The Warmwater Fish Community of Lake Roesiger, with Notes on its Fisheries History

by

Peter A. Verhey, Karl W. Mueller and Mark R. Downen
Warmwater Enhancement Program
Washington Department of Fish and Wildlife
P.O. Box 1100
La Conner, Washington 98257

January 2001

Acknowledgments

We thank Bob Warinner and Douglas H. Fletcher of the Washington Department of Fish and Wildlife (WDFW) for their unfailing, invaluable assistance in the field and lab. Curt Kraemer and Steve Jackson (WDFW) provided thoughtful criticism of the original draft of the manuscript, whereas Darrell Pruett and Peggy Ushakoff (WDFW) designed the cover. Lauren Munday, Walt Cooper, Everett Latch, and Ted Morton (WDFW) proved indispensable when preparing and printing the final report. This project was funded by the Warmwater Enhancement Program, which is providing greater opportunities to fish for and catch warmwater fish in Washington.

Abstract

The Warmwater Enhancement Program conducted a stock assessment of fish species in Lake Roesiger in late spring of 1999, because of its historical importance to recreational fishing, increasing interest in warmwater fishing there, and paucity of recent warmwater species data. Warmwater fish species, especially yellow perch, dominated our catch. Growth of largemouth bass, black crappie, pumpkinseed and yellow perch was consistent with or above western Washington state averages. However, CPUE for largemouth bass, black crappie and pumpkinseed were below average, suggesting lower abundance of these species. Obvious gaps in the length frequency distribution of these species may be due to weather-related year-class failure, competition with the abundant yellow perch, or overharvest of larger individuals. However, interaction of our gear with spatial and temporal distribution of fish cannot be ruled out. The largemouth bass population in Lake Roesiger appears robust, as evidenced by rapid growth rates, strong PSD values, and relative weights consistent with other western Washington State waters. However, a more regulated fishery could protect and enhance the structure and abundance of this population. Based on our assessment of the warmwater fish community of Lake Roesiger, enhancement options discussed include implementing a slot limit on largemouth bass to improve their size structure as well as introduction of non-reproducing channel catfish to control the overabundant yellow perch population and provide additional fishing opportunity.

Table of Contents

List of Tables

List of Figures

Introduction and Background

Lake Roesiger (Figure 1) is in the upper Woods Creek watershed 8.5 miles (13.7 km) northeast of the City of Monroe in Snohomish County. The watershed drains an area of approximately 5.5 mile^2 (1,420 hectares). The lake consists of three distinct basins at an elevation of 570-ft (174 m) with a combined surface area of 138 ha. The north basin is 81.3 ha and 23 m deep. The basin is a conical-shaped depression separated from the south basin by a shallow connecting channel that forms the central basin (Bortelson et al. 1976). The central basin has a maximum depth of 3.1 meters and is approximately 4 ha. The south basin is 20 m deep and has a surface area of 22.9 ha. Surface water inflow is from several small intermittent streams. Surface water also comes from seeps and springs. Ground water supplies 38.7% of inflow into the lake (KCM 1989). Surface water exits the lake from the south, through Roesiger Creek to Woods Creek, and eventually discharges into the Skykomish River.

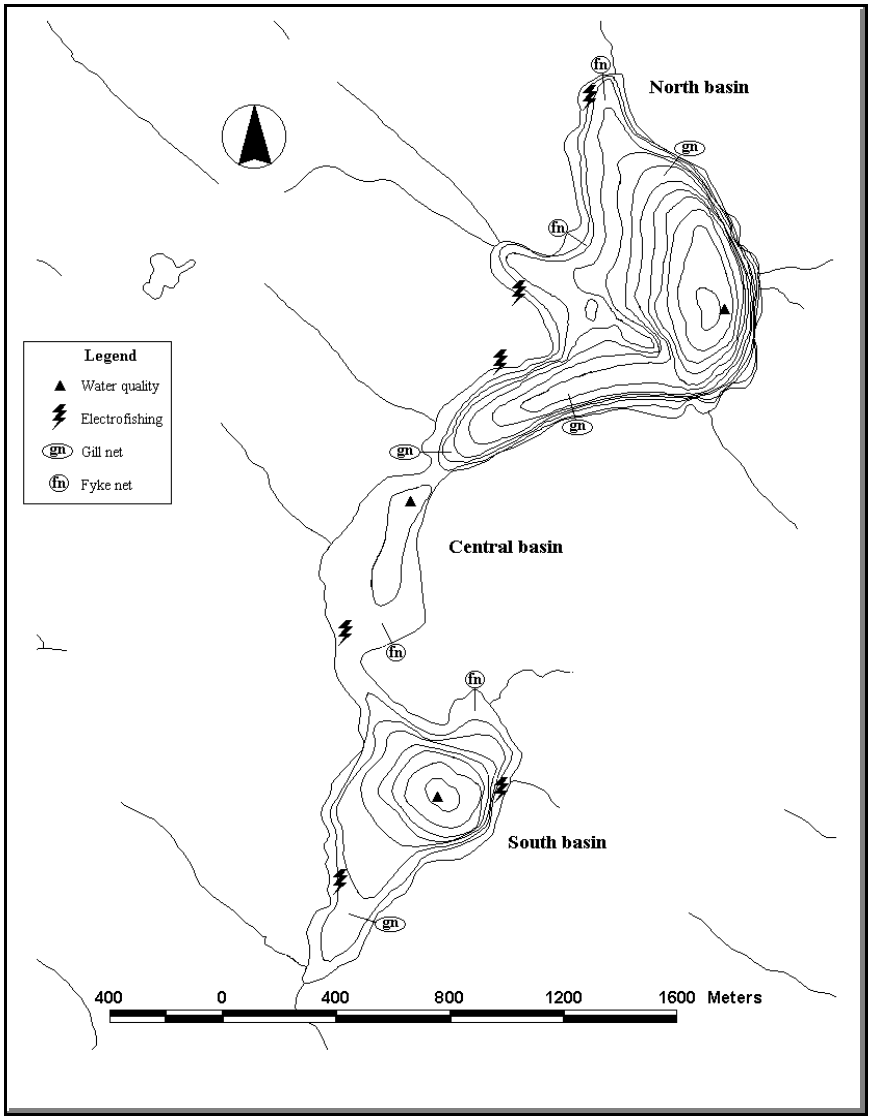

Figure 1. Map of Lake Roesiger (Snohomish County) showing sampling locations. Bolts indicate sections of shoreline where electrofishing occurred. Circled “fn” and “gn” symbols with lines extending into the lake represent fyke net and gill net sample locations, respectively. Triangles in each basin indicate water quality stations. Bathymetric isoclines represent 3.05-m (ten-foot) increments.

Uses in the drainage basin are broken up as follows: 77% forest, 15.5% lake and 7.5% residential development located near the shores of the lake (Bortelson 1976). Nearshore residential development is 100% with approximately 198 homes around the northern basin and 155 around the central and south basins. Up to 64% of the shoreline is bulkheaded and the mean number of docks ranges from 3 to 6 per 100 m of shoreline (Table 1).

Substrate types of the littoral zone of the north basin consist of silt, sand, gravel and cobble (Table 1). In the central and southern basins, the littoral zone is composed primarily of sand, fine silt, and cobble, with large deposits of flocculent mud mainly in the shallow coves. About 35 to 50 percent of the shoreline contain flocculent mud deposits.

Table 1. Nearshore habitat characteristics of three basins of Lake Roesiger during late spring 1999. Values are means derived from visual estimates made from the surface while traveling along 13 400-m sections sampled for warmwater fishes.

Basin	# Sections	Development	% Bulkhead	Mean # docks/100 m	% Emergent Vegetation	% Submerged Veg.	Coarse Woody Debris	% Silt	% Sand	% Gravel	% Cobble	% Bedrock
North	6	High	64	6.0	5	20	Moderate	30	40	10	20	0
Central	2	Moderate	23	3.1	35	75	Low	50	50	0	0	0
South	4	High	60	6.0	10	55	Moderate	30	40	0	30	0

Members of the aquatic plant community in Lake Roesiger are presented in Table 2. Plant density is highest in the central basin where fragrant waterlily (*Nymphea odorata*) covers up to 35% of the surface and bladderwort (*Utricularia* sp.) grows in the soft muddy substrate. The north basin with its steep banks and limited littoral area is characterized by thick growths of slender arrowhead (*Sagittaria gaminea*) and patches of water celery (*Valisneria americana*), common elodea (*Elodea canadensis*), and water plantain (*Alisma* sp.). The south basin of Lake Roesiger has a wider variety of species with broader distribution than the other basins. Like the north basin, the shoreline of the south basin is characterized by patchy growths of slender arrowhead and water celery. Additionally, the littoral areas of the south basin support numerous patches of common elodea, water plantain, yellow flag (*Iris pseudacorus*), quillwort (*Isoetes sp.*), stonewort (*Nitella* sp.) and Eurasian water milfoil (*Myriophullum spicatum*) among others (Table 2). The invasive nuisance macrophyte, Eurasian water milfoil was discovered in Lake Roesiger in 1998 [Jenifer Parsons, Washington Department of Ecology (WDE), unpublished data]. At that time, one to ten plants were noted in a few locations along shore of the north basin while larger colonies were found in the central and south basins. In late 1998, Snohomish County contracted scuba divers to pull the nuisance weed by hand to prevent its expansion in the lake. Dive operations continued in 1999 and 2000 with minimal impact (Gene Williams, Snohomish County Surface Water Management, personal communication).

Table 2. Summary of aquatic plant species and distribution values observed in Lake Roesiger August 6, 1998 by Washington Department of Ecology (WDE) staff [Jenifer Parsons, WDE, unpublished data].

Scientific name	Common name	Distribution values[1] by basin		
		North	Central	South
Alisma sp.	Water plantain	2	2	2
Elodea canadensis	Common elodea	2	2	2
Iris pseudacorus	Yellow flag			2
Isoetes sp.	Quillwort			2
Ludwigia palustris	Water-purslane			1
Lythrum salicaria	Purple loosestrife	1		
Myriophullum spicatum	Eurasian water-milfoil	1	2	2
Nitella sp.	Stonewort			2
Nuphar polysepala	Spatter-dock, yellow			1
Nymphea odorata	Fragrant waterlily	1	3	2
Phalaris arundinacia	Reed canarygrass			
Potamogeton pusillus	Slender pondweed	1		
Sagittaria graminea	Slender arrowhead	4	3	3
Scirpus sp.	Bullrush	2		
Typha sp.	Cat-tail		1	1
Utricularia sp.	Bladderwort		2	
Valisneria americana	Water celery	3	3	3

[1] Distribution values: 0, the value was not recorded (plant may not be submersed); 1, few plants in only one or a few locations; 2, few plants, but with a wide distribution; 3, plants growing in patches, codominant with other plants; 4, plants in nearly monospecific patches; 5, thick growth covering the substrate at the exclusion of other species.

Water quality assessments of Lake Roesiger conducted by WDE in 1992 showed that all trophic state parameters (secchi depth, total phosphorus, and chlorophyll a) indicated that the north and south basins of the lake were oligotrophic. However, low dissolved oxygen in the hypolimnion, resulting in hydrogen sulfide and internal loading of phosphorus, do not indicate oligotrophy. As a result, the lake was characterized as oligo-mesotrophic (Rector 1993). These findings, supported by KCM (1989), were attributed to forest practices, storm runoff, septic systems and internal nutrient cycling. Water quality profiles conducted from February through April 1992 indicated that the lake was thermally stratified in March and April, and during all three months dissolved oxygen was very low (0.2 to 2.0 mg/L) near the bottom of the lake (Rector 1992). Low levels of oxygen in deeper waters prevent fish habitation, reduces benthic food sources and can result in reduced growth and stunted fish populations. KCM (1989) suggested fish health and development were at risk due to hypolimnetic anoxia and recommended hypolimnetic aeration. Hypolimnetic aeration is achieved by drawing deep, oxygen depleted water up a tube using an electric pump and then spraying the water through the air to oxygenate it as it falls back into the lake. The deeper, oxygen-poor waters are eventually replaced by oxygen-rich water from above which increases the available habitat for fishes.

The expense of hypolimnetic aeration however necessitated evaluation to verify that the potential benefits justified the costs. Samples of warmwater fishes collected by Gibbons et al. in 1989 while electrofishing in littoral areas were in good condition and stunted fish were not collected. In fact, growth of fingerling rainbow trout (*Oncorhynchus mykiss*) planted in the fall averaged 25.4 mm per month [Curt Kraemer, Washington Department of Fish and Wildlife, unpublished data]. Bennett (1993) found that although poorly oxygenated water existed in the hypolimnion, growth rates for both cold- and warmwater fishes were good. Thus, he concluded that hypolimnetic aeration was not warranted because both cold- and warmwater fish populations did not appear to be harmed by oxygen poor-deep waters.

Anadromous fish passage to the lake is precluded by an impassable fall located approximately seven miles downstream of the lake on Woods Creek. However, sport fishing has been an important activity in Lake Roesiger since the turn of the century. Anecdotal reports from the 1880s indicate the presence of cutthroat trout (*Oncorhynchus clarki*), rainbow trout as well as bullhead (*Ameiurus* sp.) (Appendix A). Largemouth bass (*Micropterous salmoides*) were reportedly introduced into the lake in the 1920s. Lake Roesiger continues to support an active sports fishery composed of kokanee (*Oncorhynchus nerka*), rainbow trout, largemouth bass and yellow perch (*Perca flavescens*) (Tables 3 and 4). 1993 creel data shows angler effort concentrated in May and June following the early spring plants of trout. Anglers kept more trout than warmwater fishes, even though largemouth bass and yellow perch accounted for nearly 46% of the creel in 1993. As is common of many bass anglers, about 90% of those caught were released.

Table 3. Monthly catch per unit effort (fish per hour) and total catch record calculated from anglers sampled during a 10-month WDFW creel survey at Lake Roesiger, March through October 1993, (Curt Kraemer, WDFW, unpublished data).

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct				
#Anglers	29	23	73	77	23	31	36	26				
Effort (hrs)	122.7	66.5	183.0	179.0	55.0	94.5	117.3	44.7				
Species									**Kept**	**Released**	**Total**	**%Comp**
Coho				0.01		0.01	0.01		2	2	4	0.8
Cutthroat	0.02		0.01	0.01		0.01			5	0	5	1.0
Kokanee			0.17	0.02		0.05	0.29		62	12	74	14.9
Largemouth bass			0.14	0.30	0.13	0.30	0.08	0.04	12	112	124	24.9
Pumpkinseed			0.03	0.05	0.09	0.07	0.01		17	11	28	5.6
Rainbow trout	0.22	0.80	0.24	0.08	0.04	0.04	0.03	0.07	137	12	149	29.9
Sunfish					0.18				0	10	10	2.0
Yellow Perch			0.02	0.15	0.02	0.49	0.10	0.34	81	23	104	20.9
Total	0.24	0.80	0.60	0.62	0.46	0.97	0.52	0.45	316	182	498	

Historically, Lake Roesiger was managed primarily as a trout fishery. The lake was rehabilitated in 1955, 1961 and 1966 to remove yellow perch, pumpkinseed, and largemouth bass (Table 4). Since 1986 the lake has been managed as a mixed species fishery for annually stocked rainbow and cutthroat trout, as well as for persistent populations of warmwater species. In order to manage these fisheries more effectively, the WDFW Warmwater Enhancement Program conducted a stock assessment in spring 1999. We assessed species composition, abundance, size structure, growth, and condition of fish in the lake. We also evaluated habitat and access, then outlined options for enhancing the fishery and fishing opportunity on the lake.

Table 4. Fish species composition changes at Roesiger Lake (Snohomish County) since 1938 (Washington Department of Fish and Wildlife, unpublished data).			
Date	**Sample method**	**Sample size (# fish)**	**Species composition by number**
Summer 1952	WDG angler reports	5,858	94.9% kokanee (*Oncorhynchus nerka*), 3.5% yellow perch (*Perca flavescens*), 0.6% largemouth bass (*Micropterus salmoides*), 0.3% unidentified centrarchid, 0.3% cutthroat trout (*O. clarki*), 0.3% bullhead (*Ameiurus* sp.), 0.07% rainbow trout (*O. mykiss*), 0.07% crappie (*Pomoxis* sp.)
Fall 1953	Gill netting	151	38.4% yellow perch, 21.2% kokanee, 15.9% bullhead, 15.2% pumpkinseed (*Lepomis gibbosus*), 4.6% largemouth bass, 4.6% cutthroat trout
Fall 1955	Whole-lake rotenone treatment	65,230	30.7% largemouth bass 51 mm, 23.0% kokanee, 18.4% yellow perch, 12.3% bullhead, 12.3% sculpin (*Cottus* sp.), 3.1% brook lamprey (*Lampetra* sp.), 0.23% largemouth bass $454 g, 0.08% cutthroat trout, 0.03% sucker (*Catostomus* sp.), 0.02% crappie (*Pomoxis* sp.)
Fall 1961	"	62,000	48.4% sculpin, 32.3% largemouth bass (51 – 305 mm), 12.9% kokanee, 3.2% rainbow trout, 2.4% largemouth bass >454 g, 0.5% brook lamprey larvae, 0.32% cutthroat trout
Fall 1966	"	31,300	63.7% largemouth bass (51 – 305 mm), 31.9% sculpin, 3.2% rainbow trout, 0.96% kokanee, 0.32% largemouth bass (>454 g)
February and March, 1969-79	Gill netting	94	44.7% rainbow trout, 43.6% coho, 5.3% bullhead, 2.1% cuttroat trout, 1.1% unidentified centrarchid, 1.1% largemouth bass
1993	10-month creel survey	498	29.9% rainbow trout, 24.9% largemouth bass, 20.9% yellow perch, 14.9% kokanee, 5.6% pumpkinseed, 2.0% unidentified centrarchid, 1.0% cutthroat trout, 0.8% coho salmon

Materials and Methods

Lake Roesiger was surveyed during June 1 to June 5, 1999 by a three-person team consisting of two biologists and one scientific technician. Fish were captured using three sampling techniques: electrofishing, gill netting, and fyke netting. The electrofishing unit consisted of a 4.9 m Smith-Root 5.0 GPP 'shock boat' set to 250 volts of 6 amp pulsed DC (120 cycles/sec). Experimental gill nets (45.7 m long × 2.4 m deep) were constructed of four sinking panels (two each at 7.6 m and 15.2 m long) of variable-size (13, 19, 25, and 51 mm stretched) monofilament mesh. Fyke nets were constructed of a single 30.4 m lead and two 15.2 m wings of 130 mm nylon mesh. The bodies of the nets were stretched around four 1.2 m aluminum rings in each of two sections.

Sampling locations were selected by dividing the shoreline into 20 consecutively numbered sections of about 400 m each (determined visually from a map). Using the random numbers table from Zar (1984), 14 of these sections were then randomly selected as sampling locations. While electrofishing, the boat was maneuvered through the shallows (depth range: 0.2 - 1.5 m), adjacent to the shoreline, at a rate of 18.3 m/minute. Gill nets and fyke nets were set overnight at four locations each (=4 net nights for each gear type). Gill nets were set perpendicular to the shoreline. The small-mesh end was attached onshore while the large-mesh end was anchored offshore. The fyke nets were set in water less than 3 m deep with wings extended at 70° angles from the lead. Sampling occurred during evening hours to maximize the type and number of fish captured. Nighttime electrofishing occurred along 30% (~2.4 km) of the available shoreline (Figure 1).

With the exception of sculpin (Family Cottidae), all fish captured were identified to the species level and aged. Each fish was measured to the nearest 1 mm and assigned to a 10-mm size class based on total length (TL). For example, a fish measuring 156 mm TL was assigned to the 150-mm size class for that species, a fish measuring 113 mm TL was assigned to the 110-mm size class, and so on. When possible, up to 10 fish from each size class were weighed to the nearest 1 g. However, if a sample included several hundred individuals of a given species, then a sub-sample (n 100 fish) was measured and weighed while the remainder was counted overboard. The length frequency distribution of the sub-sample was then applied to the total number collected. Weights of individuals counted overboard were estimated using a simple linear regression of $\log_{10}$-length on $\log_{10}$-weight of fish from the sub-sample. Scales were removed from up to 10 fish from each size class for aging. Scale samples were mounted, pressed, and the fish aged according to Jearld (1983) and Fletcher et al. (1993).

Shoreline development and near-shore habitat were evaluated on June 4, 1999. The number of docks were recorded and visual estimates made of percent bulkheading, aquatic vegetation cover, and composition of substrate for each of the 400-m sections of shoreline sampled. Shoreline development and submersed coarse woody debris were rated low, moderate, or high (Table 1). Using a Hydrolab® probe and digital recorder, water quality data was collected during midday from each basin on June 4, 1999 (Figure 1). Table 5 summarizes the information gathered on dissolved oxygen, total dissolved solids, temperature, pH, and specific conductance from three of these locations.

Table 5. Water quality from three locations (north, central, and south basin) at Roesiger Lake (Snohomish County). Samples were collected mid-afternoon June 1, 1999. DO = dissolved oxygen, TDS = total dissolved solids.

Location	Depth (m)	DO (mg/L)	Temperature (EC)	pH	Conductance (µS/cm)	TDS (g/L)
North basin	1	9.81	16.64	8.59	147	0.0094
Secchi depth = 4.9 m	3	9.68	16.66	8.25	146	0.0093
	5	11.56	11.99	8.30	142	0.0091
	7	12.00	8.11	8.25	143	0.0091
	9	10.42	6.66	7.96	143	0.0092
	11	9.01	5.89	7.68	144	0.0093
	13	8.44	5.54	7.50	145	0.0093
	15	7.96	5.36	7.43	145	0.0092
	17	7.75	5.24	7.34	145	0.0092
	19	7.72	5.16	7.26	145	0.0092
	21	7.46	5.07	7.18	145	0.0093
	23	7.40	5.03	7.11	145	0.0093
	25	6.88	5.00	7.04	145	0.0094
Central Basin	1	9.51	17.39	7.99	145	0.0094
	1.9	9.02	17.41	7.97	146	0.0094
South Basin	1	9.84	17.00	8.82	142	0.0091
	3	9.75	16.97	8.49	142	0.0090
	5	11.83	11.09	8.63	139	0.0088
	7	11.56	8.71	8.33	145	0.0092
	9	7.69	6.48	7.84	146	0.0094
	11	6.82	5.72	7.53	149	0.0094
	13	6.88	5.35	7.38	146	0.0094
	15	5.95	5.26	7.14	147	0.0095
	17	5.33	5.19	7.03	150	0.0096
	19	4.47	5.16	7.00	154	0.0098

Data Analysis

Balancing predator and prey fish populations is the hallmark of warmwater fisheries management. According to Bennett (1962), the term ‘balance’ is used loosely to describe a system in which omnivorous forage fish or prey maximize food resources to produce harvestable-size stocks for fishermen and an adequate forage base for piscivorous fish or predators. Predators must reproduce and grow to control overproduction of both prey and predator species, as well as provide adequate fishing. To maintain balance, predator and prey fish must be able to forage effectively. Evaluations of species composition, size structure, growth, and condition (plumpness or robustness) of fish provide useful information on the adequacy of the food supply (Kohler and Kelly 1991), as well as the balance and productivity of the community (Swingle 1950; Bennett 1962).

We determined species composition by weight (kg) of fish captured using procedures adapted from Swingle (1950). The species composition by number of fish captured was determined using procedures outlined in Fletcher et al. (1993) with one exception. While young-of-year or small juveniles are often not considered because large fluctuations in their numbers may lead to misinterpretation of results (Fletcher et al. 1993), we chose to include them since their relative contribution to total species biomass was small. Moreover, the overall length frequency distribution of fish species may suggest successful spawning and initial survival during a given year, as indicated by a preponderance of fish in the smallest size classes. Many of these fish would be subject to natural attrition during their first winter (Chew 1974), resulting in a different length frequency distribution by the following year. However, the presence of these fish in the system relates directly to fecundity, forage base for larger fish, and interspecific and intraspecific competition at lower trophic levels (Olson et al. 1995). We therefore rely on species composition as an ecological indicator and catch per unit effort (CPUE) and proportional stock density (PSD) as stock indicators.

The percent species composition by weight was calculated as the weight of fish captured of a given species divided by the total weight of all fish captured × 100. The species composition by number was calculated as the number of fish captured of a given species divided by the total number of all fish captured × 100.

The size structure of each species captured was evaluated by constructing a stacked length frequency histogram (percent frequency of fish in a given size class captured by each gear type). Although length frequencies are generally reported by gear type, we report the length frequency of our catch with combined gear types which is then broken down by the relative contribution each gear type makes to each size class. Selectivity of gear types not only biases species catch based on body form, and behavior, but also based on size classes and subsequent habitat use within species (Willis et al. 1993). Therefore, an unbiased assessment of length frequency is unlikely under any circumstance. Our standardized 1:1:1 gear type ratio adjusts for differences in sampling effort between sampling times and locations. Furthermore, differences in size selectivity of gear types may in some circumstances result in offsetting biases (Anderson and Neumann 1996). Length frequency proportions for each gear type are divided by the total numbers of fish caught by all gear types for each size class. This changes the scale but not the shape of the length frequency percentages by gear type. If concern arises that pooled gear does not represent the least biased assessment of length frequency for a given species, then the shape of the gear type-specific distributions is still represented on the graphs, and these may be interpreted independently.

Catch per unit effort (CPUE) by gear type was determined for all species (number of fish/hour electrofishing and number of fish/net night). Only stock size fish and larger were used to determine CPUE for the warmwater species and salmonids, whereas CPUE for non-game fish were calculated for all sizes. Stock length, which varies by species (see Table 7 and discussion below), refers to the minimum size of fish having recreational value. Since sample locations were randomly selected, which might introduce high variability due to habitat differences within the lake, 80% confidence intervals (CI) were determined for each mean CPUE by species and gear type. CI was calculated as the mean ± $t_{(", N\text{-}1)} \times SE$, where t = Student's t for " confidence level with N-1 degrees of freedom (two-tailed) and SE = standard error of the mean. Since it is standardized, CPUE is a useful index for comparing relative abundance of stocks between lakes and the confidence intervals express the relative uniformity of species distributions throughout a given lake. CPUE values for Lake Roesiger were then compared to western Washington State averages compiled by the WDFW Inland Fisheries Research Unit (Table 6).

Table 6. Mean catch per unit effort (number of fish/hour electrofishing and number of fish/net night) for stock size fish collected from several western Washington State lakes while electrofishing, gill netting, and fyke netting during 1997 and 1998.

Species	Gear Type					
	Electrofishing (fish/hr)	**# lakes**	**Gillnetting (fish/hr)**	**# lakes**	**Fyke netting (fish/hr)**	**# lakes**
Largemouth bass	41.6	12	1.9	8	0.3	1
Black crappie	9.6	4	4.2	3	23.4	2
Pumpkinseed	70.8	11	3.8	9	7.9	4
Yellow perch	97.5	8	13.7	6	0.2	2

The proportional stock density (PSD) of each fish species was determined following procedures outlined in Anderson and Neumann (1996). PSD, which was calculated as the number of fish quality length/number of fish stock length × 100, is a numerical descriptor of length frequency data that provides useful information about population dynamics. Stock and quality lengths, which vary by species, are based on percentages of world-record lengths. Again, stock length (20-26% of world-record length) refers to the minimum size fish with recreational value, whereas quality length (36-41% of world-record length) refers to the minimum size fish most anglers like to catch.

The relative stock density (RSD) of each fish species was examined using the five-cell model proposed by Gabelhouse (1984). In addition to stock and quality length, Gabelhouse (1984) introduced preferred, memorable, and trophy length categories (Table 7). Preferred length (45-55% of world-record length) refers to the minimum size fish anglers would prefer to catch when given a choice. Memorable length (59-64% of world-record length) refers to the minimum size fish most anglers remember catching, whereas trophy length (74-80% of world-record length) refers to the minimum size fish considered worthy of acknowledgment. Like PSD, RSD provides useful information regarding population dynamics, but is more sensitive to changes in year-class strength. RSD was calculated as the number of fish $\$$ specified length/number of fish $\$$ stock length × 100. For example, RSD P was the percentage of stock length fish that also were longer than preferred length, RSD M, the percentage of stock length fish that also were longer than memorable length, and so on. Eighty-percent confidence intervals for PSD and RSD were selected from tables in Gustafson (1988).

Table 7. Length categories for cold- and warmwater fish species used to calculate stock density indices (PSD and RSD; Gablehouse 1984) of fish captured at Lake Roesiger (Snohomish County) during late spring 1999. Measurements are minimum total lengths (mm) for each category (Anderson and Neumann 1996; Bister et al. 2000; Hyatt and Hubert, Wyoming Cooperative Fish and Wildlife Unit, University of Wyoming, unpublished data).

Species	Minimum Size (mm)				
	Stock	Quality	Preferred	Memorable	Trophy
Black crappie	130	200	250	300	380
Cutthroat trout	200	350	450	600	750
Kokanee	200	250	300	400	500
Largemouth bass	200	300	380	510	630
Pumpkinseed	80	150	200	250	300
Rainbow trout	250	400	500	650	800
Yellow perch	130	200	250	300	380

PSD and RSD have become important tools for assessing size structures of warmwater fish populations and determining management options for warmwater fish communities (Willis et al. 1993). Three major management options commonly implemented for these communities include the panfish option, balanced predator-prey option, and big bass option and each of these has associated ranges of PSD and RSD values (Table 8).

Table 8. Stock density index ranges for largemouth bass and bluegill under three commonly implemented management strategies (from Willis et al. 1993). PSD = proportional stock density, whereas RSD = relative stock density of preferred length fish (RSD-P), and memorable length fish (RSD-M).

Option	Largemouth bass			Bluegill	
	PSD	RSD-P	RSD-M	PSD	RSD-P
Panfish	20 – 40	0 – 10		50 – 80	10 – 30
Balanced	40 – 70	10 – 40	0 – 10	20 – 60	5 – 20
Big bass	50 – 80	30 – 60	10 – 25	10 – 50	0 – 10

Age and growth of fishes in Lake Roesiger were evaluated using the direct proportion method (Jearld 1983, Fletcher et al. 1993) and Lee's modification of the direct proportion method (Carlander 1982). Using the direct proportion method, total length at annulus formation, L_n, was back-calculated as $L_n = (A \times TL)/S$, where A is the radius of the fish scale at age n, TL is the total length of the fish captured, and S is the total radius of the scale at capture. Using Lee's modification, L_n was back-calculated as $L_n = a + A\times(TL - a)/S$, where a is the species-specific standard intercept from a scale radius-fish length regression. Mean back-calculated lengths at age n for each species were presented in tabular form for easy comparison of growth between year classes, as well as between Lake Roesiger fish and the state average for the same species (listed in Fletcher et al. 1993).

While total length at the end of a given age provides valuable information on relationships of length frequency to age of a population and gives some indication of overall growth, instantaneous growth is a better measure of actual growth (Ricker 1975). Because it is an incremental measure, instantaneous growth also allows for analysis of life stage-specific patterns in growth. For example, it is not uncommon for a population to display below average total length across all age classes even though growth rates were only below average during the first or second year of life (Downen and Mueller 2000). Generally, we see a pattern of growth characterized by initially higher values that decline each year in the form of an inverse exponential relationship. Sometimes growth is highest in the second year but thereafter the same general pattern ensues. Occasionally, instantaneous growth rate values averaged across a population or populations are negative for older age classes due to the propensity of long-lived individuals or populations to become stunted. However, this does not mean actual growth is negative, but rather that the optimum overall growth rates and subsequent length frequency distributions may occur at some level of exploitation. The utility of identifying these patterns becomes apparent when assessing the ecological constraints on growth with the objective of population manipulation as a means of influencing these rates. For example, the implementation of a slot limit eloquently addresses situations where competition limits growth in both younger and older age classes of relatively long-lived fish. Yet a maximum length rule might be more effective for thinning younger age classes and reducing competition of relatively short-lived fish and allowing those remaining to attain greater size.

Annual average instantaneous growth rates, G, are defined as the difference between the natural logarithms of successive sizes over a unit of time, and were calculated according to Ricker (1975). The working formula is $G = (\log_e Y_2 - \log_e Y_1)/(t_2 - t_1)$, where t_1 is the time at the beginning of an interval and t_2 the time at the end and Y_1 and Y_2 are the respective fish sizes at those times. Because the unit time expression is calculated for one year intervals and equals one, it drops out. For fish size, Y, we used weight, w, and with reorganization, the equation becomes $G = \ln(w_t/w_0)$, where w_t is the estimated average weight at time t and w_0 is the average estimated weight at time 0. Fish weights were estimated from average total length using the linear regression of $\log_{10}$-length on $\log_{10}$-weight resulting in $w= 10^{(m\log(TL)+b)}$, where m is the standard slope and b is the standard intercept for a given species (Ricker 1975). These standardized weights represent the least biased estimate of average weight throughout the year since they are not influenced by seasonal fluctuations due to spawning, feeding, or overwintering. Mean annual G was then compared to the state average, G_{avg}, derived similarly from the data listed in Fletcher et al (1993).

A relative weight (W_r) index was used to evaluate the condition of all species except sculpin. A W_r value of 100 generally indicates that a fish is in good condition when compared to the national standard (75th percentile) for that species. Furthermore, W_r is useful for comparing the condition of different size groups within a single population to determine if all sizes are finding adequate forage or food (ODFW 1997). Following Murphy and Willis (1991), the index was calculated as $W_r = W/W_s \times 100$, where W is the weight (g) of an individual fish and W_s is the standard weight of a fish of the same total length (mm). W_s is calculated from a standard $\log_{10}$weight-$\log_{10}$length relationship defined for the species of interest. The parameters of the W_s equations for many cold- and warmwater fish species, including the minimum length recommendations for their application, have been compiled by Anderson and Neumann (1996), Bister et al. (2000), as well as Mathew W. Hyatt and Wayne A. Hubert (Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, unpublished data). With the exception of sculpin, the W_r values from this study were compared to the national standard (W_r = 100) and, where available, the mean W_r values from up to 25 western Washington lakes sampled during 1997 and 1998 (Steve Caromile, WDFW, unpublished data).

Results and Discussion

Species Composition

During late spring 1999 yellow perch and largemouth bass dominated our catch from Lake Roesiger. Yellow perch accounted for 50% of the biomass and 49% by number (Table 9). Largemouth bass comprised 40% by weight and 26% by number. Pumpkinseed accounted for 5% by weight and 16% by number. Three black crappie were captured representing only 1% by weight and 0.6% by number. Salmonids captured during the survey included cutthroat trout, rainbow trout and kokanee and, when combined, accounted for 4% of the sample by weight and 3% by number.

Table 9. Species composition by weight (kg) and number of fish captured at Lake Roesiger (Snohomish County) during late spring 1999.

Species	Species composition				
	by weight		by number		Size range
	(kg)	(%) weight	(#)	(%) n	(mm TL)
Black crappie (*Pomoxis nigromaculatus*)	0.391	1.07	3	0.62	202 – 208
Cutthroat trout (*Oncorhynchus clarki*)	0.483	1.33	7	1.45	66 – 305
Kokanee (*Oncorhynchus nerka*)	0.642	1.77	5	1.04	243 – 256
Largemouth bass (*Micropterus salmoides*)	14.564	40.01	124	25.67	33 – 515
Pumpkinseed (*Lepomis gibbosus*)	1.750	4.81	78	16.15	32 – 169
Sculpin (*Cottus* sp.)	0.278	0.76	26	5.38	46 – 124
Rainbow trout (*Oncorhynchus mykiss*)	0.245	0.67	3	0.62	104 – 241
Yellow perch (*Perca flavescens*)	18.049	49.58	237	49.07	94 – 250
Total	36.401		483		

In our survey of Lake Roesiger we did not find sucker (*Cotastomus* sp.), lamprey larvae (*Lampetra* sp.), bullhead (*Ameiurus* sp.) or coho (*O. kisutch*) which were noted in historical records (Table 4). Nor did we find bluegill which were reportedly introduced in the 1980s by parties unknown (Curt Kraemer, personal communication). However, each of the species we did capture in our survey had been noted either in angler reports, gill net samples or lake rehabilitation reports from the 1950s and 60s, or in later electrofishing samples and angler creel surveys. Largemouth bass were noted in nearly all records of fish abundance in the lake dating back to 1938. Similar to our survey, samples from 1955 showed largemouth bass and yellow perch to be the dominant warmwater species, making up 31% and 18% by number, respectively. Prior to the first rehabilitation of the lake in 1955, the fish community was probably best represented by gill net sample data collected in 1953. A total of 151 fish were captured and age and length data were recorded (Table 10) (WDFW, unpublished data). In that survey, yellow perch contributed 38% to the species composition and ranged in size 133 to 248 mm (TL) and were aged 1+ to 5+. Pumpkinseed contributed 15% and ranged from 121 to 171 and were aged 2+ to 6+ except the 5+ age class was missing. Largemouth bass made up 4.6% and were between 203 and 286 mm (TL) and were aged 2+ to 4+. Fish sizes in this sample set are considerably larger than what we found but the mean length at age data from our survey were back-calculated from annulus formation whereas it is unknown whether average lengths from the 1953 survey were. Those fish were sampled in the fall allowing extra time for growth.

Table 10. Size at age of fish captured in gill net samples at Lake Roesiger during September and October, 1953 (WDFW, unpublished data) compared to mean size at age of fish captured in late spring, 1999.

Species	Age	Number of Fish	Size Range (mm)	Average Size (mm)	1999 mean size At age (mm)
Yellow perch	1+	19	133 – 171	146	81.1
	2+	26	171 – 241	203	137.0
	3+	3	222 – 254	235	174.3
	4+	5	222 – 254	241	196.2
	5+	5	203 – 248	241	218.5
Pumpkinseed	2+	15	121 – 152	133	89.4
	3+	6	152 – 165	159	---
	4+	1	---	171	137.1
	6+	1	---	171	---
Largemouth bass	2+	1	---	203	138.6
	3+	5	229 – 260	241	201.0
	4+	1	---	286	221.4
Brown bullhead	2+	24	203 – 256	279	---
Kokanee	2+	32	235 – 318	269	---
Cutthroat trout	2+	7	203 – 311	254	---

CPUE

While electrofishing, catch rates were highest for stock-size yellow perch and pumpkinseed (Table 11). Yellow perch were the most abundant warmwater fish captured in our gill nets. Catch rates for stock length yellow perch exceeded the western Washington State average (Table 6) for all gear types suggesting a high density population. Electrofishing catch rates for largemouth bass were about half of the state average and much less for other gear types suggesting a low density population. Likewise, black crappie and pumpkinseed catch rates while electrofishing were lower than the state average suggesting a low density population as well. For species other than the warmwater variety, electrofishing catch rates were highest for sculpin. While gill netting, catch rates were highest for kokanee and cutthroat trout. While fyke netting, we captured few pumpkinseed and yellow perch.

Table 11. Mean catch per unit effort (number of fish/hour electrofishing and number of fish/net night), including 80% confidence intervals for stock size warmwater fish, salmonids, and non-game fish collected from Lake Roesiger (Snohomish County) while electrofishing, gill netting, and fyke netting during late spring 1999.						
Species	**Gear type**					
	Electroshocking (# fish/hour)	**Shock sites**	**Gill netting (# fish/hour)**	**n (net Nights)**	**Fyke netting (# fish/hour)**	**N (net Nights)**
Black crappie	2.96 [a]	6	0	4	0	4
Cutthroat trout	0	6	0.75 ± 0.61	4	0	4
Kokanee	0	6	1.25 ± 0.61	4	0	4
Largemouth bass	19.45 ± 6.66	6	0.25 [a]	4	0	4
Pumpkinseed	49.08 ± 15.96	6	0.5 [a]	4	0.5 ± 0.37	4
Sculpin	25.68 ± 11.17	6	0	4	0	4
Yellow perch	147.19 ± 37.42	6	17.25 ± 14.37	4	0.25 [a]	4

[a] Sample size too small or catch rates too variable to permit calculation of reliable confidence intervals

Stock Density Indices

Except for largemouth bass and yellow perch, few quality or preferred size fish were captured (Table 12). The electrofishing PSD and RSD values for largemouth bass and the PSD value for yellow perch were within the stock density index ranges for a body of water managed for a balance between predator and prey species. Hook and line (HO) RSD and PSD values from the Washington Bass Association tournament held at Lake Roesiger August 20, 2000 were also within this range (Table 8 and 12). For predators such as largemouth bass, the generally accepted stock density index ranges for balanced fish populations are PSD values of 40 to 70, RSD-P values of 10 to 40, and RSD-M values of 0 to 10. For balanced yellow perch populations, PSD values range from 30 to 60 (Gabelhouse 1984; Willis et al. 1993). The PSD and RSD values for black crappie, cutthroat trout, and rainbow trout (Table 12) should be viewed with caution, especially given the low catch rates for stock-size fish and small sample sizes used to determine these indices (Divens et al. 1998).

Table 12. Traditional stock density indices including 80% confidence intervals for cold and warmwater fishes collected from Lake Roesiger (Snohomish County) while electrofishing, gill netting and fyke netting during late spring 1999. PSD = proportional stock density, whereas RSD = relative stock density of preferred length fish (RSD-P), memorable length fish (RSD-M), and trophy length fish (RSD-T). EB = electrofishing, GN = gill netting and FN = fyke netting, HO = hook and line data from tournament August 20, 2000.

Species	Gear type	# Stock length fish	PSD	RSD-P	RSD-M	RSD-T
Black crappie	EB	3	100	0	0	0
	GN	0	0	0	0	0
	FN	0	0	0	0	0
Cutthroat trout	EB	0	0	0	0	0
	GN	3	0	0	0	0
	FN	0	0	0	0	0
Kokanee	EB	0	0	0	0	0
	GN	5	40 ± 28	0	0	0
	FN	0	0	0	0	0
Largemouth bass	EB	20	55 ± 14	25 ± 12	5[a]	0
	GN	1	100	0	0	0
	FN	0	0	0	0	0
	HO	44	39 ± 9	16 ± 7	7 ± 4	0
Pumpkinseed	EB	50	8 ± 5	0	0	0
	GN	2	0	0	0	0
	FN	2	0	0	0	0
Rainbow trout	EB	0	0	0	0	0
	GN	0	0	0	0	0
	FN	0	0	0	0	0
Yellow perch	EB	151	38 ± 5	0	0	0
	GN	69	56 ± 8	1[a]	0	0
	FN	0	0	0	0	0

[a] Sample size too small or catch rates too variable to permit the calculation of reliable confidence intervals.

Black Crappie

The low catch rate for black crappie (Table 11) is likely due to their preference for deeper water where our gear types are less effective. We captured a total of three black crappie while electrofishing. They were captured only in the south basin near the steeply sloping banks of the eastern shore. Black crappie exhibited strong growth characteristics with mean lengths at age exceeding the Western Washington averages for the species (Table 13). These fish were determined to be age 2+ each and ranged between 202 and 208 mm TL. Relative weights were consistent with western Washington averages for fish of this size (Figure 3).

Table 13. Age and growth of black crappie (*Pomoxis nigromaculatus*) captured at Lake Roesiger (Snohomish County) during late spring 1999. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

Year class	# fish	Mean total length (mm) at age 1	2
1998	0		
1997	3	67.6	201.3
		91.1	202.0
Overall mean		67.6	201.3
Weighted mean		91.1	202.0
Western WA average		46.0	111.2
	G	4.043	3.623
	G_{avg}	2.765	2.931

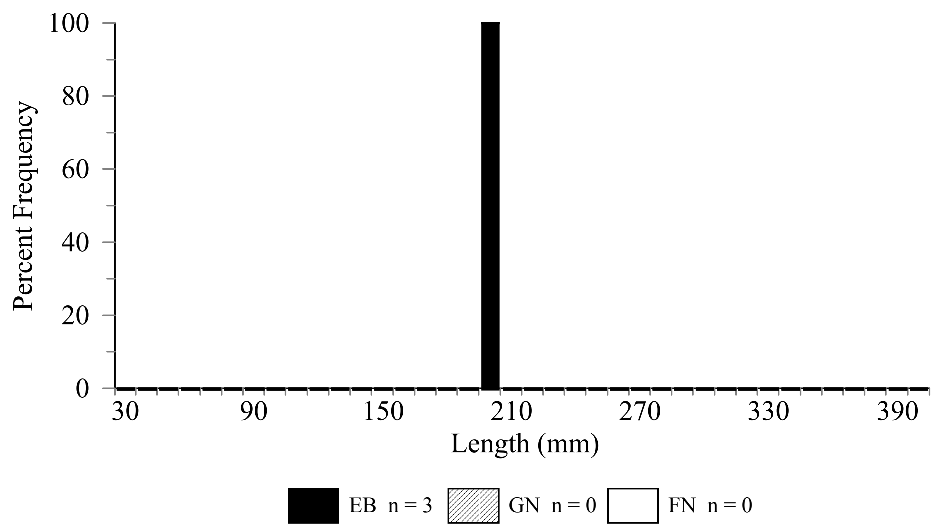

Figure 2. Length frequency histogram of black crappie sampled from Lake Roesiger (Snohomish County) in late spring 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

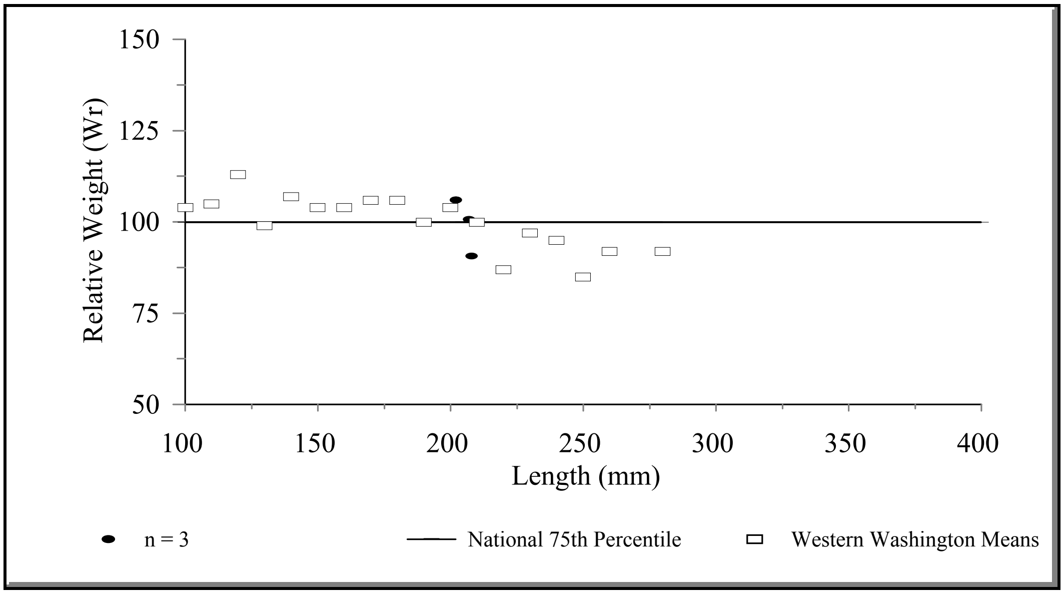

Figure 3. Relationship between total length and relative weight (W_r) of black crappie from Lake Roesiger (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Largemouth bass

Largemouth bass ranged from 60 to 508 mm TL (age 0+ to 11+) (Table 15, Figure 4). Fish through age 3+ were relatively abundant. Fish older than age 3+ were less abundant and the 1989 year class was not observed. While growth of most age classes of largemouth bass was consistent with the western Washington State averages, growth of age 4+ and 5+ fish was higher. This is not surprising since catch rates indicated a low density population (Table 6 and 11). Increased growth with size may also indicate reduced intraspecific competition or an increased utilization of abundant yellow perch or other forage as the predator becomes large enough to prey on these items. Relative weights were generally lower than the western Washington State averages, particularly for fish in the 150 to 250 mm size range (Figure 6). Lower relative weights in the 150 to 250 mm size ranges suggest interspecific competition with the more abundant yellow perch of the same size. Alternatively, lower relative weights in late spring may be related to largemouth bass fasting during the spawning season. Relative weights of seven bass captured in 1988 were similar to those seen in 1999 (Curt Kraemer, WDFW, unpublished data). Relative weights of largemouth bass captured in August 2000 during a bass tournament were higher than those seen from our survey yet closer to western Washington State averages (Figure 6). Since relative weights are a measure of current prey abundance and feeding efficiency, increased relative weights in piscivorous predators in the fall when young of year fish are abundant and vulnerable is not surprising.

The length frequency distribution of largemouth bass caught during the August 20, 2000 bass tournament (Figure 5) was not statistically different from that of our survey (Figure 4) for fish larger than 150 mm TL (Kolmogoroff-Smirnov test = 0.29, p = 0.2031). Downen and Mueller (2000) also found similarities in spring sampling and angler catch of stock sized largemouth. Tournament anglers released 82% of the catch and held 18% for weigh-in purposes. Those kept ranged in size from 302 to 554 mm (Table 14). The largest fish retained for weigh-in at the tournament judges scale measured 554 mm TL and was determined to be age 14+ (Mark Downen, WDFW, personal communication).

Table 14. Composition by weight and by number of largemouth bass captured during Washington Bass Association's tournament held at Lake Roesiger on August 20, 2000.

Species	Catch Status	Catch Composition					
		by weight		by number		Size Range	
		(kg)	(% of catch)	(#)	(% of catch)	Min (TL)	Max (TL)
Largemouth bass	Retained	18.31	67.4	16	18.4	302	554
	Culled	8.92	32.6	71	81.6	154	301
	Total	27.23		87			

Table 15. Age and growth of largemouth bass (*Micropterus salmoides*) captured at Lake Roesiger (Snohomish County) during late spring 1999. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age										
Year class	# fish	1	2	3	4	5	6	7	8	9	10	11
1998	25	60.2										
		64.1										
1997	13	51.5	138.6									
		64.2	140.3									
1996	10	60.4	139.2	210.0								
		74.6	145.9	201.8								
1995	2	44.5	112.0	195.6	221.4							
		60.6	122.3	198.6	221.1							
1994	3	53.6	136.5	215.1	253.7	297.5						
		70.1	147.6	221.0	257.1	298.1						
1993	2	40.4	103.7	164.8	237.9	297.7	348.5					
		58.1	117.9	175.6	244.5	301.0	348.9					
1992	3	46.1	122.9	196.6	250.2	305.2	345.7	365.3				
		63.7	136.3	206.0	256.7	308.8	347.1	365.6				
1991	3	55.4	128.0	229.8	289.4	329.7	356.0	383.8	400.8			
		72.7	141.7	238.6	295.3	333.5	358.6	385.0	401.2			
1990	1	57.4	146.6	221.0	278.4	380.4	420.8	446.3	465.4			
		75.0	160.5	231.7	286.7	362.0	384.4	423.1	447.5	465.8		
1989	0	0	0	0	0	0	0	0	0	0	0	0
1988	1	131.0	189.7	264.3	304.9	356.9	384.0	406.6	424.6	445.0	476.6	508.2
		145.9	202.4	274.0	313.1	363.0	389.1	410.8	428.2	447.7	478.1	508.5
Overall mean		60.1	135.3	211.0	262.3	324.0	362.9	394.1	423.9	455.2	476.6	508.2
Weighted mean		67.6	142.2	210.8	264.0	319.1	358.8	385.7	415.8	456.8	478.1	508.5
Western WA average		60.4	145.5	222.2	261.1	289.3	319.0	367.8	396.0	439.9	484.6	471.7
	G	2.145	2.509	1.374	0.672	0.653	0.350	0.255	0.220	0.220	0.142	0.199
	G_{avg}	2.162	2.717	1.308	0.498	0.317	0.302	0.228	0.228	0.325	0.299	-0.08

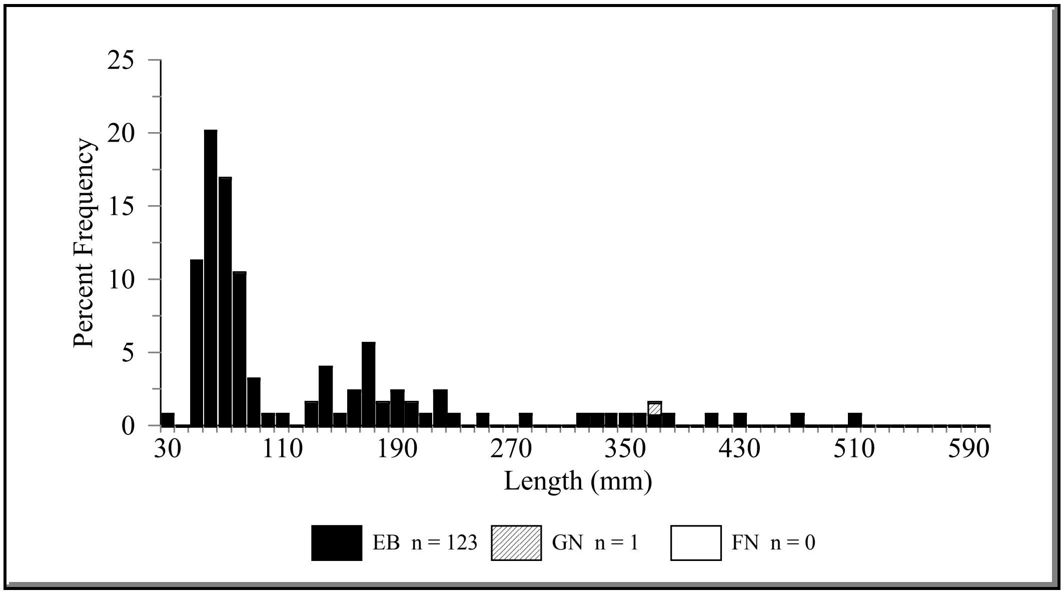

Figure 4. Length frequency histogram of largemouth bass sampled from Lake Roesiger (Snohomish County) in late spring 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

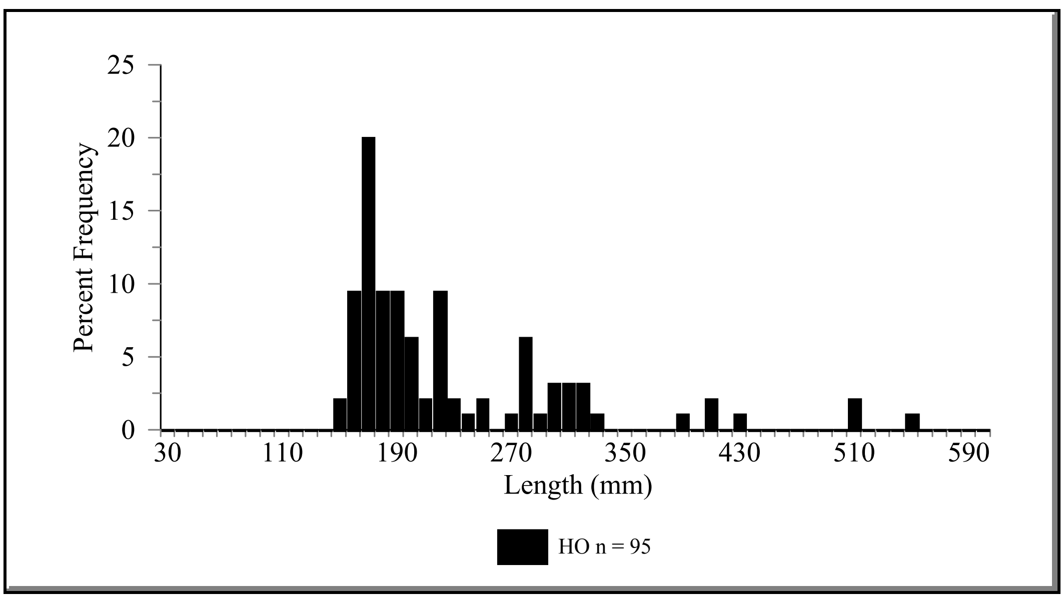

Figure 5. Length frequency histogram of largemouth bass captured by hook and line (HO) during Washington Bass Association's tournament held at Lake Roesiger (Snohomish County) on August 20, 2000.

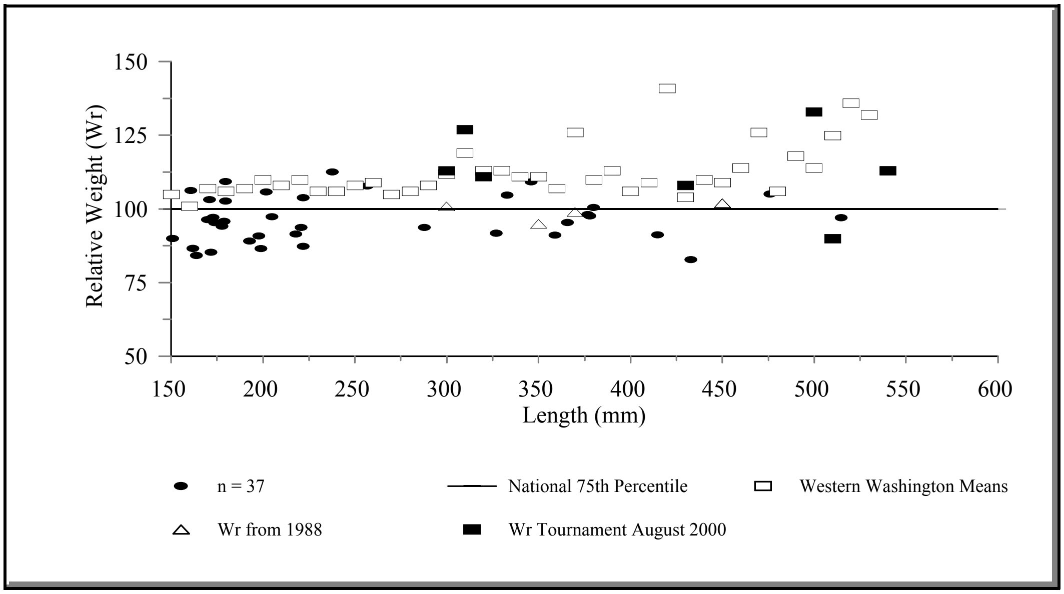

Figure 6. Relationship between total length and relative weight (W_r) of largemouth bass from Lake Roesiger (Snohomish County) compared with means from up to 25 western Washington lakes, the national 75th percentile, Lake Roesiger largemouth bass sampled in 1988, and August 2000 tournament data.

Pumpkinseed

A total of 39 pumpkinseed were captured during our survey. Pumpkinseed demonstrated a spacial preference for the south and central basins, which accounted for more than 80% of their occurrence. Age 2+ fish were dominant with nearly 62% of all pumpkinseed falling in this age class while age 3+ fish were absent (Table 16 and Figure 7). Growth for Lake Roesiger pumpkinseed slightly exceeded the average for western Washington State populations while sample sizes of other age classes were too small for comparison with state averages. Relative weights were consistent with western Washington State averages (Figure 8).

Table 16. Age and growth of pumpkinseed (*Lepomis gibbosus*) captured at Lake Roesiger (Snohomish County) during late spring 1999. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age				
Year class	# fish	1	2	3	4	5
1998	7	44.5				
		50.7				
1997	24	21.8	89.4			
		41.6	92.6			
1996	0	0	0	0		
1995	7	20.4	82.8	107.7	137.1	
		41.8	93.5	114.1	138.4	
1994	1	19.2	72.8	87.9	100.3	127.8
		40.7	84.4	96.8	106.8	129.3
Overall mean		26.5	81.7	97.8	118.7	127.8
Weighted mean		43.2	92.5	111.9	134.5	129.3
Western WA average		23.6	72.1	101.6	122.7	139.4
	G	0.844	3.391	0.543	0.583	0.222
	G_{avg}	0.498	3.362	1.032	0.568	0.384

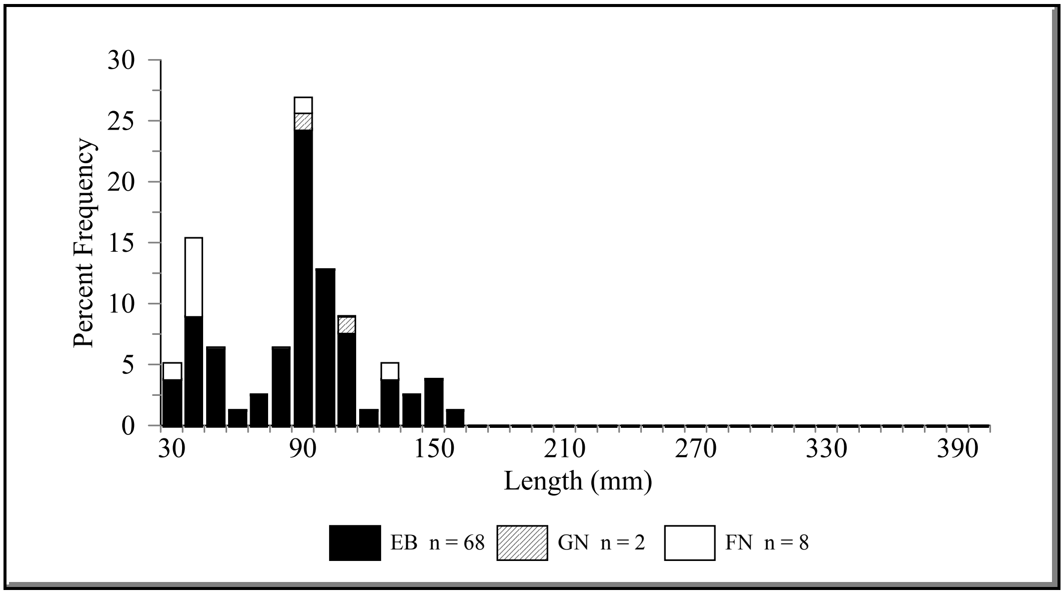

Figure 7. Length frequency histogram of pumpkinseed sampled from Lake Roesiger (Snohomish County) in late spring 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

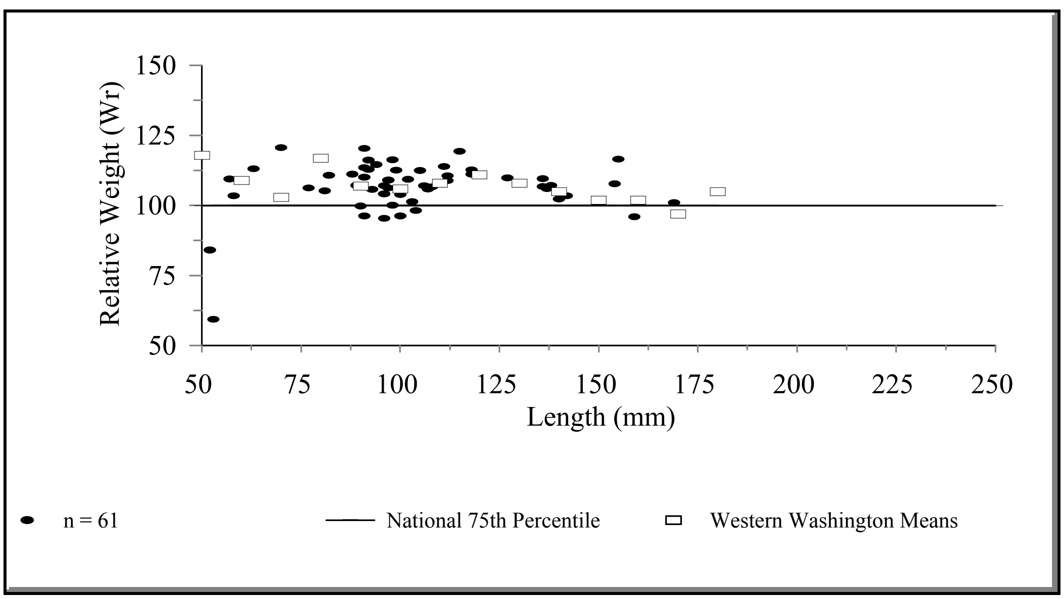

Figure 8. Relationship between total length and relative weight (W_r) of pumpkinseed from Lake Roesiger (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Yellow perch

Though yellow perch occurred at equally high frequencies in the north and south basins, abundance was low in the central basin. Yellow perch ranged in size from 64 to 218 mm (age 0+ to 5+) (Table 17, Figure 9). Age 2+ fish were in greatest abundance but all age classes through 5+ were well represented. Except for age 4+ fish, growth of Lake Roesiger yellow perch consistently exceeded western Washington State averages across available age classes. Relative weights were low when compared with western Washington State averages and the national standard suggesting intraspecific competition for available food (Figure 10). This makes sense given their high density as indicated by high catch rates (Table 6).

Table 17. Age and growth of yellow perch (*Perca flavescens*) captured at Lake Roesiger (Snohomish County) during late spring 1999. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age				
Year class	# fish	1	2	3	4	5
1998	10	81.1				
		86.9				
1997	30	57.8	137.0			
		76.0	138.9			
1996	12	74.0	129.5	174.3		
		92.0	138.6	176.0		
1995	19	51.2	134.7	172.8	196.2	
		74.0	145.7	178.5	198.7	
1994	8	57.8	139.4	172.2	198.1	218.5
		80.2	151.1	179.7	202.2	219.8
Overall mean		64.4	135.2	173.1	197.2	218.5
Weighted mean		79.7	142.1	178.0	199.7	219.8
Western WA average		59.7	119.9	152.1	192.5	206.0
	G	3.753	2.381	0.794	0.418	0.329
	G_{avg}	3.510	2.238	0.764	0.756	0.218

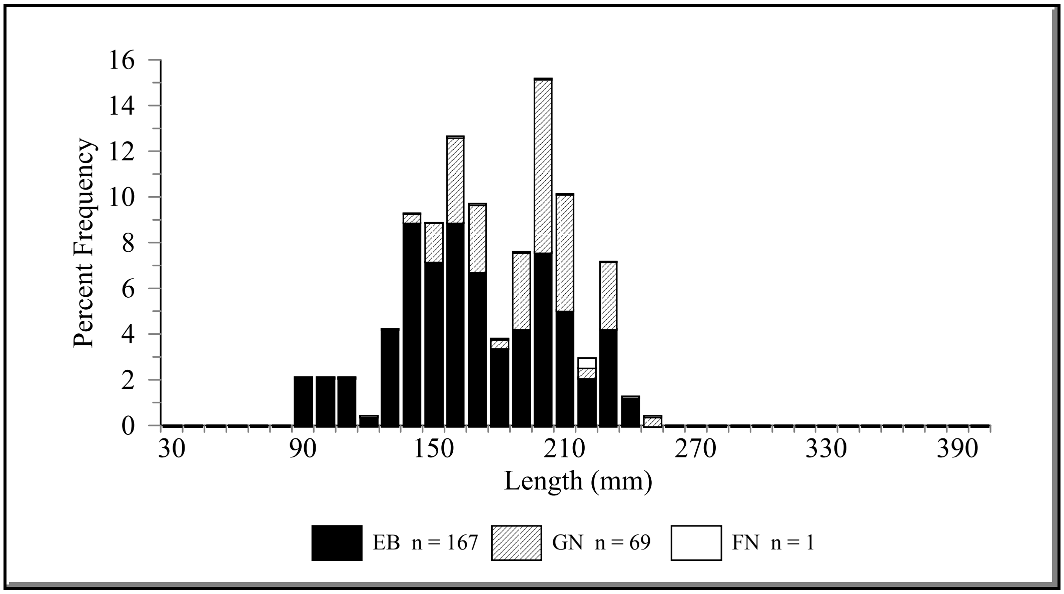

Figure 9. Length frequency histogram of yellow perch sampled from Lake Roesiger (Snohomish County) in late spring 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

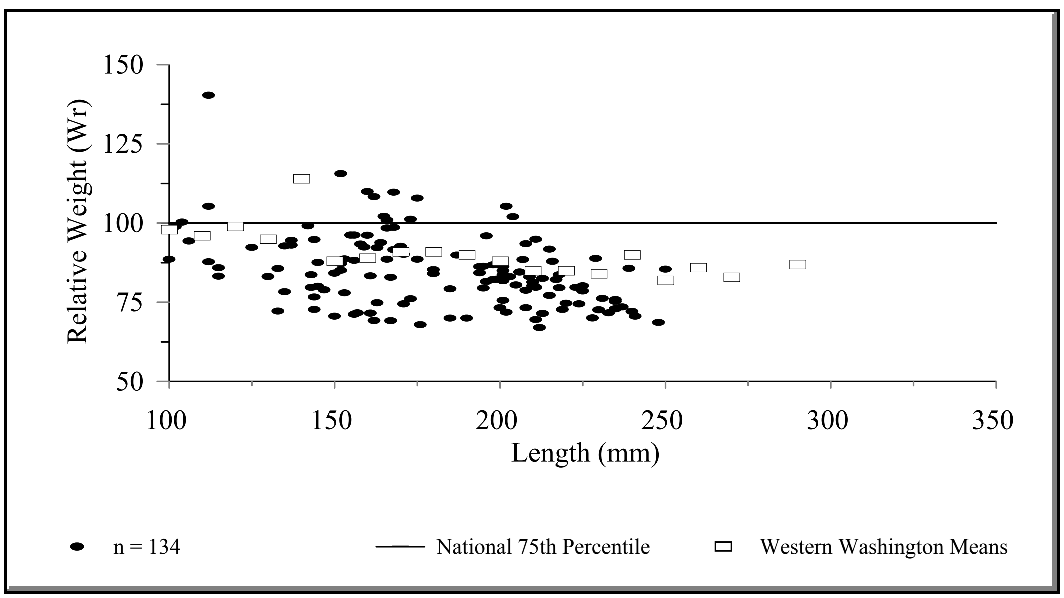

Figure 10. Relationship between total length and relative weight (W_r) of yellow perch from Lake Roesiger (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Non-game Fish

Sculpin

Sculpin (*Cottus* sp.) ranged between 35 and 124 mm TL (Figure 11). All were captured while electrofishing. Though one sculpin was captured in the central basin, most were found in the north and south basins of the lake. Sculpin may contribute to the forage base of largemouth bass and may compete with forage species that prey on benthic organisms. In 1955, sculpin contributed nearly 13% by number to the species composition. In our sample they contributed about 5%. This discrepancy is likely due to seasonal influences and gear-related biases (Pope and Willis 1996).

Members of the Family Salmonidae

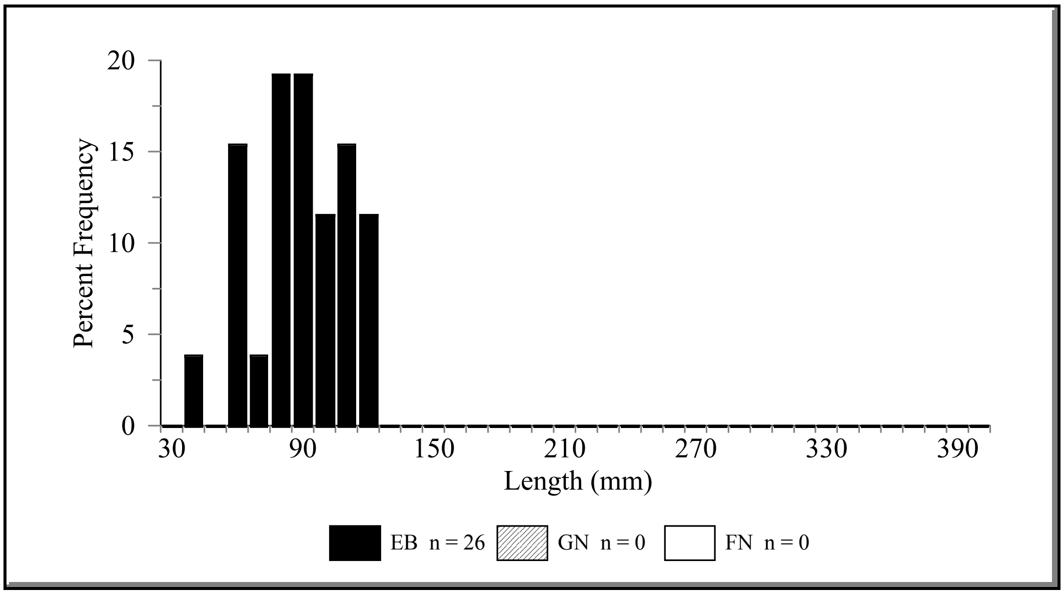

Figure 11. Length frequency histogram of sculpin (*Cottus* sp.) sampled from Lake Roesiger (Snohomish County) in late spring 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting.

Though typically more pelagic than warmwater fishes, and therefore less vulnerable to our sampling methods, salmonids were also captured during our survey. A total of eight stock sized salmonids were captured while gillnetting including, five kokanee, one rainbow trout and two cutthroat trout. No salmonids were sampled in the shallow central basin of the lake. Cutthroat and rainbow trout were determined to be age 1+ while kokanee were determined to be age 2+ (Table 18). Gill net samples conducted in February and March between 1969 and 1979 captured cutthroat and rainbow trout determined to be age 2+ and 1+ and 2+ respectively (Table 19).

Table 18. Age and growth of salmonids captured at Lake Roesiger (Snohomish County) during late spring 1999. Values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993).				
			Mean total length (mm) at age	
Species	**Year class**	**# fish**	**1**	**2**
Cutthroat trout	1998	2	94.3	
Rainbow trout	1998	1	112.8	
Kokanee	1997	5	90.1	188.3

Table 19. Size ranges at age of salmonids captured at Lake Roesiger in February and March over a ten year period, 1969-79 (WDFW, unpublished data).

Species	**Age**	**Size range (mm)**
Cutthroat trout	2+	231-267
Rainbow trout	1+	165-254
	2+	244-260
Coho salmon	1+	171-191
	2+	203-229
	3+	254-283

Cutthroat Trout

A total of seven cutthroat trout were captured during our survey of Lake Roesiger. Cutthroat trout were captured in both the north and south basins. Small, shore-oriented fish (<130 mm) were collected while electrofishing whereas larger individuals were captured in our gill nets (Figure 12). Of the seven cutthroat trout captured, three were of stock length (>200 mm TL). Relative weights of stock length cutthroat trout were low compared to the national 75th percentile (Figure 13).

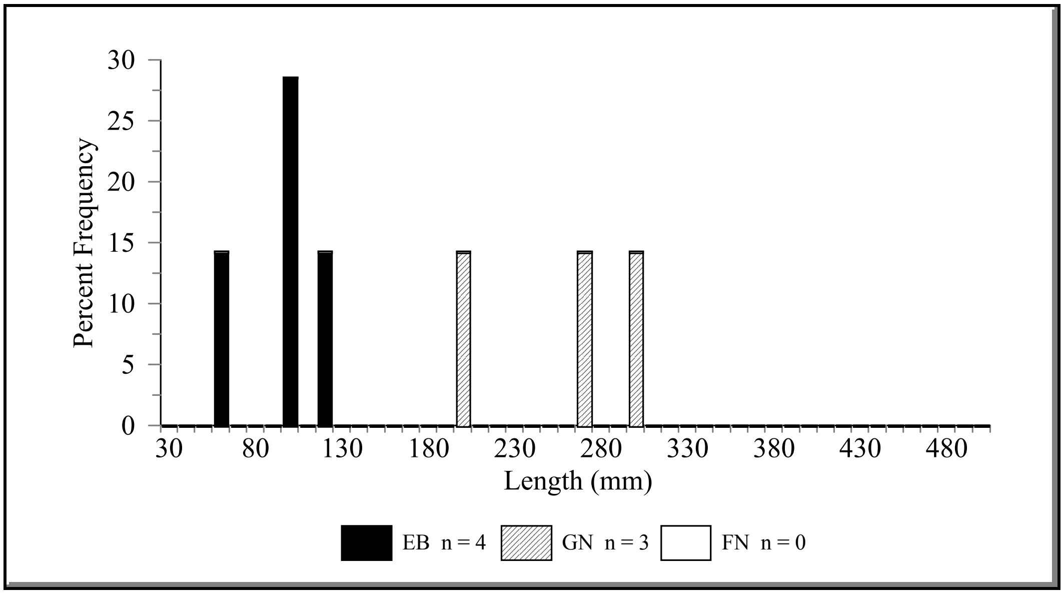

Figure 12. Length frequency histogram of cutthroat trout sampled from Lake Roesiger (Snohomish County) in late spring 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

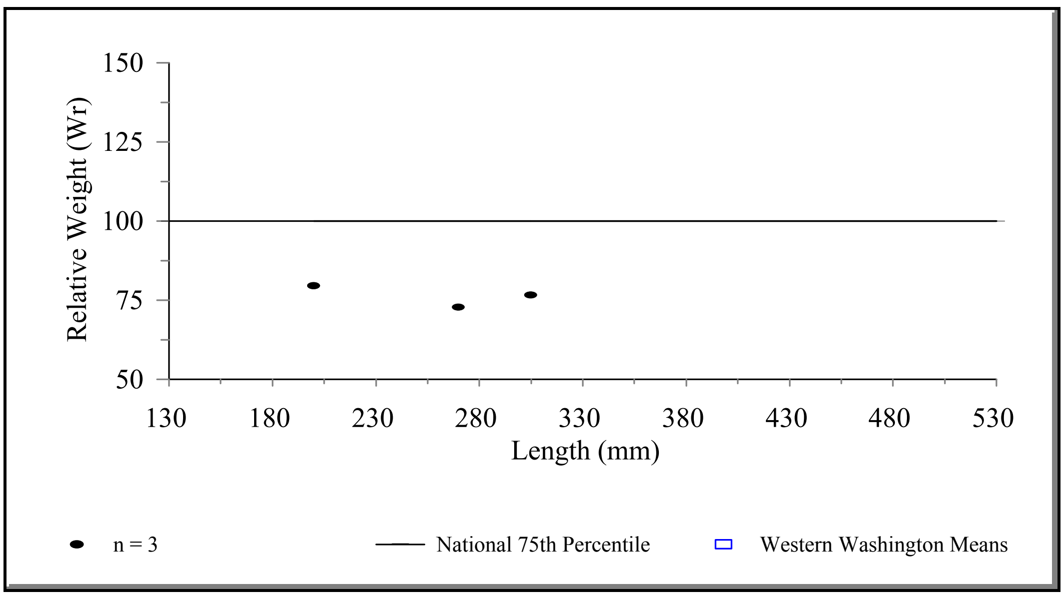

Figure 13. Relationship between total length and relative weight (W_r) of cutthroat trout from Lake Roesiger (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Rainbow Trout

A total of three rainbow trout were captured during our late spring survey of Lake Roesiger. The two stock length (>120 mm) fish were captured in our gill nets while the sub-stock length individual was captured while electrofishing (Figure 14). Relative weights, W_r, for stock length rainbow trout were low compared to the national 75^{th} percentile (Figure 15).

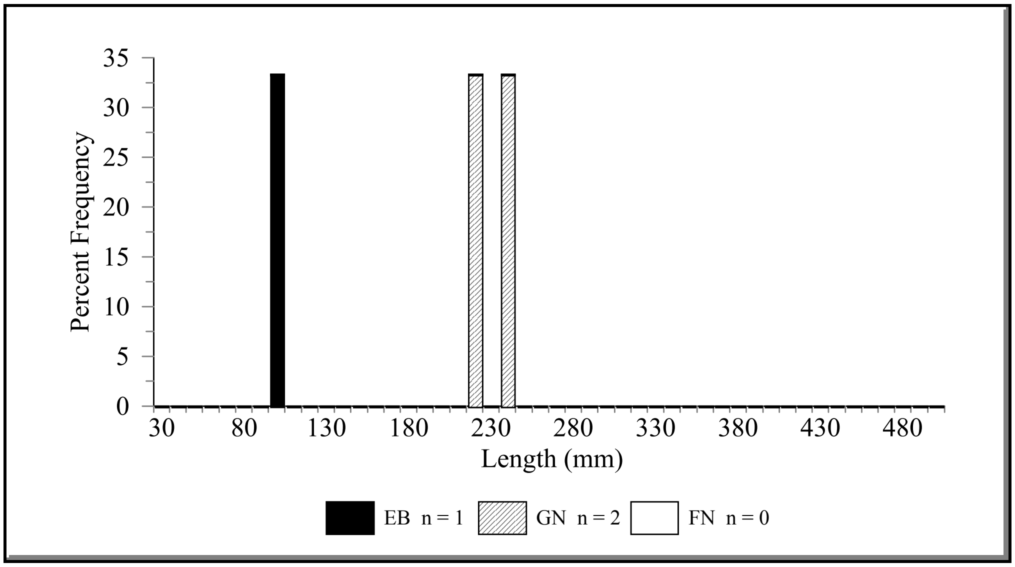

Figure 14. Length frequency histogram of rainbow trout sampled from Lake Roesiger (Snohomish County) in late summer 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

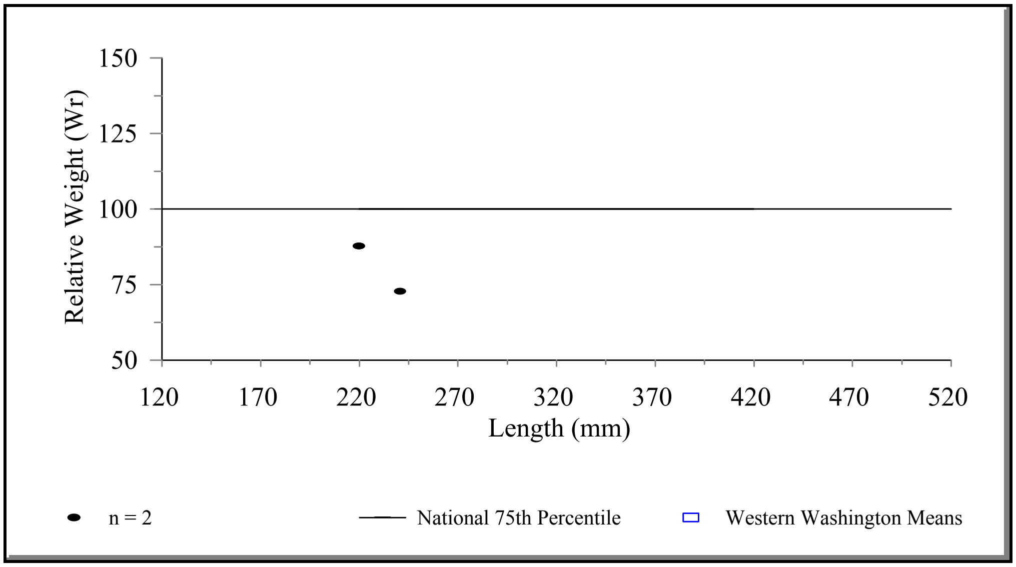

Figure 15. Relationship between total length and relative weight (W_r) of rainbow trout from Lake Roesiger (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Kokanee

Kokanee were found only in the north basin of Lake Roesiger and ranged in size from 243 to 256 mm TL. A total of five kokanee were captured in our gill nets during our survey (Figure 16). These fish were determined to be age 2+ each (Table 20). Relative weights for kokanee sampled in late spring were low compared to the national 75th percentile (Figure 17). Kokanee fork lengths we recorded were similar to those typically seen in spawning fish observed in large numbers in Lake Roesiger tributaries in November 2000 (personal communication, Mark Downen, WDFW).

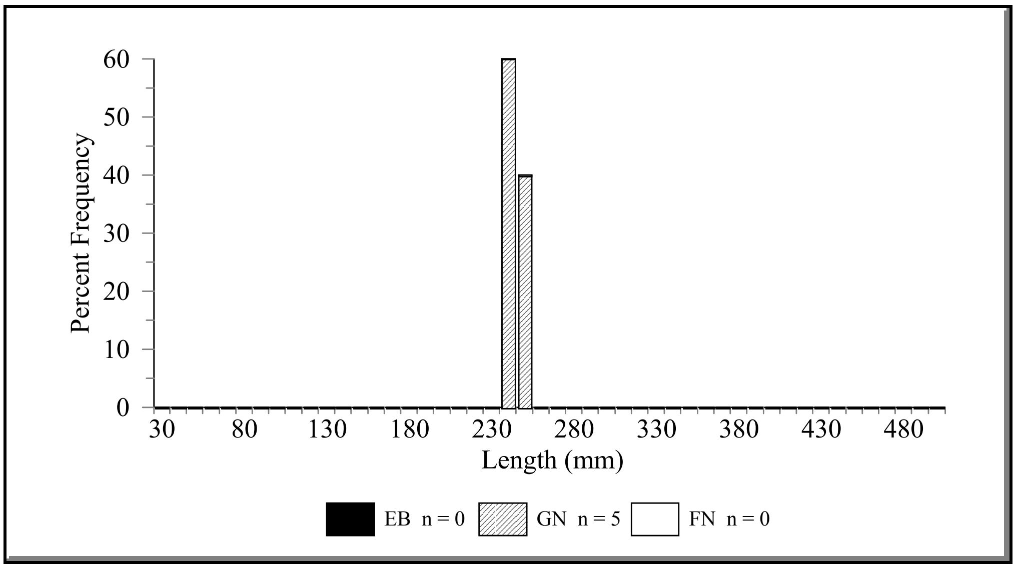

Figure 16. Length frequency histogram of kokanee sampled from Lake Roesiger (Snohomish County) in late spring 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

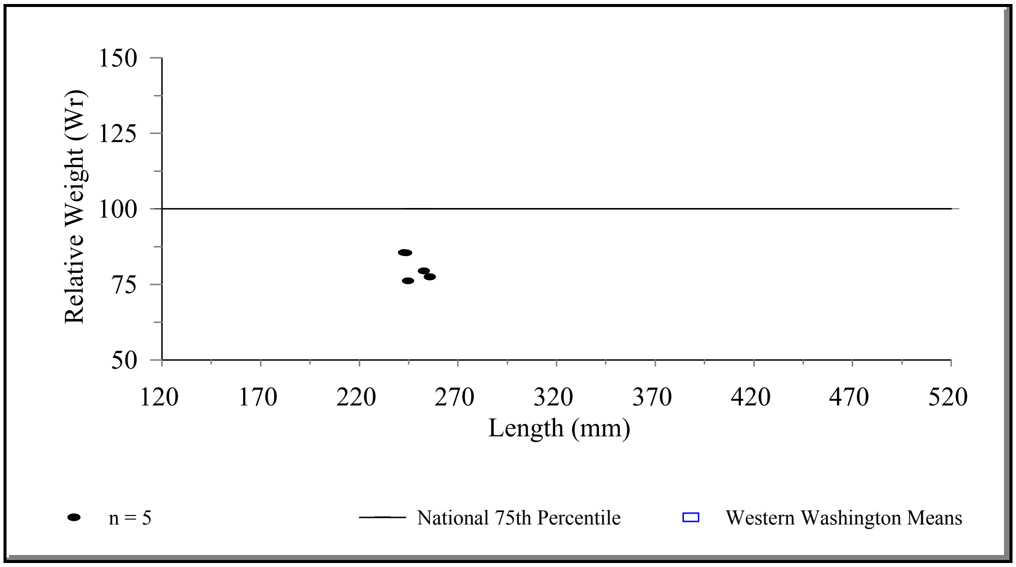

Figure 17. Relationship between total length and relative weight (W_r) of kokanee from Lake Roesiger (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Warmwater Enhancement Options

The fish community we sampled in the littoral zone of Lake Roesiger was dominated by warmwater species, particularly yellow perch and largemouth bass. Growth of largemouth bass was above average and PSD and RSD values were within ranges generally accepted for balanced communities (Willis 1993). Growth of yellow perch, the dominant forage species, was also above average and PSD values were within those generally accepted for balanced communities. Yellow perch exhibited high density in most age classes, particularly for fish age 2+. The alternative forage species, pumpkinseed, demonstrated moderate to low growth, uneven age class distribution and low density while black crappie showed rapid growth, average relative weights, and low density. Cutthroat and rainbow trout were historically prevalent in the lake and rainbow are currently planted as fingerlings on an annual basis by WDFW. Also, a robust self-sustaining population of kokanee resides in the lake. These findings suggest Lake Roesiger should continue to be managed as a mixed species fishery. Management strategies that might improve Lake Roesiger's warmwater fishery, but are not limited to, the following:

Change Existing Fishing Rules to Improve Size Structure of Largemouth Bass and Increase Predation of Yellow Perch

Currently, Lake Roesiger anglers are allowed to harvest five largemouth bass daily, including no more than three over 381 mm (15') TL. The PSD and RSD-P values for largemouth bass suggest that a balanced condition exists in the lake (Gabelhouse 1984; Willis et al. 1993). If angler harvesting pressure increases at Lake Roesiger, changes in the size structure of largemouth bass, resulting from increased harvest of its low density population may require implementing corrective length and bag limits on largemouth bass (sensu Willis 1989) to restore the population to balance.

Implementing a 305 – 432 mm (12 – 17") slot limit for largemouth bass would likely help protect and maintain the balance in Lake Roesiger. The main objective of a slot limit is to improve the size structure of largemouth bass. Under this rule, only fish less than 305 or greater than 432 mm TL may be kept. Decreasing the creel limit of harvestable large fish from three fish over 381 mm TL to one fish over 432 mm TL would stimulate harvest of small fish while still protecting large fish. A reduction of small fish may improve growth and production of predator and prey species alike (McHugh 1990) while increasing predation of the dominant yellow perch by largemouth bass..

The success of any rule change, though, depends upon angler compliance. Reasons for non-compliance include lack of angler knowledge of the rules for a particular lake, a poor understanding of the purpose of the rules, and inadequate enforcement (Glass 1984). If the fishing rules are changed to protect Lake Roesiger largemouth bass the WDFW fishing rules pamphlet must be amended accordingly. Clear and concise multilingual posters or signs should be placed at the lake describing the new regulations. Press releases should be sent to local papers, magazines, and sport fishing groups detailing the changes to, and purpose of, the rules. Furthermore, if necessary, increasing the presence of WDFW enforcement personnel at Lake Roesiger should reduce non-compliance.

Quantify, Analyze, and Monitor Habitat with Geographic Information Systems (GIS)

Multiple basin bodies of water, such as Lake Roesiger, often exhibit patches of distinct habitats with different assemblages of fish depending on such factors as life stage, species, and seasonality (Hayes et al. 1996). During late spring 1999, we observed a number of distinct habitat types and associated assemblages of fish species. GIS would be an effective tool for managing and analyzing such data since it can link data by location. Analyses of proximity, quantity (e.g., length or area of disturbed shoreline), spatial autocorrelation, and temporal change can then can allow the resource manager to predict future dynamics in fish populations and assess risks associated with human activity. Effective management of the fish populations in Lake Roesiger would benefit from an inventory and quantification of important habitats as well as disturbances likely to impact these habitats. Future development (e.g., bulkheading, pile driving, or timber harvests) of spawning, nursery, and foraging habitats throughout the lake could have direct influences on recruitment of both native fishes and introduced warmwater species and subsequent numbers of harvestable fish. However, causal relationships cannot be effectively argued without a means of quantifying habitat and disturbance and determining the extent of their spatial and temporal overlap.

Consider Stocking Channel Catfish to Control Abundant Yellow Perch

Temperature-sensitive channel catfish (*Ictalurus punctatus*) have been stocked into a number of Washington lakes in the past decade. These non-reproducing populations were introduced in an attempt to increase predation of over-abundant forage fish, such as yellow perch, and to add diversity to mixed-species fisheries (WDFW 1999). Lake Roesiger's abundant forage base (i.e., yellow perch and numerous small kokanee), low relative weight of largemouth bass, and low to moderate levels of aquatic vegetation make it suitable for stocking channel catfish. However, the lake's trophic status makes it difficult to predict the success of stocking the predator (Bonar et al. 1995).

Literature Cited

Anderson, R.O., and R.M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447-482 *in* Murphy, B.R., and D.W. Willis (eds.), Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, MD.

Bennett, G.W. 1962. Management of Artificial Lakes and Ponds. Reinhold Publishing Corporation, New York, NY.

Bennett, D.H. 1993. Hypolimnetic aeration in Lake Roesiger: importance to the fishery resources. University of Idaho, Fishery Resources. Opinion paper. Moscow, ID.

Bister, T.J., D.W. Willis, M.L. Brown, S.M. Jordan, R.M. Neumann, M.C. Quist, and C.S. Guy. 2000. Proposed standard weight (W_s) equations and standard length categories for 18 warmwater nongame and riverine fish species. North American Journal of Fisheries Management 00: 00-00.

Bonar, S. A., J. Pahutski, B. Bolding, and J. Webster. 1995. Factors related to survival and growth of stocked channel catfish in Washington Lakes. Washington Department of Fish and Wildlife, Inland Fish Division, Technical Report # IF95-03, 24 p.

Bortelson, G.C., N.P. Dion, J.B. McConnell, and L.M. Nelson. 1976. Reconnaissance Data on Lakes in Washington, Volume 3. Water Supply Bulletin 43, Vol. 3, 259 p. Washington Department of Ecology in cooperation with United States Geological Survey, Olympia, WA.

Carlander, K.D. 1982. Standard intercepts for calculating lengths from scale measurements for some centrarchid and percid fishes. Transactions of the American Fisheries Society 111: 332-336.

Chew, R.L. 1974. Early life history of the Florida largemouth bass. Florida Game and Fresh Water Fish Commission, Fishery Bulletin # 7, 76 p.

Divens, M.J., S.A. Bonar, B.D. Bolding, E. Anderson, and P.W. James. 1998. Monitoring warm-water fish populations in north temperate regions: sampling considerations when using proportional stock density. Fisheries Management and Ecology 5: 383-391.

Downen, M.R., and K.W. Mueller. 2000. 1999 Campbell Lake Survey: the warmwater fish community fifteen years after implementation of a lake restoration plan. Washington Department of Fish and Wildlife, Warmwater Enhancement Program, Technical Report # FPT 00-13, 28 p.

Fletcher, D., S. Bonar, B. Bolding, A. Bradbury, and S. Zeylmaker. 1993. Analyzing warmwater fish populations in Washington State. Washington Department of Fish and Wildlife, Warmwater Fish Survey Manual, 137 p.

Gabelhouse, D.W., Jr. 1984. A length categorization system to assess fish stocks. North American Journal of Fisheries Management 4: 273-285.

Glass, R.D. 1984. Angler compliance with length limits on largemouth bass in an Oklahoma reservoir. North American Journal of Fisheries Management 4: 457-459.

Gustafson, K.A. 1988. Approximating confidence intervals for indices of fish population size structure. North American Journal of Fisheries Management 8: 139-141.

Hayes, D.B., C.P. Farreri, and W.W. Taylor. 1996. Linking fish habitat to their population dynamics. Canadian Journal of Fisheries and Aquatic Sciences 53: 383-390.

Jearld, A. 1983. Age determination. Pages 301-324 *in* Nielsen, L.A., and D.L. Johnson (eds.), Fisheries Techniques. American Fisheries Society, Bethesda, MD.

Kohler, C.C., and A.M. Kelly. 1991. Assessing predator-prey balance in impoundments. Pages 257-260 *in* Proceedings of the Warmwater Fisheries Symposium I, June 4-8, 1991, Scottsdale, Arizona. USDA Forest Service, General Technical Report RM-207.

Kramer, Chin and Mayo, Inc. (KCM), 1989. Lake Roesiger Phase I Restoration Analysis. Prepared for Snohomish County Surface Water Management. Seattle, WA.

McHugh, J.J. 1990. Response of bluegills and crappies to reduce abundance of largemouth bass in two Alabama impoundments. North American Journal of Fisheries Management 10: 344-351.

Murphy, B.R., and D.W. Willis. 1991. Application of relative weight (W_r) to western warmwater fisheries. Pages 243-248 *in* Proceedings of the Warmwater Fisheries Symposium I, June 4-8, 1991, Scottsdale, Arizona. USDA Forest Service, General Technical Report RM-207.

ODFW (Oregon Department of Fish and Wildlife). 1997. Fishery biology 104 - Body condition. Oregon Department of Fish and Wildlife, Warmwater Fish News 4(4):3-4.

Olson, M.H., G.G. Mittelbach, and C.W. Osenburg. 1995. Competition between predator and prey: resource-based mechanisms and implications for stage-structured dynamics. Ecology 76: 1758-1771.

Pope, K.L., and D.W. Willis. 1996. Seasonal influences on freshwater fisheries sampling data. Reviews in Fisheries Science 4 (1): 57-73.

Rector, J., 1992. Washington's Citizen Lake Monitoring Program 1992 Data Summary: Lake Roesiger, Snohomish County. Washington State Department of Ecology Environmental Investigations and Laboratory Services Program.

Rector, J., 1993. Washington's Citizen Lake Monitoring Program 1993 Data Summary: Lake Roesiger, Snohomish County. Washington State Department of Ecology Environmental Investigations and Laboratory Services Program.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Board of Canada 191:382 pp.

Swingle, H.S. 1950. Relationships and dynamics of balanced and unbalanced fish populations. Auburn University, Alabama Agricultural Experiment Station, Bulletin # 274, 74 p.

WDFW (Washington Department of Fish and Wildlife). 1999. Warmwater Game Fish Enhancement Program. Washington Department of Fish and Wildlife, Publication # FM96-04, 2 p.

WDFW (Washington Department of Fish and Wildlife). 1999. Warmwater Fish of Washington. Washington Department of Fish and Wildlife, Angler Education, Technical Report # FM93-9, 17 p.

Willis, D. 1989. Understanding length limit regulations. In-Fisherman 87: 30-41.

Willis, D.W., B.R. Murphy, and C.S. Guy. 1993. Stock density indices: development, use, and limitations. Reviews in Fisheries Science 1(3): 203-222.

Zar, J.H. 1984. Biostatistical Analysis, 2nd edition. Prentice-Hall, Englewood Cliffs, NJ.

Appendix A

Letter from Richard Roesiger to Director of Game Lou Ovenden, May 1934

Snohomish, Wash.
May, 1934

R. R. 4
(Lake Roesiger)

Mr. Lou Ovenden
Director of Game

Dear Sir:

I am residing for over 47 years on Lake Roesiger in Snohomish County and will try to describe fishing conditions in this lake past and present with the hope and anticipation that you will endeavor to correct and improve the very poor fishing condition in this lake at present.

This lake is over 2 miles long, varies in width from 1 mile downward and is formed of 3 parts connected by narrows locally designated as upper, middle and lower lake and contains about 500 acres.

There is rock, gravel and mud bottom in different parts and it is deep lake – 85 ft. in lower lake and 125 feet in upper lake and middle lake, averages shallow and has mostly mud bottom. The lake has no sandy bathing beaches and as a rule drops off from shore pretty quick and steep along most of the shoreline. There is no big stream or creek as inlet. The lake is fed by mountain springs from drainage on, east, west and south side and the outlet is the main or center branch of Woods Creek, a tributary of the Skykomish river. Those springs that feed the lake are booming during the fall and winter, but most of them dry up during August. Some of them never dry up. The difference between high and low water is from $3^1/_2$ to 4 feet in this lake.

Nature was undisturbed when I (prospecting – looking for coal croppings and going east by compass) stumbled unexpectedly against and discovered this lake. The lake was teeming with fish and many beavers and muskrats were here on the lake and deers and bears, etc. in the woods. It was trout lake and cutthroat trouts and speckled trouts up to 27¢ inches long and there were also suckers, shiners, sticklebacks, crawfish, bullheads, etc. and it was easy to catch a mess of trout. Gradually the settlers came farther in and the surrounding country was settled and occupied by squatters and later homesteaders. Of course all had to rustle and work hard to get started – building shacks, slashing burning, grubbing and clearing a patch to raise potatoes and other garden vegetables, sowing grass for pasture and hay for stock and there was no time for fishing.

About the year 1900 a dam was built on the outlet with a gate and the lake raised about 6 feet. The water being used for floating bolts down woods creek to the shingle mills by Monroe, and the lake sustained a considerable loss of trouts because when they opened the gate to drive shinglebolts a lot of trouts went out and they could not get back, also their natural habit of going down the creek spawning during December and January and returning later to the lake was stopped. That lasted for 18 years until they had finished taking out shinglebolts.

The fishing by a few who lived or worked around there was good – no trouble to catch a mess. In 1918 some Seattle sports found out that this lake was good fishing for trouts and more people started coming here fishing, and as my dugouts reached nowhere, I had boats built in Snohomish and hauled out here. Fishing was good and people (mostly from Seattle) liked to come here. The County Game Warden about 1920 blew out the dam and somebody about that time had put bass in this lake. Fishing continued good and gradually the Game Wardens started planting different kinds of fish here: Silvers, Eastern Brooks, Rainbows, Mackinaws and later also perch, crappie and I heard catfish also. The bass increased and cleaned out all the shiners, sticklebacks, bullheads and crawfish. Seen a 9 lb., 8 lb., and several over 5 lbs. that were caught this season before May 15th. The fishing for trouts is very, very poor now and the good fishermen who used to make good catches as a matter of course have trouble now to catch 2 or 3 and the most of them cannot get any at all and leave here discouraged and disgusted. There have been no fish planted in this lake to my knowledge for 3 or 4 years, and fishing was very poor last season and is worse than ever this season so far.

This is a very beautiful lake and people would like to come here as they used to in years past if only the fishing would be a little better. The roads are good and there are fine green camping grounds here but fishermen like to catch a few fish and now and then if possible a limit catch or a big one, something to show and blow about to their friends and acquaintances, but that seems to be impossible here now.

There are more fishermen who like to fish for trouts than for bass from my experience here, and their fun seems to have been completely spoiled here in this lake. The crappies are not much in evidence as yet, but seem to be well established as a few small ones (6 to 8 inches long) were caught here before May 15th. Silvers are doing well here too, but there seem to be hardly any in the lake now – anyhow they did not bite here so far while they are biting well (so I am told) in Lake Stevens and other lakes. Seen only 2 eight inches long catfish caught in this lake so far. Very few Eastern Brooks are caught by trolling or still fishing, although I am told that they have been caught in the outlet in holes close to the lake, and I think they came out of the lake.

There were 25,000 Mackinaws planted about 12 years ago, but nobody is catching any nobody knows what became of them – if they were planted. Perch seem to be plentiful in the middle lake (the smallest body of the three parts) with shallow mud bottom which is grassy and weedy, but they average all very, very small – 6, 7 inches – very seldom a 8 or 9 inch long perch is caught. There seem to be also plenty small perch close to the outlet where the bottom is also weedy and muddy. Have seen only 2 eight inches long catfish being caught here so far.

Salmon, steelheads, etc. cannot get up into this lake because the east branch of Woods Creek joins with the center branch (outlet of this lake) about 3 miles southward and about 6 to 7 miles southward of this lake there is a falls where they cannot get up, preventing all saltwater fish (salmons, steelheads, cutthroats, etc) from reaching this lake. All good sports like to fish for the gamey cutthroat trouts, rainbows, etc. and they surely done very little planting (if any) of cutthroats, here, although as stated above this lake at the beginning was teeming and full of cutthroat and speckled trouts. So if cutthroats were planted, it would be greatly appreciated by many sportsmen. If many silvers were planted and the plantings kept up every year, that would help too and be satisfactory to many fishing people. Some suggest that it would be good and is necessary that new blood of all varieties here now is required to improve size and fishing conditions.

There are plenty of bass here now – all sizes and big fellows, and it seems that they can pretty well take care of themselves. They struck certainly a paradise when they had a chance to live and prosper on all those shiners, sticklebacks, bullheads and crawfish, etc. I think they are also hard on trouts and might be the cause and may be the principal cause that the fishing conditions for trouts is so very, very poor at present. I am convinced and feel sure without any doubts whatever that you desire and do the best you can to improve the fishing conditions in our state and know also that it cannot be done all at once, but I wish and hope that you will kindly take, if possible, after giving this letter careful consideration, some action to do something to improve the fishing conditions in this lake and thank you in advance for the favor which will be appreciated by many fishermen.

Lake Roesiger is 574 feet above sea level situated 20 miles due east of Everett in T 29 N, R 7, E.W.M. in Snohomish County.

Yours very respectfully

(Signed) Richard Roesiger