preserved in the same manner.

Organisms were sorted, identified to family using the taxonomic keys of Brooks (1957), Ward and Whipple (1966), Borror *et al.* (1976), Ruttner-Kolisko (1974), Edmonds *et al.* (1976), Wiggins (1977), Pennak (1978;1989), and Merritt and Cummins (1984).

Wet weight values were obtained by determining the average weight of a single organism for each specie found on a monthly basis. Excess moisture was removed from each organism and the organism was weighed to the nearest 0.0001 g using a Sartorius Model H51 analytical balance (Weber 1973, APHA 1976). Monthly values obtained were used in weight calculations.

Number and weight values obtained were converted to density and expressed as number/m^2 and grams/m^2. Number and weight density values were averaged for each season to obtain seasonal means and seasonal percent occurrence. Mean seasonal data were averaged to obtain unbiased annual means.

2.3.2 Benthic Macroinvertebrate Emergence

Benthic emergence traps were collected using a square meter emergence trap constructed of 1/4 inch thick fiberglass (Figure 2.3.1). This trap is a modification of emergence traps used by May *et al.* (1988) on Hungry Horse Reservoir. Traps were set from June to October at index stations 2 (Gifford), 4 (Porcupine Bay), 6 (Seven Bays), and 9 (Spring Canyon) (see Figure 2.2.1). Three traps were set at each index station, one trap in area 1 below elevation 1210 ft, one trap in area 2 between 1240 to 1211 ft, and one trap in area 3 between elevation 1290 and 1241 ft. Traps were filled with anti-freeze to preserve insects and checked monthly. All insects were sorted, identified to order, and counted.

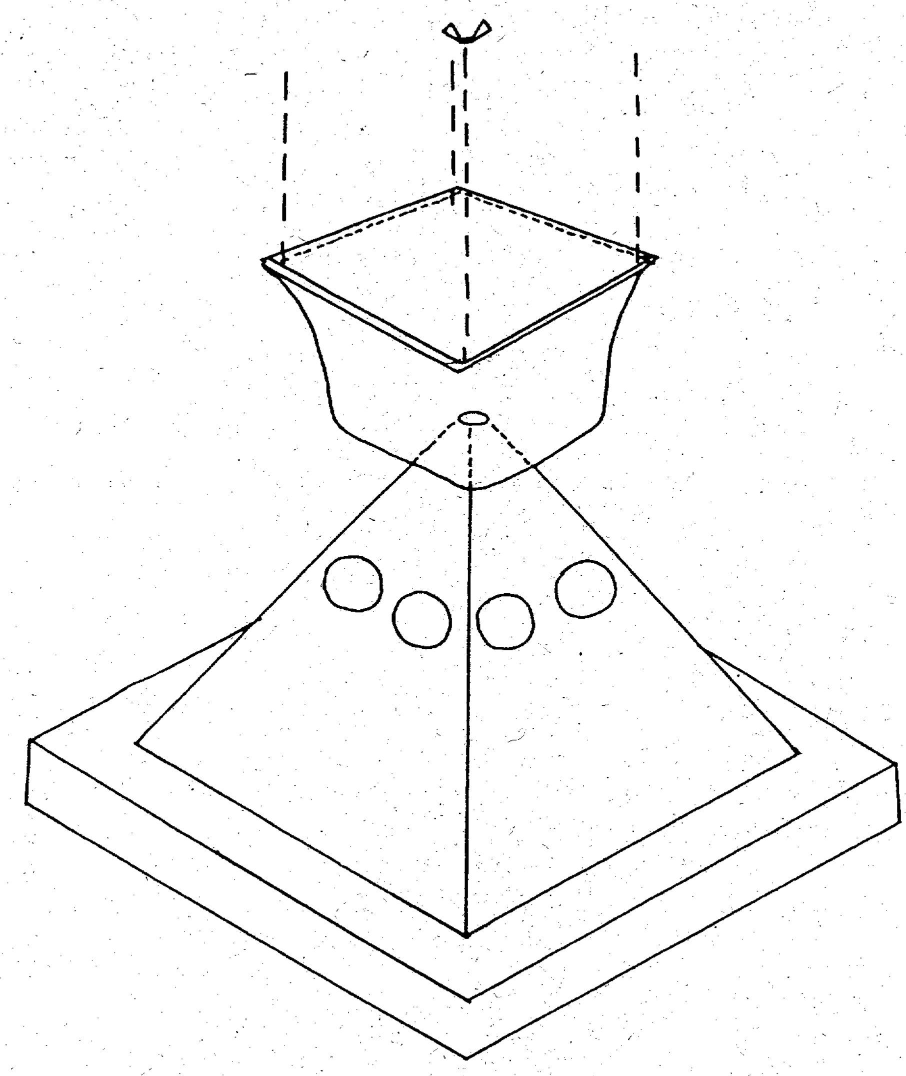

Figure 2.3.1 Benthic macroinvertebrate emergence trap used on Lake Roosevelt.

Number values obtained were converted to density and expressed as number/m^2. Number density values were averaged for each season to obtain seasonal means and seasonal percent occurrence. Mean seasonal data were averaged to obtain unbiased annual means.

2.4 FISHERIES SURVEYS

2.4.1 Field Collection

Fishery samples were collected in May, August, and October 1992 at nine index stations in the reservoir, which included: 1. Kettle Falls; 2. Gifford; 3. Hunters; 4. Porcupine Bay; 5. Little Falls Dam; 6. Seven Bays; 7. Keller Ferry; 8. Sanpoil, and 9. Spring Canyon (Figure 2.4.1). Fishery data was collected at each index station over 24 hour periods broken down into morning, afternoon, and night stratum. Principle target species included kokanee salmon, rainbow trout, and walleye, although all fish were captured in proportion to their relative abundance.

2.4.2 Relative Abundance

Relative abundance surveys were performed in littoral areas and tributaries by electrofishing 10 minute transects along 0.5 km of shoreline using a SR-23 electrofishing boat (Smith Root, Inc., Vancouver, WA) according to procedures outlined by Reynolds (1983) and Novotany and Prigel (1974). Voltage was adjusted to produce a pulsating DC current of approximately 5 amperes. Fish were collected using dip nets and placed into live wells on the boat for examination and data collection. A minimum of two 10 minute transects were performed during morning, afternoon, and night stratum.

Additional relative abundance surveys were performed in pelagic zones with bottom and surface monofilament gillnets using methodologies described by Hubert (1983). The following gillnets were used: two horizontal surface set gillnets measuring 61 m in length by 6.1 m deep, with four 15.2 m long panels graded from 1.3 to 7.6 cm stretch mesh; and two horizontal bottom set gillnets measuring 61 m in length by 6.1 m deep, with four 15.2 m long panels graded from 1.3 to 8.9 cm stretch mesh. Gillnets were set from early afternoon (2:00 p.m.), checked at sunset, and pulled at

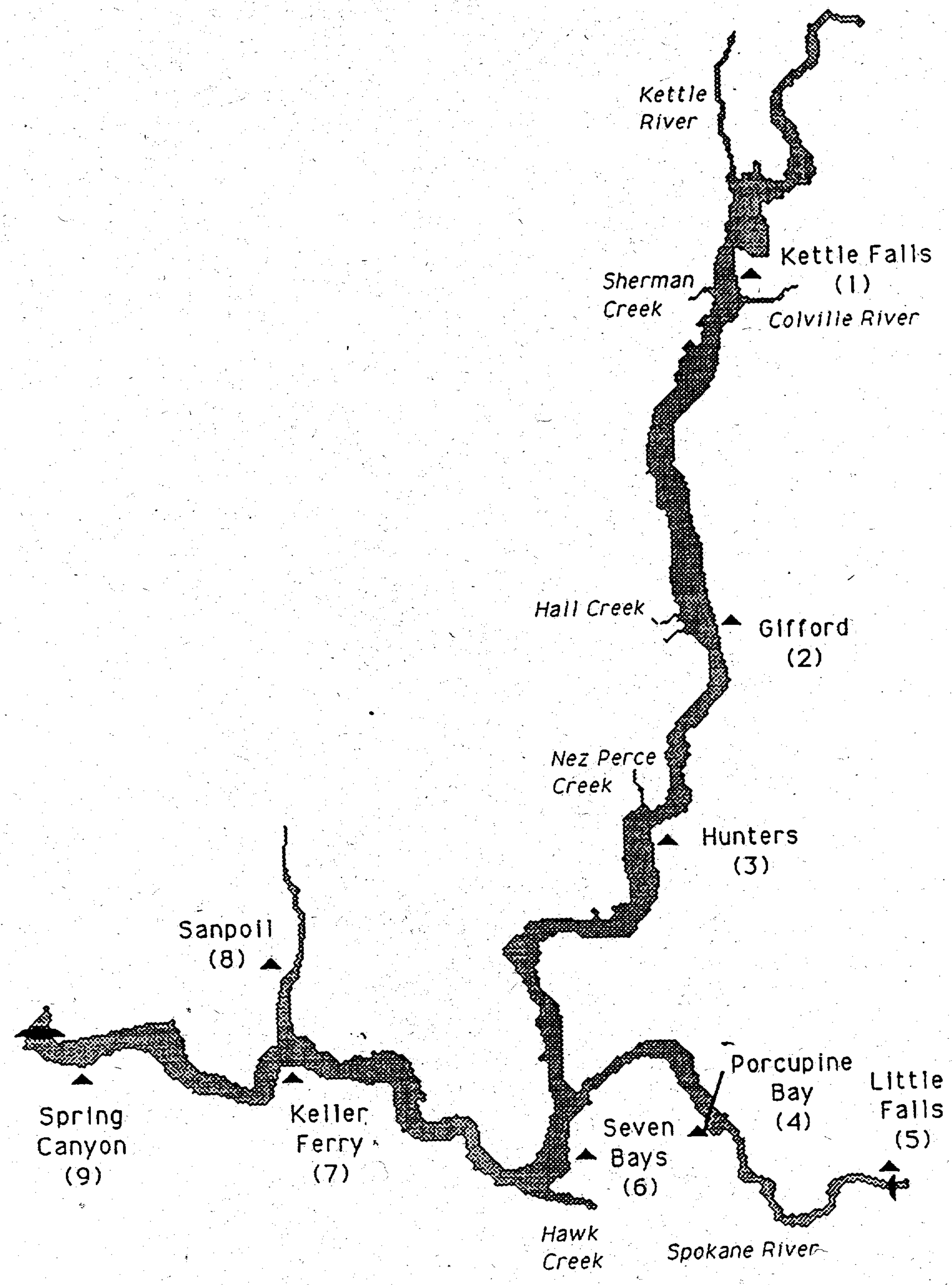

Figure 2.4.1 Lake Roosevelt, WA indicating location of nine index stations used for fisheries surveys.

10:00 p.m. Nets were managed this way to collect fresh fish for stomach samples.

Fish captured were identified to species using the taxonomic key of Wydoski and Whitney (1979). Total lengths were measured to the nearest millimeter using a metric measuring board and scale samples were removed from target fish species to determine age and growth. Target species were weighed to the nearest gram using an electronic balance. Sexes were determined when possible. Stomach samples were collected from representative sizes of target species. Remaining fish were marked with floy tags and released.

2.4.3 Diet Analysis

Fish stomachs were collected from kokanee, rainbow and walleye at each index station in May, August, and October 1992. Additional kokanee stomachs were obtained by creel clerks from anglers throughout the year. Stomachs from representative sizes of fish were collected by making an incision into the body cavity, cutting the esophagus, and pinching pyloric sphincter. The esophagus was clamped to keep prey items from being expelled and the stomach placed in 10% formalin.

In the lab, stomachs were transferred to a 70% isopropyl alcohol solution. Contents were identified to family for benthic macroinvertebrates and to species for zooplankton using the taxonomic keys of Brooks (1957), Ward and Whipple (1966), Borror *et al.* (1976), Ruttner-Kolisko (1974), Edmonds *et al.* (1976), Wiggins (1977), Pennak (1978;1989), and Merritt and Cummins (1984).

Food organisms were identified using a Nikon SMZ-1B dissecting microscope equipped with a fiber optics illumination system and 5 mm ocular micrometer.

Stomachs containing large numbers of zooplankton were sub-sampled or counted, depending on diversity of prey organisms. Sub-samples were made by diluting zooplankton contents to 100 ml in a beaker, stirring contents to uniformity, and collecting three 2 ml samples with a calibrated pipet. The following formula was used to determine the total number of a particular zooplankton species:

$$\text{Total No.} = \frac{\sum_{n=1}^{3}\left(\frac{Dv}{Sv} \times T_n\right)}{3}$$

where:

Dv = total diluted volume (100 ml);
Sv = total sub-sample volume (2 ml); and
T_n = total number of zooplankton in the sub-sample.

Length measurements of randomly chosen Cladocera were made from the top of the head to the base of the carapace, excluding the spine. This permitted calculation of electivity indices.

Sorted stomach contents were dry weighted by drying sorted organisms in an oven at 105° for 24 hours and weighing them on a Sartorius Model H51 analytical balance to the nearest 0.0001 g (Weber 1973, APHA 1976).

Number and Weight Indices

Numerical and weight frequencies of prey items (± standard deviation) were obtained for each age class of target species collected during each sampling season to obtain seasonal mean values. Unidentifiable prey items and organic detritus were discarded and non-measurable trace amounts of food items were given the value of 0.0001 grams for calculating percentages by weight.

Seasonal mean data were combined to obtain unbiased estimates of annual average number and weight, percent composition by number and weight, frequency of occurrence, and index of relative importance for each age class of target species.

Index of Relative Importance (IRI)

Index of relative importance was used to compensate for numerical estimate biases that tend to overemphasize small prey groups consumed in large numbers and weight estimate biases that overemphasize large prey items consumed in small numbers (Bowen

1983). The index of relative importance (George and Hadley 1979) was calculated using the formula:

$$RI_a = \frac{100AI_a}{\sum_{a=1}^{n} AI_a}$$

where:

RI_a = relative importance of food item a;

AI_a = absolute importance of food item a (*i.e.*, frequency of occurrence + numerical frequency + weight frequency of food item a); and

n = number of different food types.

Relative importance values range from zero to 100% with prey items near zero being relatively less important than those prey items near one hundred percent.

2.4.4 Electivity Index

The electivity index is a method of measuring the degree of selection that a fish has for a particular prey item compared to the availability of the same prey item in the environment (Ivlev 1961). Data obtained seasonally from zooplankton, benthic and relative abundance surveys were used to compute electivity indices for different prey items found in the stomachs of kokanee, rainbow trout, and walleye (Strauss 1979). The electivity index was calculated using the formula:

$$L = r_i - p_i$$

where:

L = measure of food selection;

r_i = relative abundance of prey i in the gut; and

p_i = relative abundance of same prey i in the environment.

Food selection values range from +1.0 to -1.0. Values near zero indicate fish are feeding on a prey item in relation to its abundance, or randomly. Positive values indicate fish are selecting that prey item and negative values indicate fish are not utilizing that prey item.

Advantages of using this index are: it is not biased by unequal sample sizes, and extreme values are obtained only when a prey item is very abundant in the environment and rare in the diet or when a prey item is rare in the environment and very abundant in the diet (Strauss 1979).

2.4.5 AGE DETERMINATION, BACK-CALCULATION, AND CONDITION

In the field, scales were taken from appropriate locations for each species as described by Jearld (1983) and placed in coin envelopes labeled with fish number, length, weight, location, date, and specie for later analysis. In the laboratory, back-calculation measurements and age class of each fish were determined simultaneously. To obtain data, scales were removed from the envelope and placed between two microscope slides. Slides were then placed in a Realist Vantage 5, Model 3315 microfiche reader which projected scale images onto the screen. A non-regenerated, uniform scale was selected to determine age and back-calculation using the following procedures:

1. Age was determined by counting the number of annuli (Jearld 1983).

2. Backcalculation measurements were determined using a T-square metric ruler.

   a. Scale length was determined by placing the 0 mm mark at the center of the focus with the T perpendicular to the longitudinal axis of the scale.

   b. Annulus distance was measured from the same origin to the last circuli of each annulus with the T square in the same position.

Each measurement was made under constant magnification to the nearest millimeter.

Capture length, scale length, and length of each annulus of all fish of same species were entered into StatView 512 (BrainPower 1986) on the Apple Macintosh SE computer for linear regression calculations. Lee's back-calculation method was used to determine the length of the fish at the formation of each annulus. (Carlander 1950;1981, Hile 1970).

Back-calculations were computed using the formula:

$$L_i = a + \left(\frac{L_c - a}{S_c}\right) S_i$$

where:

L_i = length of fish (in mm) at each annulus formation;
a = intercept of the body-scale regression line;
L_c = length of fish (in mm) at time of capture;
S_c = distance (in mm) from the focus to the edge of the scale; and
S_i = scale measurement to each annulus.

Age, size, and measurements used for back-calculations for each target species are listed in Appendix D.

Condition factors were determined for each fish to serve as an indicator of fish condition (Hile 1970, Everhart and Youngs 1981). Condition factor describes how a fish adds weight in relation to incremental changes in length. The relationship is shown by the formula:

$$K_{TL} = \left(\frac{W}{L^3}\right) 10^5$$

where:

K_{TL} = condition factor;
W = weight of fish (g); and
L = total length of fish (mm).

2.5 TAGGING STUDIES

Tagging studies were conducted with net-pen rainbow trout by inserting individually numbered floy tags into the musculature at the posterior base of the dorsal fin. Rainbow trout were marked, measured, and released at Kettle Falls, Gifford, Hunters, Seven Bays, Lincoln and Keller Ferry net-pens in 1992 (Figure 2.5.1). One thousand fish were tagged and released from each net-pen site in March, April, and May. In June, an additional 1,000 fish were tagged and released from Gifford and Seven Bays, and 600 were tagged and released at Lincoln. Representative samples of approximately 50 fish from each group were weighed to determine the average length and weight of the group at time of release. Scale samples were also taken to aid in determination of check marks laid down by fish at time of release.

A poster campaign was conducted by distributing posters at locations frequented by anglers in the area surrounding Lake Roosevelt. Posters contained information about the Lake Roosevelt monitoring program and requested that anglers return tags with the following information: recapture date and location, and length and weight of fish. Anglers returning tag information were sent a letter informing them of the release date and location, and length of fish at time of release.

Tag return data were compiled and analyzed to determine movement within and through Lake Roosevelt. Movement was analyzed by noting recapture location and plotting it against release location and date.

2.6 OBJECTIVES NOT ADDRESSED IN 1992

Due to time constratins and project setbacks, some of the objectives outlined in section 1.0 could not begin in 1992. Primary productivity was placed on hold for another year-after there was difficulty in obtaining permits to use C-14 by a tribal agency in non tribal waters. Other pieces of the objectives such as hydrology, flow constrains, and reservoir morphometry were performed in cooperation with other agencies and are part of the computer model and will not appear in this report.

3.0 RESULTS

3.1 RESERVOIR OPERATIONS

Table 3.1.1 summarizes mean monthly reservoir operations in 1992. Appendix A summarizes daily reservoir operations from January to December 1992.

3.1.1 Elevation, Outflow, and Water Retention Time

Mean reservoir elevations were 1,287 feet in January, 1,288 feet in February, 1,281 feet in March, 1,268 feet in April, 1,266 feet in May, 1,281 feet in June, 1,287 feet in July, 1,286 feet in August, 1,281 feet in September, 1,284 feet in October, 1,284 feet in November, and 1,273 feet in December (Table 3.1.1). Mean yearly reservoir elevation was 1,281 feet.

Mean outflow was 101 kcfs in January, 78 kcfs in February, 93 kcfs in March, 79 kcfs in April, 112 kcfs in May, 132 kcfs in June, 81 kcfs in July, 82 kcfs in August, 73 kcfs September, 66 kcfs in October, 82 kcfs in November, and 110 kcfs in December (Table 3.1.1). Mean yearly outflow was 91 kcfs.

Mean water retention times were 45 days in January, 59 days in February, 48 days in March, 51 days in April, 34 days in May, 34 days in June, 62 days in July, 57 days in August, 61 days in September, 69 days in October, 56 days in November and 37 days in December (Table 3.1.1). The yearly average water retention time for the reservoir was 51 days.

3.2 ZOOPLANKTON

3.2.1 Zooplankton Density

A total of 44 species from 36 genera of zooplankton were identified in Lake Roosevelt during 1992 (Table 3.2.1). Order Cladocera was the most diverse group, comprised of 19 species, followed by the Order Plioma with 15 species. Order Eucopepoda contained 6 species, Order Flosulariacea had 3 species, and one specie of Order Collethecacea was identified.

Monthly mean densities (#/m^3) of microcrustacean zooplankton collected at Gifford, Porcupine Bay, Seven Bays, and

Table 3.1.1 Monthly and annual means for reservoir inflow, outflow, elevation, storage capacity, and water retention time for Lake Roosevelt in 1992.

MONTH	INFLOW (KCFS)	OUTFLOW (KCFS)	RESERVOIR ELEVATION (FT)	STORAGE CAPACITY (KCFSD)	WATER RETENTION TIME (D)
January	107.5	101.5	1,287.1	4,472.9	45.1
February	74.8	77.7	1,287.8	4,501.6	59.0
March	77.0	92.6	1,281.4	4,249.4	48.4
April	75.2	79.3	1,267.9	3,744.9	51.2
May	128.6	112.1	1,266.4	3,688.9	34.4
June	157.3	131.7	1,281.1	4,238.2	33.7
July	90.8	80.6	1,286.6	4,454.2	62.1
August	87.8	81.7	1,285.9	4,422.2	56.8
September	67.9	73.0	1,281.3	4,242.7	61.0
October	76.9	65.9	1,284.1	4,351.0	69.0
November	77.8	81.9	1,284.2	4,358.0	56.3
December	97.6	109.9	1,273.0	3,930.8	37.5
Annual	**93**	**91**	**1,281**	**4,221**	**51**

Table 3.2.1. Synoptic list of zooplankton taxa identified in Lake Roosevelt during the 1992 study period.

Phylum Anthropoda
- Class Crustacea
  - Subclass Brachiopoda
    - Order Cladocera
      - Family Daphnidae
        1. *Ceriodaphnia quadranqula*
        2. *Daphnia galeata mendotae*
        3. *Daphnia retrocurva*
        4. *Daphnia schødleri*
        5. *Daphnia thorata*
        6. *Megafenestra aurita*
        7. *Simocephalus serrulatus*
      - Family Chydoridae
        8. *Alona guttata*
        9. *Alona quadrangularis*
        10. *Chydorus sphaericus*
        11. *Eurycerus lamellatus*
        12. *Pleuroxus denticulatus*
      - Family Sididae
        13. *Diaphanosoma brachyurum*
        14. *Diaphanosoma birgei*
        15. *Sida crystallina*
      - Family Macrothricidae
        16. *Macrothrix laticornis*
        17. *Streblocerus serricaudatus*
      - Family Bosminidae
        18. *Bosmina longirostris*
      - Family Leptodoriidae
        19. *Leptodora kindti*
  - Subclass Copepoda
    - Order Eucopepoda
      - Suborder Calanoida
        - Family Diaptomidae
          20. *Leptodiaptomus ashlandi*
          21. *Skistodiaptomus oregonensis*
        - Family Temoridae
          22. *Epischura nevadensis*
      - Suborder Cyclopoida
        - Family Cyclopoidae
          23. *Diacyclops bicuspidatus thomasi*
          24. *Mesocyclop edax*
      - Suborder Harpacticoida
        - Family Harpacticoidae
          25. *Bryocamptus* spp.

Phylum Rotifera
- Class Monogononta
  - Order Flosculariacea
    - Family Conochilidae
      26. *Conochilus unicornis*
    - Family Testudinellidae
      27. *Testudinella* spp.
    - Family Filiniidae
      28. *Filinia terminalis*
  - Order Collothecacea
    - Family Collothecidae
      29. *Collotheca mutabilis*
  - Order Ploima
    - Family Synchaetidae
      30. *Pleosoma truncatum*
      31. *Polyarthra* spp.
      32. *Synchaeta pectinata*
    - Family Asplanchnidae
      33. *Asplanchna herricki*
      34. *Asplanchna priodonta*
    - Family Brachionidae
      35. *Brachionus quadridentata*
      36. *Kellicottia longispina*
      37. *Keratella* spp.
      38. *Notholca* spp.
    - Family Epiphanidae
      39. *Epiphanes* spp.
    - Family Euchlanidae
      40. *Euchlanis dilatata*
      41. *Euchlanis triquetra*
    - Family Trichotriidae
      42. *Trichotria tetractis*
    - Family Trichocercidae
      43. *Trichocerca* spp.
    - Family Lecanidae
      44. *Monostyla lunaris*

Spring Canyon are shown in Tables 3.2.2 through 3.2.5. Mean density/species for each location can be found in Appendix B.

Mean *Daphnia* spp. densities at Gifford (index station 2) ranged from 0/m^3 in March in August to 283/m^3 with an annual mean of 53/m^3 (Table 3.2.2). Mean *Leptodora* spp. densities ranged from 0.0 in February, March, June, July, September, and November to 0.3/m^3 in April, with an annual mean of 0.1/m^3. Mean Cladocera densities ranged from 0.0 in March to 298/m^3 in August with an annual mean of 55/m^3. Adult Copepoda densities ranged from 0.5/m^3 in March to 119/m^3 in August with an annual mean of 25/m^3. Mean nauplii densities ranged from 1.9/m^3 in February to 144/m^3 in August with an annual mean of 40/m^3. Mean microcrustacean zooplankton densities ranged from 3/m^3 in February to 560/m^3 in August with an annual mean of 121/m^3.

Mean *Daphnia* spp. densities at Porcupine Bay (index station 4) ranged from 0.2/m^3 in March to 160/m^3 in June and November with an annual mean of 66/m^3 (Table 3.2.3). Mean *Leptodora* spp. densities ranged from 0.0 in January, February, March, April, July, August, October, and November to 5.9/m^3 in June with an annual mean of 0.7/m^3. Mean Cladocera densities ranged from 0.5/m^3 to 167/m^3 in September with an annual mean of 74/m^3. Mean adult Copepoda densities ranged from 6.4/m^3 in March to 412/m^3 in November with an annual mean of 137/m^3. Mean nauplii densities ranged from 4/m^3 in March to 578/m^3 in June with an annual mean of 187/m^3. Mean microcrustacean zooplankton densities ranged from 11/m^3 in March to 1,032/m^3 in November with an annual mean of 397/m^3.

Mean *Daphnia* spp. densities at Seven Bays (index station 6) ranged from 0.0/m^3 in March to 349/m^3 in August with an annual mean of 107/m^3 (Table 3.2.4). Mean *Leptodora* spp. densities ranged from 0.0 in January, March, April, July, August, September, October, and November to 8.8/m^3 in June with an annual mean of 1.0/m^3. Mean Cladocera densities ranged from 0.0/m^3 in March to 349/m^3 in August with an annual mean of 119/m^3. Mean adult Copepoda densities ranged from 1.5/m^3 in February to 582/m^3 in October with an annual mean of 268/m^3. Mean nauplii densities ranged from 2/m^3

Table 3.2.2 Mean monthly density values (#/m^3) and standard deviations of different categories of zooplankton at Gifford (Index Station 2) in 1992.

Taxon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Mean
Daphnia spp.													
# / m^3	-	0.1	0.0	4.4	6.7	10.7	16.5	283.0	60.3	46.3	88.8	-	52
± S.D.	-	± 0.1	± 0.0	± 0.9	± 0.9	± 3.2	± 1.7	± 101.6	± 5.0	± 12.1	±15.5	-	
Leptodora													
# / m^3	-	0.0	0.0	0.3	0.1	0.0	0.0	0.1	0.0	0.1	0.0	-	0.1
± S.D.	-	± 0.0	± 0.0	± 0.0	± 0.2	± 0.0	± 0.0	± 0.19	± 0.0	± 0.19	± 0.0	-	
Cladocera													
# / m^3	-	0.1	0.0	6.2	8.3	18.1	16.9	297.8	61.2	47.6	95.2	-	55
± S.D.	-	± 0.1	± 0.0	± 1.7	± 2.4	3.9	± 1.6	± 114.3	± 5.6	± 12.1	± 17.4	-	
Adult Copepoda													
# / m^3	-	0.9	0.5	42.0	14.1	13.5	6.6	118.8	23.6	12.0	19.8	-	25
± S.D.	-	± 1.2	± 0.2	± 9.3	± 2.4	± 7.1	± 1.6	± 10.4	± 3.2	± 3.9	± 3.7	-	
Nauplii													
# / m^3		1.9	4.3	31.4	16.9	70.9	8.0	143.7	57.3	33.0	33.8	-	40
± S.D.	-	± 0.6	±0.4	± 2.2	± 1.1	± 3.5	± 4.3	± 29.0	± 3.0	± 11.6	± 9.0	-	
Total Zooplankton													
# / m^3	-	3	5	80	40	102	32	560	142	93	149	-	121
± S.D.	-	± 2	± 1	± 13	± 6	± 15	± 4	± 154	± 12	± 28	± 30	-	

(- represents no samples were collected).

Table 3.2.3 Mean monthly density values (#/m^3) and standard deviations of different categories of zooplankton at Porcupine Bay (Index Station 4) in 1992.

Taxon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Mean
Daphnia spp.													
# / m^3	66.9	4.0	0.2	6.3	33.5	159.9	130.5	8.7	165.7	88.4	159.8	-	66
± S.D.	± 7.7	± 0.2	± 0.0	± 2.6	± 21.3	± 6.2	± 184.6	± 9.7	± 6.2	± 26.8	± 72.6	-	
Leptodora													
# / m^3	0.0	0.0	0.0	0.0	1.7	5.9	0.0	0.0	0.1	0.0	0.0	-	0.7
± S.D.	± 0.0	± 0.0	± 0.0	± 0.0	± 0.9	± 1.2	± 0.0	± 0.0	± 0.2	± 0.0	± 0.0	-	
Cladocera													
# / m^3	72.5	5.2	0.5	14.1	43.6	112.5	130.5	9.9	167.3	89.3	162.8	-	74
± S.D.	± 7.7	± 0.1	± 0.2	± 5.4	± 23.1	± 52.5	± 184.6	± 11.4	± 8.5	± 28	± 76.7	-	
Adult Copepoda													
# / m^3	62.6	11.2	6.4	143.5	43.4	142.3	250.8	31.8	352.0	48.3	412.1	-	137
± S.D.	± 1.9	± 0.6	± 1.5	± 25.6	± 32.3	± 19.0	± 354.6	± 43.1	± 37.3	± 24.9	± 85.0	-	
Nauplii													
# / m^3	33.5	12.5	3.8	67.2	50.5	578.3	376.9	31.9	391.5	48.1	457.5	-	187
± S.D.	± 6.0	± 0.7	± 1.1	± 5.0	± 9.5	± 17.1	± 533.0	± 37.7	± 47.7	± 57.6	± 41.5	-	
Total Zooplankton													
# / m^3	168	29	11	225	136	833	758	74	911	186	1,032	-	397
± S.D.	± 3	+ 2	± 3	± 36	± 65	± 89	± 1,072	± 92	± 94	± 111	± 203	-	

(- represents no samples were collected).

Table 3.2.4 Mean monthly density values ($\#/m^3$) and standard deviations of different categories of zooplankton at Seven Bays (Index Station 6) in 1992.

Taxon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Mean
Daphnia spp.													
$\#/m^3$	6.8	0.4	0.0	14.7	30.8	93.9	272.8	349.0	71.9	224.4	76.3	-	107
± S.D.	± 1.1	± 0.4	± 0.1	± 4.1	± 31.1	± 20.7	± 37.3	± 95.4	± 22.8	± 14.5	± 16.6	-	
Leptodora													
$\#/m^3$	0.0	0.04	0.0	0.0	1.5	8.8	0.0	0.0	0.0	0.0	0.0	-	1.0
± S.D.	± 0.0	± 0.1	± 0.0	± 0.0	± 2.1	± 0.0	± 0.0	± 0.0	± 0.0	± 0.0	± 0.0	-	
Cladocera													
$\#/m^3$	7.5	0.5	0.0	27.9	51.3	146.6	272.8	349.0	104.1	231.7	79.2	-	119
± S.D.	± 1.1	± 0.4	± 0.1	± 6.2	± 47.7	± 41.5	± 37.3	± 95.4	± 39.4	± 16.6	± 20.7	-	
Adult Copepoda													
$\#/m^3$	5.8	1.5	2.0	218.5	324.1	271.3	181.8	560.2	532.3	582.2	217.0	-	268
± S.D.	± 0.5	± 0.4	± 0.4	± 35.3	± 192.9	± 80.9	± 37.3	± 103.7	± 76.7	± 39.4	± 37.3	-	
Nauplii													
$\#/m^3$	6.6	4.4	2.1	302.1	485.4	265.4	432.6	504.5	747.9	759.6	309.4	-	351
± S.D.	± 0.3	± 0.9	± 0.1	± 8.3	± 105.8	± 27.0	± 139.0	± 107.8	± 74.7	± 49.8	± 2.1	-	
Total Zooplankton													
$\#/m^3$	20	7	4	549	861	683	887	1,414	1,384	1,574	606	-	738
± S.D.	± 0.3	+ 2	± 1	± 73	± 346	± 149	± 213	± 307	± 191	± 106	± 60	-	

(- represents no samples were collected).

in March to 760/m^3 in October with an annual mean of 351/m^3. Mean microcrustacean zooplankton densities ranged from 4/m^3 in March to 1,574/m^3 in October with an annual mean of 738/m^3.

Mean *Daphnia* spp. densities at Spring Canyon (index station 9) ranged from 1.0/m^3 in February to 305/m^3 in August with an annual mean of 68/m^3 (Table 3.2.5). Mean *Leptodora* spp. densities ranged from 0.0 in February, March, April, May, August, September, October, and November to 13/m^3 in June with an annual mean of 1.5/m^3. Mean Cladocera densities ranged from 1/m^3 in February to 305/m^3 in August with an annual mean of 73/m^3. Mean adult Copepoda densities ranged from 13/m^3 in February to 964/m^3 in August with an annual mean of 220/m^3. Mean nauplii densities ranged from 17/m^3 in February to 856/m^3 in June with an annual mean of 240/m^3. Mean microcrustacean zooplankton densities ranged from 31/m^3 in February to 1,620/m^3 in August with an annual mean of 532/m^3.

3.2.2 Zooplankton Lengths

Monthly mean lengths (mm) of microcrustacean zooplankton collected at Gifford, Porcupine Bay, Seven Bays, and Spring Canyon are shown in Tables 3.2.6 through 3.2.9. Length ranges and mean lengths/species for each location can be found in Appendix B.

Mean lengths of *Daphnia galeata mendotae* at Gifford (index station 2) ranged from 0.9 mm to 1.2 mm and averaged 1.0 mm (Table 3.2.6). Mean lengths of *Daphnia retrocurva* ranged from 1.0 mm to 1.2 mm and averaged 1.1 mm. Mean lengths of *Daphnia schødleri* ranged from 0.7 mm to 1.6 mm and averaged 1.0 mm. Mean lengths of *Daphnia thorata* ranged from 1.2 mm to 1.4 mm and averaged 1.3 mm. Mean lengths of *Leptodora kindti* ranged from 3.5 mm to 4.0 mm and averaged 3.8 mm.

Mean lengths of *D. galeata mendotae* at Porcupine Bay (index station 4) ranged from 0.6 mm to 1.6 mm and averaged 1.1 mm (Table 3.2.7). Mean lengths of *D. retrocurva* averaged 2.1 mm. Mean lengths of *D. schødleri* ranged from 0.8 mm to 1.5 mm and averaged 1.2 mm. Mean lengths of *D. thorata* ranged from 0.9 mm to 2.0 mm and averaged 1.5 mm. Mean lengths of *L. kindti* ranged from 3.6 mm to 8.5 mm and averaged 5.4 mm.

Table 3.2.5 Mean monthly density values (#/m^3) and standard deviations of different categories of zooplankton at Spring Canyon (Index Station 9) in 1992.

Taxon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Mean
Daphnia spp.													
# / m^3	-	0.7	56.5	3.8	26.4	120.3	-	305.0	67.8	8.8	18.6	-	68
± S.D.	-	± 0.1	± 24.6	± 0.9	± 24.9	± 4.1	-	± 29.0	± 13.7	± 1.2	± 0.6	-	
Leptodora													
# / m^3	-	0.0	0.0	0.0	0.0	13.2	-	0.0	0.0	0.0	0.0		1.5
± S.D.		± 0.0	± 0.0	± 0.0	± 0.0	±2.1	-	± 0.0	± 0.0	± 0.0	± 0.0	-	
Cladocera													
# / m^3	-	1.2	61.5	5.3	32.3	148.1	-	305.0	72.6	10.1	19.4	-	73
± S.D.	-	± 0.2	± 25.4	± 1.9	± 29.0	± 18.7	-	± 29.0	± 15.6	± 3.1	± 0.9	-	
Adult Copepoda													
# / m^3	-	12.9	69.8	59.7	140.8	288.9	-	963.5	248.6	125.8	69.6	-	220
± S.D.	-	± 1.1	± 35.7	± 6.7	± 33.2	± 14.5	-	± 201.2	± 10.6	± 28.6	±15.1	-	
Nauplii													
# / m^3	-	17.0	34.3	31.7	542.6	856.4	-	352.0	118.3	177.7	25.7	-	240
± S.D.	-	± 1.3	± 22.4	± 2.6	± 37.3	± 199.1	-	± 116.1	± 66.6	± 77.1	±3.2	-	
Total Zooplankton													
# / m^3	-	**31**	**166**	**97**	**716**	**1,293**	-	**1,620**	**440**	**314**	**115**	-	**532**
± S.D.	-	**± 2**	**± 83**	**± 11**	**± 100**	**± 232**	-	**± 346**	**± 93**	**± 109**	**± 19**	-	

(- represents no samples were collected).

Table 3.2.6 Mean monthly size values (mm) (± S.D.) of different Cladocera species at Gifford (Index Station 2) in 1992.

	D. galeata mendotae (mm)	*Daphnia retrocurva* (mm)	*Daphnia schødleri* (mm)	*Daphnia thorata* (mm)	*Leptodora kindti* (mm)
Jan.	-	-	1.6	-	-
± S.D.	-	-	± 0.4	-	-
Feb.	-	-	-	-	-
± S.D.	-	-	-	-	-
Mar.	-	-	-	-	-
± S.D.	-	-	-	-	-
Apr.	-	-	0.7	-	-
± S.D.	-	-	± 0.2	-	-
May	-	-	0.8	-	-
± S.D.	-	-	± 0.2	-	-
Jun.	0.9	-	0.9	-	-
± S.D.	± 0.2	-	0.3	-	-
Jul.	0.9	1.2	0.9	-	
± S.D.	± 0.4	± 0.3	± 0.3	-	
Aug.	1.2	1.2	1.1	1.3	
± S.D.	± 0.4	± 0.0	± 0.5	± 0.4	
Sep.	1.0	1.0	1.2	1.2	4.0
± S.D.	± 0.3	± 0.1	± 0.4	± 0.2	± 0.0
Oct.	1.2	-	1.1	1.4	3.5
± S.D.	± 0.2	-	± 0.3	± 0.2	± 0.0
Nov.	-	-	1.1	-	-
± S.D.	-	-	± 0.3	-	-
Dec.	-	-	-	-	-
± S.D.	-	-	-	-	-
Yearly Mean	**1.0**	**1.1**	**1.0**	**1.3**	**3.8**

(- indicates no data were obtained due to lack of sample or organisms in sample.)

Table 3.2.7 Mean monthly size values (mm) (± S.D.) of different Cladocera species at Porcupine Bay (Index Station 4) in 1992.

	D. galeata mendotae (mm)	*Daphnia retrocurva* (mm)	*Daphnia schødleri* (mm)	*Daphnia thorata* (mm)	*Leptodora kindti* (mm)
Jan.	1.6	-	1.4	-	-
± S.D.	± .03	-	± 0.5	-	-
Feb.	-	-	1.5	-	-
± S.D.	-	-	± 0.5	-	-
Mar.	-	-	1.4	-	-
± S.D.	-	-	± 0.2	-	-
Apr.	0.8	-	0.8	-	-
± S.D.	± 0.1	-	± 0.2	-	-
May	0.9	-	0.8	0.9	3.6
± S.D.	± 0.3	-	± 0.1	± 0.3	± 1.8
Jun.	1.1	2.1	1.3	-	8.5
± S.D.	± 0.3	± 0.1	± 0.6	-	± 2.1
Jul.	1.5	-	1.3	-	-
± S.D.	± 0.3	-	± 0.4	-	-
Aug.	0.6	-	1.2	2.0	-
± S.D.	± 0.2	-	± 0.3	± 0.4	-
Sep.	-	-	1.2	-	4.0
± S.D.	-	-	± 0.3	-	± 0.0
Oct.	-	-	1.2	-	-
± S.D.	-	-	± 0.3	-	-
Nov.	-	-	1.5	-	-
± S.D.	-	-	± 0.6	-	-
Dec.	-	-	-	-	-
± S.D.	-	-	-	-	-
Yearly Mean	**1.1**	**2.1**	**1.2**	**1.5**	**5.4**

(- indicates no data were obtained due to lack of sample or organisms in sample.)

Mean lengths of *D. galeata mendotae* at Seven Bays (index station 6) ranged from 0.7 mm to 1.1 mm and averaged 0.9 mm (Table 3.2.8). Mean lengths of *D. retrocurva* averaged 0.5 mm. Mean lengths of *D. schødleri* ranged from 0.7 mm to 1.6 mm and averaged 1.2 mm. Mean lengths of *D. thorata* ranged from 0.9 mm to 1.5 mm and averaged 1.2 mm. Mean lengths of *L. kindti* ranged from 2.0 mm to 5.2 mm and averaged 3.6 mm.

Mean lengths of *D. galeata mendotae* at Spring Canyon (index station 9) ranged from 1.0 mm to 1.8 mm and averaged 1.4 mm (Table 3.2.9). *D. retrocurva* were not found at this location. Mean lengths of *D. schødleri* ranged from 0.8 mm to 1.6 mm and averaged 1.2 mm. Mean length of *D. thorata* averaged 1.5 mm. Mean length of *L. kindti* averaged 7.3 mm.

3.2.3 Zooplankton Biomass

Monthly mean biomass (μg/m^3) values of microcrustacean zooplankton collected at Gifford, Porcupine Bay, Seven Bays, and Spring Canyon are shown in Tables 3.2.10 through 3.2.13. Mean biomass/species for each location can be found in Appendix B.

Daphnia spp. biomass at Gifford (index station 2) ranged from 0.0 μg/m^3 in March to 3,493 μg/m^3 in August and averaged 660 μg/m^3 for the year (Table 3.2.10). *Leptodora kindti* biomass ranged from 0.0 μg/m^3 for the majority of the year to 2.6 μg/m^3 in September and averaged 1 μg/m^3 annually. Total Cladocera biomass ranged from 0.0 μg/m^3 in March to 3,493 μg/m^3 in August and averaged 661 μg/m^3 annually.

Daphnia spp. biomass at Porcupine Bay (index station 4) ranged from 5 μg/m^3 in March to 5,274 μg/m^3 in November and averaged 1,679 μg/m^3 for the year (Table 3.2.11). *L. kindti* biomass ranged from 0.0 μg/m^3 for the majority of the year to 782 μg/m^3 in June and averaged 74 μg/m^3 annually. Total Cladocera biomass ranged from 5 μg/m^3 in March to 5,274 μg/m^3 in November and averaged 1,753 μg/m^3 annually.

Daphnia spp. biomass at Seven Bays (index station 6) ranged from 1 μg/m^3 in March to 11,440 μg/m^3 in August and averaged 2,022 μg/m^3 for the year (Table 3.2.12). *L. kindti* biomass ranged

Table 3.2.8 Mean monthly size values (mm) (± S.D.) of different Cladocera species at Seven Bays (Index Station 6) in 1992.

	D. galeata mendotae (mm)	*Daphnia retrocurva* (mm)	*Daphnia schødleri* (mm)	*Daphnia thorata* (mm)	*Leptodora kindti* (mm)
Jan.	-	-	1.6	-	-
± S.D.	-	-	± 0.4	-	-
Feb.	-	-	1.2	-	-
± S.D.	-	-	± 0.1	-	-
Mar.	-	-	1.2	-	-
± S.D.	-	-	± 0.0	-	-
Apr.	-	-	0.7	-	-
± S.D.	-	-	± 0.1	-	-
May	0.7	0.5	0.9	-	2.0
± S.D.	± 0.3	± 0.0	± 0.4	-	± 0.0
Jun.	0.9	-	1.0	-	5.2
± S.D.	± 0.2	-	± 0.4	-	± 2.9
Jul.	0.9	-	1.0	-	-
± S.D.	± 0.3	-	± 0.4	-	-
Aug.	1.1	-	1.5	1.5	-
± S.D.	± 0.4	-	± 0.4	± 0.3	-
Sep.	0.9	-	1.2	0.9	-
± S.D.	± 0.1	-	± 4	± 0.2	-
Oct.	1.1	-	1.4	-	-
± S.D.	± 0.2	-	± 0.3	-	-
Nov.	-	-	1.4	-	-
± S.D.	-	-	± 0.3	-	-
Dec.	-	-	-	-	-
± S.D.	-	-	-	-	-
Yearly Mean	**0.9**	**0.5**	**1.2**	**1.2**	**3.6**

(- indicates no data were obtained due to lack of sample or organisms in sample.)

Table 3.2.9 Mean monthly size values (mm) (± S.D.) of different Cladocera species at Spring Canyon (Index Station 9) in 1992.

	D. galeata mendotae (mm)	*Daphnia retrocurva* (mm)	*Daphnia schødleri* (mm)	*Daphnia thorata* (mm)	*Leptodora kindti* (mm)
Jan.	-	-	-	-	-
± S.D.	-	-	-	-	-
Feb.	-	-	1.3	-	-
± S.D.	-	-	± 1.3	-	-
Mar.	-	-	1.2	-	-
± S.D.	-	-	±1.2	-	-
Apr.	-	-	1.0	-	-
± S.D.	-	-	±0.3	-	-
May	-	-	0.8	-	-
± S.D.	-	-	± 0.3	-	-
Jun.	1.0	-	1.1	-	7.3
± S.D.	± 0.4	-	± 0.5	-	± 2.3
Jul.	-	-	-	-	-
± S.D.	-	-	-	-	-
Aug.	1.8	-	1.6	-	-
± S.D.	± 0.2	-	± 0.4	-	-
Sep.	1.5	-	1.5	1.5	-
± S.D.	± 0.4	-	± 0.5	± 0.5	-
Oct.	-	-	1.3	-	-
± S.D.	-	-	± 0.3	-	-
Nov.	-	-	1.0	-	-
± S.D.	-	-	± 0.3	-	-
Dec.	-	-	-	-	-
± S.D.	-	-	-	-	-
Yearly Mean	**1.4**	**-**	**1.2**	**1.5**	**7.3**

(- indicates no data were obtained due to lack of sample or organisms in sample.)

Table 3.2.10 Mean monthly biomass values (µg/m^3) of different Cladocera at Gifford (Index Station 2) in 1992.

	Daphnia spp. µg/m^3	*Leptodora kindti* µg/m^3	Total Cladocera µg/m^3
Jan.	-	-	-
Feb.	304.0	0.0	304.0
Mar.	0.0	0.0	0.0
Apr.	16.4	1.7	18.1
May	31.2	0.7	31.9
Jun.	73.8	0.0	73.8
Jul.	83.8	0.0	83.8
Aug.	3,492.7	0.0	3,492.7
Sep.	902.5	2.3	904.8
Oct.	550.9	1.6	552.5
Nov.	1,146.8	0.0	1,146.8
Dec.	-	-	-
Reservoir Mean	**660**	**1**	**661**

(- represents no samples were collected).

Table 3.2.11 Mean monthly biomass values ($\mu g/m^3$) of different Cladocera at Porcupine Bay (Index Station 4) in 1992.

	Daphnia spp. $\mu g/m^3$	*Leptodora kindti* $\mu g/m^3$	Total Cladocera $\mu g/m^3$
Jan.	2,032.0	0.0	2,032.0
Feb.	142.0	0.0	141.0
Mar.	4.7	0.0	4.7
Apr.	31.3	0.0	31.5
May	223.0	24.0	247.0
Jun.	3,288.0	782.0	4,070.0
Jul.	2,983.3	0.0	2,983.3
Aug.	154.3	0.0	154.3
Sep.	2,893.6	2.3	2,895.9
Oct.	1,447.1	0.0	1,447.1
Nov.	5,274.3	0.0	5,274.3
Dec.	-	-	-
Yearly Mean	**1,679**	**74**	**1,753**

(- represents no samples were collected).

Table 3.2.12 Mean monthly biomass values ($\mu g/m^3$) of different Cladocera at Seven Bays (Index Station 6) in 1992.

	Daphnia spp. $\mu g/m^3$	*Leptodora kindti* $\mu g/m^3$	Total Cladocera $\mu g/m^3$
Jan.	304.0	0.0	304.0
Feb.	24.7	0.0	24.7
Mar.	0.8	0.0	0.8
Apr.	56.5	0.0	56.5
May	179.5	4.1	183.6
Jun.	838.8	310.3	1,149.1
Jul.	2,046.2	0.0	2,046.2
Aug.	11,440.1	0.0	11,440.1
Sep.	1,083.0	0.0	1,083.0
Oct.	6,072.4	0.0	6,072.4
Nov.	195.9	0.0	195.9
Dec.	-	-	-
Yearly Mean	**2,022**	**29**	**2,051**

(- represents no samples were collected).

from 0.0 μg/m^3 for the majority of the year to 310 μg/m^3 in June and averaged 29 μg/m^3 annually. Total Cladocera biomass ranged from 1 μg/m^3 in March to 11,440 μg/m^3 in August and averaged 2,051 μg/m^3 annually.

Daphnia spp. biomass at Spring Canyon (index station 9) ranged from 16 μg/m^3 in February to 13,313 μg/m^3 in August and averaged 2,324 μg/m^3 for the year (Table 3.2.13). *L. kindti* biomass ranged from 0.0 μg/m^3 for the majority of the year to 1,186 μg/m^3 in June and averaged 132 μg/m^3 annually. Total Cladocera biomass ranged from 16 μg/m^3 in February to 13,313 μg/m^3 in August and averaged 2,456 μg/m^3 annually.

3.3 BENTHIC MACROINVERTEBRATES

3.3.1 Annual and Seasonal Benthic Density

A total of 10 benthic macroinvertebrate families from 7 orders were found in the substrate samples from Lake Roosevelt (Appendix C). Tables 3.3.1 to 3.3.4 show the mean benthic macroinvertebrate number and weight densities from Gifford, Porcupine Bay, Seven Bays, and Spring Canyon from March to October 1992.

Gifford

At depths of 80 feet or greater at full pool (area 1), mean benthic macroinvertebrate density at Gifford in March was highest for caddisflies at 189/m^2 followed by midges with 94/m^2 (Table 3.3.1). May number density was highest for midges at 71/m^2 followed by caddisflies at 19/square meter. June number density was highest for midges at 94/m^2 followed by worms at 19/square meter. July number density was highest for midges at 333/m^2 followed by caddisflies at 57/square meter. August number density was highest for midges at 443/m^2 followed by scuds with 85/square meter. October number density was highest for midges at 657/m^2 followed by worms at 588/square meter.

Weight density at depths of 80 feet or greater at full pool (area 1) at Gifford in March was highest for caddisflies at 0.57 g/m^2 followed by snails with 0.45 g/square meter. May weight density

Table 3.2.13 Mean monthly biomass values ($\mu g/m^3$) of different Cladocera at Spring Canyon (Index Station 9) in 1992.

	Daphnia spp. $\mu g/m^3$	*Leptodora kindti* $\mu g/m^3$	Total Cladocera $\mu g/m^3$
Jan.	-	-	-
Feb.	15.6	0.0	15.6
Mar.	978.1	0.0	978.1
Apr.	36.2	0.0	36.2
May	150.4	0.0	150.4
Jun.	1,787.9	1,185.6	2,973.5
Jul.	-	-	-
Aug.	13,312.7	0.0	13,312.7
Sep.	2,443.3	0.0	2,443.3
Oct.	178.4	0.0	178.4
Nov.	2,015.1	0.0	2,015.1
Dec.	-	-	-
Yearly Mean	**2,324**	**132**	**2,456**

(- represents no samples were collected).

Table 3.3.1 Mean number ($\#/m^2$) and weight (g/m^2) density values for groups of benthic organisms at Gifford sampling locations on Lake Roosevelt, WA in 1992.

	SNAILS		CLAMS		MIDGES		CADDISFLIES		WORMS		SCUDS		OTHER	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Area 1														
March	18.9	0.45	0.0	0.000	94.3	0.142	188.7	0.566	0.0	0.000	0.0	0.000	0.0	0.000
May	0.0	0.000	0.0	0.000	71.3	0.102	18.9	0.052	0.0	0.000	0.0	0.000	0.0	0.000
June	0.0	0.000	0.0	0.000	94.3	0.215	12.6	0.072	18.9	0.076	0.0	0.000	0.0	0.000
July	6.3	0.090	0.0	0.000	333.3	1.500	56.6	0.040	50.3	0.131	0.0	0.000	0.0	0.000
August	9.4	0.030	0.0	0.000	443.4	0.709	0.0	0.000	0.0	0.000	84.9	1.647	0.0	0.000
October	0.0	0.000	0.0	0.000	657.2	3.035	37.7	0.712	588.1	1.941	0.0	0.000	0.0	0.000
Area 2														
March	0.0	0.000	0.0	0.000	264.2	0.396	0.0	0.000	94.3	0.264	0.0	0.000	0.0	0.000
May	0.0	0.000	0.0	0.000	8.4	0.013	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000
June	0.0	0.000	0.0	0.000	147.8	0.351	0.0	0.000	28.3	0.136	0.0	0.000	0.0	0.000
July	9.4	0.140	0.0	0.000	308.2	1.169	0.0	0.000	276.7	0.720	0.0	0.000	9.4	0.017
August	0.0	0.000	0.0	0.000	522.0	0.920	0.0	0.000	110.1	0.242	9.4	0.183	0.0	0.000
October	0.0	0.000	0.0	0.000	996.9	2.443	72.3	0.137	569.2	1.878	0.0	0.000	37.7	0.026
Area 3														
March No Samples														
May	0.0	0.000	0.0	0.000	155.1	0.184	2.1	0.006	21.0	0.059	0.0	0.000	0.0	0.000
June	0.0	0.000	0.0	0.000	94.3	0.226	0.0	0.000	226.4	1.087	94.3	0.377	0.0	0.000
July	0.0	0.000	0.0	0.000	128.9	0.549	0.0	0.000	47.2	0.123	0.0	0.000	0.0	0.000
August	0.0	0.000	0.0	0.000	345.9	0.570	0.0	0.000	119.5	0.263	0.0	0.000	56.6	0.223
October	0.0	0.000	0.0	0.000	97.5	0.283	12.6	0.024	415.1	1.370	3.1	0.062	0.0	0.000

was highest for midges at 0.10 g/m^2 followed by caddisflies at 0.05 g/square meter. June weight density was highest for midges at 0.22 g/m^2 followed by worms at 0.08 g/square meter. July weight density was highest for midges with 1.5 g/m^2 followed by worms at 0.13 g/square meter. August weight density was highest for scuds at 1.65 g/m^2 followed by midges at 0.71 g/square meter. October weight density was highest for midges at 3.04 g/m^2 followed by worms at 1.94 g/square meter.

At depths of 50 to 79 feet at full pool (area 2), mean benthic macroinvertebrate density at Gifford in March was highest for midges at 264/m^2 followed by worms at 94/m^2 (Table 3.3.1). May number density was highest for midges at 8/m^2 the only benthic organisms found. June number density was highest for midges at 148/m^2 followed by worms at 28/square meter. July number density was highest for midges at 308/m^2 followed by worms with 277/square meter. August number density was highest for midges at 522/m^2 followed by worms at 110/square meter. October number density was highest for midges at 997/m^2 followed by worms at 569/square meter.

At depths of 50 to 79 feet at full pool (area 2), mean benthic weight density at Gifford in March was highest for midges at 0.40 g/m^2 followed by worms at 0.26 g/square meter. May weight density was highest for midges at 0.01 g/m^2 the only benthic organisms found. June weight density was highest for midges at 0.35 g/m^2 followed by worms at 0.14 g/square meter. July weight density was highest for midges at 1.17 g/m^2 followed by worms with 0.72 g/square meter. August weight density was highest for midges at 0.92 g/m^2 followed by worms at 0.24 g/square meter. October weight density was highest for midges at 2.44 g/m^2 followed by worms at 1.88 g/square meter.

At depths of 0-49 feet at full pool (area 3), mean benthic macroinvertebrate density at Gifford in May was highest for midges at 155/m^2 followed by worms at 21/m^2 (Table 3.3.1). June number density was highest for worms at 226/m^2 followed by midges and scuds each with 94/square meter. July number density was highest for midges at 129/m^2 followed by worms at 47/square meter. August number density was highest for midges at 346/m^2 followed by worms at 120/square meter. October number density was highest for worms at 415/m^2 followed by midges at 98/square meter.

At depths of 0-49 feet at full pool (area 3), mean benthic weight density at Gifford in May was highest for midges at 0.18 g/m^2 followed by worms at 0.6 g/m^2 (Table 3.3.1). June weight density was highest for worms at 1.09 g/m^2 followed by scuds at 0.38 g/square meter. July weight density was highest for midges at 0.55 g/m^2 followed by worms at 0.12 g/square meter. August weight density was highest for midges at 0.57 g/m^2 followed by worms at 0.26 g/square meter. October weight density was highest for worms at 1.37 g/m^2 followed by midges at 0.28 g/square meter.

Snail densities were highest at Gifford in area one in March followed by area two in July (Table 3.3.1). Clams were not found in any month at any area. Highest midge density occurred in October in area two followed by October in area one. Caddisflies were most abundant in area one in March followed by area two in October. Worms had the highest density in October in area one followed by area two for the same month. Scud density was most abundant in May in area three followed by area one in August.

Porcupine Bay

At depths of 80 feet or greater at full pool (area 1), mean benthic macroinvertebrate density at Porcupine Bay in March was highest for midges at 170/m^2 followed by worms with 124/m^2 (Table 3.3.2). May number density was highest for worms at 138/m^2 followed by midges at 57/square meter. June number density was highest for midges at 241/m^2 followed by worms at 138/square meter. July number density was highest for midges at 236/m^2 followed by worms at 138/square meter. August number density was highest for scuds at 225/m^2 followed by midges with 167/square meter. October number density was highest for worms at 167/m^2 followed by midges at 97/square meter.

Weight density at depths of 80 feet or greater at full pool (area 1) at Porcupine Bay in March was highest for worms at 0.35 g/m^2 followed by midges with 0.26 g/square meter. May weight density was highest for worms at 0.39 g/m^2 followed by midges at 0.09 g/square meter. June weight density was highest for worms at

Table 3.3.2 Mean number ($\#/m^2$) and weight (g/m^2) density values for groups of benthic organisms at Porcupine Bay sampling locations on Lake Roosevelt, WA in 1992.

	SNAILS		CLAMS		MIDGES		CADDISFLIES		WORMS		SCUDS		OTHER	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Area 1														
March	0.0	0.000	0.0	0.000	169.8	0.255	48.2	0.126	123.7	0.346	6.3	0.025	0.0	0.000
May	0.0	0.000	0.0	0.000	56.6	0.085	0.0	0.000	138.4	0.387	0.0	0.000	0.0	0.000
June	0.0	0.000	0.0	0.000	241.1	0.561	0.0	0.000	138.4	0.664	0.0	0.000	0.0	0.000
July	0.0	0.000	0.0	0.000	235.9	1.031	3.1	0.007	138.4	0.360	0.0	0.000	0.0	0.000
August	0.0	0.000	0.0	0.000	166.7	0.267	0.0	0.000	94.3	0.208	224.8	4.362	0.0	0.000
October	0.0	0.000	0.0	0.000	97.48	0.244	9.4	0.018	166.7	0.550	0.0	0.000	0.0	0.000
Area 2														
March	0.0	0.000	0.0	0.000	56.6	0.085	6.3	0.019	18.9	0.053	0.0	0.000	0.0	0.000
May	0.0	0.000	0.0	0.000	144.7	0.194	9.4	0.028	3.1	0.009	0.0	0.000	0.0	0.000
June	0.0	0.000	0.0	0.000	342.8	0.811	0.0	0.000	9.4	0.045	9.4	0.038	0.0	0.000
July	0.0	0.000	0.0	0.000	339.6	1.497	0.0	0.000	3.1	0.008	9.4	0.071	0.0	0.000
August	0.0	0.000	0.0	0.000	150.9	0.242	0.0	0.000	40.9	0.090	113.2	2.013	9.4	0.004
October	0.0	0.000	0.0	0.000	188.7	0.495	9.4	0.018	650.9	2.148	264.2	0.523	0.0	0.000
Area 3														
March No samples														
May	0.0	0.000	0.0	0.000	594.3	0.688	9.4	0.0283	0.0	0.000	0.0	0.000	0.0	0.000
June	9.4	0.040	0.0	0.000	1128.9	2.476	0.0	0.000	380.5	1.826	735.9	2.943	0.0	0.000
July	0.0	0.000	0.0	0.000	110.1	0.495	0.0	0.000	39.3	0.102	0.0	0.000	0.0	0.000
August	0.0	0.000	0.0	0.000	163.5	0.331	0.0	0.000	194.0	0.429	37.7	0.732	0.0	0.000
October	0.0	0.000	0.0	0.000	72.3	0.181	0.0	0.000	207.6	0.685	28.3	0.560	0.0	0.000

0.66 g/m^2 followed by midges at 0.56 g/square meter. July weight density was highest for midges with 1.03 g/m^2 followed by worms at 0.36 g/square meter. August weight density was highest for scuds at 4.36 g/m^2 followed by midges at 0.27 g/square meter. October weight density was highest for worms at 0.55 g/m^2 followed by midges at 0.24 g/square meter.

At depths of 50 to 79 feet at full pool (area 2), mean benthic macroinvertebrate density at Porcupine Bay in March was highest for midges at 57/m^2 followed by worms at 19/m^2 (Table 3.3.2). May number density was highest for midges at 145/m^2 followed by caddisflies at 9/square meter. June number density was highest for midges at 343/m^2 followed by worms and scuds, each with 9/square meter. July number density was highest for midges at 340/m^2 followed by scuds with 9/square meter. August number density was highest for midges at 151/m^2 followed by scuds at 113/square meter. October number density was highest for worms at 651/m^2 followed by scuds at 264/square meter.

At depths of 50 to 79 feet at full pool (area 2), mean benthic weight density at Porcupine Bay in March was highest for midges at 0.08 g/m^2 followed by worms at 0.05 g/square meter. May weight density was highest for midges at 0.19 g/m^2 followed by caddisflies at 0.03 g/square meter. June weight density was highest for midges at 0.815 g/m^2 followed by worms at 0.05 g/square meter. July weight density was highest for midges at 1.50 g/m^2 followed by scuds with 0.07 g/square meter. August weight density was highest for scuds at 2.01 g/m^2 followed by midges at 0.24 g/square meter. October weight density was highest for worms at 2.15 g/m^2 followed by scuds at 0.52 g/square meter.

At depths of 0-49 feet at full pool (area 3), mean benthic macroinvertebrate density at Porcupine Bay in May was highest for midges at 594/m^2 followed by caddisflies at 9/m^2 (Table 3.3.2). June number density was highest for midges at 1,129/m^2 followed by scuds at 736/square meter. July number density was highest for midges at 110/m^2 followed by worms at 39/square meter. August number density was highest for worms at 194/m^2 followed by midges at 164/square meter. October number density was highest for worms at 208/m^2 followed by midges at 72/square meter.

At depths of 0-49 feet at full pool (area 3), mean benthic weight density at Porcupine Bay in May was highest for midges at 0.69 g/m^2 followed by caddisflies at 0.03 g/square meter. June weight density was highest for scuds at 2.94 g/m^2 followed by midges at 2.48 g/square meter. July weight density was highest for midges at 0.50 g/m^2 followed by worms at 0.10 g/square meter. August weight density was highest for scuds at 0.73 g/m^2 followed by worms at 0.43 g/square meter. October weight density was highest for worms at 0.69 g/m^2 followed by scuds at 0.56 g/square meter.

Snail densities were highest at Porcupine Bay in area three in June (Table 3.3.2). Clams were not found in any month at any area. Highest midge density occurred in June of area three followed by May in area three. Caddisflies were most abundant in area one in March. Worms had the highest density in October in area two followed by area three in June. Scud density was most abundant in May in area three followed by area two in October.

Seven Bays

At depths of 80 feet or greater at full pool (area 1), mean benthic macroinvertebrate density at Seven Bays in March was highest for midges at 151/m^2 followed by worms with 19/m^2 (Table 3.3.3). May number density was highest for midges at 50/m^2 followed by worms at 3/square meter. June number density was highest for midges at 824/m^2 followed by worms at 141/square meter. July number density was highest for midges at 667/m^2 followed by worms at 135/square meter. August number density was highest for worms at 135/m^2 followed by midges with 148/square meter. October number density was highest for midges at 201/m^2 followed by worms at 195/square meter.

Weight density at depths of 80 feet or greater at full pool (area 1) at Seven Bays in March was highest for midges at 0.23 g/m^2 followed by worms with 0.04 g/square meter. May weight density was highest for midges at 0.07 g/m^2 followed by worms at 0.01 g/square meter. June weight density was highest for midges at 1.90 g/m^2 followed by worms at 0.67 g/square meter. July weight density was highest for midges with 3.0 g/m^2 followed by scuds at 0.57 g/square meter. August weight density was highest for scuds

Table 3.3.3 Mean number ($\#/m^2$) and weight (g/m^2) density values for groups of benthic organisms at Seven Bays sampling locations on Lake Roosevelt, WA in 1992.

	SNAILS		CLAMS		MIDGES		CADDISFLIES		WORMS		SCUDS		OTHER	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Area 1														
March	0.0	0.000	0.0	0.000	150.9	0.226	0.0	0.000	18.9	0.043	0.0	0.000	0.0	0.000
May	0.0	0.000	0.0	0.000	50.3	0.070	0.0	0.000	3.1	0.009	0.0	0.000	0.0	0.000
June	0.0	0.000	0.0	0.000	823.9	1.899	25.2	0.166	140.5	0.674	100.6	0.403	0.0	0.000
July	0.0	0.000	0.0	0.000	666.7	3.000	18.9	0.023	135.2	0.352	75.5	0.566	0.0	0.000
August	0.0	0.000	0.0	0.000	147.8	0.253	9.4	0.029	220.1	0.484	144.7	2.806	0.0	0.000
October	37.7	0.120	0.0	0.000	201.3	0.503	3.1	0.006	195.0	0.643	75.5	0.560	0.0	0.000
Area 2														
March	0.0	0.000	0.0	0.000	333.3	0.500	56.6	0.125	0.0	0.000	0.0	0.000	0.0	0.000
May	0.0	0.000	0.0	0.000	47.2	0.065	37.7	0.098	0.0	0.000	0.0	0.000	0.0	0.000
June	9.4	0.220	0.0	0.000	201.3	0.472	3.1	0.018	18.9	0.045	0.0	0.000	0.0	0.000
July	0.0	0.000	0.0	0.000	625.8	2.692	0.0	0.000	836.5	2.175	75.5	0.566	0.0	0.000
August	0.0	0.000	0.0	0.000	1443.4	2.326	3.1	0.010	283.0	0.623	62.9	1.220	9.4	0.004
October	22.0	0.070	0.0	0.000	421.4	1.124	31.5	0.060	132.1	0.436	301.9	5.977	0.0	0.000
Area 3														
March	188.7	4.470	0.0	0.000	0.0	0.000	75.5	0.226	75.5	0.211	0.0	0.000	0.0	0.000
May	0.0	0.000	0.0	0.000	201.3	0.298	12.6	0.019	18.9	0.053	0.0	0.000	0.0	0.000
June	0.0	0.000	0.0	0.000	677.2	1.421	21.0	0.154	48.2	0.231	0.0	0.000	0.0	0.000
July	0.0	0.000	0.0	0.000	446.5	2.000	0.0	0.000	261.0	0.670	550.3	4.127	0.0	0.000
August	386.8	1.270	0.0	0.000	1283.0	2.085	9.4	0.029	84.9	0.187	0.0	0.000	0.0	0.000
October	0.0	0.000	0.0	0.000	66.0	0.180	6.3	0.112	37.7	0.405	311.3	6.164	0.0	0.000

at 2.81 g/m^2 followed by worms at 0.48 g/square meter. October weight density was highest for worms at 0.64 g/m^2 followed by scuds at 0.56 g/square meter.

At depths of 50 to 79 feet at full pool (area 2), mean benthic macroinvertebrate density at Seven Bays in March was highest for midges at 333/m^2 followed by caddisflies at 57/m^2 (Table 3.3.3). May number density was highest for midges at 47/m^2 followed by caddisflies at 38/square meter. June number density was highest for midges at 201/m^2 followed by worms at 19/square meter. July number density was highest for worms at 837/m^2 followed by midges with 626/square meter. August number density was highest for midges at 1,443/m^2 followed by worms at 283/square meter. October number density was highest for midges at 421/m^2 followed by scuds at 302/square meter.

At depths of 50 to 79 feet at full pool (area 2), mean benthic weight density at Seven Bays in March was highest for midges at 0.50 g/m^2 followed by caddisflies at 0.13 g/square meter. May weight density was highest for caddisflies at 0.10 g/m^2 followed by midges at 0.07 g/square meter. June weight density was highest for midges at 0.47 g/m^2 followed by worms at 0.05 g/square meter. July weight density was highest for midges at 2.70 g/m^2 followed by worms with 2.18 g/square meter. August weight density was highest for midges at 2.33 g/m^2 followed by scuds at 1.22 g/square meter. October weight density was highest for scuds at 5.98 g/m^2 followed by midges at 1.12 g/square meter.

At depths of 0-49 feet at full pool (area 3), mean benthic macroinvertebrate density at Seven Bays in March was highest for snails at 189/m^2 followed by caddisflies at 76/m^2 (Table 3.3.3). May number density was highest for midges at 201/m^2 followed by worms at 19/square meter. June number density was highest for midges at 677/m^2 followed by worms at 48/square meter. July number density was highest for scuds at 550/m^2 followed by midges at 447/square meter. August number density was highest for midges at 1,283/m^2 followed by snails at 387/square meter. October number density was highest for scuds at 311/m^2 followed by midges at 66/square meter.

At depths of 0-49 feet at full pool (area 3), mean benthic weight density at Seven Bays in March was highest for snails at 4.47 g/m^2 followed by caddisflies at 0.23 g/square meter. May weight density was highest for midges at 0.30 g/m^2 followed by worms at 0.05 g/square meter. June weight density was highest for midges at 1.42 g/m^2 followed by worms at 0.23 g/square meter. July weight density was highest for scuds at 4.13 g/m^2 followed by midges at 2.00 g/square meter. August weight density was highest for midges at 2.08 g/m^2 followed by snails at 1.27 g/square meter. October weight density was highest for scuds at 6.16 g/m^2 followed by worms at 0.41 g/square meter.

Snail densities were highest at Seven Bays in area three in August followed by area one in October (Table 3.3.3). Clams were not found in any month at any area. Highest midge density occurred in area two in august followed by Area three in August. Caddisflies were most abundant in area three in March followed by area two in March. Worms had the highest density at area two in July followed by area three in July. Scud density was most abundant in July at area three followed by area three in October.

Spring Canyon

At depths of 80 feet or greater at full pool (area 1), mean benthic macroinvertebrate density at Spring Canyon in March was highest for snails at 19/m^2 while worms had the highest density in May at 3/m^2 (Table 3.3.4). No samples were collected in June or July. August number density was highest for midges at 129/m^2 followed by hydracarina with 9/square meter. October number density was highest for worms at 472/m^2 followed by midges at 85/square meter.

Weight density at depths of 80 feet or greater at full pool (area 1) mean benthic weight density at Spring Canyon in March was highest for snails at 0.45g/m^2 while worms had the highest weight density in May at 0.01g/square meter. August weight density was highest for midges at 0.21g/m^2 followed by hydracarina at 0.004g/square meter. October weight density was highest for worms at 1.56g/m^2 followed by scuds at 0.37g/square meter.

Table 3.3.4 Mean number (#/m^2) and weight (g/m^2) density values for groups of benthic organisms at Spring Canyon sampling locations on Lake Roosevelt, WA in 1992.

		SNAILS		CLAMS		MIDGES		CADDISFLIES		WORMS		SCUDS		OTHER	
		No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Area 1															
March		18.9	0.450	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000
May		0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	3.1	0.009	0.0	0.000	0.0	0.000
June	No Samples														
July	No Samples														
August		0.0	0.000	0.0	0.000	128.9	0.206	0.0	0.000	0.0	0.000	0.0	0.000	9.4	0.004
October		0.0	0.000	0.0	0.000	84.9	0.212	0.0	0.000	471.7	1.557	18.9	0.374	0.0	0.000
Area 2															
March		0.0	0.000	18.9	0.077	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000
May		0.0	0.000	0.0	0.000	37.7	0.034	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000
June	No Samples														
July	No Samples														
August		0.0	0.000	0.0	0.000	496.9	0.795	18.9	0.036	893.1	1.965	0.0	0.000	9.4	0.004
October		0.0	0.000	0.0	0.000	66.0	0.165	0.0	0.000	18.9	0.062	0.0	0.000	0.0	0.000
Area 3															
March		0.0	0.000	0.0	0.000	94.3	0.142	75.5	0.226	0.0	0.000	0.0	0.000	0.0	0.000
May	No Samples														
June	No Samples														
July	No Samples														
August		9.4	0.020	0.0	0.000	712.3	1.145	9.4	0.018	267.3	0.588	0.0	0.000	0.0	0.000
October	No Samples														

At depths of 50 to 79 feet at full pool (area 2), mean benthic macroinvertebrate density at Spring Canyon in March was highest for clams at 19/m^2 while midges had the highest density in May at 38/m^2 (Table 3.3.4). No samples were collected in June or July. August number density was highest for worms at 893/m^2 followed by midges with 497/square meter. October number density was highest for midges at 66/m^2 followed by worms at 19/square meter.

At depths of 50 to 79 feet at full pool (area 2) mean benthic weight density at Spring Canyon in March was highest for clams at 0.08g/m^2 while midges had the highest weight density in May at 0.03g/square meter. August weight density was highest for worms at 1.97g/m^2 followed by midges at 0.80g/square meter. October weight density was highest for midges at 0.17g/m^2 followed by worms at 0.06g/square meter.

At depths of 0-49 feet at full pool (area 3), mean benthic macroinvertebrate density at Spring Canyon in March was highest for midges at 94/m^2 followed by caddisflies at 76/m^2 (Table 3.3.4). No samples were collected in May, June, July, or October. August number density was highest for midges at 712/m^2 followed by worms at 267/square meter.

At depths of 0-49 feet at full pool (area 3) mean benthic weight density at Spring Canyon in March was highest for caddisflies at 0.23g/m^2 followed by midges at 0.14g/square meter. No samples were collected in May, June, July, or October. August weight density was highest for midges at 1.15g/m^2 followed by worms at 0.59g/square meter.

Snail densities were highest at Spring Canyon in area one in March followed by area three in August (Table 3.3.4). Clam density was highest at area two in March. Highest midge density occurred area three in August followed by area two in August. Caddisflies were most abundant in area three in March followed by area two in August. Worms had the highest density at area two in August followed by area one in October. Scud density was most abundant in area one in October.

3.3.2 Benthic Emergence

A total of 5 benthic macroinvertebrate orders were found in emergence traps located at Gifford, Porcupine Bay, Seven Bays and Spring Canyon from July to October 1992. Tables 3.3.5 to 3.3.8 show the number and annual mean of benthic macroinvertebrates found in emergence traps.

Gifford

In area one (depths of 80 feet or greater) benthic emergence at Gifford in July, August and October was highest for diptera at 87/m^2, 26/m^2, and 30/m^2 respectively (Table 3.3.5). Ephemeroptera were second highest in October with 20/square meter. Annually, diptera had the highest emergence numbers at 48/m^2 followed by Ephemeroptera at 6/square meter.

In area two (depths between 50 and 79 feet) benthic emergence in July and August was highest for diptera at 3/m^2 and 15/m^2 respectively (Table 3.3.5). No other benthic adults were found. Annually, diptera emergence numbers were 6/square meter.

In area three (depths between 0 and 49 feet) benthic emergence in July, August, and October was highest for diptera at 30/m^2, 53/m^2, and 73/m^2 respectively (Table 3.3.5). Hepimtera was second highest in July with 2/square meter. Trichoptera were second highest in August and October with 2/m^2 and 3/square meter. Annually, diptera had the highest emergence numbers at 52/m^2 followed by Tricoptera at 2/square meter.

Porcupine Bay

In area one (depths of 80 feet or greater) benthic emergence at Porcupine Bay in July was highest for diptera at 32/m^2 followed by Odonata at 3/square meter (Table 3.3.6). No samples were sollected in August and no benthics were found in the trap in October. Annually, diptera had the highest emergence numbers at 16/m^2 followed by Odonata at 2/square meter.

In area two (depths between 50 and 79 feet) benthic emergence in July, August, and October was highest for diptera at 23/m^2, 22/m^2, and 16/m^2 respectively (Table 3.3.6). Hepimtera

Table 3.3.5 Mean number (#/m^2) density values for groups of benthic organisms captured in emergence traps located at Gifford on Lake Roosevelt, WA in 1992.

	DIPTERA (midges)	TRICHOPTERA (caddisflies)	EPHEMEROPTERA (mayflies)	HEMIPTERA (bugs)	ODONATA (dragonflies)
Area 1					
July	87	0	0	0	0
August	26	0	0	0	0
October	30	0	20	0	0
Annual ± s.d.	47.7 ± 34.1	0	5.6 ± 12.1	0	0
Area 2					
July	3	0	0	0	0
August	15	0	0	0	0
October	0	0	0	0	0
Annual ± s.d.	6.0± 7.9	0	0	0	0
Area 3					
July	30	0	0	2	0
August	53	2	0	1	1
October	73	3	0	0	2
Annual ± s.d.	52.0 ± 21.5	1.7 ± 1.5	0	1.0 ± 1.0	1.0 ± 1.0

Table 3.3.6 Mean number (#/m^2) density values for groups of benthic organisms captured in emergence traps located at Porcupine Bay on Lake Roosevelt, WA in 1992.

	DIPTERA (midges)	TRICHOPTERA (caddisflies)	EPHEMEROPTERA (mayflies)	HEMIPTERA (bugs)	ODONATA (dragonflies)
Area 1					
July	32	0	0	2	3
August	No Sample				
October	0	0	0	0	0
Annual ± s.d.	16.0 ± 22.6	0	0	1.0 ± 1.4	1.5 ± 2.1
Area 2					
July	23	0	0	0	0
August	22	0	0	3	0
October	16	0	0	2	0
Annual ± s.d.	20.3 ± 3.8	0	0	1.7 ± 1.5	0
Area 3					
July	65	2	0	0	2
August	17	0	0	0	0
October	27	7	2	0	4
Annual ± s.d.	36.3 ± 25.3	3.0 ± 3.6	0.7 ± 1.2	0	2.0 ± 2.0

was second highest in August and October with 3/m^2 and 2/m^2 respectively. Annually, diptera emergence numbers were highest at 20/m^2 followed by Hemiptera with 2/square meter.

In area three (depths between 0 and 49 feet) benthic emergence in July, August, and October was highest for diptera at 65/m^2, 17/m^2, and 27/m^2 respectively (Table 3.3.6). Trichoptera and Odonata tied for second in July with 2/m^2 each. No other adult benthics were found in August. In October, Trichoptera had second highest emergence with 7/square meter. Annually, diptera emergence numbers were highest at 36/m^2 followed by Tricoptera with 3/square meter.

Seven Bays

In area one (depths of 80 feet or greater) benthic emergence in July, August, and October was highest for diptera at 47/m^2, 27/m^2, and 1/m^2 respectively (Table 3.3.7). No other adult benthics were found in any other month. Annually, diptera had a mean emergence number of 25/square meter.

In area two (depths between 50 and 79 feet) benthic emergence in July, August, and October was highest for diptera at 38/m^2, 39/m^2, and 3/m^2 respectively (Table 3.3.7). Ephemeroptera was second highest in July with 13/square meter. Odonata were second highest in August with 1/m^2 and no other benthic adults were found in October. Annually, diptera emergence numbers were highest at 27/m^2 followed by Ephemeroptera with 4/square meter.

In area three (depths between 0 and 49 feet) benthic emergence in July, August, and October was highest for diptera at 27/m^2, 29/m^2, and 15/m^2 respectively (Table 3.3.7). Odonata were second highest in July with 3/square meter. No other adult benthics were found in August and in October. Annually, diptera emergence numbers were highest at 24/m^2 followed by Odonata with 1/square meter.

Spring Canyon

In area one (depths of 80 feet or greater) benthic emergence in July and August was highest for diptera at 5/m^2 and 10/m^2 respectively (Table 3.3.8). Odonata emregence was second highest in

Table 3.3.7 Mean number (#/m^2) density values for groups of benthic organisms captured in emergence traps located at Seven Bays on Lake Roosevelt, WA in 1992.

	DIPTERA (midges)	TRICHOPTERA (caddisflies)	EPHEMEROPTERA (mayflies)	HEMIPTERA (bugs)	ODONATA (dragonflies)
Area 1					
July	47	0	0	0	0
August	27	0	0	0	0
October	1	0	0	0	0
Annual ± s.d.	25.0 ± 23.1	0	0	0	0
Area 2					
July	38	0	13	0	2
August	39	0	0	0	1
October	3	0	0	0	0
Annual ± s.d.	26.7 ± 20.5	0	4.3 ± 7.5	0	1.0 ± 1.0
Area 3					
July	27	2	0	0	3
August	29	0	0	0	0
October	15	0	0	0	0
Annual ± s.d.	23.7 ± 7.6	0.7 ± 1.2	0	0	1.0 ± 1.7

Table 3.3.8 Mean number (#/m^2) density values for groups of benthic organisms captured in emergence traps located at Spring Canyon on Lake Roosevelt, WA in 1992.

	DIPTERA (midges)	TRICHOPTERA (caddisflies)	EPHEMEROPTERA (mayflies)	HEMIPTERA (bugs)	ODONATA (dragonflies)
Area 1					
July	5	0	0	1	7
August	10	0	0	0	5
October	No samples				
Annual ± s.d.	7.5 ± 3.5	0	0	1.0 ± 0.5	6.0 ± 1
Area 2					
July	5	0	0	0	2
August	8	0	0	0	2
October	No samples				
Annual ± s.d.	6.5 ± 2.1	0	0	0	2.0 ± 0
Area 3					
July	3	0	0	0	0
August	1	0	0	0	0
October	No samples				
Annual ± s.d.	2.0 ± 1.4	0	0	0	0

July and August at 7/m^2 and 5/m^2 respectively. No samples were collected in October. Annually, diptera had the highest mean emergence at 8/m^2 followed by Odonata at 6/square meter.

In area two (depths between 50 and 79 feet) benthic emergence in in July and August was highest for diptera at 5/m^2 and 8/m^2 respectively (Table 3.3.8). Odonata emregence was second highest in July and August at 2/m^2 for both months. Annually, mean diptera emergence numbers were highest at 7/m^2 followed by Odonata with 2/square meter.

In area three (depths between 0 and 49 feet) benthic emergence in in July and August was highest for diptera at 3/m^2 and 1/m^2 respectively (Table 3.3.8). No other adult benthics were found in August and in October. Annually, mean diptera emergence numbers were 2/square meter.

3.4 FISHERIES SURVEYS

3.4.1 Relative Abundance

Electrofishing surveys of littoral areas in May found largescale suckers to have the highest relative abundance 68%, followed by walleye with 9%, and smallmouth bass with 7 percent (Table 3.4.1). Largescale suckers had the highest abundance in August with 46%, followed by yellow perch with 18%, and smallmouth bass with 13 percent. In October, yellow perch had the highest abundance with 45%, followed by largescale suckers with 20%, and rainbow trout with 11 percent. When seasonal numbers were combined, largescale suckers had the highest relative abundance at 46%, followed by yellow perch at 20%, and walleye at 8 percent.

Gillnet surveys of pelagic areas in May found walleye to have the highest relative abundance at 42%, followed by lake whitefish at 38%, and smallmouth bass at 15% (Table 3.4.2). Walleye had the highest abundance in August with 50%, followed by rainbow trout at 22%, and smallmouth bass at 10 percent. In October, walleye had the highest abundance at 52%, followed by largescale sucker at 20%, and lake whitefish at 12 percent. When seasonal gillnet numbers were combined, walleye had the highest relative abundance at 48%, followed by lake whitefish at 15%, and rainbow trout at 14 percent.

Table 3.4.1 Seasonal summary of total catch and relative abundance of fish species captured during electrofishing surveys on Lake Roosevelt in 1992.

	MAY		AUGUST		OCTOBER		TOTAL	
FAMILY SPECIES	TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%
CATOSTOMIDAE								
Bridgelip sucker	2	0	2	0	0	0	4	0
Longnose sucker	1	0	0	0	4	0	5	0
Largescale sucker	839	68	529	46	203	20	1,571	46
CENTRARCHIDAE								
Black crappie	1	0	0	0	16	2	17	1
Largemouth bass	1	0	0	0	0	0	1	0
Smallmouth bass	87	7	152	13	4	0	243	7
White crappie	0	0	0	0	2	0	2	0
COTTIDAE								
Piute sculpin	12	1	26	2	24	2	62	2
CATOSTOMIDAE								
Carp	7	1	53	5	0	0	60	2
Chiselmouth	4	0	0	0	0	0	4	0
Peamouth	16	1	0	0	0	0	16	0
Redside shiner	2	0	0	0	0	0	2	0
Squawfish	59	5	21	2	0	0	80	2
Tench	1	0	0	0	0	0	1	0
GADIDAE								
Burbot	2	0	0	0	0	0	1	0
PERCIDAE								
Walleye	109	9	101	9	68	7	278	8
Yellow perch	28	2	206	18	461	45	695	20
SALMONIDAE								
Brook trout	3	0	6	1	8	1	17	1
Brown trout	0	0	2	0	4	0	6	0
Chinook salmon	0	0	0	0	3	0	3	0
Kokanee salmon	0	0	10	1	97	10	107	3
Lake whitefish	1	0	3	0	1	0	5	0
Mountain whitefish	1	0	0	0	3	0	4	0
Rainbow trout	49	4	37	3	112	11	198	6

Table 3.4.2 Seasonal summary of total catch and relative abundance of fish species captured during gillnet surveys on Lake Roosevelt in 1992.

	MAY		AUGUST		OCTOBER		TOTAL	
FAMILY SPECIES	TOTAL	%	TOTAL	%	TOTAL	%	TOTAL	%
CATOSTOMIDAE								
Bridgelip sucker	0	0	0	0	0	0	0	0
Longnose sucker	1	2	2	2	0	0	3	2
Largescale sucker	1	2	5	4	5	20	11	6
CENTRARCHIDAE								
Black crappie	0	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0	0
Smallmouth bass	7	15	12	10	0	0	19	10
White crappie	0	0	0	0	0	0	0	0
COTTIDAE								
Piute sculpin	0	0	0	0	0	0	0	0
CATOSTOMIDAE								
Carp	0	0	0	0	0	0	0	0
Chiselmouth	0	0	0	0	0	0	0	0
Peamouth	0	0	0	0	0	0	0	0
Redside shiner	0	0	0	0	0	0	0	0
Squawfish	1	2	3	2	2	8	6	3
Tench	0	0	0	0	0	0	0	0
GADIDAE								
Burbot	0	0	0	0	0	0	0	0
PERCIDAE								
Walleye	20	42	63	50	13	52	96	48
Yellow perch	0	0	3	2	2	8	5	3
SALMONIDAE								
Brook trout	0	0	0	0	0	0	0	0
Brown trout	0	0	0	0	0	0	0	0
Chinook salmon	0	0	0	0	0	0	0	0
Kokanee salmon	0	0	1	1	0	0	1	1
Lake whitefish	18	38	9	7	3	12	30	15
Mountain whitefish	0	0	0	0	0	0	0	0
Rainbow trout	0	0	27	22	0	0	27	14

Combining all fish species from all seasons found 3,590 fish captured in 1992 (Table 3.4.3). Annual number and relative abundance figures were: 1,582 largescale sucker (44%), 700 yellow perch (19%), 374 walleye (10%), 262 smallmouth bass (7%), 225 rainbow trout (6%), 108 kokanee salmon (3%), 86 squawfish (2%), 62 piute sculpin (2%), 60 carp (2%), 35 lake whitefish (1%), 17 brook trout (0%), 16 peamouth (0%), 11 burbot (0%), 8 longnose sucker (0%), 6 brown trout (0%), 4 each of bridgelip sucker, chiselmouth, and mountain whitefish (0% each), 3 chinook salmon (0%), 2 each of white crappie and redside shiner (0%), and 1 each of largemouth bass and tench (0%).

3.4.2 Seasonal Feeding Habits

See Thatcher *et al.* 1994 for feeding habit results.

3.4.3 Electivity Indices

See Thatcher *et al.* 1994 for electivity indicie results.

3.4.4 Annual Age, Growth and Condition

See Thatcher *et al.* 1994 for age, growth, and condition factor results.

3.5 TAGGED FISH RECOVERY

Tables 3.5.1 through 3.5.6 summarize fish tag recoveries from each net-pen tagging effort on Lake Roosevelt from 1988 to 1992.

Kettle Falls

In September 1989, 584 fish were tagged and released from the Kettle Falls net-pen (Table 3.5.1). Subsequent tag returns found 15 fish recaptured for a 3% recovery rate. Fourteen of these fish were recovered above Grand Coulee and one fish was recaptured below Grand Coulee. In March 1990, 508 fish were tagged and released. Subsequent tag returns found two fish recaptured, both above Grand Coulee. In April 1990, 498 fish were tagged and released. Tag returns found 23 fish recaptured for a 5 percent recovery rate. Seventeen fish were recovered above Grand Coulee, while the remaining 6 were recovered below. In April 1991, 1,000 fish were tagged and released. Tag returns found 57 fish recaptured

Table 3.4.3 Synoptic list of fish species, total numbers and % relative abundance of fish collected during electrofishing and gillnet surveys on Lake Roosevelt, in May, August, and October of 1992.

FAMILY	COMMON NAME	SCIENTIFIC NAME	TOTAL No.	% REL. ABUND.
Catostomidae	Bridgelip sucker	*Catostomus columbianus*	4	0%
	Longnose sucker	*Catostomus catostomus*	8	0%
	Largescale sucker	*Catostomus macrocheilus*	1,582	44%
Centrarchidae	Black crappie	*Pomoxis nigromaculatus*	17	0%
	Largemouth bass	*Micropterus salmoides*	1	0%
	Smallmouth bass	*Micropterus dolomieui*	262	7%
	White crappie	*Pomoxis annularis*	2	0%
Cottidae	Piute sculpin	*Cottus beldingi*	62	2%
Cyprinidae	Carp	*Cyprinus carpio*	60	2%
	Chiselmouth	*Acrocheilus alutaceus*	4	0%
	Peamouth	*Mylocheilus caurinus*	16	0%
	Redside shiner	*Richardsonius balteatus*	2	0%
	Squawfish	*Ptychocheilus oregonensis*	86	2%
	Tench	*Tinca tinca*	1	0%
Gadidae	Burbot	*Lota lota*	11	0%
Percidae	Walleye	*Stizostedion vitreum vitreum*	374	10%
	Yellow perch	*Perca flavescens*	700	19%
Salmonidae	Brook trout	*Salvelinus fontinalis*	17	0%
	Brown trout	*Salmo trutta*	6	0%
	Chinook salmon	*Oncorhynchus tshawytscha*	3	0%
	Kokanee salmon	*Oncorhynchus nerka*	108	3%
	Lake whitefish	*Coregonus clupeaformis*	35	1%
	Mountain whitefish	*Prosopium williamsoni*	4	0%
	Rainbow trout	*Oncorhynchus mykiss*	225	6%
TOTAL			3,590	

Table 3.5.1 Summary of release dates, numbers, and subsequent capture locations of net-pen rainbow trout tagged and released from Kettle Falls.

Release Date	Total # Tagged	Total # Recovered	Percent Recovered	Number Recovered in FDR	Percent Recovered in FDR	Recoveries Below Grand Coulee: Number Recovered in Rufus Woods	Recoveries Below Grand Coulee: Number Recovered at Rock Is. or McNary	Recoveries Below Grand Coulee: Percent Recovered Below FDR
Sep. 89	584	15	3%	14	93%	1	0	7%
Mar. 90	508	2	0%	2	100%	0	0	0%
Apr. 90	498	23	5%	17	74%	5	1	26%
Apr. 91	1,000	57	6%	44	77%	11	2	21%
Mar. 92	1,000	8	1%	8	100%	0	0	0%
Apr. 92	1,000	31	3%	30	97%	1	0	3%
May 92	1,000	36	4%	36	100%	0	0	0%

for a 6 percent recovery rate. Forty four of the fish were recaptured above Grand Coulee, while 11 were recaptured below. In March 1992 1,000 fish were tagged and released. To date, 8 fish have been recovered for a recapture rate of 1 percent . All eight fish were recaptured within Lake Roosevelt. In April 1992, 1,000 fish were tagged and released. Thirty one fish have been recaptured for a 3 percent recovery rate. Thirty of the fish were recaptured within Lake Roosevelt, while one was captured below Grand Coulee. In May 1992, 1,000 fish were tagged and released. To date 36 fish have been recaptured for a recovery rate of 4 percent. All 36 fish were recaptured within Lake Roosevelt.

Gifford

In March 1992 1,000 fish were tagged and released (Table 3.5.2). To date, 11 fish have been recovered for a recapture rate of 1 percent . All 11 fish were recaptured within Lake Roosevelt. In April 1992, 1,000 fish were tagged and released. Twenty four fish have been recaptured for a 2 percent recovery rate. All 24 fish were recaptured within Lake Roosevelt. In May 1992, 1,000 fish were tagged and released. To date 27 fish have been recaptured for a recovery rate of 3 percent. All 27 fish were recaptured within Lake Roosevelt. In June 1992, 1,000 fish were tagged and released. Thirty eight fish have been recaptured for a 4 percent recovery rate. All fish were recovered within Lake Roosevelt.

Hunters

In May 1989, 768 fish were tagged and released (Table 3.5.3). Tag returns found 8 fish recaptured for a 1% recovery rate. Three fish were recovered in Lake Roosevelt, while 5 fish were recaptured below Grand Coulee. In October 1989, 447 fish were tagged and released. Subsequent tag returns found 10 fish recaptured for a 10% recovery rate. All fish were recaptured within Lake Roosevelt. In March 1990, 490 fish were tagged and released. Tag returns found 3 fish recaptured for a 1 percent recovery rate. One fish was recovered within Lake Roosevelt, while the other two were recovered below Grand Coulee. In April 1990, 498 fish were tagged an released. Subsequent tag returns found 9 fish recaptured for a 2% recovery. Seven fish were recovered within Lake Roosevelt, while two were recovered below Grand Coulee. In May 1990, 492 fish were tagged and released. Tag returns found 7 fish recovered for a 1% recovery. Six fish were recovered in Lake Roosevelt, while one fish

Table 3.5.2 Summary of release dates, numbers, and subsequent capture locations of net-pen rainbow trout tagged and released from Gifford.

Release Date	Total # Tagged	Total # Recovered	Percent Recovered	Number Recovered in FDR	Percent Recovered in FDR	Recoveries Below Grand Coulee: Number Recovered in Rufus Woods	Recoveries Below Grand Coulee: Number Recovered at Rock Is. or McNary	Recoveries Below Grand Coulee: Percent Recovered Below FDR
Mar. 92	1,000	11	1%	11	100%	0	0	0%
Apr. 92	1,000	24	2%	24	100%	0	0	0%
May 92	1,000	27	3%	27	100%	0	0	0%
Jun. 92	1,000	38	4%	38	100%	0	0	0%

Table 3.5.3 Summary of release dates, numbers, and subsequent capture locations of net-pen rainbow trout tagged and released from Hunters.

Release Date	Total # Tagged	Total # Recovered	Percent Recovered	Number Recovered in FDR	Percent Recovered in FDR	Recoveries Below Grand Coulee		
						Number Recovered in Rufus Woods	Number Recovered at Rock Is. or McNary	Percent Recovered Below FDR
Mar. 89	768	8	1%	3	38%	0	5	63%
Oct. 89	447	10	2%	10	100%	0	0	0%
Mar. 90	490	3	1%	1	33%	0	2	67%
Apr. 90	498	9	2%	7	78%	2	0	22%
May 90	492	7	1%	6	86%	1	0	14%
Oct. 90	366	5	1%	3	60%	1	1	40%
Mar. 92	1,000	10	1%	10	100%	0	0	0%
Apr. 92	1,000	27	3%	27	100%	0	0	0%
May 92	1,000	35	4%	34	97%	1	0	3%

was recaptured below Grand Coulee. In October 1990, 366 fish were tagged and released. Tag returns found 5 fish recaptured for a 1% recovery. Three fish were recovered in Lake Roosevelt, while two were recovered below Grand Coulee. In March 1992 1,000 fish were tagged and released. To date, 10 fish have been recovered for a recapture rate of 1 percent . All 10 fish were recaptured within Lake Roosevelt. In April 1992, 1,000 fish were tagged and released. Twenty seven fish have been recaptured for a 3 percent recovery rate. All 27 fish were recaptured within Lake Roosevelt. In May 1992, 1,000 fish were tagged and released. To date 35 fish have been recaptured for a recovery rate of 4 percent. Thirty four fish were recaptured within Lake Roosevelt, while one fish was caught below Grand Coulee.

Seven Bays

In May 1988, 1,171 fish were tagged and released (Table 3.5.4). Subsequent tag returns found 98 fish recaptured for an 8 percent recovery rate. All 98 fish were recaptured in Lake Roosevelt. In April 1989, 985 fish were tagged and released. Tag returns found 20 fish recaptured for a 2 percent recovery rate. Eleven fish were recaptured within Lake Roosevelt, while 9 fish were recaptured below Grand Coulee. In May 1990, 443 fish were tagged and released. Tag returns found 2 fish recaptured for a 0 percent recovery. One fish was recovered within Lake Roosevelt and the other below Grand Coulee. In April 1990, 474 fish were tagged and released. Tag returns found 20 fish recaptured for a 4 percent recovery. Fourteen fish were recovered within Lake Roosevelt, while 6 fish were captured below Grand Coulee. In May 1990, 499 fish were tagged and released. Subsequent tag returns found 30 fish recaptured for a 6 percent recovery. Twenty-four fish were recovered within Lake Roosevelt, while 6 fish were recovered below Grand Coulee. In June 1991, 296 fish were tagged and released. Tag returns found 32 fish recovered for an 11 percent recapture rate. Twenty-seven fish were recovered within Lake Roosevelt, while 5 fish were recovered below Grand Coulee. In July 1991, 1,749 fish were tagged and released. Tags found 152 fish recovered for a recapture rate of 9 percent. One hundred forty-six fish were recovered from Lake Roosevelt, while 6 fish were recaptured below Grand Coulee. In March 1992, 999 fish were tagged and released. To date 44 fish have been recaptured for a 4 percent recovery rate. Forty-two fish were recovered from Lake Roosevelt, while 2 fish

Table 3.5.4 Summary of release dates, numbers, and subsequent capture locations of net-pen rainbow trout tagged and released from Seven Bays.

Release Date	Total # Tagged	Total # Recovered	Percent Recovered	Number Recovered in FDR	Percent Recovered in FDR	Recoveries Below Grand Coulee		
						Number Recovered in Rufus Woods	Number Recovered at Rock Is. or McNary	Percent Recovered Below FDR
May 88	1,171	98	8%	98	100%	0	0	0%
Apr.89	985	20	2%	11	55%	3	6	45%
Mar 90	443	2	0%	1	50%	0	1	50%
Apr 90	474	20	4%	14	70%	3	3	30%
May 90	499	30	6%	24	80%	5	1	21%
Apr 91	1,300	21	2%	8	38%	2	11	62%
Jun. 91	296	32	11%	27	84%	5	0	18%
Jul. 91	1,749	152	9%	146	96%	6	0	4%
Mar. 92	999	44	4%	42	95%	2	0	5%
Apr. 92	1,000	30	3%	29	97%	1	0	0%
May 92	1,000	48	5%	48	100%	0	0	0%
Jun. 92	1,000	28	3%	28	100%	0	0	0%

were recovered below Grand Coulee. In April 1992, 1,000 fish were tagged and released. To date 30 fish have been recaptured for a 3 percent recovery rate. Twenty-nine fish were recovered from Lake Roosevelt, while 1 fish was recovered below Grand Coulee. In May 1992, 1,000 fish were tagged and released. To date 48 fish have been recaptured for a 5 percent recovery rate. All fish were recovered from Lake Roosevelt. In June 1992, 1,000 fish were tagged and released. To date 28 fish have been recaptured for a 3 percent recovery rate. All fish were recovered from Lake Roosevelt.

Lincoln

In March 1992, 1,000 fish were tagged and released (Table 3.5.5). To date 8 fish have been recaptured for a 1 percent recovery rate. All fish were recovered from Lake Roosevelt. In April 1992, 1,000 fish were tagged and released. To date 25 fish have been recaptured for a 3 percent recovery rate. All fish were recovered from Lake Roosevelt. In May 1992, 1,000 fish were tagged and released. To date 42 fish have been recaptured for a 4 percent recovery rate. Forty-one fish were recovered from Lake Roosevelt, while one fish was recovered below Grand Coulee. In June 1992, 1,000 fish were tagged and released. To date 30 fish have been recaptured for a 3 percent recovery rate. All fish were recovered from Lake Roosevelt.

Keller Ferry

In May 1990, 459 fish were tagged and released from the Keller Ferry net-pen (Table 3.5.6). Subsequent tag returns found 16 fish recaptured for a 3 percent recovery. Thirteen fish were recovered within Lake Roosevelt, while 3 fish were recovered below Grand Coulee. In March 1992, 998 fish were tagged and released. To date 12 fish have been recaptured for a 1 percent recovery rate. All fish were recovered from Lake Roosevelt. In April 1992, 998 fish were tagged and released. To date 24 fish have been recaptured for a 3 percent recovery rate. Twenty-three fish were recovered within Lake Roosevelt, while one fish was recovered below Grand Coulee. In May 1992, 1,000 fish were tagged and released. To date 35 fish have been recaptured for a 4 percent recovery rate. Thirty-four fish were recovered from Lake Roosevelt, while one fish was recovered below Grand Coulee.

Table 3.5.5 Summary of release dates, numbers, and subsequent capture locations of net-pen rainbow trout tagged and released from Lincoln.

Release Date	Total # Tagged	Total # Recovered	Percent Recovered	Number Recovered in FDR	Percent Recovered in FDR	Recoveries Below Grand Coulee: Number Recovered in Rufus Woods	Recoveries Below Grand Coulee: Number Recovered at Rock Is. or McNary	Recoveries Below Grand Coulee: Percent Recovered Below FDR
Mar. 92	1,000	8	1%	8	100%	0	0	0%
Apr. 92	1,000	25	3%	25	100%	0	0	0%
May 92	1,000	42	4%	41	98%	1	0	2%
Jun. 92	1,000	30	3%	30	100%	0	0	0%

Table 3.5.6 Summary of release dates, numbers, and subsequent capture locations of net-pen rainbow trout tagged and released from Keller Ferry.

Release Date	Total # Tagged	Total # Recovered	Percent Recovered	Number Recovered in FDR	Percent Recovered in FDR	Recoveries Below Grand Coulee: Number Recovered in Rufus Woods	Recoveries Below Grand Coulee: Number Recovered at Rock Is. or McNary	Recoveries Below Grand Coulee: Percent Recovered Below FDR
May 90	459	16	3%	13	81%	2	1	19%
Mar. 92	998	12	1%	12	100%	0	0	0%
Apr. 92	998	24	2%	23	96%	1	0	4%
May 92	1,000	35	4%	34	97%	1	0	3%

4.0 DISCUSSION

4.1 RESERVOIR OPERATIONS

Lake Roosevelt's annual spring drawdown began on March 1st. The lowest reservoir elevation (1262) occurred on May 22nd, at which time the reservoir began actively refilling. A second minor drawdown occurred from August to October and was due to downstream requests. The reservoir then was drafted for winter power production beginning in November.

Mean water retention times were relatively high when compared to the previous years operation (Figure 4.1.2). Mean monthly water retention time did not go below the thirty day mark for any time period in 1992.

4.2 ZOOPLANKTON

4.2.1 Affect of Reservoir Operations on Zooplankton Dynamics

Zooplankton density and biomass values in 1992 were not as high as expected. Mean microcrustacean zooplankton density (including nauplii) was determined to be 743/m^3 for May, August, and October. Highest recorded *Daphnia* spp. was 349/m^3 at Seven Bays in August (Figure 4.2.1). Spring Canyon had the highest total zooplankton density in August at 1,620/m^3 (Figure 4.2.2).

From data gathered in previous years regarding the effects of water retention time on zooplankton production, 1992 should have been an excellent year for zooplankton biomass and density. Water temperatures in the spring were warmer than previous years and mean monthly water retention times did not drop below thirty days. These values should have predicted zooplankton production success. However, when zooplankton density and biomass values are compared to earlier years, there is a large difference between the amount of zooplankton that were produced low water retention years when compared to 1992 (Table 4.2.1).

Using the linear regression analysis equation developed in the 1991 report, 1992 biomass should have been between 150,000 and 180,000 $\mu g/m^3$.

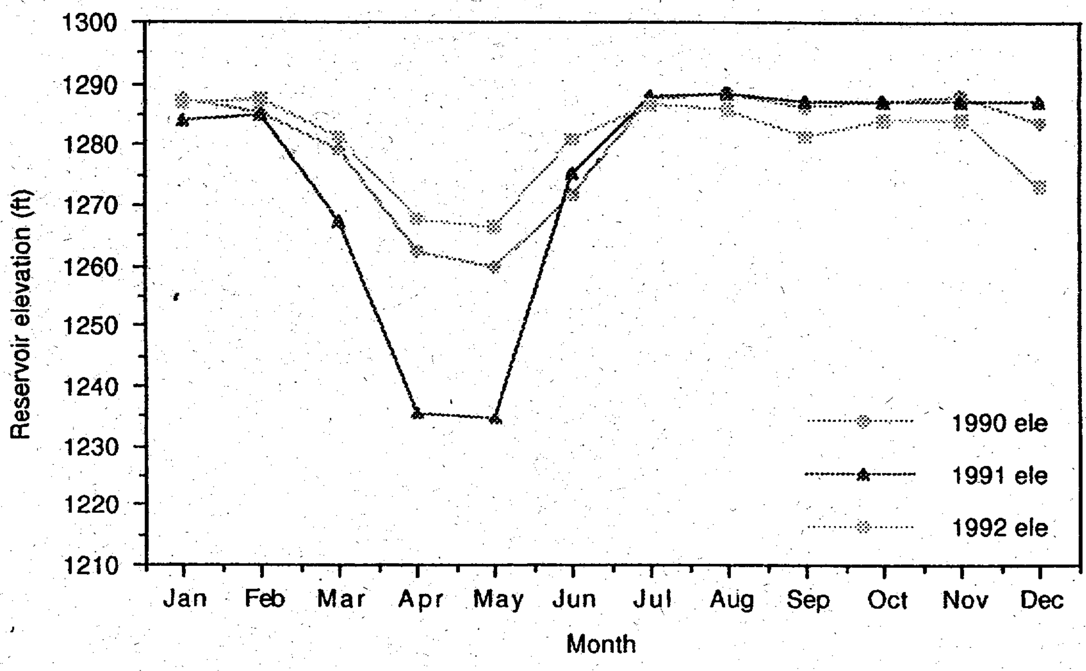

Figure 4.1.1 Mean monthly Lake Roosevelt reservoir elevations from 1990 to 1992.

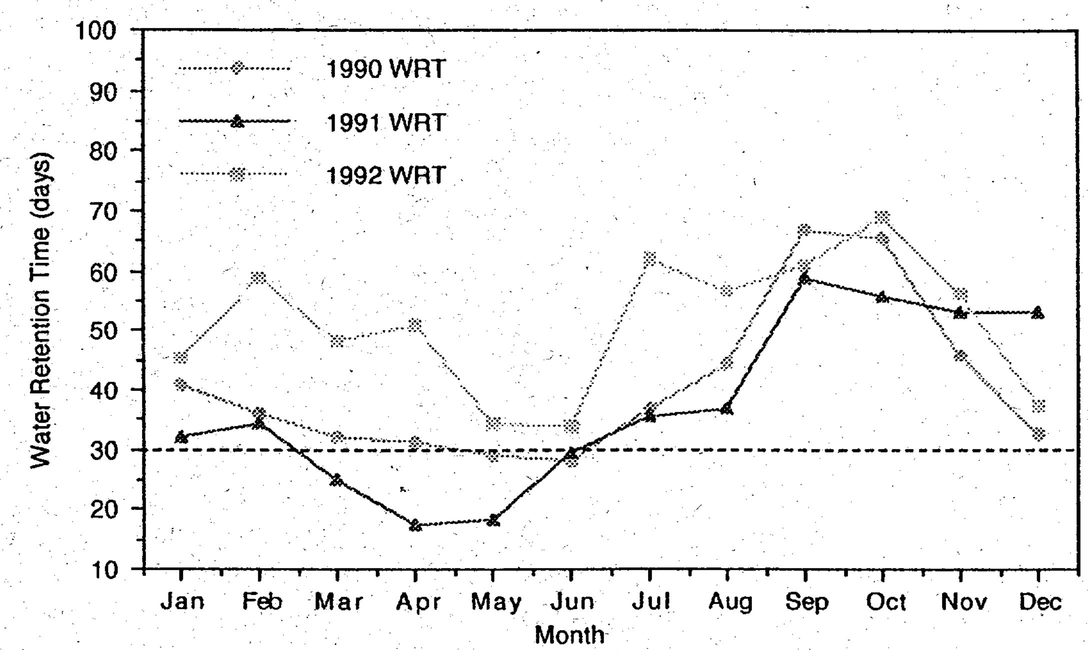

Figure 4.1.2 Mean monthly Lake Roosevelt water retention time from 1990 to 1992.

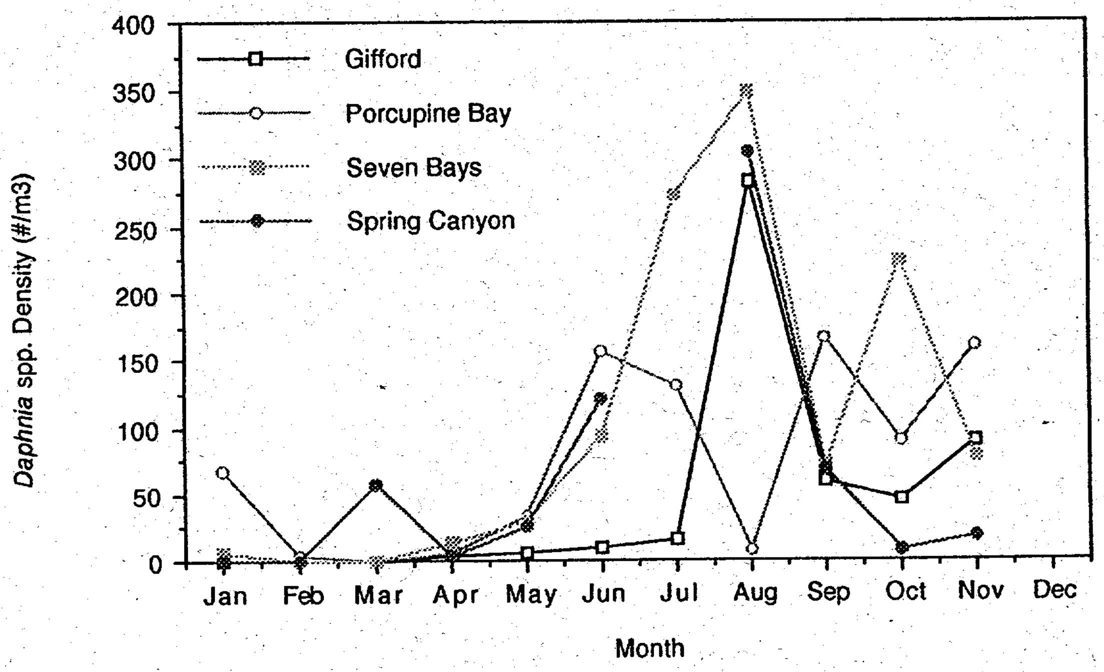

Figure 4.2.1 Mean monthy *Daphnia* spp. density (#/m3) for Gifford, Porcupine Bay, Seven Bays, and Spring Canyon in 1992.

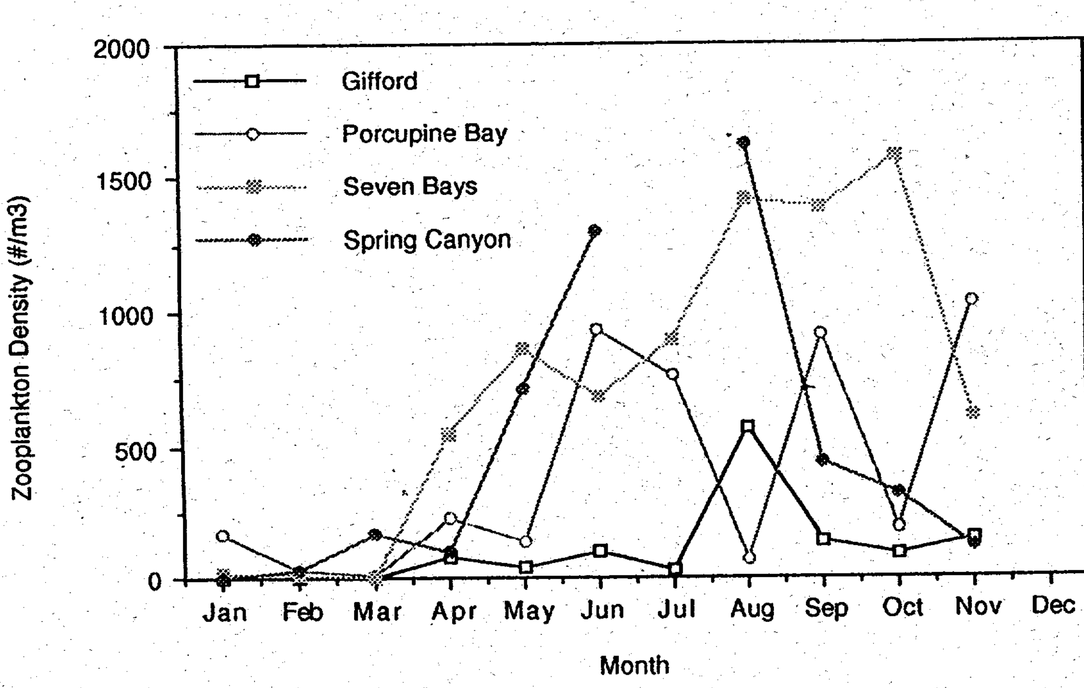

Figure 4.2.2 Mean monthy zooplankton density (#/m3) for Gifford, Porcupine Bay, Seven Bays, and Spring Canyon in 1992.

Table 4.2.1 **Mean values of different catagories of zooplankton collected in January through December at Porcupine Bay (loc. 4) and Seven Bays (loc. 6) from 1989 to 1992.**

Mean Water Retention Time (days)				
Month	**1989**	**1990**	**1991**	**1992**
JAN	26	41	32	45
FEB	25	36	34	59
MAR	36	32	25	48
APR	33	31	18	51
MAY	23	29	19	34
JUN	40	28	29	34
JUL	65	37	36	62
AUG	70	45	37	57
SEP	68	67	59	61
OCT	60	66	56	69
NOV	49	46	53	56
DEC	46	33	53	38

Mean *Daphnia* spp. Density (#/m^3)				
Month	**1989**	**1990**	**1991**	**1992**
JAN	279	218	16	25
FEB	200	99	457	3
MAR	364	238	34	1
APR	604	155	300	149
MAY	4,024	848	57	244
JUN	9,540	8,037	187	271
JUL	20,804	4,516	163	391
AUG	12,506	7,216	675	530
SEP	8,503	25,327	513	431
OCT	12,368	10,575	397	530
NOV	7,352	2,790	430	230
DEC	7,318	2,328	55	0

Mean Cladocera Density (#/m^3)				
Month	**1989**	**1990**	**1991**	**1992**
JAN	301	237	16	42
FEB	200	103	459	4
MAR	366	240	36	1
APR	603	173	299	149
MAY	4,018	873	59	247
JUN	10,958	9,328	211	276
JUL	19,736	5,661	192	355
AUG	15,007	7,200	597	445
SEP	11,136	24,998	493	455
OCT	16,940	11,977	426	496
NOV	5,739	2,971	309	252
DEC	5,597	2,288	109	0

Table 4.2.1 continued;

	Mean Zooplankton Density (#/m^3)			
Month	**1989**	**1990**	**1991**	**1992**
JAN	759	1,762	15	82
FEB	425	525	676	11
MAR	666	636	191	4
APR	2,089	751	295	199
MAY	6,506	3,313	161	269
JUN	20,557	11,395	405	447
JUL	25,843	22,543	732	477
AUG	30,392	15,240	892	377
SEP	29,995	32,787	764	657
OCT	31,119	23,844	712	484
NOV	4,838	4,269	193	490
DEC	5,734	4,956	256	0

	Mean Zooplankton Biomass (µg/m^3)			
Month	**1989**	**1990**	**1991**	**1992**
JAN	2,874	2,203	6	1,168
FEB	0	14	0	84
MAR	0	3	0	3
APR	8	11	12	44
MAY	295	2,022	4	215
JUN	123,051	73,673	63	2,610
JUL	349,693	44,910	276	2,515
AUG	374,203	70,035	6,543	5,797
SEP	275,555	228,261	3,761	1,989
OCT	292,593	240,025	6,908	3,760
NOV	314,541	23,007	7,658	2,735
DEC	319,544	13,464	3,779	0

When biomass values from Porcupine Bay and Seven Bays are plotted in succession with the corresponding water retention times from 1989 to 1992 you can see that something happened to Lake Roosevelt's zooplankton population in 1991 and 1992 (Figures 4.2.3 and 4.2.4). In the 1991 report we hypothesized that the low numbers of zooplankton were a result of low water retention times in the spring which helped to flush zooplankton and nutrients through the reservoir making them unavailable to the Roosevelt system. However in 1992 the water retention times were not a severe nor as prolonged as in previous years, yet biomass values showed levels lower than in 1991 when the reservoir was drained in the spring.

At this point in time we can only hypothesize as to what happened to the zooplankton population in 1992. One suggestion is that it is purely a sampling error on our part. In the early years of the Lake Roosevelt Monitoring Project a Clarke-Bumpus zooplankton sampler was used to collect zooplankton and a Wisconsin tow was used as a back up collection method. Due to the high rate of mechanical failure that was experienced with the Clarke-Bumpus the Wisconsin tow became the primary collection tool. The 1992 values could be a result of an entire years worth of data collected with the Wisconsin net that was less effective in collecting the zooplankton samples. The difficulty with this theory is that if the Wisconsin net only caught fewer zooplankton than the Clarke-Bumpus then the percent composition of the samples should be similar, if the percents were different then one might expect the differences to be caused by something other than the sampling device. We examined the percent composition of Daphnia, Cladocera, and nauplii for each month from 1989 to 1992 and compared the values. Upon first glance the numbers do seem to be quite different, however due to collection procedures not corresponding from year to year, or site to site and a relatively small set of data points we were unable to run a statistical analysis to determine if the differences were significant.

Another reason for the low density and biomass values found in 1992 could have been due to the fact that 1991 was such a bad water year. The extremely low water retention times flushed so many nutrients and zooplankton out of the system that there were too few left within the reservoir to produce good density and biomass regardless of a high water retention times in 1992.

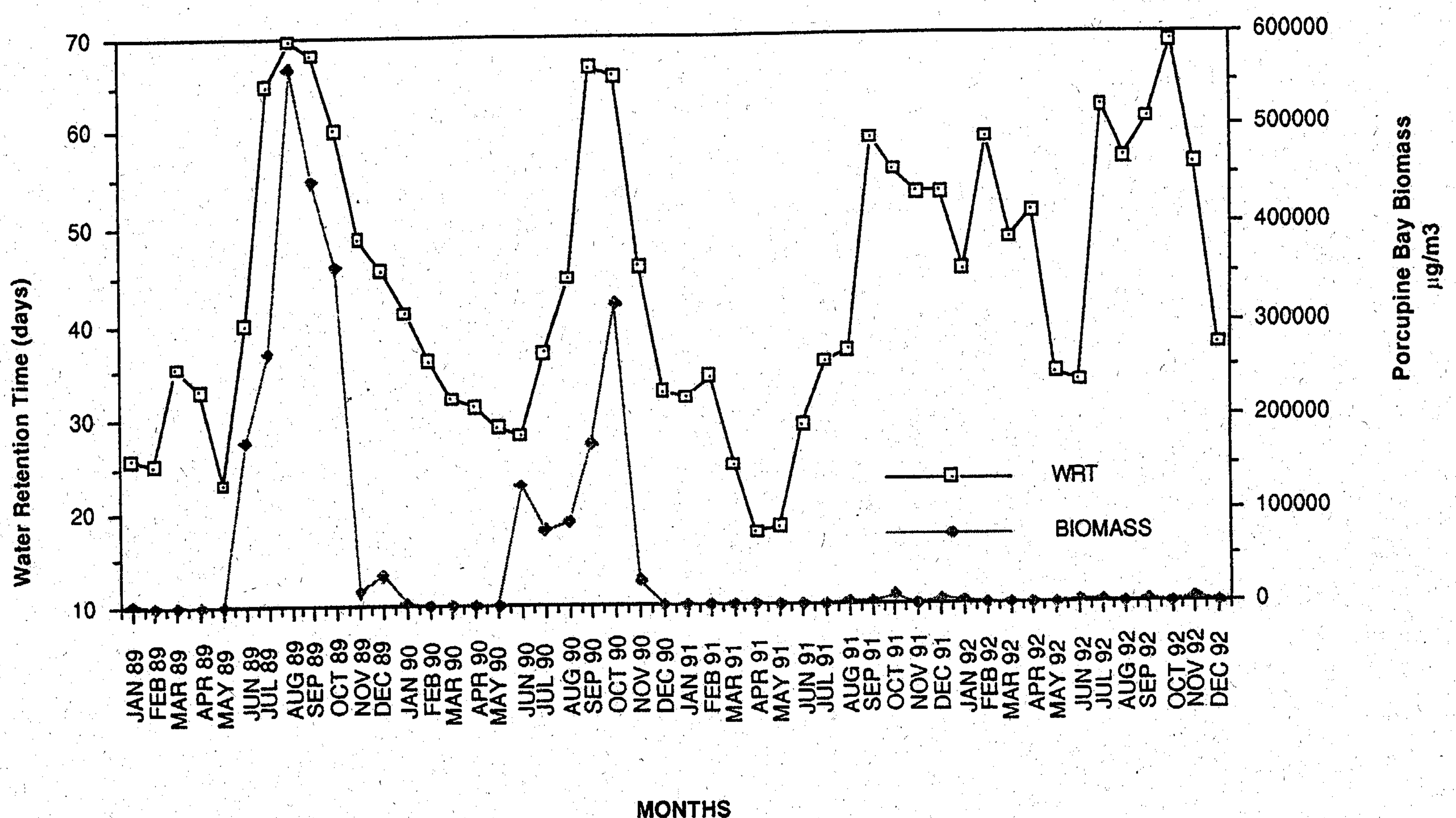

Figure 4.2.3 Biomass and water retention times found at Porcupine Bay from1989 to 1992.

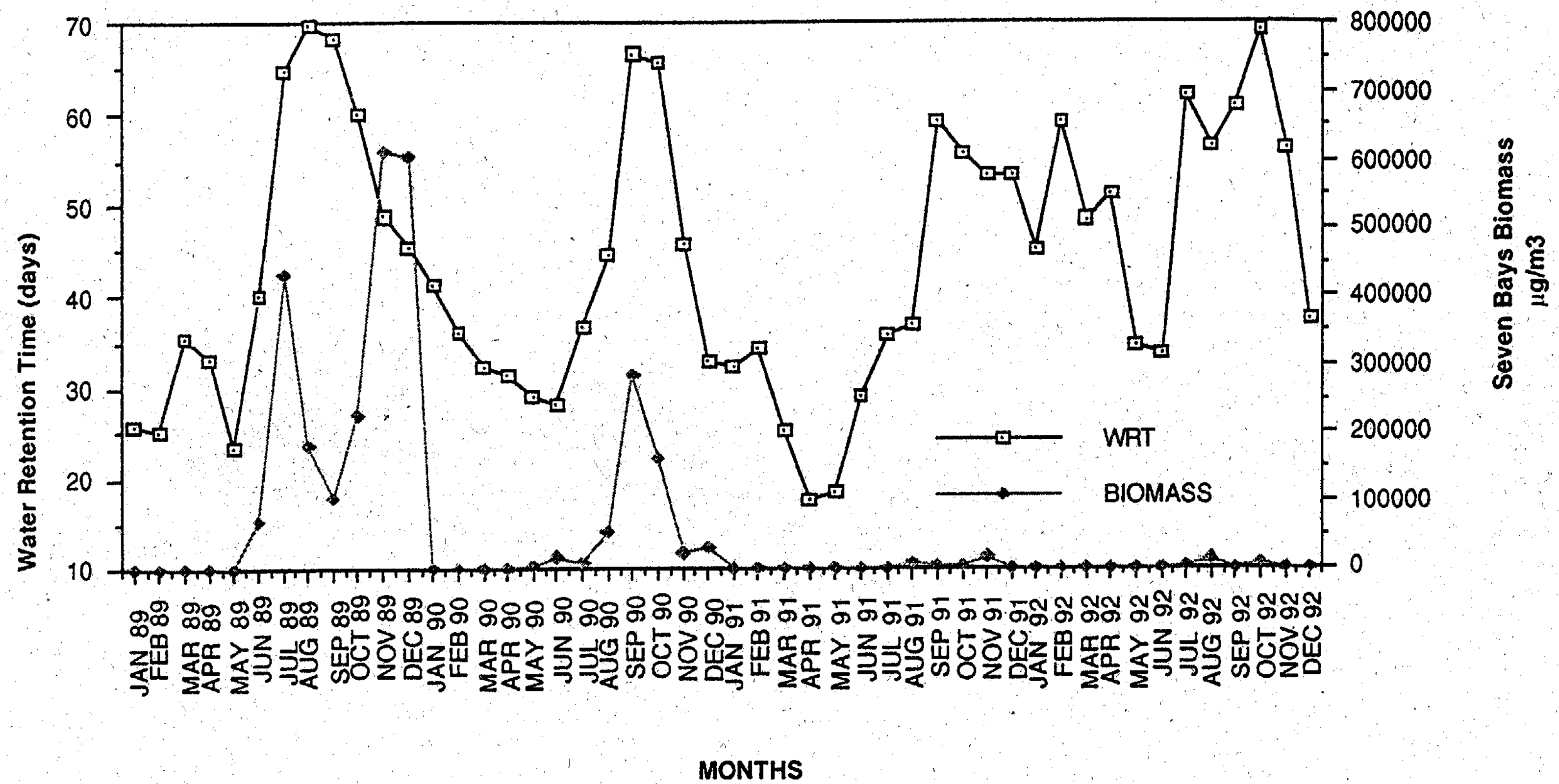

Figure 4.2.4 Biomass and water retention times found at Seven Bays from 1989 to 1992.

Both theories for the decline of the zooplankton in 1992 are valid, however, it will most likely take several more years of study to determine what the true influences were for the decline in zooplankton. One fact still remains, 1992 showed the lowest zooplankton production in the past five years of monthly zooplankton study of Lake Roosevelt. It is clear that water retention times heavily influence production levels of zooplankton. It could just be possible that 1992 zooplankton levels were the result of extreme reservoir operations in 1991.

4.3 BENTHIC MACROINVERTEBRATES

4.3.1 Affect of Reservoir Operations on Benthic Macroinvertebrates

Midges were found to be most abundant benthic macroinvertebrate at all depth locations throughout the reservoir with the exceptions of depths one and two at Spring Canyon (Table 4.3.1). Seven Bays had the highest densities of snails, midges, and caddisflies. Spring Canyon had the highest densities of clams and worms. Porcupine Bay had the highest density of scuds. Seven Bays had the highest grand mean for the year with density of 1,931 organisms per square meter. Midges had the highest annual mean density at each depth interval followed by worms and scuds.

Density and weight values of organisms in exposed vs non-exposed substrate did not show a degree of difference within the season but showed some differentiation when viewed across the seasons (Table 4.3.2). Spring density number and weight values were highest in area 1. As reservoir elevations increased and re-flooded areas of the reservoir during the summer months area 3 showed the highest density values. Area 1 had the highest density values during the fall season. Throughout the year only area 1 (the deepest location was there a steady increase in number values with the other areas showing decreases in density from summer to fall. Weight density values increased at each depth location between all seasons.

Table 4.3.1 **Mean density values (#/m^2) of benthic organisms collected at sampling locations between March and October 1992 in Lake Roosevelt.** (Area 1 represents reservoir depth intervals greater than 80 feet below full pool, area 2 represents depths between 79 and 50 feet below full pool, and area 3 represents depths between 49 and 0 feet below full pool.)

	Gifford			Porcupine			Seven Bays			Spring Canyon			Annual Mean		
Area ⇒ Grouped Taxon	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Snails	6	2	0	0	0	2	6	5	96	5	0	5	4	2	26
Clams	0	0	0	0	0	0	0	0	0	0	5	0	0	1	0
Midges	282	335	164	161	204	414	240	512	446	53	150	403	184	300	357
Caddisflies	5	12	3	10	4	2	9	22	21	0	5	42	18	11	17
Worms	110	178	144	133	121	129	119	212	88	119	228	134	120	185	124
Scuds	15	2	19	39	66	160	66	73	144	5	0	0	31	35	81
Other	0	8	11	0	2	0	0	2	0	2	2	0	1	4	3
Total	465	537	341	198	397	707	440	826	665	184	390	584	359	540	611

Table 4.3.2 Mean seasonal number and weight density values for each depth location on Lake Roosevelt

Number Density

Area	Spring Mean #/m^2	Summer Mean #/m^2	Fall Mean #/m^2
1	219	632	760
2	203	737	640
3	202	790	525

Weight Density

Area	Spring Mean g/m^2	Summer Mean g/m^2	Fall Mean g/m^2
1	0.619	2.243	3.584
2	0.559	2.373	3.038
3	0.562	2.420	2.876

4.4 AFFECT OF RESERVOIR OPERATIONS ON FISHERY

4.4.1 Comparisons Between Food Selection and Prey Abundance

Comparisons between food selection and prey abundance could not be determined at this time. See Thatcher *et al.* 1994 for this information.

4.4.2 Trends in Fish Growth

Trends in fish growth could not be determined at this time. See Thatcher *et al.* 1994 for fish growth trends.

4.5 AFFECT OF RESERVOIR OPERATIONS ON STOCKED FISH

Trends in tag returns continue to indicate that entrainment Lake Roosevelt net-pen fish is influenced by water retention and release times. Percent of fish recovered below Grand Coulee Dam has ranged from 0 to 63% over the past four years when releases were grouped monthly (Table 4.5.1). This data again confirms that later releases in the year increase the chances fish will remain within the reservoir. This data also shows that when early releases are paired with high water retention timed it produces decreased entrainment levels as evidenced by 98, 94, and 99% recovery rates for 1992 releases of fish in March, April, and May respectively.

Seasonal grouping of net-pen releases show trends between releases and mean water retention times more effectively (Table 4.5.2). Spring releases where water retention times were below 40 days, the percent of fish entrained ranged from 24 to 50% with the average being 37 percent. Spring releases in 1988 and 1992 where the water retention times were 43 and 45 days respectively showed entrainment levels of 0 and 2 percent. Summer releases in 1991 and 1992 differed in both percent recovered and water retention times for the season. The summer of 1991 had an average water retention time of 34 days and showed a 6% entrainment level while the summer of 1992 had a 51 day water retention time and a 0% entrainment level.

Clearly the longer the fish can remain in the net-pens the higher the chance that they will remain within the reservoir. Tagging will continue to be carried out monthly from March to July at each net-pen location. This data coupled with tag return

Table 4.5.1 Summary of rainbow trout release times, water retention times and subsequent recapture numbers and percentages.

Release Date	Water Retention Time	Total No. Tagged	Total No. Recovered	Percent Recovered	Number Recovered in FDR	Percent Recovered in FDR	Recoveries Below Grand Coulee		
							Number Recovered in Rufus Woods	Number Recovered at Rock Is. or McNary	Percent Recovered Below FDR
Mar. 89	36	768	8	1%	3	38%	0	5	63%
Mar. 90	32	1,441	7	0%	4	57%	0	3	43%
Mar. 92	48	5,997	93	2%	91	98%	2	0	2%
Apr. 89	33	985	20	2%	11	55%	3	6	45%
Apr. 90	31	1,470	52	4%	38	73%	10	4	27%
Apr. 91	18	2,300	78	3%	52	67%	13	13	33%
Apr. 92	51	5,998	161	3%	158	94%	3	0	2%
May 88	40	1,171	98	8%	98	100%	0	0	0%
May 90	29	1,450	53	4%	43	81%	8	2	19%
May 92	34	6,000	223	4%	220	99%	3	0	1%
Jun. 91	29	296	32	11%	27	99%	5	0	1%
Jun. 92	34	3,000	96	3%	96	100%	0	0	0%
Jul. 91	62	1,749	152	9%	146	96%	6	0	4%

Table 4.5.2 Summary of seasonal releases, mean water retention time and numbers of rainbow trout released from Lake Roosevelt net-pens, and their subsequent capture locations.

Release Date	Mean WRT	Total # Tagged	Total # Recovered	Percent Recovered	Number Recovered in FDR	Percent Recovered in FDR	Recoveries Below Grand Coulee		
							Number Recovered in Rufus Woods	Number Recovered at Rock Is. or McNary	Percent Recovered Below FDR
Spring 88	43	1,171	98	8%	98	100%	0	0	0%
Spring 89	31	1,753	28	2%	14	50%	3	11	50%
Spring 90	31	4,361	112	3%	85	76%	18	9	24%
Spring 91	20	2,300	78	3%	52	67%	13	13	33%
Summer 91	34	2,045	184	9%	173	94%	11	0	6%
Spring 92	45	17,995	477	3%	469	98%	8	0	2%
Summer 92	51	3,000	96	3%	96	100%	0	0	0%

information will help identify in predicting the number of fish entrained given certain water years but will also further aid in determine how the growth of the net-pen fish is affected by reservoir operations.

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