2000 Warmwater Fish Survey of Silver Lake, Cowlitz County

by

Stephen J. Caromile
and
Chad S. Jackson
Department of Fish and Wildlife
Fish Program
Fish Management Division
Warmwater Enhancement Program

June 2002

Acknowledgments

This project was funded by the Warmwater Enhancement Program which is providing greater opportunity to fish for and catch warmwater fish in Washington. We would like to thank the myriad volunteers that helped out with our large spring survey, including: three warmwater teams, Moses Lake team, Steve Jackson, Jeff Skriletz, Dan Collins, Chuck Baranski, John Long, John Weinheimer, Jim Byrd and Jeff Johnson from Smith Root, Inc.

Abstract

Silver Lake was surveyed during the spring and fall of 2000. Spring sampling occurred between May 1-4, 2000, by all members of the Warmwater Enhancement Program (six electrofishing boats). Fall sampling occurred on October 18 and 19 by a 3-person team. Multiple gear types (electrofishing, gill nets, and trap nets) were utilized to reduce any sampling bias associated with each sampling method. The surveys were undertaken to track the rebuilding of the fish community after the breach of the dam on Outlet Creek, and subsequent draining of the lake. Sample sizes for most species were very low (total 2,800 fish for spring and 472 fish for fall). Stock density indices show a lack of smaller fish, with higher abundances of fish quality sized and larger. The 1998 year class of many species is either missing or greatly reduced. The dam breach had a definite effect on the fish community as a whole, but no supplemental stocking is recommended at this time. Instead, recommendations for Silver Lake include: 1.) an angler creel survey to estimate angler preference, effort, and harvest ; 2.) continued fish community surveys during both spring and fall seasons to track population rebuilding; and 3.) continued grass carp population monitoring and, if possible, vegetation assessments.

Table of Contents

List of Tables

List of Figures

Introduction and Background

Silver Lake is a 1,400 acre impoundment located in Cowlitz County. The lake is large and shallow, with a maximum depth of only 2.5 meters and a mean depth of 1.5 meters. The lake has been studied extensively since the 1940's, primarily because of its overabundance of aquatic vegetation and means for its control (Lavier 1973). This attention culminated in 1992 with the stocking of approximately 83,000 triploid grass carp (*Ctenopharyngodon idella*). Silver Lake is fed, primarily, by Hemlock Creek and Sucker Creek, and outlets into the Toutle River through Outlet Creek. Historically, these creeks have supported runs of steelhead (*Oncorhynchus mykiss*), sea run cutthroat trout (*O. clarkii*) and coho salmon (*O. kisutch*). Warmwater fish populations have been reported from Silver Lake since the 1880's.

Silver Lake was naturally dammed by a mudflow from an eruption of Mount St. Helens. In the early 1970's, the lake level was augmented by the construction of an earthen and concrete dam at the eastern end of the lake on Outlet Creek. The dam, with its 925 meter long earthen dam and 91 meter long concrete spillway, was constructed mainly for flood and lake level control. Prior to construction of the dam, the lake level was highly variable and home damage and road closures due to flood waters were common occurrences. Anadromous fish passage was originally provided by a Denil steep pass fishway, which was upgraded to a pool and weir design in 1988. To block the downstream movement of grass carp, a fish screen was installed across the face of the spillway. Prior to the construction of the dam, lake level was reportedly maintained by a series of beaver dams.

On May 3, 1999, the concrete spillway failed. The spillway was undermined, and the foundation soils were washed away as water rushed under the structure. The lake level dropped approximately 1.5 meters, and remained at this level for the entire summer. Repairs were made to the dam by the end of September, 1999, and the lake was back to maximum pool level by the end of November, 1999.

This report summarizes the findings of our fish population surveys during the spring and late summer of 2000. Our intention was to determine the status of the fish community after the dam breech and subsequent reconstruction, and to determine future sampling needs and management strategies.

Materials and Methods

Data Collection

Silver Lake was surveyed during the spring and fall of 2000. Spring sampling occurred between May 1 - 4, 2000 by all members of the Warmwater Enhancement Program (six electrofishing boats). Fall sampling occurred on October 18 and 19 by a three person team. During the spring, fish were captured using 3 sampling techniques: electrofishing, gill netting, and fyke netting. During the fall, only electrofishing was used. The electrofishing unit consisted of a Smith-Root SR-16s electrofishing boat, with a 5.0GPP pulsator unit. The boat was fished using a DC current of 6-8 amps and a pulse frequency of 120 Hz, as close to peak efficiency as possible. Peak efficiency of the electrofishing unit is defined as producing a ¼ sine wave. Experimental gill nets, 45.7 meters (m) long x 2.4 m deep, were constructed of four sinking panels (two each at 7.6 m and 15.2 m long) of variable-size (1.3, 1.9, 2.5, and 5.1 cm stretch) monofilament mesh. Fyke (modified hoop) nets were constructed of five 1.2 m diameter hoops with two funnels, and a 2.4 m cod end (6 mm nylon delta mesh). Attached to the mouth of the net were two 7.6 m wings, and a 30.5 m lead.

In order to reduce the gear induced bias in the data, the sampling time for each gear was standardized so that the ratio of electrofishing to gill netting to fyke netting was 1:1:1. The standardized sample is 1800 sec of electrofishing (3 sections), 2 gill net nights, and 2 fyke net nights. Sampling occurred during the evening hours to maximize the type and number of fish captured. Sampling locations were selected from a map by dividing the entire shoreline into 400 m sections, numbering them consecutively and randomly choosing them without replication. While electrofishing, the boat was maneuvered slowly through the shallows for a total of 600 seconds of "pedal-down" time. Gill nets were fished perpendicular to the shoreline; the small-mesh end was tied off to shore, and the large- mesh end was anchored off shore. Fyke nets were fished perpendicular to the shoreline as well. The lead was tied on shore, and the cod-end was anchored off shore, with the wings anchored at approximately a 45E angle from the net lead. Fyke nets are fished with the hoops 0.3 - 0.5 m below the water surface, this sometimes requires shortening the lead. During the spring, gill nets were set overnight at 24 locations around the lake and fyke nets were also set overnight at 24 locations. Spring electrofishing covered a total of 58 sampling sections, or the entire circumference of the lake, while fall electrofishing only covered nine (9) index sections.

With the exception of sculpin (family Cottidae), all fish captured were identified to the species level. Each fish was measured to the nearest millimeter (mm) and weighed to the nearest gram (g). For aging purposes, scales or dorsal spines were taken from five individuals of each species per centimeter size class.

Water quality data was collected during midday from deepest part of the lake on May 1, 2000. Using a Hydrolab® probe and digital recorder, dissolved oxygen (mg/l), temperature (CE), pH, turbidity (NTU), and conductivity (Fsiemens/cm) data was gathered in the deepest section of the lake at 1 m intervals through the water column.. Secchi disk readings, used to measure transparency, were taken by the methods outlined by Wetzel (1983).

Data Analysis

Species Composition

The species composition by number of fish captured, was determined using procedures outlined by Fletcher et al.(1993). Species composition by weight (kg) of fish captured, was determined using procedures adapted from Swingle (1950). Only fish estimated to be at least one year old were used to determine species composition. These were inferred from the length-frequency distributions described below, in conjunction with the results of the aging process. Young of year were not considered in biomass and species composition estimates because large fluctuations in their numbers may cause distorted results. Also, most of these fish would be subject to natural attrition during their first winter, resulting in a different size distribution by the following year.

Catch Per Unit of Effort

The catch per unit of effort (CPUE) of electrofishing for each species was determined by dividing the total number in all size classes equal or greater than stock size (defined in Appendix A), by the total electrofishing time (sec) and all multiplied by 3,600 to get catch per hour. The CPUE for gill nets and fyke nets was determined similarly, except the number equal or greater than stock size was divided by the number of net-nights for each net (usually one).

For fishes in which there is no published stock size (i.e., sculpins, suckers, etc.), CPUE is calculated using all individuals captured.

Length-Frequency

A length-frequency histogram was calculated for each species and gear type in the sample. Length-frequency histograms are constructed using individuals that are age one and older (determined by the aging process), and calculated as the number of individuals of a species in a given size class, divided by the total individuals of that species sampled. Plotting the histogram this way tends to flatten out large peaks created by an abundant size class, and makes the graph easier to read. These length-frequency histograms are helpful when trying to evaluate the size and age structure of the fish community, and their relative abundance in the lake.

Stock Density Indices

To assess the size structure of fish populations, stock density indices were calculated as described by Gablehouse (1984). Proportional stock density (PSD) and relative stock density (RSD) are calculated as proportions of various size-classes of fish in a sample. The size classes are referred to as minimum stock (S), quality (Q), preferred (P), memorable (M), and trophy (T). Lengths have been published to represent these size classes for each species, and were developed to represent a percentage of world-record lengths as listed by the International Game Fish Association (Gablehouse 1984). These lengths are presented in Appendix A.

The indices are accompanied by a 80% confidence interval (Gustafson 1988) to provide an estimate of statistical precision.

Relative Weight

A relative weight index (W_r) was used to evaluate the relative condition of fish in the lake. A W_r value of 100 generally indicates a fish in good condition when compared to the national average for that species and size. Furthermore, relative weights are 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). Relative weights were calculated following Murphy and Willis (1991). The parameters for the standard weight (W_s) equations of many fish species, including the minimum length recommendations for their application, are listed in Anderson and Neumann (1996).

For grass carp (*Ctenopharyngodon idella*), Fulton-type condition factors (C) were calculated (Anderson and Neumann 1996) to allow comparison to older data.

Age and Growth

Age determination and annuli measurements from scales or other structures were determined by the Washington Department of Fish and Wildlife Aging Unit. Total length at annulus formation was back-calculated using the Fraser-Lee method with *y*-axis intercepts specified by Carlander (1982). Mean back-calculated lengths at each age for each species were presented in tabular form for easy comparison between year classes. Mean back-calculated lengths at each age for each species were compared to averages calculated from scale samples gathered at lakes sampled by the warmwater enhancement teams.

Results and Discussion

Water Quality and Habitat

Water chemistry data was collected from Silver Lake on May 1, 2000 (Table 1). The lake does not stratify due to its shallow nature, and the fact that it is well mixed by wind action. The lake has become quite turbid since the addition of grass carp (KCM 1998). The removal of the dense mats of vegetation by the grass carp allow the bottom sediments to get stirred up by wind and wave action. Additionally, common carp and grass carp add to the turbidity by rooting around the bottom sediments for available food.

Table 1. Water chemistry taken from Silver Lake May 1, 2000.

	Depth (m)	Temp (C)	pH	0_2 mg/l	Turbidity NTU	Conductance F siemens/cm
Location 1	0.0	16.5	6.8	9.7	23.3	29.1
	1.0	15.1	6.8	9.6	22.6	29.2
	2.0	14.8	6.8	9.7	21.6	29.2
	2.3	14.4	6.3	7.7	21.6	31.6

During the summer of 1999, we visited the lake on several occasions to monitor the temperature and dissolved oxygen levels (Table 2). An abnormally hot or dry summer could have easily led to a large scale fish kill at Silver Lake, given the level it had been drawn down to. As it happened, a mild August helped keep water temperatures and dissolved oxygen levels within tolerable levels for warmwater fish.

Table 2. Temperature and dissolved oxygen levels taken during the draw down at Silver Lake, Cowlitz County, summer 1999.

	Temp (C)		0_2 (mg/l)	
Date	**0 m**	**1 m**	**0 m**	**1 m**
06/11/99	21.1	17.7	10.1	8.7
06/18/99	20.5	20.3	8.8	8.3
08/04/99	22.8	22.5	6.9	5.7

Species Composition and Relative Abundance

Species composition has not changed in terms of the total number of species known to inhabit Silver Lake. But, the relative abundance of these fish has changed since the addition of grass carp. Also, the dam breech and subsequent draining of the lake had a definite impact on a lake community as a whole. Table 3 shows the species composition of our sampling activities in the spring of 2000.

Three species consistently account for roughly 75% of the total biomass in Silver Lake: grass carp, largescale sucker and common carp. These fish are also fairly abundant in number.

Table 3. Species composition of the sample at Silver Lake, Cowlitz County, during the spring 2000 sampling season.

	Species Composition					
	by Weight		by Number		Size Range (mm TL)	
Species	**(kg)**	**(%w)**	**(#)**	**(%n)**	**Min**	**Max**
Bluegill	27.64	1.82	589	21.04	34	650
Brown bullhead	220.31	14.47	482	17.21	84	427
Yellow perch	6.12	0.40	476	17.00	78	170
Black crappie	18.51	1.22	333	11.89	63	300
Largescale sucker	365.03	23.97	332	11.86	93	592
Largemouth bass	126.57	8.31	214	7.64	61	565
Grass carp	514.97	33.82	133	4.75	720	770
Yellow bullhead	16.48	1.08	81	2.89	98	365
Rainbow trout	18.00	1.18	50	1.79	134	475
Common carp	206.53	13.56	47	1.68	186	866
White crappie	0.43	0.03	25	0.89	64	197
Warmouth	1.24	0.08	13	0.46	66	275
Sculpin	0.15	0.01	13	0.46	73	112
Pumpkinseed	0.20	0.01	8	0.29	94	125
Cutthroat trout	0.39	0.03	4	0.14	120	270

Swingle (1950), developed a useful ratio that is based on available biomass of predators and prey. This index states that for predators to be in balance with prey, the ratio of their biomass should be between 1:3 and 1:6 (predator biomass **:** prey biomass). Based on this year's sampling, the predator - prey biomass ratio for Silver Lake is 3:1 for spring 2000 and 2:1 for fall 2000, drastically higher than what is considered healthy. We excluded large carp and suckers when calculating this ratio, though smaller individuals of these species could have been included.

Catch per unit of effort (CPUE) can be used as an index of abundance. Also, when viewed with a confidence interval, it can be used to measure the homogeneity of the distribution of fish around the lake. Table 4 shows the CPUE of our spring 2000 sample by species and gear type.

Table 5 shows the same data from our fall 2000 sample from electrofishing. Comparisons cannot be made between spring and fall data because of differences in fish distribution between seasons.

Table 4. Catch per unit of effort by gear type during the spring survey of Silver Lake, Cowlitz County.

	Electrofishing			Gill Netting			Fyke Netting		
Species	**(#/hour)**	**80% CI**	**Sample Sites**	**#/net night**	**80% CI**	**# net nights**	**#/net night**	**80% CI**	**# net night**
Bluegill	45.31	11.34	58	0.58	0.34	24	0.42	0.40	24
Brown bullhead	30.88	5.30	58	1.46	0.63	24	3.08	1.92	24
Largescale sucker	13.08	3.29	58	4.83	0.84	24	0.00	0.18	24
Grass carp	12.48	2.18	58	0.13	0.20	24	—	—	24
Largemouth bass	10.86	2.19	58	0.00	0.07	24	0.00	0.05	24
Black crappie	9.82	3.05	58	2.50	1.25	24	2.46	1.30	24
Yellow bullhead	2.76	1.11	58	0.88	1.03	24	0.08	0.47	24
Common carp	2.68	0.68	58	0.38	0.29	24	—	—	24
Sculpin, Unknown	1.34	0.50	58	—	—	24	—	—	24
Yellow perch	1.03	0.38	58	1.00	0.07	24	—	—	24
Warmouth	0.31	0.23	58	0.17	0.23	24	—	—	24
Pumpkinseed	0.31	0.22	58	—	—	24	0.13	0.15	24
Rainbow trout	0.10	0.13	58	0.54	0.40	24	—	—	24
White crappie	0.00	0.00	58	—	—	24	0.04	0.09	24

* CPUE of LMB (>=0 mm) = 180.35 (+/- 36.8)

Table 5. Catch per unit of effort (fish/hour) for the fall 2000 electrofishing sample of Silver Lake, Cowlitz County.

	Electrofishing			Gill Netting			Fyke Netting		
Species	**(#/hour)**	**80% CI**	**Sample Sites**	**#/net night**	**80% CI**	**# net nights**	**#/net night**	**80% CI**	**# net night**
Bluegill	23.28	14.36	9	—	—	—	—	—	—
Largemouth bass*	19.86	8.98	9	—	—	—	—	—	—
Yellow perch	12.00	5.73	9	—	—	—	—	—	—
Largescale sucker	4.67	3.08	9	—	—	—	—	—	—
Grass carp	4.67	3.57	9	—	—	—	—	—	—
Black crappie	3.33	3.42	9	—	—	—	—	—	—
Brown bullhead	3.32	2.60	9	—	—	—	—	—	—
Warmouth	1.98	1.81	9	—	—	—	—	—	—
Pumpkinseed	0.67	0.85	9	—	—	—	—	—	—
Common carp	0.67	0.85	9	—	—	—	—	—	—
White crappie	0.67	0.85	9	—	—	—	—	—	—
Sculpin	0.66	0.85	9	—	—	—	—	—	—
Rainbow trout	0.66	0.85	9	—	—	—	—	—	—

CPUE of all largemouth bass (>=0 mm) = 21.6 (80% ci 2.8)

Stock density indices (Tables 6 and 7) are used to determine the "balance" of a fish population. These indices tell a manager the proportions of big fish and small fish in the population, and help to determine if the predators and prey are in balance with each other.

Table 6. Stock density indices, by gear type and species, for the spring 2000 sample at Silver Lake, Cowlitz County.

	# Stock	Quality		Preferred		Memorable		Trophy	
Species	**Length**	**PSD**	**80% CI**	**RSD-P**	**80% CI**	**RSD-M**	**80% CI**	**RSD-T**	**80% CI**
Electrofishing									
Bluegill	441	24	3	1	1	0	0	0	0
Brown bullhead	301	100	0	94	2	1	1	0	0
Largemouth bass	106	92	3	58	6	5	3	0	0
Black crappie	96	16	5	11	4	1	1	0	0
Yellow bullhead	27	96	5	37	12	0	0	0	0
Common carp	26	96	5	88	8	69	12	4	5
Yellow perch	10	0	0	0	0	0	0	0	0
Warmouth	3	33	35	0	0	0	0	0	0
Pumpkinseed	3	0	0	0	0	0	0	0	0
Gill Net									
Black crappie	102	7	3	5	3	0	0	0	0
Brown bullhead	40	95	4	85	7	8	5	0	0
Yellow bullhead	38	71	9	26	9	21	8	0	0
Rainbow trout	30	37	11	0	0	0	0	0	0
Bluegill	24	13	9	0	0	0	0	0	0
Common carp	18	100	0	100	0	72	14	0	0
Warmouth	9	33	20	11	13	11	13	0	0
Largemouth bass	2	100	0	0	0	0	0	0	0
Yellow perch	2	0	0	0	0	0	0	0	0
Fyke Net									
Brown bullhead	138	100	0	76	5	1	1	0	0
Black crappie	76	8	4	1	2	0	0	0	0
Bluegill	23	30	12	4	5	0	0	0	0
Yellow bullhead	15	100	0	47	17	20	13	7	8
Pumpkinseed	5	0	0	0	0	0	0	0	0
White crappie	3	0	0	0	0	0	0	0	0

Table 7. Stock density indices, by species, for the fall 2000 electrofishing survey Silver Lake, Cowlitz County.

Species	# Stock Length	Quality		Preferred		Memorable		Trophy	
		PSD	80% CI	RSD-P	80% CI	RSD-M	80% CI	RSD-T	80% CI
Electrofishing									
Bluegill	35	31	10	0	0	0	0	0	0
Largemouth bass	30	10	7	7	6	3	4	0	0
Yellow perch	18	0	0	0	0	0	0	0	0
Black crappie	5	40	28	0	0	0	0	0	0
Brown bullhead	5	60	28	0	0	0	0	0	0
Warmouth	3	33	35	0	0	0	0	0	0

Proportional stock densities (PSD's) that are close to "100" reflect a population that has a high abundance of large fish, and a much lower abundance of mid-sized fish. This seems to be the case for the fish community at Silver Lake. For example, a largemouth bass PSD in the range of 40-70 together with a prey PSD of 20-60 would be a target range to hit when managing a lake for a balanced bass population. This would mean that you would have, proportionally, an adequate number of mid-sized bass to larger bass. For a full discussion of PSD's and RSD's, review Gablehouse (1984) or Anderson and Neumann (1996).

Largemouth bass PSD's for Silver Lake definitely show a strong seasonal trend. Spring PSD's can be artificially high due to the higher abundance of larger fish in shallow during spawning time. These fish displace some smaller bass during the spring, and then move back into deeper water during late spring and early summer.

One can determine an average PSD for all prey species together by calculating a weighted mean, weighting PSD by the number of stock length fish (Goedde and Coble 1981). This gives a prey PSD of 22 for both the spring and fall 2000 surveys. This is on the low side of what we would want to maintain a balanced bass and prey community. Using PSD's together with Swingle's biomass ratio, you can see that Silver Lake is far from being in a balanced bass/panfish state.

Summary by Species

A total of 15 species of fish were encountered while sampling Silver Lake during the spring and fall of 2000. With the exception of grass carp (*Ctenopharyngodon idella*), there have been no new species added to the lake. Other species include: bluegill (*Lepomis macrochirus*), brown bullhead (*Ameiurus nebulosus*), yellow perch (*Perca flavescens*), black crappie (*Pomoxis nigromaculatus*), largescale sucker (*Catostomus macrocheilus*), largemouth bass (*Micropterus salmoides*), grass carp (*Ctenopharyngodon idella*), rainbow trout (*Onchorynchus mykiss*), yellow bullhead (*Ameiurus natalis*), common carp (*Cyprinus carpio*), white crappie (*Pomoxis annularis*), warmouth (*Lepomis gulosus*), sculpin (family Cottidae), pumpkinseed (*Lepomis* *gibbosus*) and cutthroat trout (*Onchorynchus clarki*). These species are listed in decreasing number of abundance from the spring 2000 sample.

Lepomis macrochirus, bluegill

Bluegill were the most abundant fish captured by number (Table 3) during the spring 2000 sample. During the fall sample, they were the fifth abundant by number (Table 4). This difference in abundance can be contributed to seasonal variation in species location.

Table 8 shows the back calculated lengths at age for bluegill. Growth was pretty comparable to the state average for bluegill, although growth for the first two age classes was higher than normal. Few fish were measured to be age one. Most of this age class was probably consumed during the drawdown. Warmer than normal water resulted in better than average growth for the smaller fish that were left.

Table 8. Back calculated length at age (Fraser-Lee) for Silver Lake bluegill from spring 2000.

		Mean Length at Age (mm)							
Year class	**n**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
1999	2	**62**							
1998	42	38	**85**						
1997	90	36	71	**134**					
1996	8	35	80	149	**178**				
1995	6	37	80	135	168	**183**			
1994	5	37	78	139	160	176	**186**		
1993	3	37	67	131	168	187	196	**202**	
1992	2	38	91	133	148	179	190	200	**204**
Fraser-Lee	158	37	76	135	168	181	190	201	204
Direct		20	67	133	166	180	189	201	204
State Avg (Direct)		37	97	132	148	170	201	196	

Figure 1 shows the length frequency distribution of bluegill in our spring sample. This figure clearly shows the missing first age class. The length frequency distribution from our fall 2000 sample pretty closely resembled, and is not shown. The relative weight distribution (W_r) (Figure 2) of bluegill from our spring 2000 sample shows a wide range of condition. Overall, W_r's are slightly higher than 100, and decrease slightly with increasing length. Mueller (1998) reported relative weights to be lower than 100 on average.

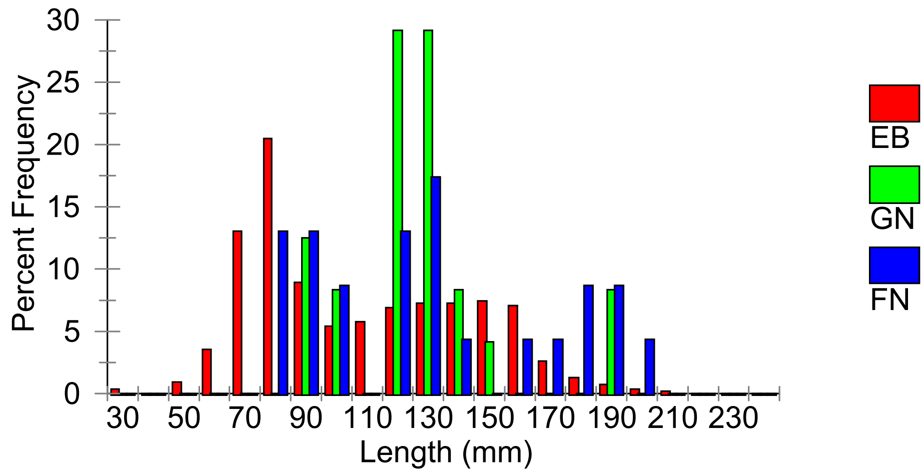

Figure 1. Length frequency distribution of bluegill, by gear type, for the spring 2000 fish community sample at Silver Lake, Cowlitz County.

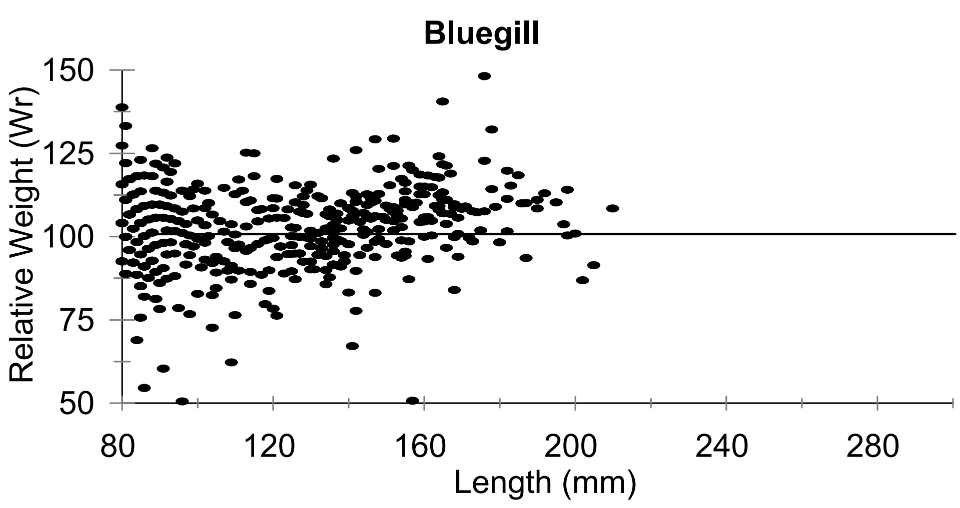

Figure 2. Relative weights of bluegill from the spring sample of Silver Lake, Cowlitz County.

Ameiurus nebulosus, brown bullhead

Brown bullhead were the second most abundant fish during the spring survey, but were scarce during the fall survey (Tables 3 and 4). The spring survey consisted of mainly large fish that were in close to shore for spawning purposes. These fish moved off shore during the summer and fall seasons. No bullhead spines were collected for aging purposes.

Figure 3 shows the length frequency distribution of the brown bullhead catch during our spring 2000 survey. Our sample was dominated by larger fish that were in close to shore, probably in preparation for spawning. During our fall 2000 sample, we did not capture nearly the same number of brown bullhead, but the bimodal peaks of the sample centered around 130mm and 210mm. Together with the two peaks on Figure 3 (around 310 and 370), we can estimate that there are at least four age classes of brown bullhead. The lack of smaller fish in the sample may partially be due to predation that occurred during the drawdown period, or due to displacement by larger, spawning fish.

Relative weights of brown bullhead are generally centered around, but average slightly lower than 100 showing in general a good condition (Figure 4).

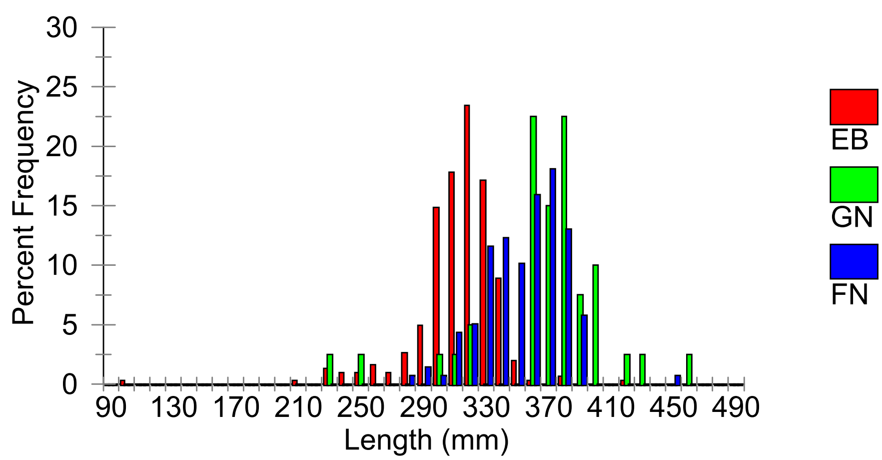

Figure 3. Length frequency distribution, by ger type, of brown bullhead captured during the spring 2000 population sample at Silver Lake, Cowlitz County.

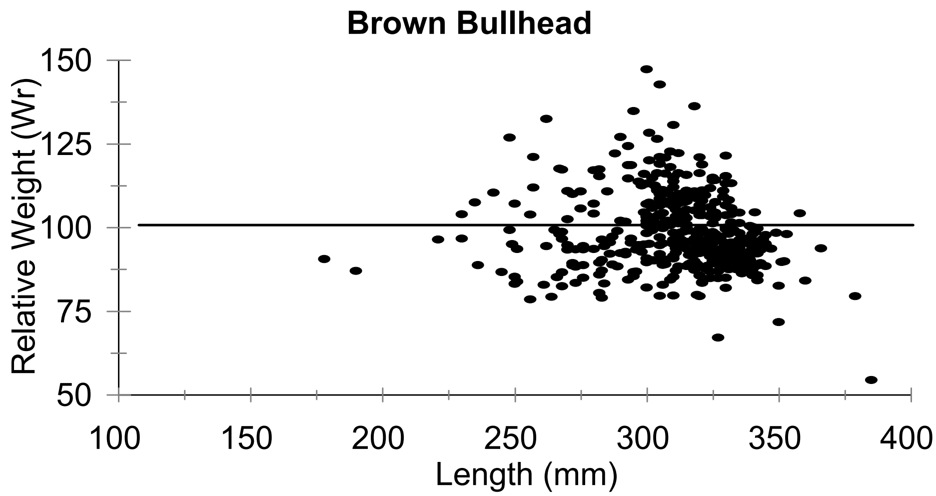

Figure 4. Relative weight distribution of brown bullhead captured during the spring 2000 sample at Silver Lake, Cowlitz County.

Perca flavescens, yellow perch

Yellow perch were, previously, the most abundant fish by number in Silver Lake (Mueller 1998). Yellow perch were the third most abundant in the spring (Table 3) and the second most abundant in the fall (Table 4) of 2000. No young of year fish were captured during our fall survey.

Back calculated length at age of yellow perch (Table 9) shows that there were basically two age classes of fish found during our sampling. These fish are growing faster than average for western Washington, but there were no large fish in the sample. Mueller (1998) showed the largest perch to be around 224 mm and approximately five years old. Our largest yellow perch was 192 mm.

Table 9. Back calculated age and growth of yellow perch from the spring 2000 sample of Silver Lake, Cowlitz County.

		Mean Length at Age (mm)	
Year Class	**n**	**I**	**II**
1999	53	**92**	
1998	9	69	**152**
Fraser-Lee		89	152
Direct		83	150
State Avg (Direct)		60	120

Figure 5 below represents the length frequency distribution of yellow perch during our spring survey. The large peak corresponds to age one fish, and the small peak to the right represents age two fish. No older fish were encountered, and age two fish were not extremely abundant. Yellow perch were probably hit pretty hard during the summer drawdown, and most age classes suffered. The length frequency distribution of the fall 2000 survey closely resembled the peaks of Figure 5.

As is typical for yellow perch in western Washington, relative weights are below 100 (Figure 6). This shows that yellow perch are either not foraging efficiently, or are not very competitive at foraging with other species. This data compares well with previous years.

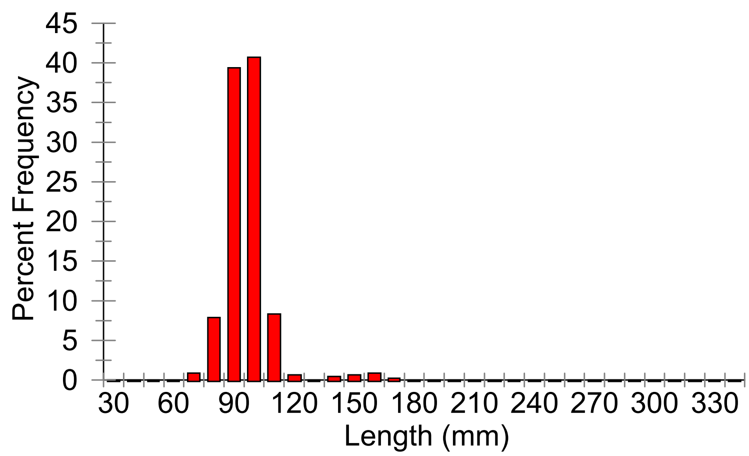

Figure 5. Length frequency distribution of yellow perch caught by electrofishing during the spring 2000 sample at Silver Lake, Cowlitz County.

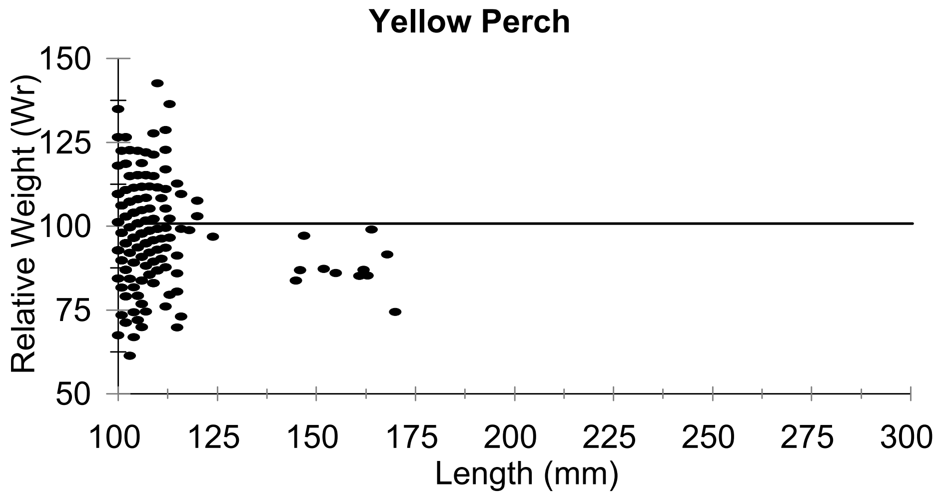

Figure 6. Relative weight distribution of yellow perch captured during the spring 2000 sample of Silver Lake, Cowlitz County.

Pomoxis nigromaculatus, black crappie

Black crappie were the fourth most abundant (Table 3) species in our spring sample, and the third in the fall (Table 4). Our sampling does not always reflect the true relative abundance and size structure of open water species like crappie, even though we use multiple gear types to minimize our sampling biases.

Back calculated length at age for black crappie shows that Silver Lake crappie are growing faster than average for western Washington (Table 10). The oldest fish aged was six years old.

Table 10. Back calculated length at age for black crappie captured during the spring 2000 sample at Silver Lake, Cowlitz County.

		Mean Length at Age (mm)					
Year Class	**n**	**I**	**II**	**III**	**IV**	**V**	**VI**
1999	24	76					
1998	53	66	150				
1997	5	69	141	207			
1996	4	69	137	217	262		
1995	11	72	146	213	259	277	
1994	2	65	133	202	251	280	293
Fraser-Lee	99	69	147	212	259	277	293
Direct		49	142	204	257	277	293
State Avg (Direct)		46	111	157	183	220	224

The length frequency histogram (Figure 7) clearly mimics the back calculated length at age. The peak furthest to the right represents age 4 through age 6 fish. Also, a clear gear related bias is shown. Electrofishing captures the smaller fish, while gill netting and fyke netting captures the larger fish that are further from shore.

Relative weights of black crappie (Figure 8) are below 100, on average. This is pretty typical for western Washington crappie populations. In their native range, larger crappie usually switch over to a mainly piscivorus diet. Here in Washington, crappie mainly consume zooplankton and aquatic invertebrates. Other reasons for a low W_r would be increased competition due to a lack of prey.

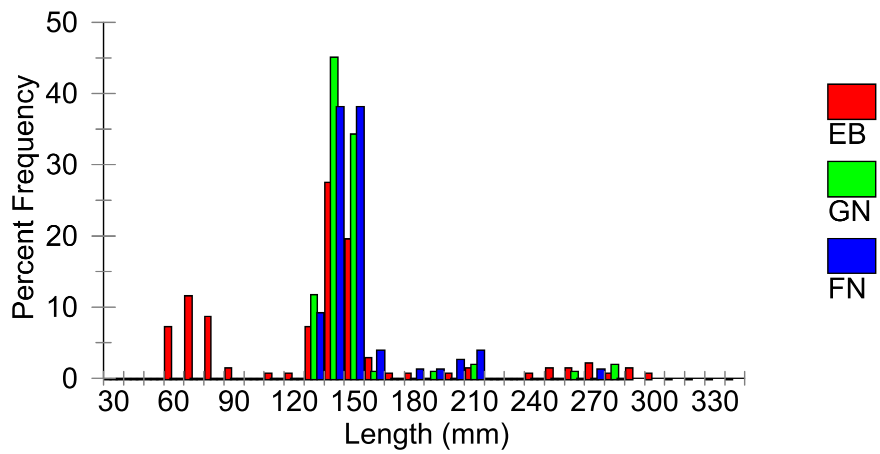

Figure 7. Length frequency distribution (by gear type) of black crappie from our spring 2000 sample of Silver Lake, Cowlitz County.

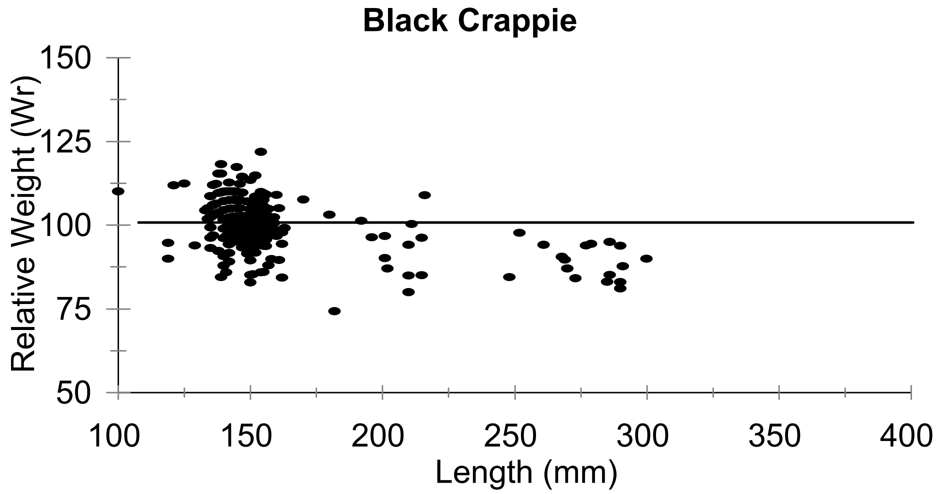

Figure 8. Relative weight distribution of black crappie from the spring 2000 sample of Silver Lake, Cowlitz County.

Catostomus macrocheilus, largescale sucker

Largescale suckers account for roughly 20% of the total biomass in Silver Lake (Tables 3 and 4). Most of this biomass is unavailable to predators, as largescale suckers quickly grow to a large size. Biomass estimates for largescale suckers from the fall survey should be considered conservative. Gill nets appear to be a more effective sampling technique for suckers, and none were used during our fall sample. No largescale suckers were aged.

Though members of the family Catostomidae are utilized as food and for sport in other parts of the country, they are underutilized for these purposes here in Washington.

Micropterus salmoides, largemouth bass

Largemouth bass represent 10-15% of the total biomass of our sampling in Silver Lake during the spring and fall of 2000 (Tables 3 and 4). The total biomass of largemouth bass is greater than the total biomass of all of the prey species combined. This suggests an unhealthy fish community when predator biomass is greater than prey biomass.

Back calculated length at age (Table 11) for largemouth bass is pretty surprising. Largemouth bass from Silver Lake are about two years ahead of what is average for western Washington. Bass reach 305mm (12") in their third year, and reach the legal length of 355mm (14") late in their fourth year. 1999 growth is higher than average across years.

Table 11. Back calculated length at age for largemouth bass sampled spring 2000 from Silver Lake, Cowlitz County.

Year Class	n	Mean Length at Age (mm) I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
1999	37	**83**													
1998	3	73	**197**												
1997	15	80	200	**295**											
1996	17	70	190	294	**353**										
1995	20	87	173	284	340	**379**									
1994	9	75	209	283	347	381	**407**								
1993	3	73	201	293	353	392	420	**437**							
1992	5	75	163	257	326	372	402	430	**447**						
1991	4	84	168	268	322	362	406	439	466	**485**					
1990	11	63	151	246	294	336	371	400	430	448	**463**				
1989	8	80	162	245	290	323	360	398	432	450	465	**477**			
1988	2	62	162	229	286	323	350	386	410	439	462	481	**496**		
1987	2	86	174	287	357	386	410	450	473	493	515	530	543	**552**	
1986	2	59	98	191	242	284	315	342	373	417	438	455	472	488	**501**
Fraser-Lee	138	78	179	275	328	360	384	409	435	454	465	482	504	520	501
Direct		65	168	269	324	357	381	407	433	453	465	481	503	520	501
State Avg		60	146	222	261	289	319	368	396	440	485	472	496		

The length frequency distribution (Figure 9) shows that there is a missing age class. The 1998 year class was probably consumed (as one year old fish) during the drawdown period. These fish are clearly missing from our sample. About half of the total number of bass sampled were one year old fish. If two year old fish were present, this would represent a very healthy distribution, although density is somewhat low. The high springtime PSD of 92, again, shows that the bass population has a lot of larger fish and few stock sized fish. Two year old bass would represent the majority of our stock sized fish.

The relative weight distribution (Figure 10) shows that largemouth bass are pretty healthy. On average, W_r's tend to be above 100, and increase with increasing length. The overabundance of prey during the drawdown period was a benefit to the largemouth bass community, and probably led to increased biomass.

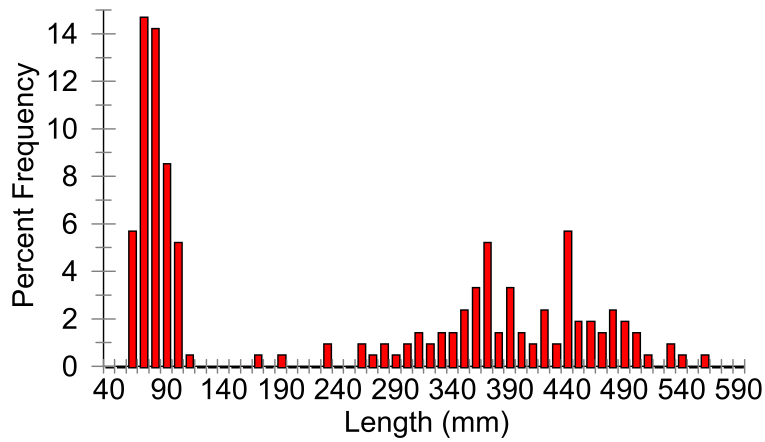

Figure 9. Length frequency distribution of largemouth bass from the spring 2000 sample of Silver Lake, Cowlitz County.

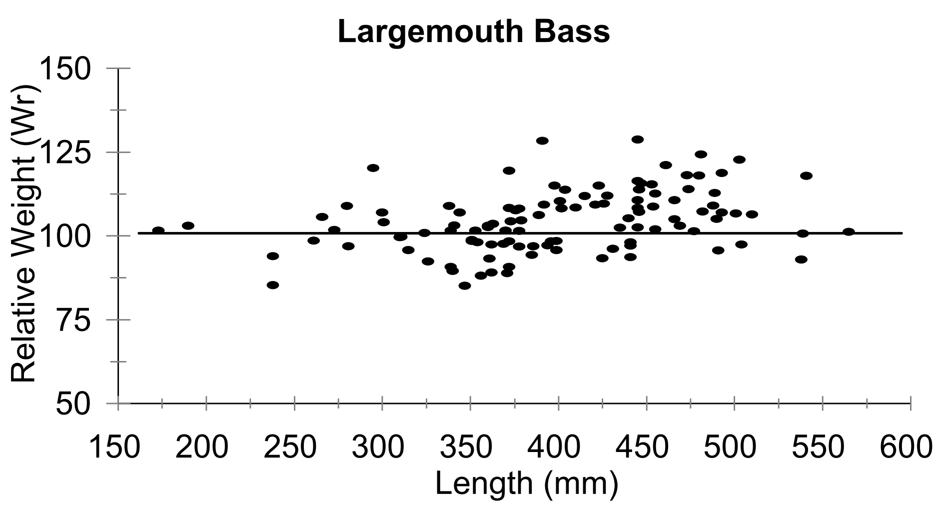

Figure 10. Relative weight distribution of largemouth bass from the spring 2000 sample of Silver Lake, Cowlitz County.

Ctenopharyngodon idella, grass carp

Grass carp account for 30 - 50% of the total biomass in Silver Lake (Tables 3 and 4). Grass carp catch per effort has not changed since the 1997 survey. Although condition factors have decreased slightly over time (Table 12), it must be noted that there is a size related bias when using Fulton-type condition factors; as fish get longer, the condition factor gets higher, even if overall condition decreased (Anderson and Neumann 1996). These types of condition factors are really only useful when comparing individuals of equal size.

Table 12. Fulton-type condition factors (C) calculated for grass carp, compared to historical data from Silver Lake. Historical data taken from KCM (1998).

	1994	1995	1996	2000
Length (mm)	575	616	638	667
Weight (g)	2,780	2,990	3,280	3,872
Condition (C)	5.18	4.6	4.55	4.69

The only time there is an abundance of food is during the spring as the yellow pond lily (*Nuphar polysepalum*) is sending up new shoots. Grass carp have been observed coming slightly out of the water to eat overhanging vegetation. Additionally, they are being fed grass clippings by residents along the lake shore.

There was probably a loss of some grass carp during the dam breech, as some were observed swimming in outlet creek during the summer months, but the total number lost downstream is uncertain. Also, overall mortality rates of the grass carp are unknown at this time.

Ameiurus natalis, yellow bullhead

Yellow bullhead were not an abundant fish during the spring survey, and did not exist in our fall survey (Tables 3 & 4). The length frequency of our catch (Figure 11) shows that there is a good size range of yellow bullhead, and although no fish were aged, it is probable that the larger fish are around 5-7 years old. Calculated relative weights (Figure 12) shows that yellow bullhead are in good condition, and are not having a hard time finding food.

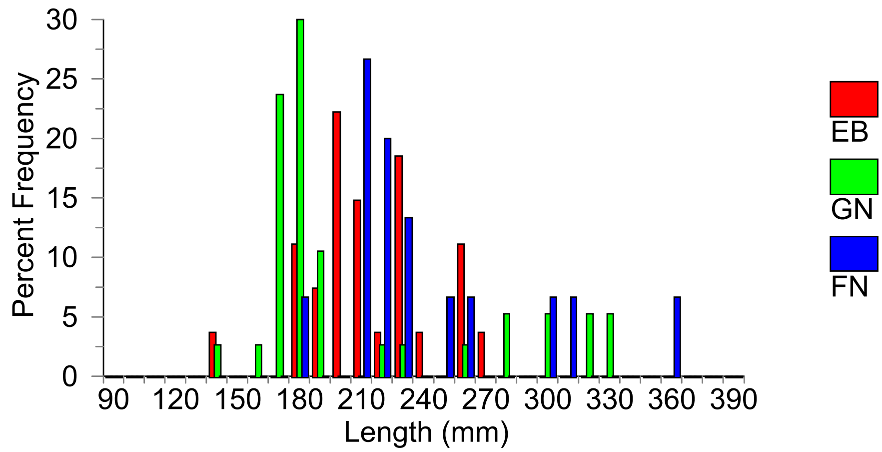

Figure 11. Length frequency distribution, by gear type**,** for yellow bullhead sampled from Silver Lake, Cowlitz County, during spring 2000.

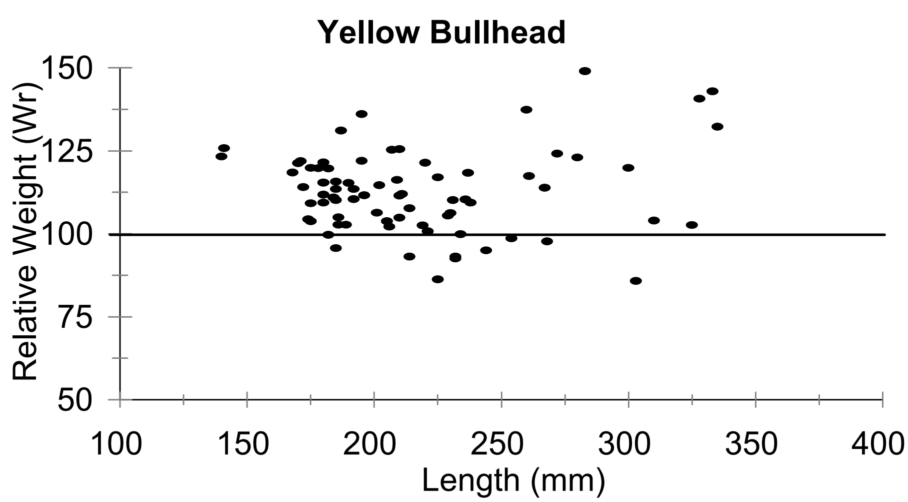

Figure 12. Relative weight distribution of yellow bullhead from the spring 2000 sample of Silver Lake, Cowlitz County.

Oncorhynchus mykiss, rainbow trout

Rainbow trout are planted by WDFW to support a put-and-take trout fishery. On average, about 11,500 legal sized rainbow trout are planted yearly to support this fishery. The few fish that do not get harvested may holdover to the following year. These fish that holdover have the opportunity to grow well over the winter, and attain sizes of up to 18 inches.

Cyprinus carpio, common carp

Together, grass carp, largescale sucker and common carp account for nearly 75% of the total biomass in Silver Lake. Most of this biomass is unavailable to predator species, as these fish are relatively fast growing.

Many of the carp sampled were of the “mirror carp” variety; a genetic trait of the common carp where the fish has few, large scales, and large patches of bare skin.

Pomoxis annularis, white crappie

White crappie were not abundant in our spring or fall samples (Tables 3 and 4) and were less abundant than black crappie by about a factor of 10. Because behavior is similar between the two crappie species, we can probably lump their data together and treat them as one. This is done in many southern states, as the two crappie species can be hard to differentiate.

Back calculated length at age for white crappie (Table 13) shows that they are growing slightly faster than black crappie. Usually, white crappie have been known to perform better than black crappie in turbid environments. This is the case at Silver Lake, but their total abundance is less than that of black crappie. There is no average developed for western Washington.

Table 13. Back calculated length at age for white crappie, Silver Lake 2000.

		Mean Length at Age (mm)	
Year Class	**n**	**I**	**II**
1999	12	**87**	
1998	4	69	**173**
Fraser-Lee		82	173
Direct		75	173

Lepomis gulosus, warmouth

Warmouth were not extremely abundant in our spring or fall samples. Back calculated length at age (Table 14) shows that warmouth are growing above average for western Washington. A state record sized warmouth was captured during our spring sample, and released live back into the lake.

Table 14. Back calculated length at age for warmouth from Silver Lake, Cowlitz County, spring 2001 survey.

		Mean Length at Age (mm)									
Year Class	**n**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
1999	0										
1998	2	48	**103**								
1997	3	40	72	**124**							
1996	3	41	75	124	**153**						
1995	1	38	71	100	113	**135**					
1994	0										
1993	0										
1992	0										
1991	0										
1990	1	41	57	79	103	146	204	236	252	265	**275**
Fraser-Lee		42	77	115	135	141	204	236	252	265	275
Direct		25	67	111	131	136	198	233	251	264	275
State Avg (Direct)		23	58	89	116	131	135	155	171		

Cottidae, sculpin

Sculpin are probably more abundant than our sampling efforts show (Tables 3 and 4). The combination of muddy substrate and murky water conditions decreases the capture efficiency for these species when electrofishing. No sculpin were aged.

Lepomis gibbosus, pumpkinseed

Pumpkinseed were not very abundant in our sampling. Of the fish sampled, the mean back calculated length at age reflects above average growth (Tables 3 and 4).

Oncorhynchus clarki, cutthroat trout

Cutthroat trout are not planted by WDFW into Silver Lake. These fish are naturally produced in the tributaries to Silver Lake, and rear in the lake itself.

Discussion

The purpose of this year's sampling at Silver Lake was to determine what had happened to the warmwater fish community during the extended drawdown period during 1999. A secondary purpose was to determine future sampling needs, and devise a plan to monitor the rebuilding of the lake fish community.

The 1999 dam breach at Silver Lake clearly had an impact on the fish community. Low water levels concentrated the fish into a smaller area, increasing prey availability to predators. The result was that the smaller, younger age classes of most fish species were consumed by larger predators (largemouth bass). This can be seen most effectively by viewing the largemouth bass length frequency histogram (Figure 9); the whole 1998 year class is missing (fish that are one year old during 1999). This can also be seen by the lack of larger yellow perch (age 2+) reported by Mueller (1998), and the low overall abundance of most fish species. Controlled lake level drawdowns have been used by agencies for both fish population and aquatic macrophyte management (Ploskey 1986). Large drawdowns that concentrate the fish community for more than two months can greatly increase predator foraging efficiency, which will initially result in increased growth rates. After the initial drawdown, growth rates may decrease for a few years due to the decreased abundance of prey. This year's growth rates were the highest reported from Silver Lake thus far. Now, we expect growth rates to slow down for a few years until the prey base is built back up again.

Future Sampling

Our plans for the upcoming sampling seasons are to continue spring and fall sampling for at least the next two years, then determine further sampling needs at that time. An angler creel survey will help us track trends in angler effort and catch of bass and panfish species. These data can be compared to the pervious creel surveys conducted before and after grass carp were introduced.

No supplemental stocking is recommended at this time. Warmwater fish populations are extremely resilient to major events like the one that happened here. Although it will probably take a few years for the fish community to rebuild itself to levels seen during the 1997 survey, missing year classes will eventually work their way through the population. We will be monitoring the rebuilding of the entire fish community over the next few years by continued spring and fall electrofishing.

The current state and size of the grass carp population is not well understood. It is known that grass carp condition is slowly on the decline (Table 13), but what they are eating is not known. Though CPUE has remained relatively constant, it is not known how many grass carp are left in the population. It is possible that an estimate of the current population size can be made through either a mark-recapture program, or through a Zippin-type 3-pass depletion estimate. Confidence intervals may be wide on such estimates, but it is possible they may provide a little insight to the current population density. Unfortunately, without knowledge of how many fish escaped during the dam breach, total mortality rates would be impossible to calculate with any confidence.

Vegetation surveys should also be done, using the same vegetation plots used by KCM if possible. Re-growth of vegetation is probably the single most important factor in the rebuilding of the fish community in Silver Lake.

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.

Bortleson, G. C., N.P. Dion, and J. B. McConnell. 1976. Reconaissance Data on Lakes in Washington, Volume 4, Clark, Grays Harbor, Lewis, Pacific, Skamania, and Thurston Counties. State of Washington Department of Ecology, Water-Supply Bulletin 43, Vol. 4.

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.

DeVries, D., and R. Frie. 1996. Determination of Age and Growth. Pages 483-512 *in* Murphy, B. R., and D. W. Willis (eds.), Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, MD.

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, 173 p.

Gablehouse, D. W. 1984. A Length-Categorization System to Assess Fish Stocks. North American Journal of Fisheries Management 4:273-285.

Gablehouse, D. W. 1991. Seasonal Changes in Body Condition of White Crappies and Relations to Length and Growth in Melvern Reservoir, Kansas. North American Journal of Fisheries Management 11:50-56.

Goedde, L., and D. Cobl. 1981. Effects of angling on a previously fished and an unfished warmwater fish community in two Wisconsin lakes. Transactions of the American Fisheries Society 110:594-603.

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

Guy, C. S., and D. W. Willis. 1991. Evaluation of Largemouth Bass - Yellow Perch Communities in Small South Dakota Impoundments. North American Journal of Fisheries Management 11:43-49.

KCM. 1998. Silver Lake Phase II Restoration Monitoring - Final report. KCM, Inc., Seattle, WA.

Lucas, B. 1986. Evaluation of the 14-inch minimum size limit on Silver Lake. Washington Department of Game, Fishery Management Report 86-19, 41 pp.

Murphy, B. R., and D. W. Willis. 1991. Application of relative weight (*Wr*) 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.

Mueller, K. 1998. 1997 Silver Lake Survey: The forage fish community after removal of aquatic vegetation by grass carp. Washington Department of Fish and Wildlife. 32pp.

Ploskey, G. R. 1986. Effects of water-level changes on reservoir ecosystems, with implications for fisheries management. Pages 86-97 *in* G. E. Hall and M. J. Van Den Avyle, editors. Reservoir Fisheries Management: Strategies for the 80's. Reservoir Committee, Southern Division American Fisheries Society, Bethesda, Maryland. 1986.

Ricker, W. E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations Fisheries Research Board of Canada Bulletin 191.

Swingle, H. S. 1950. Relationships and dynamics of balanced and unbalanced fish populations. Auburn University, Alabama Agricultural Experiment Station Bulletin No 274, 74 p.

Westerdahl , H. E., K. D. Getsinger, eds. 1988. Aquatic Plant Identification and Herbicide Use Guide; Volume 1: Aquatic Herbicides and Application Equipment. Technical Report A-88-9, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Wetzel, R. G. 1983. Limnology, 2nd edition. Saunders College Publishing, Philadelphia, PA.

Willis, D. W., B. R. Murphy, 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

Table A1. Length categories that have been proposed for various fish species. Measurements are total lengths (updated from Neumann and Anderson 1996).

	Category									
	Stock		Quality		Preferred		Memorable		Trophy	
	(in)	(cm)	(in)	(cm)	(in)	(cm)	(in)	(cm)	(in)	(cm)
Black bullhead	6	15	9	23	12	30	15	38	18	46
Black crappie	5	13	8	20	10	25	12	30	15	38
Bluegill	3	8	6	15	8	20	10	25	12	30
Brook trout	5	13	8	20						
Brown bullhead	5	13	8	20	11	28	14	36	17	43
Brown trout	6	15	9	23	12	30	15	38	18	46
Burbot	8	20	15	38	21	53	26	67	32	82
Channel catfish	11	28	16	41	24	61	28	71	36	91
Common carp	11	28	16	41	21	53	26	66	33	84
Cutthroat trout	8	20	14	35	18	45	24	60	30	75
Flathead catfish	11	28	16	41	24	61	28	71	36	91
Green sunfish	3	8	6	15	8	20	10	25	12	30
Largemouth bass	8	20	12	30	15	38	20	51	25	63
Pumpkinseed	3	8	6	15	8	20	10	25	12	30
Rainbow trout	10	25	16	40	20	50	26	65	31	80
Rock bass	4	10	7	18	9	23	11	28	13	33
Smallmouth bass	7	18	11	28	14	35	17	43	20	51
Walleye	10	25	15	38	20	51	25	63	30	76
Warmouth	3	8	6	15	8	20	10	25	12	30
White catfish	8	20	13	33	17	43	21	53	26	66
White crappie	5	13	8	20	10	25	12	30	15	38
Yellow bullhead	4	10	7	18	9	23	11	28	14	36
Yellow perch	5	13	8	20	10	23	12	30	15	38