2001 Beaver Lake Survey: The Warmwater Fish Community of a Lake Dominated by Non-game Fish and Aquatic Vegetation

by

Peter A. Verhey
Warmwater Fish Enhancement Program
Washington Department of Fish and Wildlife
P.O. Box 1100
La Conner, Washington 98257

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Abstract

The WDFW Warmwater Fish Enhancement Program conducted a stock assessment survey of the fish community in the littoral zone of Beaver Lake (Skagit County) in fall 2001. Fish were captured using boat electrofishing, gill netting and fyke netting. Of the 817 fish captured, 10 species were identified, including: largescale sucker; largemouth bass; brown bullhead; yellow perch; black crappie; peamouth; pumpkinseed; cutthroat trout; rainbow trout; and, sculpin. Largescale sucker contributed nearly 90% of the fish biomass sampled in the lake during our survey. The ecological significance of such a large population of largescale suckers is unclear, however, it is likely that their benthic feeding habits may, at times, disrupt centrarchid nests, particularly those of the smaller pumpkinseed. While yellow perch densities were relatively high, centrarchid densities were low. Dense beds of floating and submergent aquatic vegetation may have contributed to low catch rates by providing abundant cover during electrofishing. Largemouth bass were represented by individuals ranging in age from young-of-year to nine-years old. Of the stock-size bass sampled (11 fish >200mm), 55% were less than 300 mm (11.8 inches) and 36% were between 380 to 510 mm (15 - 20 inches). Stock density indices for largemouth bass, yellow perch, black crappie and pumpkinseed were similar to populations with predator/prey balance. However the lack of preferred-size prey species suggest more of a "big bass" scheme. The small population of black crappie surveyed exhibited higher than average catch rates and faster than average growth. Management options include: monitoring water quality; implementing vegetation and nutrient control; selective removal of largescale suckers; improvement of boat ramp and bank access; and conducting a creel survey.

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Introduction and Background

Beaver Lake (Figure 1) is a small (29.5 hectares), shallow (average depth 1.7 m) lake approximately 6 kilometers (4 miles) south of the City of Sedro Wooley in Skagit County, Washington.
The lake lies in a flat valley floor (elevation 9.1 m, above MSL) surrounded by agricultural pasture lands to the north and south, a nearly 70 m tall wooded hill to the west and the foothills of the Cascade Mountain Range to the east. Cultus Mountain, which stands 1,200 m high, is less than 7.5 kilometers east of the lake.

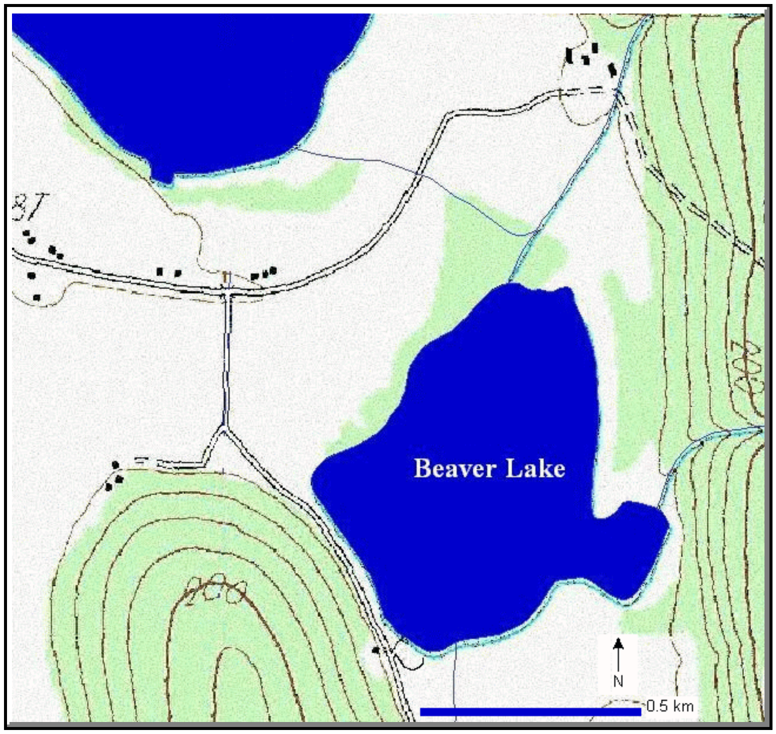

Figure 1. Topographic map of Beaver Lake (Skagit County) and surrounding area (USGS 1985).

Surface water flows into the lake from Fox Creek, which flows year round, and empties into the north end of the lake. Also, an unnamed intermittent creek empties into the east arm of the lake. Water from nearby Clear Lake (89 hectares, elevation 9.1 m) flows seasonally into Fox Creek approximately 90 meters upstream of Beaver Lake. The lake also is fed by surface runoff and groundwater flows. Surface water exits the lake to the south, through a drainage ditch to Turner Creek, then flows to Nookachamps Creek and eventually into the Skagit River.

Development around the lake is lacking. The nearshore habitat is characterized by abundant aquatic vegetation. Emergent aquatic vegetation grows unimpeded around the perimeter of the lake. Floating vegetation forms dense patches to depths of approximately 1.5 m. Submersed aquatic vegetation extends from the shoreline to the center of the lake, essentially forming one large littoral zone. The distribution of submersed vegetation is inhibited by shading from the floating vegetation, and by a few small subsurface springs emanating in the bottom of the lake.

WDFW maintains the only public access to the lake, which includes a gravel boat ramp and parking lot with concrete vault toilet. The access area is on the southwest side of the lake off Beaver Lake road and was donated to WDFW in 1954 by landowner Harley Hewitt. The deed, recorded in August 1954, includes 46 m of shoreline frontage and a total area of approximately 2.4 hectares.

Beaver Lake's main tributary, Fox Creek, supports cutthroat trout along its length. Coho salmon have been observed spawning in Fox Creek up to an anadromous barrier in the vicinity of the power transmission lines to the east of the lake (Kurt Buchanan, WDFW, personal communication).

It is not clear how much the lake was used by anglers prior to the donation of land for the public access area. However, the county road (Beaver Lake Rd) along the west side of the lake probably provided some access for shoreline anglers. Also, anglers and vacationers from the resort at nearby Clear Lake likely explored Beaver Lake using small boats or canoes. Anecdotal reports suggest that during the late 1800s, a channel between the two lakes had been dredged to transport logs from Beaver Lake to the mill works on Clear Lake. Using this channel, small boats would have been able to navigate between the lakes. However, numerous floods over the years have silted in the channel. Today, both the outlet of Clear Lake and the Beaver Lake inlet are barely discernable through the dense brush that covers these broad shallow water ways. A ditch has been dug to establish a channel between the lakes and minimize the flooding of adjacent agricultural lands during periods of high water. This ditch and the one dug to channelize Beaver Lake's outlet are cleaned approximately every 8-10 years to control local flooding, effectively resetting the lake level (Buchanan, WDFW, personal communiction). Flows from Clear Lake are intermittent because the level of the lake is usually below that of the outlet during dry months (WDFW, unpublished data).

Early management of Beaver Lake was driven by that of Clear Lake, a put-and-take trout fishery. In the 1930s, the Washington Department of Game (WDG) stocked trout fry extensively into Clear Lake. By 1950, WDG determined that trout fry survival was low enough to warrant treating the lake with rotenone, a plant derived piscicide, to rid it of undesirable and competitive fishes. Both Clear and Beaver Lakes were treated with the piscicide in the fall of 1950. The latter was treated because it was assumed to be the source of undesirable fishes that re-invaded Clear Lake during local flooding events. Following the 1950 rotenone treatments both lakes were restocked with trout fry. The lakes were retreated with rotenone every few years until 1965. Fish eradicated from the lake during these treatments included brown bullhead (*Ameiurus nebulosus*), suckers (*Catostomus* sp.), peamouth (*Mylocheilus caurinus*), threespine stickleback (*Gasterosteus aculeatus*), yellow perch (*Perca flavescens*), largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), and sculpin (*Cottus* sp.) (Table 1). After 1965, the agency discontinued rotenone treatments of the lakes and managed them for mixed-species, including persistent warmwater species and seasonally stocked fry and catchable-size rainbow trout. By 1982, the agency stopped stocking trout in Beaver lake, choosing instead to put catchable-size fish in Clear Lake only.

Table 1. Fish species composition changes at Beaver Lake (Skagit County) since 1937 (Washington Department of Fish and Wildlife, unpublished data).

Date	Sample method	Sample size (# fish)	Species composition by number
1937-1939	angling	12	75% bullhead catfish, 25% largemouth bass
1940-1949	angling	114	48% largemouth bass, 31% crappie, 19% yellow perch, 2% cutthroat trout
August, 1950	whole-lake rotenone	417,000	25% bullhead catfish, 18% stickleback, 13% sucker, 12% yellow perch, 11% largemouth bass, 10% peamouth, 8% crappie, 3% sculpin
1951, 1953	angling	57	44% rainbow trout, 35% smallmouth bass, 21% cutthroat trout
September, 1954	whole-lake rotenone	88,000	21% yellow perch, 17% bullhead catfish, 14% largemouth bass, 14% sucker, 14% stickleback, 11% peamouth, 5% sculpin, 3% cutthroat trout, 1% silver trout
1955-1959	angling	2,251	73% rainbow trout, 23% yellow perch, 3% cutthroat trout, 1% silver trout
August, 1959	whole-lake rotenone	71,000	28% yellow perch, 28% peamouth, 14% bullhead catfish, 14% largemouth bass, 14% sucker, 1% crappie, 1% sculpin
1960-1965	angling	2,215	99% rainbow trout, 1% yellow perch
October, 1965	whole-lake rotenone	46,200	44% yellow perch, 22% peamouth, 17% sucker, 11% crappie, 2% sculpin, 2% stickleback, 1% bullhead catfish, 1% largemouth bass
1966-1970	angling	3,286	93% rainbow trout, 4% cutthroat trout, 2% steelhead, 1% yellow perch
1971-1973, 1976	angling	1,398	65% rainbow trout, 23% yellow perch, 6% bullhead catfish, 3% cutthroat trout, 2% crappie, 1% largemouth bass
1978-1980	angling	240	65% rainbow trout, 23% yellow perch, 6% bullhead catfish, 3% cutthroat trout, 2% bluegill, 1% largemouth bass
1982, 1983, 1986	angling	38	68% yellow perch, 24% rainbow trout, 8% bluegill

Since the mid-1980s, Beaver Lake has supported a mixed species fishery for naturally reproducing cutthroat trout and persistent populations of warmwater species, including largemouth bass, black crappie, yellow perch and bullhead catfish. Beaver Lake's shallow basin, low altitude and relief, and undeveloped shoreline provides good habitat for warmwater species. Given the easy access and proximity to urban centers such as Mount Vernon and Sedro Wooley, the lake could provide the basis for a popular warmwater fishery . To help determine the status of this fishery and provide data for its effective management, the WDFW Warmwater Fish Enhancement Program conducted a stock assessment in fall 2001. We assessed species composition, relative 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 opportunities on the lake.

Materials and Methods

Beaver Lake was surveyed from September 17 to 20, 2001, by a 3-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 1.2 m diameter hoops with funnels attached to a 2.5 m cod end (6.4 mm nylon mesh). Attached to the mouth of the net were two 15.2 m wings and a 31 m lead.

Sampling locations were selected by dividing the shoreline into six consecutively numbered sections of about 400 m each (determined visually from a map) (Figure 2). This included the bleb, a shallow embayment on the southeast side of the lake, which we could not survey because the entrance was overgrown with vegetation. The five accessible sections were systematically sampled to maximize dispersion of gear types. Nighttime electrofishing was done along five sections, or 100% of the available shoreline. The shock boat was maneuvered through the shallows (depth range: 0.2 - 1.5 m), adjacent to the shoreline, at a rate of 18 m/minute. Gill nets and fyke nets were set overnight at three locations each (=3 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 45-90E angles from the lead. Sampling occurred during evening hours to maximize the type and number of fish captured.

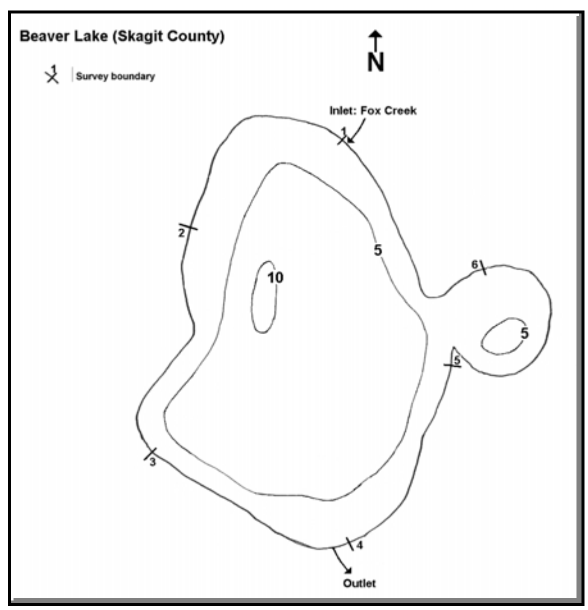

Figure 2. Map of Beaver Lake showing survey section boundaries and depth contours in feet.

All fish captured were identified to the species level. 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 ten 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 were estimated for fish not individually weighed using a 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). However, brown bullhead were not aged.

Water quality data was collected near the deepest part of the lake at 1-m intervals during midday September 19, 2001. Using a Hydrolab® probe and digital recorder, information was gathered on dissolved oxygen, temperature, pH, specific conductance and total dissolved solids. Shoreline characteristics, including littoral substrate types, and aquatic vegetation coverage were estimated visually.

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 maximize food resources to grow to harvestable-size and become abundant enough to feed predators. Predators must reproduce and grow to control overproduction of 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, catch rates, 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).

Species Composition

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.

Catch Per Unit Effort

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 (Table 3), 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 ± $t_{(\alpha, N\text{-}1)} \times SE$, where t = Student's t for α confidence level with N-1 degrees of freedom (two-tailed) and SE = standard error of the mean. Because it is standardized, CPUE is a useful way to compare relative abundance of stocks between lakes. Furthermore, the confidence intervals reflect the relative uniformity of species distributions throughout a given lake. CPUE values for Beaver Lake were compared to western Washington State averages for lakes sampled during the same time of year (Table 2 and Appendix A).

Table 2. Mean catch per unit effort (number of fish/hr 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 fall 1997 through fall 2000 (Appendix A).

Species	Gear Type					
	Electrofishing (fish/hr)	**# Lakes**	**Gill Netting (fish/hr)**	**# Lakes**	**Fyke Netting (fish/hr)**	**# Lakes**
Brown bullhead	6.3	18	9.2	11	9.6	8
Black crappie	10.1	8	1.9	8	16.5	3
Sculpin	20.7	15	0.4	5	0.4	5
Cutthroat trout	8.2	3	1.0	7	0.3	1
Largemouth bass	29.0	22	1.4	16	0.3	2
Largescale sucker	10.2	2	3.2	2		
Peamouth	43.6	4	18.5	4		
Pumpkinseed	77.1	18	2.8	17	2.8	9
Rainbow trout	5.0	6	1.0	12		
Yellow perch	92.4	17	13.9	19	2.5	4

Stock Density Indices

The proportional stock density (PSD) of each fish species was determined following procedures outlined in Anderson and Neumann (1996). PSD, calculated as the number of fish ≥ quality length/number of fish ≥ stock length × 100, is an index of length frequency data that gives the percentage of fish in a population that are of recreational value to anglers. 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 3). 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 3. Length categories for cold- and warmwater fish species used to calculate stock density indices (PSD and RSD; Gablehouse 1984) of fish captured at Beaver Lake (Skagit County) during fall 2001. Measurements are minimum total lengths (mm) for each category (Anderson and Neumann 1996.

Species	Minimum size (mm)				
	Stock	Quality	Preferred	Memorable	Trophy
Brown bullhead	130	200	280	360	430
Black crappie	130	200	250	300	380
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 4).

Table 4. 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

Scale samples from fish sampled at Beaver Lake were evaluated to determine age and growth characteristics using Lee's modification of the direct proportion method (Carlander 1982). The direct proportion method (Jearld 1983, Fletcher et al. 1993) back-calculates total length at annulus formation, L_n, using the formula, $L_n = (A \times TL)/S$, 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 Beaver Lake fish and the state average for the same species (Appendix B).

Length Frequency

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.

Relative Weight

A relative weight (W_r) index was used to evaluate the condition of all species except sculpin, largescale sucker, and peamouth. 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 Hyatt and Hubert (2000). 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

Water Quality and Habitat

On September 19, Beaver Lake was completely mixed with respect to dissolved oxygen, temperature, pH, conductance, and total dissolved solid (TDS) (Table 5). Dissolved oxygen levels in the lake, sampled at midday under cloudy skies, averaged 4.3 mg/L. If the dissolved oxygen levels in the lake are sustained at this level, slight to moderate production impairment for non-salmonid species may occur (Whitmore *et al*. 1975, Moore 1942). For salmonid species, moderate to severe impairment could be expected (Whitmore *et al*. 1975). However, given the extensive growth (and decomposition) of aquatic vegetation in the lake, it is likely that oxygen levels fluctuate diurnally as plant photosynthesis pumps oxygen into the water during the day and organic decomposition depletes it during hours of darkness. An average of hourly levels of dissolved oxygen taken for one or more days would be more useful in determining oxygen availability for fish in the lake. A black and white Secchi disk was used to characterize the water transparency and color at the sample site in Beaver Lake. Transparency was measured at 0.8 m and color was described as yellowish brown and tanic. Conductivity was 140 µS/cm throughout the water column and was within the optimum range (100-400 µS/cm) for electrofishing efficiency outlined by Willis (1998).

Table 5. Water quality at Beaver Lake (Skagit County). Samples were collected at noon September 19, 2001. DO = dissolved oxygen, TDS = total dissolved solids.

Secchi Depth	Depth (m)	DO (mg/L)	Temperature (EC)	pH	Conductance (FS/cm)	TDS (g/L)
	Surface	4.5	16.7	7.6	140.3	0.09
0.8 m	1	4.3	16.7	7.6	140.5	0.09
	2	4.2	16.7	7.5	140.4	0.09

Floating vegetation coverage within the survey sections ranged between 40 and 100% (visual estimate) (Table 6) and extended from the shoreline toward the center of the lake to a depth of approximately two meters. Together, emergent and floating vegetation covered approximately 12.1 ha around the fringe of the lake, leaving approximately 17.4 ha of open water. The small bleb, or embayment, on the east side of the lake (~2.8 ha) was completely inaccessible by boat because of emergent vegetation. Submergent vegetation coverage in the main body of the lake ranged from 50 to 80% and extended out into the center of the lake. Submersed plants were scarce under the floating vegetation, which effectively blocked out any sunlight. Nearshore bottom substrates were composed of mud (45-90%), sand (10-40%) and gravel (0-15%). Large woody debris, such as fallen trees and branches, was found only in the section of shoreline along Beaver Lake Road.

Table 6. Nearshore habitat characteristics of Beaver Lake during fall 2001. Values were derived from visual estimates made from the surface while traveling by boat along the shoreline of the lake.

Section #	Development	% Bulkhead	Mean # docks/100 m	% Emergent Vegetation	% Floating Veg.	% Submergent Veg.	Coarse, Woody Debris	% Silt	% Sand	% Gravel	% Cobble	% Bedrock
1	agricultural	0	0	100	80	50	none	80	20	0	0	0
2	agricultural	0	0	100	40	80	none	45	40	15	0	0
3	road	0	0	100	70	70	low	70	15	15	0	0
4	agricultural	0	0	100	100	60	none	80	10	10	0	0
5	natural/agricultural	0	0	100	100	70	none	90	10	0	0	0
6	natural	0	0	100	100	60	none	90	10	0	0	0

Species Composition

Ten species were identified from samples collected during our fall 2001 survey of Beaver Lake (Table 7 and Figure 3) Of the 817 fish examined, largescale sucker made up the bulk of the biomass accounting for 87% of the species composition by weight and 25% by number. Largemouth bass accounted for 5.5% by weight but nearly 42% by number, most of which were juvenile fish (n=306) less than 130 mm. Yellow perch were third most abundant contributing 20% to the species composition by number and 7.2% by weight and included juvenile fish. Black crappie contributed 7.5% by number and 1% by weight. A total of 20 brown bullhead were sampled and made up 2.5% of the species composition by number and 7.7% by weight. Pumpkinseed contributed 1.5% by number and less than 1% by weight. The remaining species, including peamouth, cutthroat trout, rainbow trout, and sculpin accounted for less than 1% by number and weight each.

Table 7. Species composition by weight (kg) and number of fish captured at Beaver Lake (Skagit County) during fall 2001.

Species	Species composition				Size range (mm TL)
	by weight		by number		
	(kg)	(%)	(#)	(%)	
Largescale Sucker (*Catostomus macrocheilus*)	203.3	87.36	204	24.97	168 - 568
Largemouth Bass (*Micropterus salmoides*)	10.4	4.48	341	41.74	49 - 485
Brown Bullhead (*Ameiurus nebulosus*)	7.7	3.30	20	2.45	225 - 345
Yellow Perch (*Perca flavescens*)	7.2	3.08	167	20.44	65 - 232
Black Crappie (*Pomoxis nigromaculatus*)	2.3	1.00	61	7.47	53 - 230
Peamouth (*Mylocheilus caurinus*)	0.7	0.29	6	0.73	179 - 270
Pumpkinseed (*Lepomis gibbosus*)	0.7	0.31	13	1.59	71 - 157
Cutthroat Trout (*Oncorhynchus clarki*)	0.3	0.13	2	0.24	237 - 250
Rainbow Trout (*Oncorhynchus mykiss*)	0.1	0.04	1	0.12	214 - 214
Sculpin (*Cottus* spp.)	0.0	0.01	2	0.24	46 - 104
Total	232.7		817		

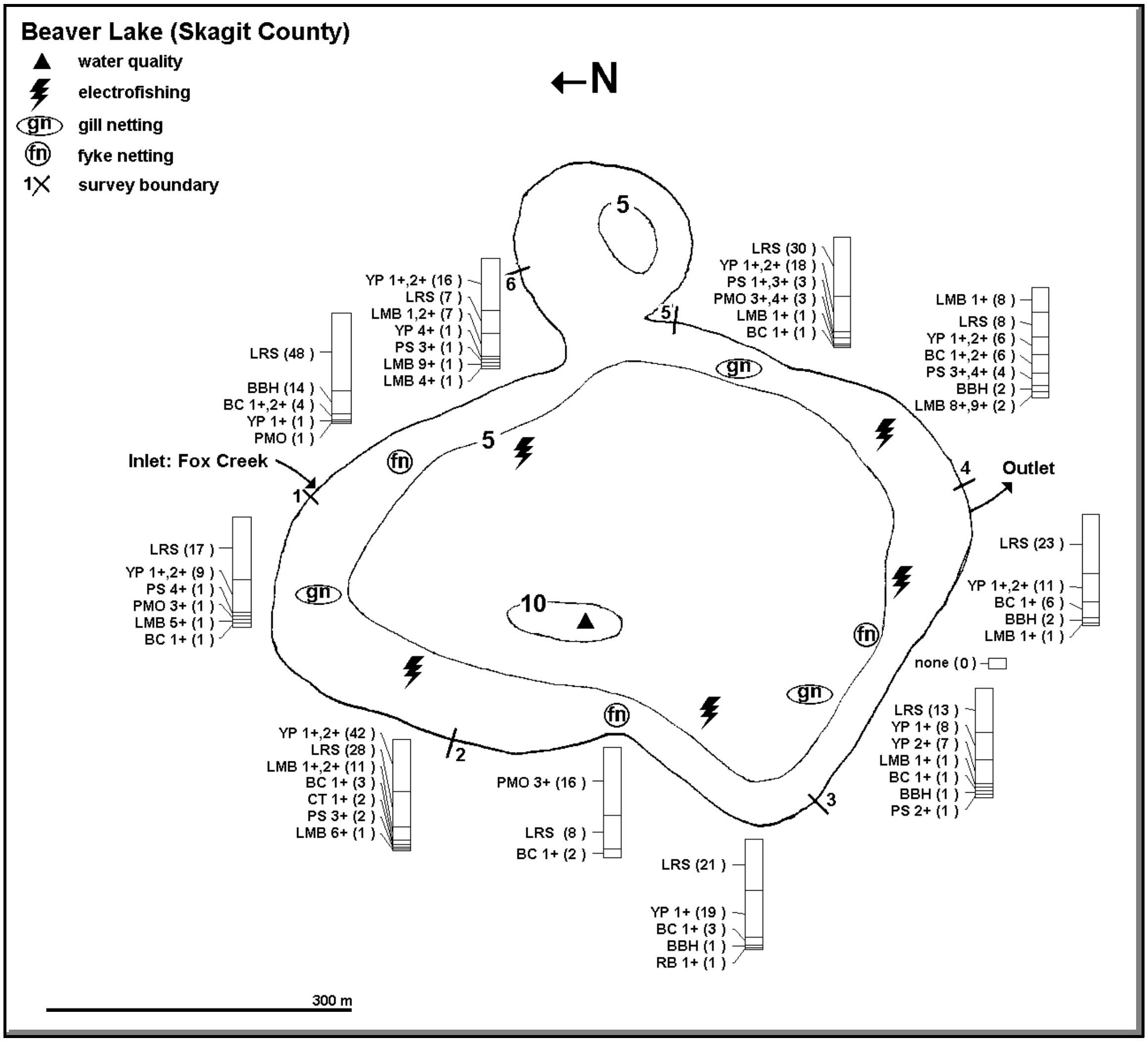

Figure 3. Map of Beaver Lake (Skagit County) showing depth contours (in feet), sample sites by gear type, and catch data. Bar charts near adjacent gear-type markers indicate species and numbers (in parenthesis) of fish, excluding young-of-year, captured September, 2001. Electrofishing occurred along the length of each survey section indicated. Species key: BBH = brown bullhead, BC = black crappie, COT = sculpin, CT = cutthroat trout, LMB = largemouth bass, LRS = largescale sucker, PMO = peamouth, PS = pumpkinseed, RB = rainbow trout, YP = yellow perch. Age classes: 1+ = one year old, 2+ = two years old, etc.

CPUE

Electrofishing CPUE for stock-size (>200mm) largemouth bass was low, 13 fish per hour, compared to the average of the mean CPUEs (29 fish/hr) from 22 western Washington lakes (Table 2, Table 8 and Appendix A). Similarly, pumpkinseed catch rates while electrofishing (9.6 fish/hr) were much lower than the western Washington average of 77 fish per hour. However, electrofishing catch rates for black crappie (31 fish/hr) and yellow perch (116 fish/hr) were high compared to state averages of 10 and 92 fish per hour, respectively. The electrofishing catch rate for brown bullhead (6 fish/hr) was nearly equal to the state average, while the gill netting and fyke netting rates were lower than average. Except for largescale sucker, catch rates while gill netting and fyke netting were generally lower than state averages for most species sampled at Beaver Lake. Largescale sucker catch rates at Beaver Lake exceeded state averages for each of our gear types. In fact, of the three index lakes in western Washington (Appendix A) where largescale sucker have been captured, Beaver Lake supports the population with the highest catch rate. Other non-game fish captured in Beaver Lake include peamouth and sculpin, but both were found in relatively low numbers. Of the cold water fishes, including cutthroat and rainbow trout, captured during the survey, only cutthroat trout were of stock size. Cutthroat trout catch rates were low compared to western Washington State averages.

Electrofishing catch rates during our survey may have been reduced by the presence of dense aquatic vegetation. Our access to the nearshore littoral zone was limited by dense patches of floating vegetation (lily pads). Furthermore, visibility while electrofishing in or near these pad fields was reduced as the plants obscured the area below. In this way, some fish using this habitat may have escaped capture during electrofishing. The ample submersed vegetation in the lake may also provide refuge for fish from capture during electrofishing. At least one larger largemouth bass was observed darting into the vegetation and escaping.

Table 8. 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 Beaver Lake (Skagit County) while electrofishing, gill netting, and fyke netting during fall 2001.

Species	Gear type					
	Electroshocking (#fish/hour)	Shock Sites	Gill Netting (# fish/hour)	n (net nights)	Fyke Netting (# fish/hour)	n (net nights)
Largemouth bass	13.2 ± 7.8	5	0.3[a]	3	0	3
Black crappie	31.1 ± 8.6	5	1.0[a]	3	2.0 ± 1.5	3
Yellow perch	116.0 ± 44.9	5	14.0 ± 3.4	3	0.3[a]	3
Pumpkinseed	9.6 ± 5.2	5	1.3 ± 0.4	3	0	3
Brown bullhead	6.0 ± 3.4	5	0.3[a]	3	4.7[a]	3
Cutthroat trout	2.4[a]	5	0	3	0	3
Largescale sucker	105.1 ± 33.2	5	20.0 ± 6.6	3	18.7[a]	3
Peamouth	0	5	1.3 ± 1.1	3	0.7 ± 0.4	3
Sculpin	2.4 ± 1.9	5	0	3	0	3

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

Stock Density Indices

Except for yellow perch caught while electrofishing and gill netting and black crappie caught electrofishing, sample sizes for stock-size warmwater fishes were relatively small (Table 9), making calculation of reliable stock density indices difficult. Although few stock-size largemouth bass (n=12) were captured, stock density index values for largemouth bass (PSD=45, RSD-P=36) were similar to those generally accepted for populations that exhibit predator-prey balance (Table 9). Similarly, PSD values for the primary prey species, yellow perch (PSD=7 to 14), pumkinseed (PSD=38), and black crappie (PSD=4 to 33), are also similar to balanced populations. However, RSD-P values for these species were either zero, in the case of yellow perch and pumpkinseed, or 100 for black crappie (n=3) caught gill netting, and do not conform to values expected for balanced populations and may more closely resemble populations managed for "Big Bass." No memorable-size largemouth bass ($510 mm TL), preferred-size pumpkinseed ($200 mm TL), or preferred-size yellow perch ($250 mm TL) were captured. However, most stock-size brown bullhead were also preferred size. The PSD and RSD values 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 9. Traditional stock density indices including 80% confidence intervals for cold- and warmwater fishes collected from Beaver Lake (Skagit County) while electrofishing, gill netting and fyke netting during fall 2001. 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.

Species	Gear Type	# Stock Length Fish	PSD	RSD-P	RSD-M	RSD-T
Largemouth bass	EB	11	45 ± 19	36 ± 19	0	0
	GN	1	100	0	0	0
	FN	0	0	0	0	0
Black crappie	EB	26	4 ± 5	0	0	0
	GN	3	0	100	0	0
	FN	6	33 ± 25	0	0	0
Yellow perch	EB	97	7 ± 3	0	0	0
	GN	42	14 ± 7	0	0	0
	FN	1	0	0	0	0
Pumpkinseed	EB	8	38 ± 22	0	0	0
	GN	4	0	0	0	0
	FN	0	0	0	0	0
Brown bullhead	EB	5	100	60 ± 28	0	0
	GN	1	100	100	0	0
	FN	14	100	57 ± 17	0	0
Cutthroat trout	EB	2	0	0	0	0
	GN	0	0	0	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.

Largemouth Bass

Successful reproduction of largemouth bass in Beaver Lake was evident given the numerous young-of-year captured during our survey. Of the 341 largemouth bass captured, 90% were young-of-year ranging in size from 49 to 130 mm TL (Figure 4). The 2000 year class was well represented with 23 fish while few older individuals were sampled (Table 10). No age 3 fish (1998 year class) were sampled and may constitute a year class failure. Subsequent year classes were weak with only one fish representing each age class from age 4 through age 9.

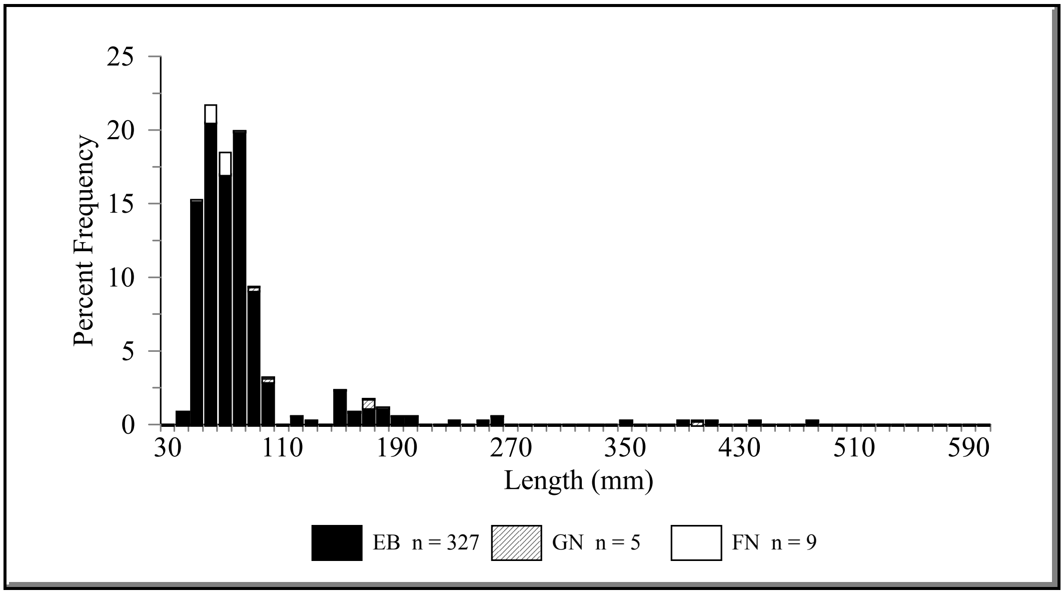

Figure 4 . Length frequency histogram of largemouth bass sampled from Beaver Lake (Skagit County) in fall 2001. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

Table 10. Age and growth of largemouth bass (*Micropterous salmoides*) captured at Beaver Lake (Skagit County) during fall 2001. 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	3	4	5	6	7	8	9
2000	23	63.5								
1999	4	57.8	155.4							
1998	0									
1997	1	61.2	127.2	213.2	302.7					
1996	1	80.3	162.4	216.3	297.1	363.8				
1995	1	84.5	134.5	217.3	250.2	310.7	358.1			
1994	1	67.0	129.2	176.2	250.9	321.4	364.2	396.0		
1993	1	74.9	156.4	212.9	321.1	368.2	390.1	410.5	424.6	
1992	1	60.6	113.3	263.8	325.5	372.1	408.3	433.8	451.9	468.4
Weighted mean		64.2	144.5	216.6	291.2	347.2	380.2	413.5	438.3	468.4
Western WA average (mean of weighted means)		77.2	145.3	191.0	242.8	295.7	347.3	371.8	394.3	417.0

Relative weights for stock-size and smaller fish were above average compared to western Washington averages while relative weights for larger fish were consistent with state averages (Figure 5). These findings suggest the fish are able to find adequate forage and do not appear to suffer from overcrowding or excessive competition. However, low catch rates for larger fish may suggest limited survival of older fish, or overharvest, or our inability to capture them in the dense vegetation.

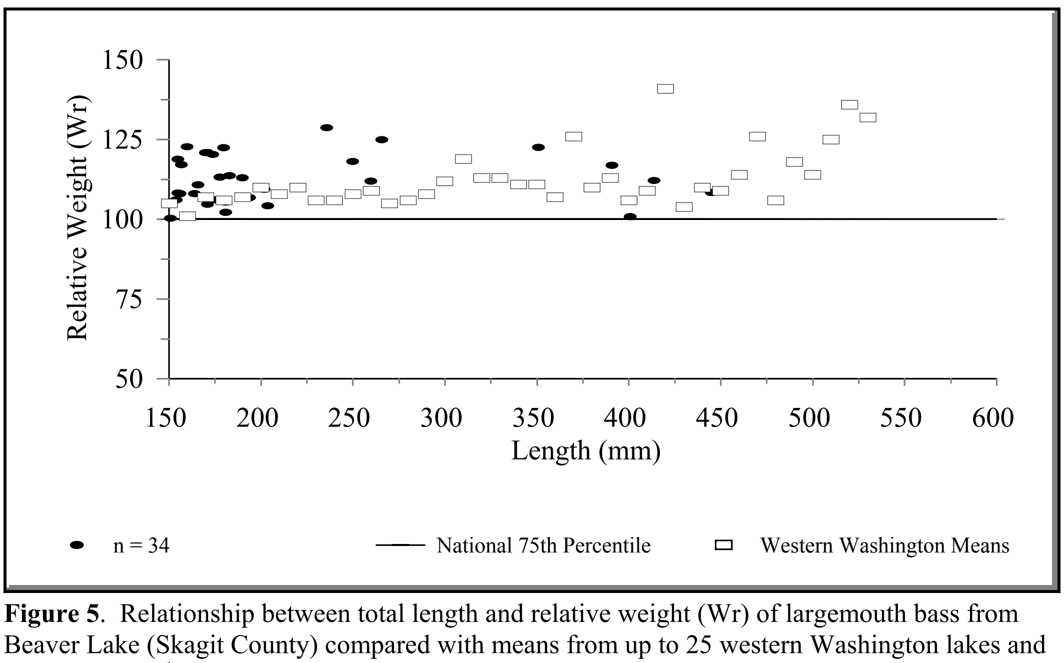

Figure 5. Relationship between total length and relative weight (Wr) of largemouth bass from Beaver Lake (Skagit County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Black Crappie

Beaver Lake black crappie ranged from 53 to 230 mm TL (age 0 to 2)(Table 11, Figure 6). Of the 61 fish captured, more than half (n=37) were young-of-year, 19 were age 1 and 5 were age 2. Growth of age 1 fish was slower than average compared to ten western Washington black crappie lakes while growth of age 2 fish was faster than average (Appendix B). Also, black crappie relative weights were higher than the state average and the national 75th percentile (Figure 7).

Table 11. Age and growth of black crappie (*Pomoxis nigromaculatus*) captured at Beaver Lake (Skagit County) during fall 2001. 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**
2000	19	66.4	
1999	5	60.3	133.3
Weighted mean		65.1	133.3
Western WA average (mean of weighted means)		70.6	127.1

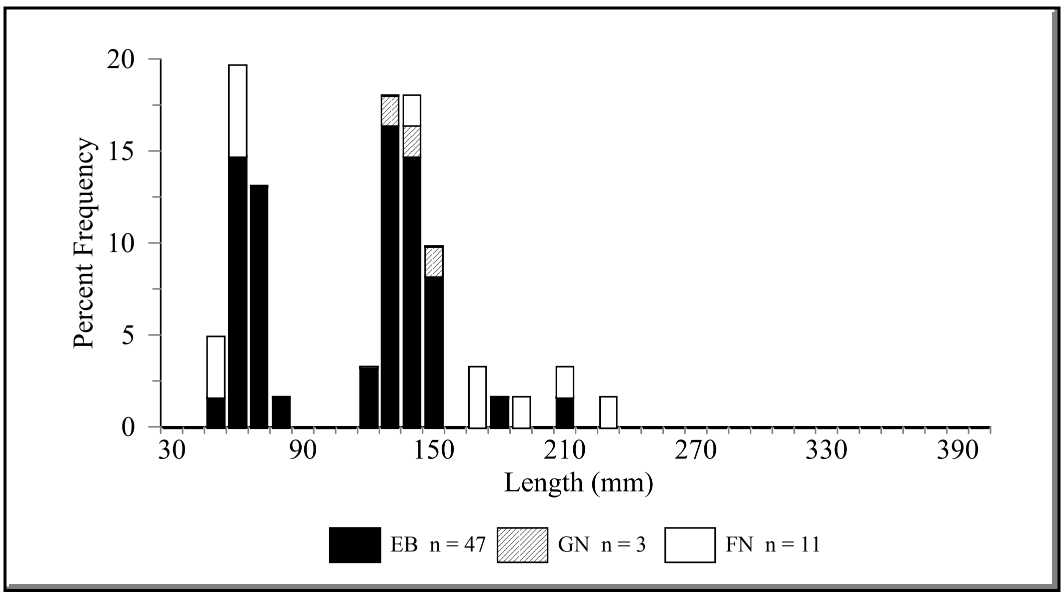

Figure 6. Length frequency histogram of black crappie sampled from Beaver Lake (Skagit County) in fall 2001. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

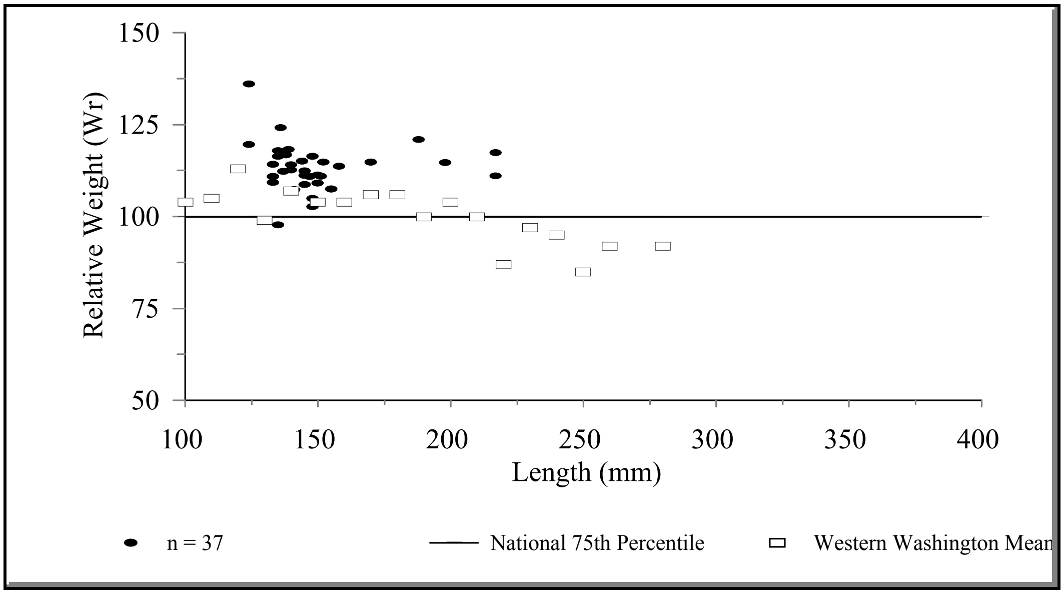

Figure 7 . Relationship between total length and relative weight (Wr) of black crappie from Beaver Lake (Skagit County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Yellow Perch

A total of 167 yellow perch were collected and ranged in size from 69 to 231 mm (age 0 to 4) (Table 12 and Figure 8). Most were determined to be age 1 (n=115) and age 2 (n=26) fish. Successful reproduction was detected as 25 young-of-year fish were captured. However, recruitment to older year classes appears limited since only one fish older than age 3 was captured. Mean length of age 1 fish (80 mm) was consistent with the western Washington average (83 mm) while age 2 fish displayed higher than average growth. Relative weights for smaller fish (<170 mm) were low when compared with the national standard and with western Washington averages, while relative weights of larger fish were consistent with state averages (Figure 9). These results suggest age 1 yellow perch may be affected by competition for available resources within their trophic level, either among themselves, or with largescale sucker, largemouth bass, or crappie.

Table 12. Age and growth of yellow perch (*Perca flavescens*) captured at Beaver Lake (Skagit County) during fall 2001. 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**
2000	22	85.4			
1999	24	75.3	150.2		
1998	0				
1997	1	68.9	137.0	186.7	218.0
Weighted mean		79.8	149.7	186.7	218.0
Western WA average (mean of weighted means)		83.0	133.9	161.2	194.6

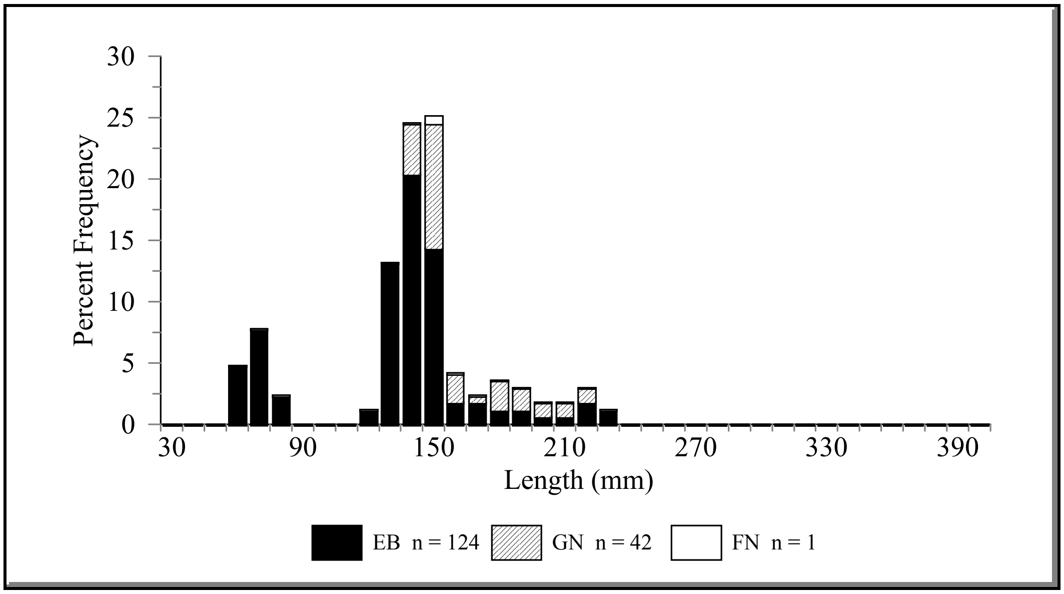

Figure 8. Length frequency histogram of yellow perch sampled from Beaver Lake (Skagit County) in fall 2001. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

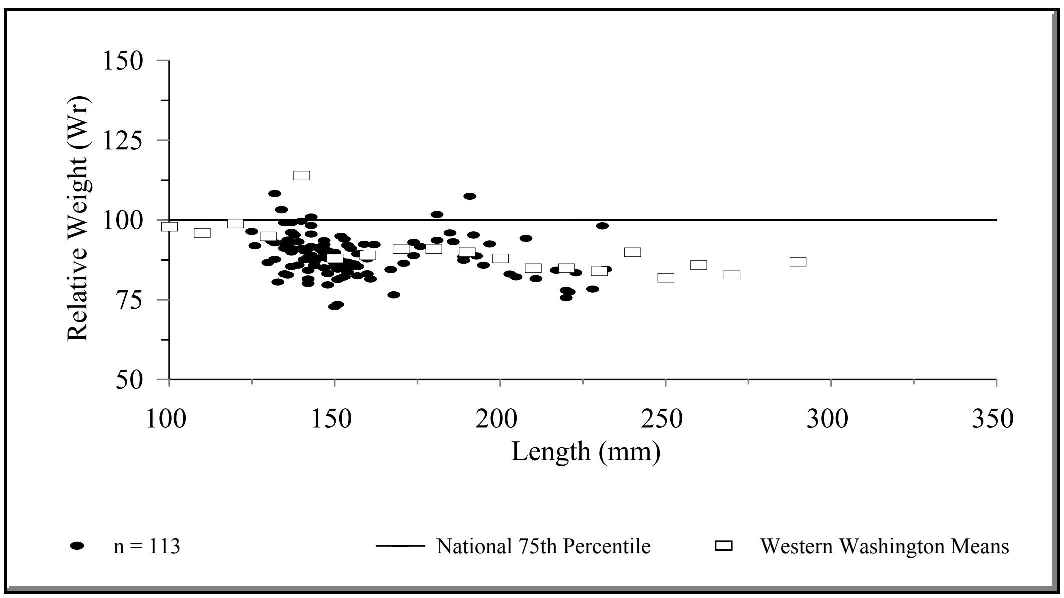

Figure 9. Relationship between total length and relative weight (Wr) of yellow perch from Beaver Lake (Skagit County) compared with means from up to 25 western Washington lakes and the national 75^{th} percentile.

Pumpkinseed

A total of 13 pumpkinseed were captured electrofishing and gill netting and ranged in size from 71 to 157 mm TL (age 1 to age 5) (Table 13, Figure 10). No young-of-year fish were captured. Growth was slow compared to western Washington State averages. Relative weights were consistent with western Washington averages suggesting this species is able to forage adequately. However, their relative abundance was low and reproduction might be limited for this species, possibly as a result of heavy predation.

Table 13. Age and growth of pumpkinseed (*Lepomis gibbosus*) captured at Beaver Lake (Skagit County) during fall 2001. 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	3	4	5
2000	1	37.6				
1999	2	41.7	84.0			
1998	6	41.1	73.8	117.4		
1997	3	44.1	75.2	97.7	120.2	
1996	1	44.6	73.7	87.8	109.8	117.7
Weighted mean		41.9	75.8	108.6	117.6	117.6
Western WA average		50.1	88.8	111.2	129.8	137.1

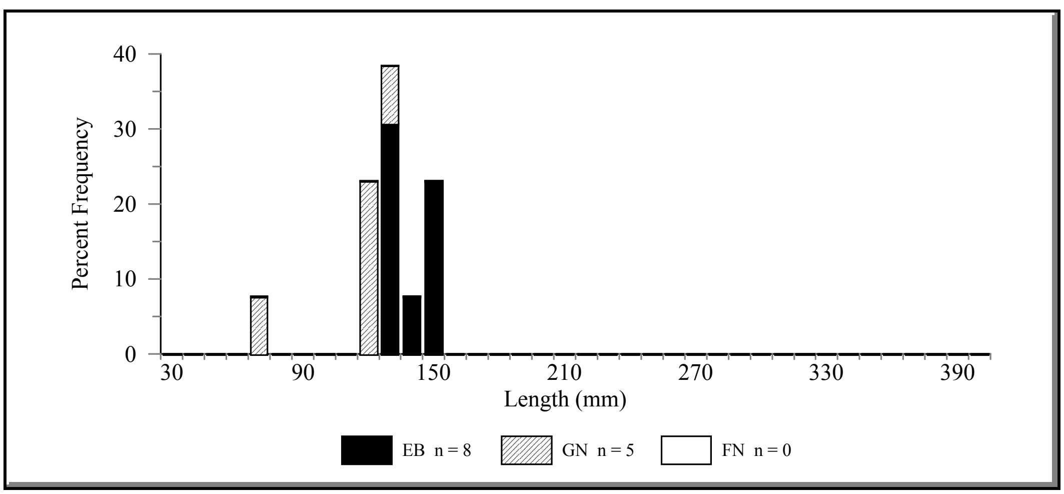

Figure 10. Length frequency histogram of pumpkinseed sampled from Beaver Lake (Skagit County) in fall 2001. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

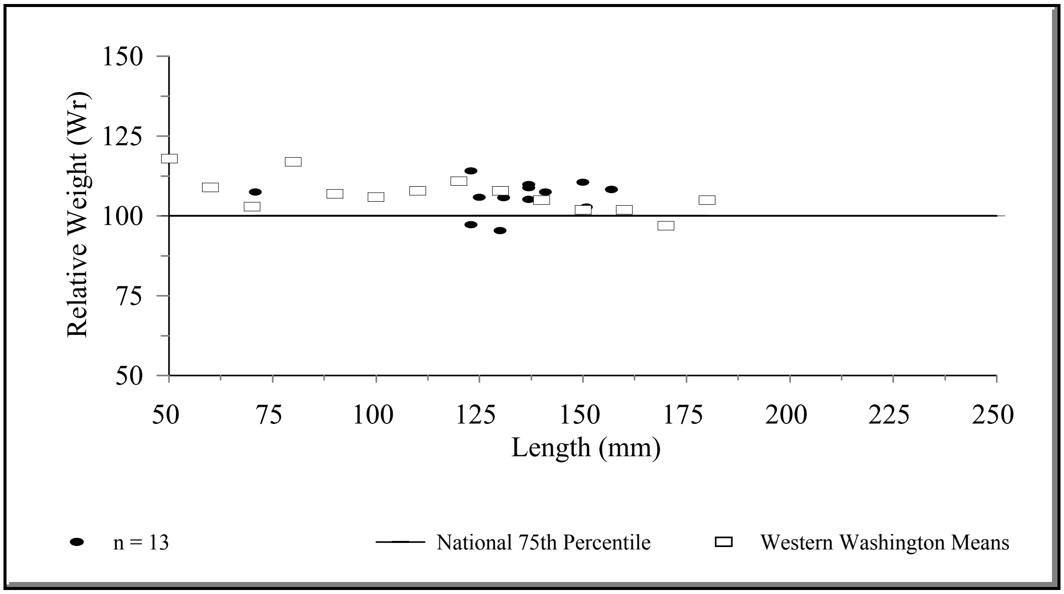

Figure 11 . Relationship between total length and relative weight (Wr) of pumpkinseed from Beaver Lake (Skagit County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Brown Bullhead

Twenty brown bullhead ranging in size from 225 to 345 mm TL were captured during our survey (Figure 12). These fish were not aged. The relative weights were low for smaller size classes (Figure 13). Relative weights increased with size suggesting smaller fish are not foraging as effectively, possibly because of competition with abundant largescale sucker.

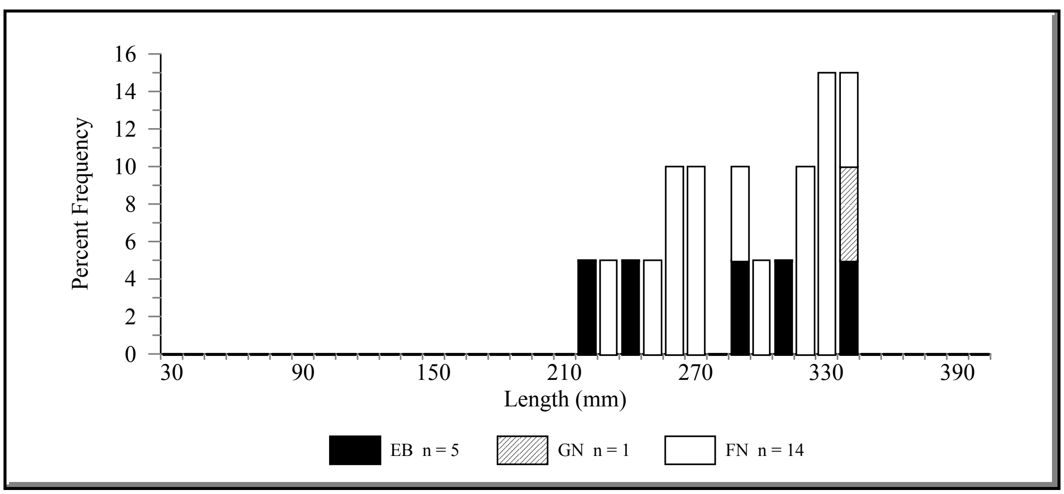

Figure 12. Length frequency histogram of brown bullhead sampled from Beaver Lake (Skagit County) in fall 2001. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

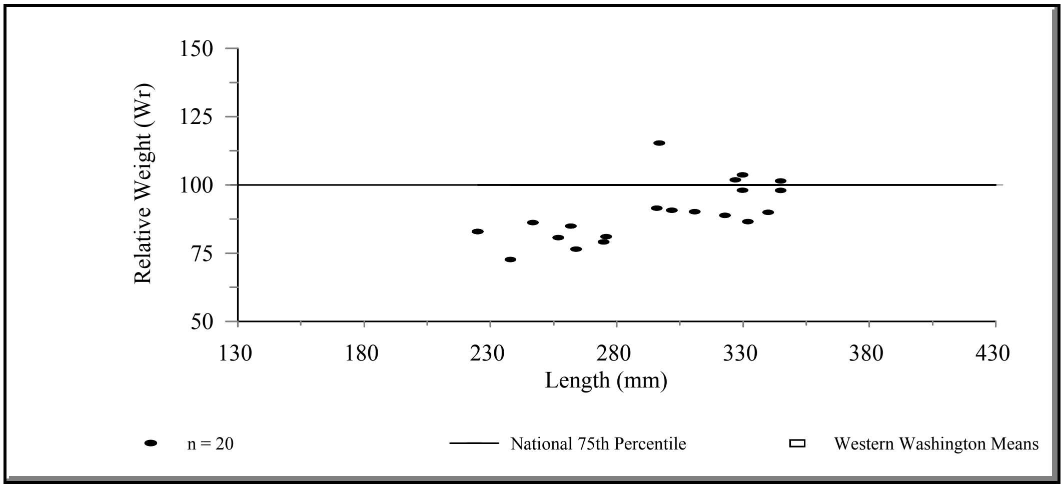

Figure 13. Relationship between total length and relative weight (Wr) of brown bullhead from Beaver Lake (Skagit County) compared the national 75th percentile.

Largescale Sucker

Largescale sucker comprised nearly 90% of the biomass sampled during our survey and, excluding all young-of-year fish, more than 44% of species composition by number. A total of 204 largescale sucker, ranging in size from 168 to 568 mm TL (age 1 through 7), were sampled from Beaver Lake (Table 14 and Figure 14).

Table 14. Age and growth of largescale sucker (*Catostomus macrocheilus*) captured at Beaver Lake (Skagit County) during fall 2001. Values are mean back-calculated lengths using the direct proportion method (Carlander 1982).

Year Class	**# Fish**	**Mean Total Length (mm) at Age**						
		1	**2**	**3**	**4**	**5**	**6**	**7**
2000	13	186.1						
1999	0							
1998	14	115.8	229.6	347.0				
1997	24	121.9	242.1	354.9	426.1			
1996	25	111.0	214.2	326.7	431.6	481.2		
1995	9	98.7	191.5	294.1	396.6	454.8	495.5	
1994	1	66.5	164.9	279.3	372.4	425.6	492.1	524.0
Weighted mean		124.4	222.8	335.2	423.0	472.8	495.2	524.0

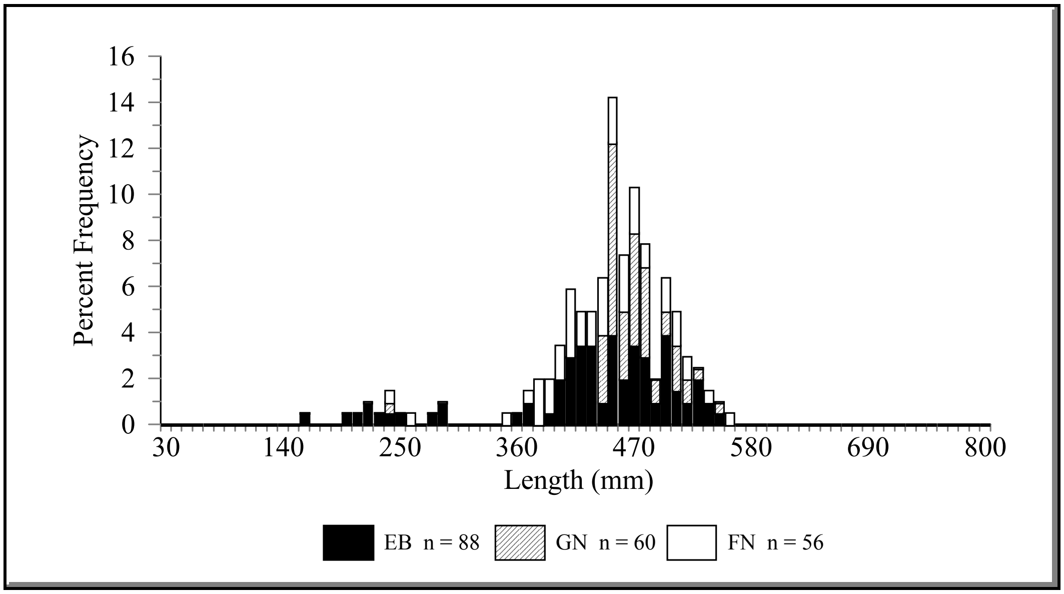

Figure 14. Length frequency histogram of largescale sucker sampled from Beaver Lake (Skagit County) in fall 2001. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

Length at age data suggest largescale sucker grow rapidly in the first years of life, adding nearly 100 mm of length each year up to about age 4 (Table 14). The length frequency distribution was skewed toward mid- to larger sized fish, suggesting these fish quickly reach a size refuge from predation. By age 3, most largescale sucker are too large for largemouth bass and other predators to consume (Lawrence 1956). Additionally, the high concentration of mid-size (and mid-aged) fish represented in the length frequency distribution fits the classic description of an unexploited population described by Bennett, 1962.

The presence of age 1 individuals suggests that largescale sucker use the lake for spawning and rearing. These fish might also immigrate from nearby lotic habitats, characteristic of their distribution, such as the Nookachamps Creek and the Skagit River. Other lakes in the Skagit River drainage with known populations of largescale sucker include Clear Lake, which is upstream of and seasonally connected to Beaver Lake, and Big Lake further upstream off Nookachamps creek (Mueller and Downen 1999).

Few small-sized largescale sucker were captured in our survey while many larger fish were sampled. In fact, Beaver Lake appears to support the most abundant population of this species (based on CPUE) of western Washington lakes visited by Warmwater Fish Enhancement Program personnel. Provided largescale sucker reproduce successfully, they may provide a substantial forage base for the lake's predator species. The young are pelagic until they are about 18 mm in length (Scott and Crossman 1998) when they begin to move to the bottom and into deeper water. This may explain, at least in part, why we were unable to intercept juvenile fish with our sample gear. Alternatively, the limited number of small sized largescale sucker found during our survey may suggest that young of this species may be vulnerable to predation, contributing to higher than average growth in largemouth bass, while reducing the pressure on other species such as black crappie and yellow perch.

Peamouth

A total of six peamouth (179 - 270 mm TL) (age 2 - 4) were captured during our survey (Table15, Figure 15). No young-of-year fish or age 1 fish were sampled.

Table 15. Age and growth of peamouth (*Mylocheilus caurinus*) captured at Beaver Lake (Skagit County) during fall 2001. Values are mean back-calculated lengths using the direct proportion method (Carlander 1982).

		Mean total length (mm) at age			
Year class	# fish	1	2	3	4
2000	0				
1999	1	70.4	140.8		
1998	3	88.2	155.2	192.9	
1997	2	107.8	176.5	216.9	252.4
Weighted mean		91.8	159.9	202.5	252.4

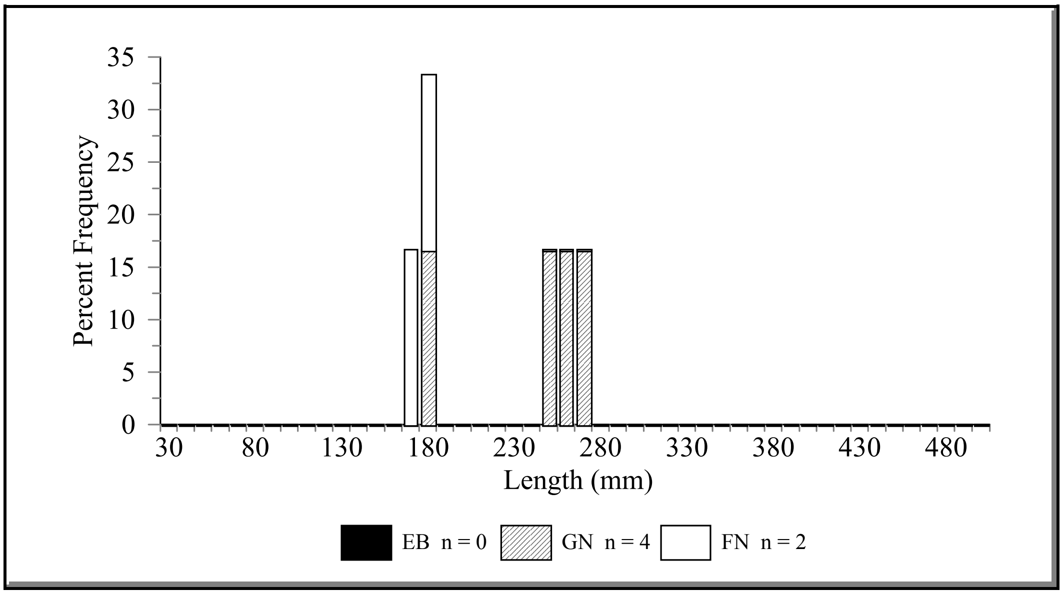

Figure 15. Length frequency histogram of peamouth sampled from Beaver Lake (Skagit County) in Fall 2001. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

Rainbow Trout

One rainbow trout (214 mm FL) was captured while electrofishing and determined to be age 1. The length at age 1 was 200 mm FL. The relative weight for this fish was low (W_r = 70) compared to the national average. Its origin is somewhat puzzling. While Beaver Lake is not stocked with trout, Clear Lake received 5,000 triploid rainbow trout (>300 mm FL) in 2001 and 5,000 catchable-size rainbow trout (196 - 294 mm FL) in 2000 (WDFW 2000, 2001). Although the two lakes are seasonally connected, allowing travel between the lakes when water levels are high, fish from either of these stocking events should be considerably larger than the one we sampled in Beaver Lake. An alternate scenario to explain the presence of this fish might be that it is a juvenile steelhead that strayed into the lake from downstream, or possibly is the offspring of fish that spawned in Fox Creek.

Cutthroat Trout

Two cutthroat trout (255 and 265 mm FL) were captured while electrofishing. These fish were determined to be age 1. Their length at age 1 was 237 and 250 mm FL, respectively. Relative weights were 97 and 112, respectively, and were consistent with the national standard.

Cutthroat trout most likely enter Beaver Lake from Fox Creek, the primary source of surface water flow into the lake. These fish have consistently been detected in the creek during walking surveys for many years (Kurt Buchanan, WDFW, personal communication).

Warmwater Enhancement Options

Stock density indices (PSD and RSD) for Beaver Lake largemouth bass, black crappie, and pumpkinseed were similar to those of communities managed for balance, while PSD for yellow perch were more suggestive of a "big bass" management scheme. However sample sizes of stock size largemouth bass were low and no memorable-size largemouth bass were captured. For warmwater species, catch rates (CPUE) were highest for stock-size black crappie and yellow perch, exceeding averages for western Washington lakes. Growth rates for largemouth bass, black crappie, and yellow perch exceeded state averages while pumpkinseed growth was slower than average.

Of the fish sampled, largescale sucker comprised nearly 90% of the species composition by weight and 25% by number. Of these, most were too large for the largest predators to consume. The ecological significance of this species as it relates to the warmwater community in Beaver Lake is unclear. Ostensibly, if fewer largescale sucker were in the lake, some other species may increase in abundance to compensate, possibly one desirable to anglers. Alternatively, the large reproductive potential of the abundant largescale sucker may provide substantial forage for predators such as largemouth bass while competing for resources with yellow perch, pumpkinseed, and crappie, thereby keeping those populations in check.

Although abundant aquatic vegetation was observed at Beaver Lake during our survey, it is likely more of a nuisance to anglers than a detriment to the fish that inhabit the lake. Anecdotal reports from at least one angler suggest some fishers have stopped going to Beaver Lake because of the "weed problem." For this reason, Beaver Lake is probably best fished in the early spring before aquatic macrophytes have grown enough to significantly foul angler gear.

Dissolved oxygen levels found in the lake during our survey were relatively low (<5 mg/L). However, our sample only represented conditions at a single time and location and probably is not representative of dissolved oxygen conditions overall. Size at age data (growth) and relative weights of most fish sampled suggest fish in the lake are not limited by food availability or water quality concerns.

Management options that might improve the warmwater fishery at Beaver Lake include, but are not limited to, the following:

Water Quality Monitoring

Although dissolved oxygen levels observed during our survey indicated less than optimal growing conditions for fish, age and growth data suggest fish growth and condition is not hampered by water quality. It appears that dissolved oxygen levels may change substantially during the course of a day, season or year. To better understand the dynamics and the mechanism by which dissolved oxygen levels fluctuate in the lake we recommend periodic sampling occur to collect data on diurnal and seasonal water quality parameters, such as, dissolved oxygen, water temperature, and aquatic vegetation densities.

Vegetation Control

Aquatic plant cover is an important habitat constituent for most warmwater fishes, which are more likely to be found around plant cover than away from it (Killgore et al. 1989). Submerged aquatic vegetation provides important foraging, refuge, and spawning habitat (see review by Willis et al. 1997), improving survival and recruitment to harvestable sizes (Durocher et al. 1984). Changes in the standing crop of aquatic plants can alter fish production (Willis et al. 1993) and the structure of the fish community itself (Bettoli et al. 1993).

Much of the littoral zone (60 to 80%) of Beaver Lake is densely or moderately vegetated with submerged, floating, and emergent plants. Dense vegetation reduces foraging efficiency of many predatory warmwater fish species (Wiley et al. 1984). Hence, the dense plant communities of lily pads and pondweeds may inhibit foraging by larger largemouth bass and black crappie while providing too much refuge for forage fish such as pumpkinseed and yellow perch. Fish communities seem to maximize their numbers under conditions of intermediate plant density. Balancing the contribution to habitat structure with the potential for reduced foraging efficiency should be an important aspect of aquatic plant control.

Several options are available to reduce the density of aquatic vegetation in Beaver Lake. Selective application of a pelletted aquatic herbicide may reduce vegetation density without eliminating it, thus increasing foraging efficiency of predators without eliminating the beneficial contributions of the vegetation to fish habitat. Mechanical removal of vegetation by means of harvester that cuts aquatic plants below the water line may also be an option.

Nutrient Reduction

Although no nutrient budget information is available for Beaver Lake, the abundance of aquatic vegetation suggests that eutrophication is well under way. The lake lies in an area where land use is primarily agricultural. Runoff from adjacent pasture lands and fields may carry increased levels of inorganic nutrients, such as phosphorus and nitrogen, into the lake and contribute to its eutrophic state. Best management practices for surrounding agricultural lands should be employed to minimize this effect.

Selective Removal of Largescale Sucker

The abundant largescale sucker population in Beaver Lake may impact the warmwater fish community in a variety of ways. For example, they may compete directly with forage fish for resources, or they may alter water quality by stirring up nutrients while feeding, or they may impact spawning activities of other fishes by disturbing nests while feeding. Further, no young-of-year and few juvenile largescale sucker were captured, suggesting inhibited reproductive success in largescale sucker, possibly from intraspecific competition. In Minnesota, selective removal of approximately 85% of the adult white sucker (*Catostomus commersoni*) population increased juvenile white sucker by 17-fold, yellow perch by 15-fold, and increased the standing crop of walleye (*Stizostedion vitreum vitreum*) by one-third (Johnson 1977). White suckers were found to feed almost exclusively on immature insects and other invertebrates. After their removal, these food items increased in the diets of one- and two-year old yellow perch and juvenile walleye. Selective removal of largescale sucker from Beaver Lake may similarly increase food availability for yellow perch, black crappie, and young largemouth bass, while providing better forage (larger yellow perch and more juvenile sucker) for larger largemouth bass. The effect of white sucker removal in the Minnesota lake, which had a screened outlet, lasted approximately seven years until the sucker population rebounded (Johnson 1977). Since the outlet of Beaver Lake is not screened, which could allow largescale sucker to repopulate the lake, the expected duration of improved conditions may be less than in the Minnesota example.

Improve Boat Ramp at Access

The agency maintains a gravel boat launch, gravel parking lot, and concrete vault toilet at the access site. The boat ramp, which is composed of gravel with sand, is subject to deterioration from excessive prop-wash and wheel spin-outs. The ramp is relatively steep for its composition. Although it is unlikely that 4-wheel drive vehicles would encounter much difficulty hauling trailered craft out of the lake, 2-wheel drive vehicles may tend to have trouble. This access could be improved by the addition of a concrete ramp or concrete planks, or possibly larger sized gravel that is compacted.

Improve Bank Access

Approximately 150 meters of Beaver Lake's shoreline lies adjacent to the WDFW access and a county road. The road embankment provides limited access to the lake for shore anglers. Opportunities to enhance bank access from the road (and WDFW access) should be investigated. A trail system from the parking lot of the boat access area to and along the roadside bank may be an economical way to enhance fishing access for the lake for those who do have access to a boat.

Creel Survey

Little is known about the fishing pressure the lake receives during the year. At this time it is unclear whether the relatively low abundance of largemouth bass in the lake is due to variable recruitment success or overharvest or both. A creel survey could provide information on angler harvest and help determine overall mortality of largemouth bass.

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Appendices

Appendix A. Catch rates (CPUE), stock density indices (PSD and RSD-P, and average relative weights (*Wr*) of fish sampled during surveys of select western Washington State lakes

Appendix A. Catch rates (CPUE), stock density indices (PSD and RSD-P), and average relative weights (Wr) of fish sampled during surveys of select western Washington State lakes.

Lake	County	Size (acres)	Trophic status	Season	Year	Species	CPUE			PSD	RSD-P	PSD	RSD-P	PSD	RSD-P	Avg Wr	Source
							EB	GN	FN	EB		GN		FN			
Sunset	Whatcom	12	Eutrophic	Fall	1998	BBH	2		1	100	100						Downen & Mueller; FPT99-02
Whatcom	Whatcom	4872	OligoMesotrophic	Fall	1998	BBH	2.1	0.1									Mueller et al; FPT99-12
Hummel	San Juan	36	Eutrophic	Fall	1998	BBH	6	2	2	100		100	25	100			Downen & Mueller; FPT00-03
Campbell	Skagit	360	Mesotrophic	Fall	1999	BBH	5.9	8.5	1.3	67	33	74	35	100		95	Downen & Mueller; FPT00-13
Goodwin	Snohomish	537	Mesotrophic	Fall	1998	BBH	0.7										Downen & Mueller; FPT00-02
Cassidy	Snohomish	115	Eutrophic	Fall	1998	BBH	2	0.3	4.5	100				94	33		Downen & Mueller; FPT99-07
Stevens	Snohomish	1039	Mesotrophic	Fall	1997	BBH	10.7	12.5		14		19					Mueller; April 1999
Leland	Jefferson	110	Eutrophic	Fall	1999	BBH	7			89	22						Jackson & Caromile; FPT00-22
Green	King	255	Eutrophic	Fall	1997	BBH	3	1.2		33		40				84	Mueller & Downen; FPT00-25
Meridian	King	150	Oligotrophic	Fall	2000	BBH	1.6									89	Verhey and Mueller; FPT01-11
Sawyer	King	291	Mesotrophic	Fall	1999	BBH	4			50	25					96	Downen & Mueller; FPT00-23
Limerick	Mason	132	MesoEutrophic	Fall	1998	BBH	6.1	0.6	1.6	29		25	25	50	10		Meyer & Caromile; FPT00-10
Island	Mason	110	OligoMesotrophic	Fall	1998	BBH	0.7										Caromile & Meyer; FPT00-11
Black	Thurston	570	Eutrophic	Fall	1999	BBH	1	1	0.2								Jackson & Caromile; FPT00-16
Kapowsin	Pierce	590		Fall	1999	BBH	0.4	0.5									Jackson & Caromile; FPT00-18
SLCRP Pond	Lewis	17		Fall	1997	BBH	6.3			50						82	Mueller & Downen; FPT00-09
Black	Pacific	32		Fall	1997	BBH	2.3			33						86	Mueller & Downen; FPT00-05
Rowland	Klickitat	87		Fall	1999	BBH		1	1								Jackson & Caromile; FPT00-15
Vancouver	Clark	2286	Eutrophic	Fall	1998	BBH	52	73	65	4		1		6			Caromile et al; FPT00-19
						Avg.	6.3	9.2	9.6	55.8	45.0	43.2	28.3	70.0	21.5	88.7	
						Median	2.7	1.0	1.5	50.0	29.0	32.5	25.0	94.0	21.5	87.5	
Campbell	Skagit	360	Mesotrophic	Fall	1999	BC		3.8								110	Downen & Mueller; FPT00-13
Goodwin	Snohomish	537	Mesotrophic	Fall	1998	BC		1.3				38				105	Downen & Mueller; FPT00-02
Cassidy	Snohomish	115	Eutrophic	Fall	1998	BC	3	2.3	4.8	33	33	33		53		107	Downen & Mueller; FPT99-07
Leland	Jefferson	110	Eutrophic	Fall	1999	BC	11	2		100	60	67					Jackson & Caromile; FPT00-22
Sawyer	King	291	Mesotrophic	Fall	1999	BC	3	1		33		25				113	Downen & Mueller; FPT00-23
Black	Thurston	570	Eutrophic	Fall	1999	BC	6	0.5		92							Jackson & Caromile; FPT00-16
Kapowsin	Pierce	590		Fall	1999	BC	0.9	0.5		50							Jackson & Caromile; FPT00-18
Black	Pacific	32		Fall	1997	BC	12.6	3.5		6		14				102	Mueller & Downen; FPT00-05
Rowland	Klickitat	87		Fall	1999	BC	16		1	13							Jackson & Caromile; FPT00-15
Vancouver	Clark	2286	Eutrophic	Fall	1998	BC	27.9		43.7	4							Caromile et al; FPT00-19
						Avg.	10.1	1.8625	16.5	41.375	46.5	35.4		53		107.4	
						Median	8.5	1.65	4.8	33	46.5	33		53		107	

Appendix A. Catch rates (CPUE), stock density indices (PSD and RSD-P), and average relative weights (Wr) of fish sampled during surveys of select western Washington State lakes (cont'd

Lake	County	Size (acres)	Trophic status	Season	Year	Species	CPUE			PSD	RSD-P	PSD	RSD-P	PSD	RSD-P	Avg Wr	Source
							EB	GN	FN	EB		GN		FN			
Whatcom	Whatcom	4872	OligoMesotrophic	Fall	1998	COT	57	1									Mueller et al; FPT99-12
Campbell	Skagit	360	Mesotrophic	Fall	1999	COT			1								Downen & Mueller; FPT00-13
Goodwin	Snohomish	537	Mesotrophic	Fall	1998	COT	9.3										Downen & Mueller; FPT00-02
N. Twin	Snohomish	7		Fall	1998	COT	71.7										Downen & Mueller; FPT00-04
Leland	Jefferson	110	Eutrophic	Fall	1999	COT	2										Jackson & Caromile; FPT00-22
Green	King	255	Eutrophic	Fall	1999	COT	13.9	0.2	0.2								Mueller & Downen; FPT00-25
Green	King	255	Eutrophic	Fall	1997	COT	6.9	0.2									Mueller & Downen; FPT00-25
Meridian	King	150	Oligotrophic	Fall	2000	COT	1										Verhey and Mueller; FPT01-11
Mason	Mason	1000	OligoMesotrophic	Fall	1997	COT	11.9										Mueller; February 1999
Sawyer	King	291	Mesotrophic	Fall	1999	COT	15.9										Downen & Mueller; FPT00-23
Limerick	Mason	132	MesoEutrophic	Fall	1998	COT	20.9		0.1								Meyer & Caromile; FPT00-10
Island	Mason	110	OligoMesotrophic	Fall	1998	COT	4.6										Caromile & Meyer; FPT00-11
American	Pierce	1070	Mesotrophic	Fall	1997	COT	49.13	0.2									Mueller & Downen; FPT99-14
Black	Thurston	570	Eutrophic	Fall	1999	COT	30	0.2	0.3								Jackson & Caromile; FPT00-16
Black	Pacific	32		Fall	1997	COT	2.7										Mueller & Downen; FPT00-05
Rowland	Klickitat	87		Fall	1999	COT	13										Jackson & Caromile; FPT00-15
Vancouver	Clark	2286	Eutrophic	Fall	1998	COT			0.3								Caromile et al; FPT00-19
						Avg.	20.7	0.4	0.4								
						Median	13.0	0.2	0.3								
Sunset	Whatcom	12	Eutrophic	Fall	1998	CT	21.9	2.5								111	Downen & Mueller; FPT99-02
Whatcom	Whatcom	4872	OligoMesotrophic	Fall	1998	CT	1.7	1.1				18				91	Mueller et al; FPT99-12
Goodwin	Snohomish	537	Mesotrophic	Fall	1998	CT		0.2								94	Downen & Mueller; FPT00-02
Cassidy	Snohomish	115	Eutrophic	Fall	1998	CT			0.3							83	Downen & Mueller; FPT99-07
Leland	Jefferson	110	Eutrophic	Fall	1999	CT		0.5									Jackson & Caromile; FPT00-22
Mason	Mason	1000	OligoMesotrophic	Fall	1997	CT		0.2									Mueller; February 1999
Sawyer	King	291	Mesotrophic	Fall	1999	CT		0.8								110	Downen & Mueller; FPT00-23
American	Pierce	1070	Mesotrophic	Fall	1997	CT		1.5								93	Mueller & Downen; FPT99-14
Rowland	Klickitat	87		Fall	1999	CT	1										Jackson & Caromile; FPT00-15
						Avg.	8.2	1.0	0.3							97	
						Median	1.7	0.8	0.3							93.5	

Appendix A. Catch rates (CPUE), stock density indices (PSD and RSD-P), and average relative weights (Wr) of fish sampled during surveys of select western Washington State lakes (cont'd.).

Lake	County	Size (acres)	Trophic status	Season	Year	Species	CPUE			PSD	RSD-P	PSD	RSD-P	PSD	RSD-P	Avg Wr	Source
							EB	GN	FN	EB		GN		FN			
Sunset	Whatcom	12	Eutrophic	Fall	1998	LMB	41.8			24	19					100	Downen & Mueller; FPT99-02
Hummel	San Juan	36	Eutrophic	Fall	1998	LMB	174.8	2.5		14	13	40	20			108	Downen & Mueller; FPT00-03
Campbell	Skagit	360	Mesotrophic	Fall	1999	LMB	40.3	2.3		34	32	56	44			107	Downen & Mueller; FPT00-13
Goodwin	Snohomish	537	Mesotrophic	Fall	1998	LMB	5.3	0.2		75	25	100	100			99	Downen & Mueller; FPT00-02
N. Twin	Snohomish	7		Fall	1998	LMB	18	2.5		13	7					105	Downen & Mueller; FPT00-04
S. Twin	Snohomish	10		Fall	1998	LMB	19.9			10						97	Downen & Mueller; FPT00-04
Cassidy	Snohomish	115	Eutrophic	Fall	1998	LMB	68.7	2		17	9	25				101	Downen & Mueller; FPT99-07
Stevens	Snohomish	1039	Mesotrophic	Fall	1997	LMB	0.7	0.2									Mueller; April 1999
Leland	Jefferson	110	Eutrophic	Fall	1999	LMB	67	2		26	18						Jackson & Caromile; FPT00-22
Green	King	255	Eutrophic	Fall	1997	LMB										112	Mueller & Downen; FPT00-25
Green	King	255	Eutrophic	Fall	1999	LMB	1	0.5								109	Mueller & Downen; FPT00-25
Meridian	King	150	Oligotrophic	Fall	2000	LMB	14.5	0.5								106	Verhey and Mueller; FPT01-11
Mason	Mason	1000	OligoMesotrophic	Fall	1997	LMB	4	0.2								117	Mueller; February 1999
Sawyer	King	291	Mesotrophic	Fall	1999	LMB	10.9	0.5		18	9					104	Downen & Mueller; FPT00-23
Limerick	Mason	132	MesoEutrophic	Fall	1998	LMB	4.7	1.4		40	10	90	20				Meyer & Caromile; FPT00-10
Island	Mason	110	OligoMesotrophic	Fall	1998	LMB	68.7	3.2	0.3	33	14	23	15				Caromile & Meyer; FPT00-11
American	Pierce	1070	Mesotrophic	Fall	1997	LMB	0.7									123	Mueller & Downen; FPT99-14
Black	Thurston	570	Eutrophic	Fall	1999	LMB	16	0.5	0.2	28	9						Jackson & Caromile; FPT00-16
Kapowsin	Pierce	590		Fall	1999	LMB	31	1		12	7						Jackson & Caromile; FPT00-18
SLCRP Pond	Lewis	17		Fall	1997	LMB	3.2									97	Mueller & Downen; FPT00-09
Black	Pacific	32		Fall	1997	LMB	21.7	3		38	13	67	25			105	Mueller & Downen; FPT00-05
Rowland	Klickitat	87		Fall	1999	LMB	15										Jackson & Caromile; FPT00-15
Vancouver	Clark	2286	Eutrophic	Fall	1998	LMB	10			80	30						Caromile et al; FPT00-19
						Avg.	29.0	1.4	0.3	30.8	15.4	57.3	37.3			106.0	
						Median	15.5	1.2	0.3	26.0	13.0	56.0	22.5			105.0	
Mason	Mason	1000	OligoMesotrophic	Fall	1997	LRS	1.3	5.8									Mueller; February 1999
Sawyer	King	291	Mesotrophic	Fall	1999	LRS		0.5									Downen & Mueller; FPT00-23
SLCRP Pond	Lewis	17		Fall	1997	LRS	19										Mueller & Downen; FPT00-09
						Avg.	10.2	3.2									
						Median	10.2	3.2									

Appendix A. Catch rates (CPUE), stock density indices (PSD and RSD-P), and average relative weights (Wr) of fish sampled during surveys of select western Washington State lakes (con'd.).

Lake	County	Size (acres)	Trophic status	Season	Year	Species	CPUE EB	CPUE GN	CPUE FN	PSD EB	RSD-P EB	PSD GN	RSD-P GN	PSD FN	RSD-P FN	Avg Wr	Source
Whatcom	Whatcom	4872	OligoMesotrophic	Fall	1998	PMO	57.2	15.4									Mueller et al; FPT99-12
Mason	Mason	1000	OligoMesotrophic	Fall	1997	PMO	115.1	48.3									Mueller; February 1999
Sawyer	King	291	Mesotrophic	Fall	1999	PMO	1	5.3									Downen & Mueller; FPT00-23
Black	Pacific	32		Fall	1997	PMO	1	4.8									Mueller & Downen; FPT00-05
						Avg.	43.6	18.5									
						Median	29.1	10.4									
Whatcom	Whatcom	4872	OligoMesotrophic	Fall	1998	PS	10.9	0.7		7						106	Mueller et al; FPT99-12
Campbell	Skagit	360	Mesotrophic	Fall	1999	PS	34.5	4.5	2.3	3		6		22		103	Downen & Mueller; FPT00-13
Goodwin	Snohomish	537	Mesotrophic	Fall	1998	PS	353.3	4.2	0.2	5		8		100		94	Downen & Mueller; FPT00-02
N. Twin	Snohomish	7		Fall	1998	PS	39.8	2	15					3		103	Downen & Mueller; FPT00-04
S. Twin	Snohomish	10		Fall	1998	PS	125	6	0.5							105	Downen & Mueller; FPT00-04
Cassidy	Snohomish	115	Eutrophic	Fall	1998	PS	15.9	0.3		50						107	Downen & Mueller; FPT99-07
Stevens	Snohomish	1039	Mesotrophic	Fall	1997	PS	101.3	6.7		1							Mueller; April 1999
Green	King	255	Eutrophic	Fall	1997	PS	208.8	3.2								113	Mueller & Downen; FPT00-25
Green	King	255	Eutrophic	Fall	1999	PS	140.2	2	0.5	4			100			113	Mueller & Downen; FPT00-25
Meridian	King	150	Oligotrophic	Fall	2000	PS	24.7	1		7						98	Verhey and Mueller; FPT01-11
Sawyer	King	291	Mesotrophic	Fall	1999	PS	22.8	0.8	4					6		108	Downen & Mueller; FPT00-23
Limerick	Mason	132	MesoEutrophic	Fall	1998	PS	0.5	0.4									Meyer & Caromile; FPT00-10
Island	Mason	110	OligoMesotrophic	Fall	1998	PS	91.1	2.8	0.7	24		7					Caromile & Meyer; FPT00-11
American	Pierce	1070	Mesotrophic	Fall	1997	PS	156.6	7.5								119	Mueller & Downen; FPT99-14
Black	Thurston	570	Eutrophic	Fall	1999	PS	2		0.2								Jackson & Caromile; FPT00-16
Kapowsin	Pierce	590		Fall	1999	PS	4	0.3									Jackson & Caromile; FPT00-18
SLCRP Pond	Lewis	17		Fall	1997	PS	11.1									99	Mueller & Downen; FPT00-09
Rowland	Klickitat	87		Fall	1999	PS	46	3	2								Jackson & Caromile; FPT00-15
Vancouver	Clark	2286	Eutrophic	Fall	1998	PS		3									Caromile et al; FPT00-19
						Avg.	77.1	2.8	2.8	12.6		7.0	100.0	32.8		105.7	
						Median	37.2	2.8	0.7	6.0		7.0	100.0	14.0		105.5	
Whatcom	Whatcom	4872	OligoMesotrophic	Fall	1998	RB	0.2	0								77	Mueller et al; FPT99-12
Hummel	San Juan	36	Eutrophic	Fall	1998	RB	12	1.5									Downen & Mueller; FPT00-03
Goodwin	Snohomish	537	Mesotrophic	Fall	1998	RB		1.5				11					Downen & Mueller; FPT00-02
N. Twin	Snohomish	7		Fall	1998	RB	8	2.5									Downen & Mueller; FPT00-04
S. Twin	Snohomish	10		Fall	1998	RB		0.5								70	Downen & Mueller; FPT00-04
Green	King	255	Eutrophic	Fall	1997	RB		1.5				33	33			91	Mueller & Downen; FPT00-25
Green	King	255	Eutrophic	Fall	1999	RB	3.9	0.5								90	Mueller & Downen; FPT00-25
Meridian	King	150	Oligotrophic	Fall	2000	RB		0.5								84	Verhey and Mueller; FPT01-11
Sawyer	King	291	Mesotrophic	Fall	1999	RB	1					100				104	Downen & Mueller; FPT00-23
Limerick	Mason	132	MesoEutrophic	Fall	1998	RB		0.6				25					Meyer & Caromile; FPT00-10
Island	Mason	110	OligoMesotrophic	Fall	1998	RB		0.2									Caromile & Meyer; FPT00-11
American	Pierce	1070	Mesotrophic	Fall	1997	RB		1				17				91	Mueller & Downen; FPT99-14
Black	Thurston	570	Eutrophic	Fall	1999	RB	5	2		50	20						Jackson & Caromile; FPT00-16

Appendix A. Catch rates (CPUE), stock density indices (PSD and RSD-P), and average relative weights (Wr) of fish sampled during surveys of select western Washington State lakes (cont'd.).

Lake	County	Size (acres)	Trophic status	Season	Year	Species	CPUE			PSD	RSD-P	PSD	RSD-P	PSD	RSD-P	Avg Wr	Source
							EB	GN	FN	EB		GN		FN			
Sunset	Whatcom	12	Eutrophic	Fall	1998	YP	41.8	11		76	19	91	9			98	Downen & Mueller; FPT99-02
Whatcom	Whatcom	4872	OligoMesotrophic	Fall	1998	YP	29.5	2.3		7	1	79	4			93	Mueller et al; FPT99-12
Campbell	Skagit	360	Mesotrophic	Fall	1999	YP	91.2	48.5	3.8	4		26	1			103	Downen & Mueller; FPT00-13
Goodwin	Snohomish	537	Mesotrophic	Fall	1998	YP	61	4		3		29				85	Downen & Mueller; FPT00-02
Cassidy	Snohomish	115	Eutrophic	Fall	1998	YP	441.2	37	0.3	14		3	1			86	Downen & Mueller; FPT99-07
Stevens	Snohomish	1039	Mesotrophic	Fall	1997	YP	98	21.7		10		25	2				Mueller; April 1999
Leland	Jefferson	110	Eutrophic	Fall	1999	YP	23	16		20		42					Jackson & Caromile; FPT00-22
Green	King	255	Eutrophic	Fall	1997	YP		0.5				100				89	Mueller & Downen; FPT00-25
Meridian	King	150	Oligotrophic	Fall	2000	YP	145.9	28.3		35	1	84	2			85	Verhey and Mueller; FPT01-11
Mason	Mason	1000	OligoMesotrophic	Fall	1997	YP	15.2	8.5								88	Mueller; February 1999
Sawyer	King	291	Mesotrophic	Fall	1999	YP	335	11.8	5.8	3	1	85	9	4	4	86	Downen & Mueller; FPT00-23
Limerick	Mason	132	MesoEutrophic	Fall	1998	YP	81.7	6.6	0.1	90		83	7				Meyer & Caromile; FPT00-10
Island	Mason	110	OligoMesotrophic	Fall	1998	YP	68.3	22.2		17	1	57					Caromile & Meyer; FPT00-11
American	Pierce	1070	Mesotrophic	Fall	1997	YP	2	29				79	3			96	Mueller & Downen; FPT99-14
Black	Thurston	570	Eutrophic	Fall	1999	YP	1	1		33							Jackson & Caromile; FPT00-16
Kapowsin	Pierce	590		Fall	1999	YP	73	7		16							Jackson & Caromile; FPT00-18
Black	Pacific	32		Fall	1997	YP	52.8	0.8								87	Mueller & Downen; FPT00-05
Vancouver	Clark	2286	Eutrophic	Fall	1998	YP	11	7									Caromile et al; FPT00-19
						Avg.	92.4	13.9	2.5	25.2	4.6	60.2	4.2	4.0	4.0	90.5	
						Median	61.0	8.5	2.1	16.0	1.0	79.0	3.0	4.0	4.0	88.0	

Appendix B. Total length (mm) at age of select warmwater species sampled during surveys of western Washington State lakes

Appendix B. Total length (mm) at age of select warmwater species sampled during surveys of western Washington State lakes.

Lake	County	Year	Species	Length at age														Source
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Campbell	Skagit	1999	BC	62	89													Downen & Mueller; FPT00-13
Goodwin	Snohomish	1998	BC	80	137	165												Downen & Mueller; FPT00-02
Cassidy	Snohomish	1998	BC	61	126	195	243											Downen & Mueller; FPT99-07
Leland	Jefferson	1999	BC	77	122	168	207	225	237									Jackson & Caromile; FPT00-22
Sawyer	King	1999	BC	75	183													Downen & Mueller; FPT00-23
Black	Thurston	1999	BC	68	149	202												Jackson & Caromile; FPT00-16
Kapowsin	Pierce	1999	BC	64	124	191												Jackson & Caromile; FPT00-18
Black	Pacific	1997	BC	69	99	137	164	203										Mueller & Downen; FPT00-05
Rowland	Klickitat	1999	BC	77	117	145	161	187	193									Jackson & Caromile; FPT00-15
Vancouver	Clark	1998	BC	72	126	170												Caromile et al; FPT00-19
			Avg.	70.6	127.1	171.6	193.8	204.8	215.0									
			Median	70.6	125.0	169.0	185.5	202.5	215.0									
Sunset	Whatcom	1998	CT	129	203	242												Downen & Mueller; FPT99-02
			Avg.	129	203	242												
			Median	129	203	242												
Sunset	Whatcom	1998	LMB	89	187	241	308	373	411									Downen & Mueller; FPT99-02
Hummel	San Juan	1998	LMB	84	147	191	237	309	343	367	392	419	443	463	482			Downen & Mueller; FPT00-03
Campbell	Skagit	1999	LMB	65	109	156	198	256	300	348	376	393	417	496				Downen & Mueller; FPT00-13
Goodwin	Snohomish	1998	LMB	83	150	208	270	309	358	393	419	442	459	472	507			Downen & Mueller; FPT00-02
N. Twin	Snohomish	1998	LMB	75	128	162	200	325	350	362	382							Downen & Mueller; FPT00-04
S. Twin	Snohomish	1998	LMB	76	154	214												Downen & Mueller; FPT00-04
Cassidy	Snohomish	1998	LMB	65	141	229	308	366										Downen & Mueller; FPT99-07
Stevens	Snohomish	1997	LMB	79	104	126	151	183										Mueller; April 1999
Leland	Jefferson	1999	LMB	70	134	193	238	290	339	377	413	435	456	477	508	533	547	Jackson & Caromile; FPT00-22
Green	King	1999	LMB	91														Mueller & Downen; FPT00-25
Meridian	King	2000	LMB	71	165													Verhey and Mueller; FPT01-11
Mason	Mason	1997	LMB	68	106	134	160	213	249	279	301	355	415					Mueller; February 1999
Sawyer	King	1999	LMB	80	173	239	288	353	403	442	462	487	502					Downen & Mueller; FPT00-23
Limerick	Mason	1998	LMB	79	178	213	280	307	364	413								Meyer & Caromile; FPT00-10
Island	Mason	1998	LMB	68	123	188	255	319	351	384	423	450	484					Caromile & Meyer; FPT00-11
American	Pierce	1997	LMB	88	217													Mueller & Downen; FPT99-14
Black	Thurston	1999	LMB	82	137	186	225	294	386	425	446							Jackson & Caromile; FPT00-16
Kapowsin	Pierce	1999	LMB	69	128	176	232	307	340	383	409	433						Jackson & Caromile; FPT00-18
Black	Pacific	1997	LMB	68	116	157	196	227	259	289	315	339	361	388	411	453		Mueller & Downen; FPT00-05
Rowland	Klickitat	1999	LMB	83	137	177	228	251										Jackson & Caromile; FPT00-15
Vancouver	Clark	1998	LMB	88	172	248	352	345	408									Caromile et al; FPT00-19
			Average	77.2	145.3	191.0	242.8	295.7	347.3	371.8	394.3	417.0	442.1	459.0	476.9	493.1	547.0	

Appendix B. Total length (mm) at age of select warmwater species sampled during surveys of western Washington State lakes (cont'd.).

Lake	County	Year	Species	Length at age														Source
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Whatcom	Whatcom	1998	PS	42	96	113	131											Mueller et al; FPT99-12
Campbell	Skagit	1999	PS	44	70	91	110	126	136									Downen & Mueller; FPT00-13
Goodwin	Snohomish	1998	PS	66	87	115	131	144	152	162								Downen & Mueller; FPT00-02
N. Twin	Snohomish	1998	PS	58	87	106	118	135										Downen & Mueller; FPT00-04
S. Twin	Snohomish	1998	PS	59	98	112												Downen & Mueller; FPT00-04
Cassidy	Snohomish	1998	PS	40	89	119	149											Downen & Mueller; FPT99-07
Stevens	Snohomish	1997	PS	57	76	92	111	123	136									Mueller; April 1999
Green	King	1999	PS	40	111	131												Mueller & Downen; FPT00-25
Meridian	King	2000	PS	43	97													Verhey and Mueller; FPT01-11
Sawyer	King	1999	PS	47	116	162	173											Downen & Mueller; FPT00-23
Limerick	Mason	1998	PS	53	99													Meyer & Caromile; FPT00-10
Island	Mason	1998	PS	45	81	119	148	160	168									Caromile & Meyer; FPT00-11
American	Pierce	1997	PS	52	78	99	122											Mueller & Downen; FPT99-14
Kapowsin	Pierce	1999	PS	51	77	113	125	139										Jackson & Caromile; FPT00-18
Rowland	Klickitat	1999	PS	48	73	95	112	132										Jackson & Caromile; FPT00-15
Vancouver	Clark	1998	PS	56	86	90												Caromile et al; FPT00-19
			Average	50.1	88.8	111.2	129.8	137.1	147.9	161.8								
			Median	49.5	86.8	112.3	125.0	135.3	143.8	161.8								
Sunset	Whatcom	1998	YP	88	149	195	235	263										Downen & Mueller; FPT99-02
Whatcom	Whatcom	1998	YP	75	124	178	206	262										Mueller et al; FPT99-12
Campbell	Skagit	1999	YP		134	167	178	187										Downen & Mueller; FPT00-13
Goodwin	Snohomish	1998	YP	85	121	158	180	198	213									Downen & Mueller; FPT00-02
Cassidy	Snohomish	1998	YP	72	123	168	202	215	234									Downen & Mueller; FPT99-07
Stevens	Snohomish	1997	YP	80	104	130	154	179	205	224	236	248	257					Mueller; April 1999
Leland	Jefferson	1999	YP	86	143	177	208											Jackson & Caromile; FPT00-22
Meridian	King	2000	YP	75	143	187	220	242										Verhey and Mueller; FPT01-11
Mason	Mason	1997	YP	95	132	156	178	197	212	229								Mueller; February 1999
Sawyer	King	1999	YP	84	163	203	234											Downen & Mueller; FPT00-23
Limerick	Mason	1998	YP	117	187	207												Meyer & Caromile; FPT00-10
Island	Mason	1998	YP	82	118	152	171	181										Caromile & Meyer; FPT00-11
American	Pierce	1997	YP	80	132	172	204	232	262	277								Mueller & Downen; FPT99-14
Black	Thurston	1999	YP	79	134	168	195	279										Jackson & Caromile; FPT00-16
Kapowsin	Pierce	1999	YP	67	123	164	175											Jackson & Caromile; FPT00-18
Black	Pacific	1997	YP	82	127	154	180	190										Mueller & Downen; FPT00-05
Vancouver	Clark	1998	YP	82	119	142												Caromile et al; FPT00-19
			Average	83.0	133.9	169.2	194.6	218.8	225.2	243.1	236.1	247.8	257.1					
			Median	82.0	131.7	168.0	195.0	206.6	213.1	228.5	236.1	247.8	257.1					