1999 Campbell Lake Survey: The Warmwater Fish Community Fifteen Years After Implementation of a Lake Restoration Plan

by

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Abstract

Due to warmwater fishery history and due to suitability of habitat and environmental conditions for these species in Lake Campbell, the WDFW Warmwater Enhancement Program conducted a stock assessment in fall 1999. We assessed species composition, abundance, size structure, growth, and condition of fish in the lake. We also evaluated habitat, access, and the effects of current fishing rules, and outlined options for enhancing the fishery and fishing opportunity. The fish community in Lake Campbell was composed almost entirely of warmwater species, the size structures of which were heavily skewed toward sub stock and stock length fish. Smaller, older forage fish, particularly bluegill were extremely abundant, suggesting reduced foraging efficiency of largemouth bass. A sizable gap in the length frequency distribution of largemouth bass was the product of initial slow growth prior to an ontological shift to piscivory. These patterns may be the result of interspecific competition at early life stages and reduced foraging efficiency due to high densities of aquatic vegetation. Results of our survey suggest channel catfish survival is low, possibly due to small size at the time of stocking. While one public boat launch exists on Lake Campbell, shoreline access is limited. Based on these assessments, we outlined options for improving access and fishing opportunity in Lake Campbell by installing a dock at the WDFW access. We suggested altering the stocking regime for channel catfish to improve survival and outlined options for vegetation control to improve growth and accessibility of fish in the lake.

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Introduction and Background

Lake Campbell is a medium-sized (150 ha), shallow (2.4 m and 4.9 m, mean and maximum depth, respectively), lowland lake occurring south and east of rocky formations on west Fidalgo Island, Skagit County. Several intermittent streams drain into Campbell Lake, including a 0.75 km outlet of Lake Erie (44 ha) (Figure 1). Historically, Campbell Lake also received the outflow of Whistle Lake before the city of Anacortes diverted those waters into their water supply. A single unscreened outlet drains Campbell Kake from its southern shore and discharges directly into Deception Pass. A kettle lake of glacial origin, Lake Campbell was formed in recessional moraines during the Pleistocene, and has since filled considerably with eroded soils and detritus. The 1,470 ha drainage basin is characterized by sedimentary and metamorphic geology, and watershed land uses include second growth forest and undeveloped lands (75%), agricultural (15%), and rural residential (10%) (Entranco Engineers 1983). Shoreline land use is evenly distributed between rural residential and undeveloped second growth forest (50% and 42% respectively) with the remaining 7% of shoreline consisting of cattle pasture.

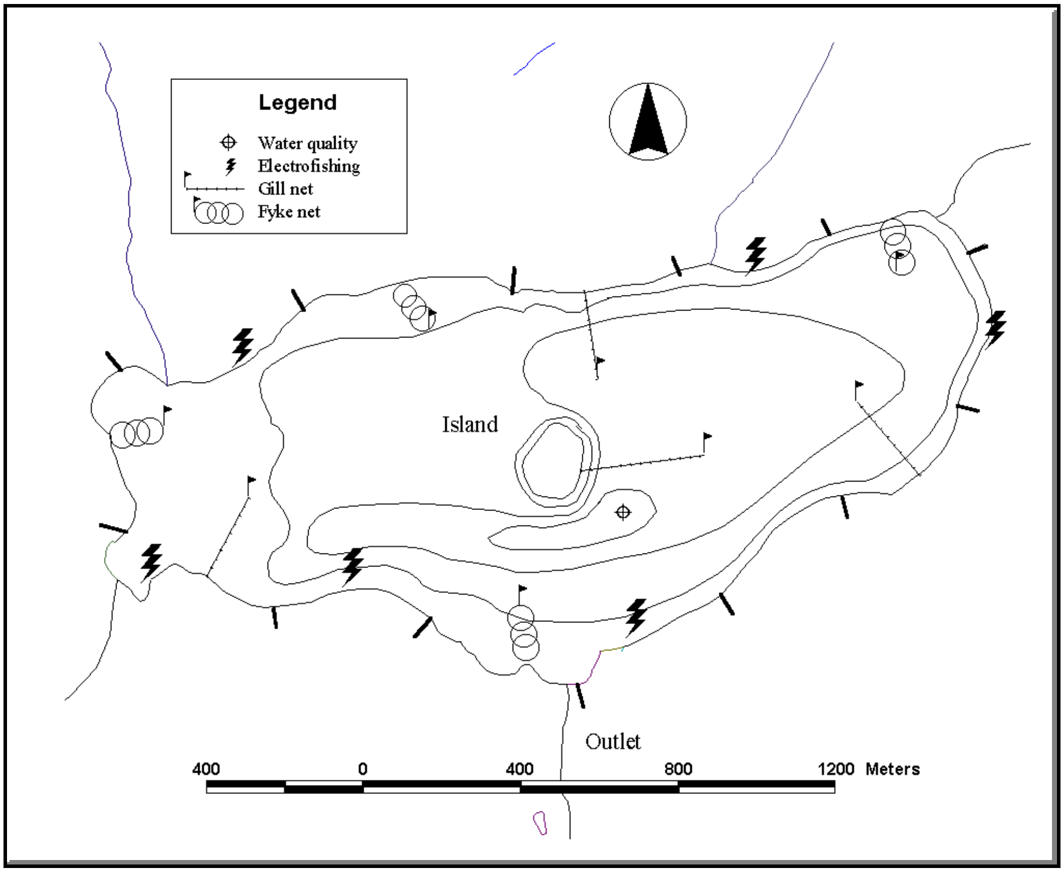

Figure 1. Hydrology, bathymetry, and 1999 sampling sites on Campbell Lake (Skagit County).

Lake Campbell is a productive lake and has long history of regular and sometimes wide-spread algal blooms. Evaluations of trophic status carried out in the early 1980's (Figure 1)according to Carlson (1977) revealed a seasonal pattern of eutrophication with high total phosphorus during late summer and chloraphyll-*a* concentrations at eutrophic levels for a least six months out of the year (Entranco Engineers 1983). However, water quality assessments following the implementation of a lake restoration plan in 1986 demonstrated reductions in levels of these trophic status indicators (Entranco Engineers 1987). Measurements of total phosphorus and chlorophyll-a, collected by Washington Department of Ecology in 1999, are consistent with post-restoration levels (Figure 2). Despite high inputs of organic matter, high primary productivity, and subsequent decomposition of these materials, water quality with respect to dissolved oxygen has remained within acceptable ranges for fish (Figure 3). A thermocline is rarely detectable due to shallow lake depth and prevailing winds, and anoxic conditions have not been observed.

Productive conditions support a diverse and extensive aquatic plant community in Lake Campbell. Dense stands of submersed coontail (*Ceratophyllum demersum*), northern watermilfoil (*Myriophyllum sibircum*), and pondweed (*Potamogeton spp.*) occur throughout much of the littoral zone, and dense patches of yellow water lily (*Nuphar polysepala*) occur in several near shore areas. Eurasian watermilfoil (*Myriophyllum spicatum*) has also become well established, forming dense beds at the east end of the lake (Jenifer Parsons, Washington Department of Ecology, unpublished data).

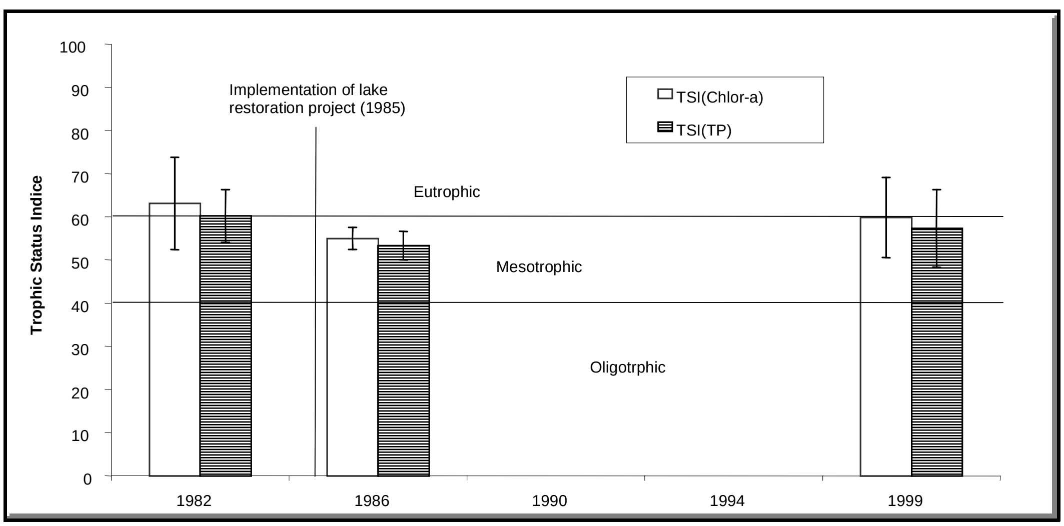

Figure 2. Trophic indices (Carlson 1977) derived from median epilimnetic total phosphorus and chlorophyll a concentrations for Campbell Lake between June and September. (Sources: Entranco Engineers 1987, Washington Department of Ecology 1999, unpublished data.)

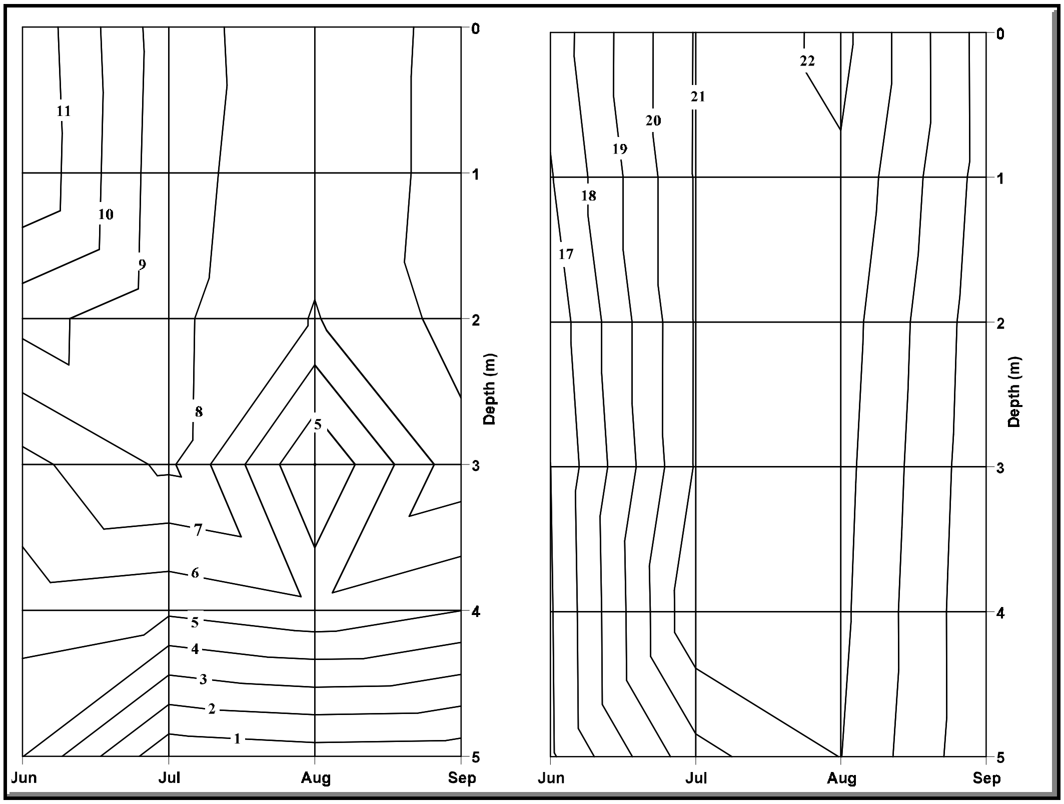

Figure 3. Campbell Lake 1999 vertical dissolved oxygen (mg/L) and temperature (°C) profile dynamics through time. Contour lines are at one degree Celsius intervals (Source: Washington Department of Ecology, 1999, unpublished data).

Materials and Methods

Two WDFW biologists and one scientific technician surveyed Lake Campbell during 8 through 9 September 1999. 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 electrofishing boat set to a DC current of 120 cycles/sec at 6 amps current. Experimental gill nets (45.7 m long × 2.4 m deep) were constructed of four sinking panels (two each at 7.6 m and 15.2 m long) of variable-size (13, 19, 25, and 51 mm stretched) monofilament mesh. Fyke nets were constructed of a single 30.4-m lead and two 15.2 m-wings of 130 mm nylon mesh with the body of the nets stretched around four 1.2 m aluminum rings in each of two sections.

Sampling locations were selected by dividing the shoreline into 14 consecutively numbered sections of about 400 m each as determined from a 1:24,000 USGS map. A portion of the shoreline was sampled by electrofishing 6 randomly selected sections for a total of 5,400 seconds. While electrofishing, the boat was maneuvered through the shallows (depth range: 0.2 - 1.5 m), adjacent to the shoreline, at a rate of 18 m/minute. Four gill nets were set perpendicular to the shoreline with the small-mesh end attached onshore and the large-mesh end anchored offshore. Four fyke nets were set in water less than three meters deep, perpendicular to the shoreline with wings extended at 70^o angles from the lead. Sampling occurred during evening hours to maximize the type and number of fish captured. In order to reduce bias between techniques and to standardize effort, the sampling time for each gear type was standardized to a ratio of 1:1:1 (Fletcher et al. 1993). One unit of electrofishing time equal to three 600-second sections (actual pedal-down time) was applied for each 24 hour unit (= 2 net nights) of gill netting time and fyke netting time so that three sites were electrofished for every two sites of gill netting and fyke netting.

All fish captured were identified to species. Each fish was measured to the nearest millimeter 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. Fish were weighed to the nearest 0.5 g. If a sample included several hundred individuals of a given species, then a sub-sample ($n \geq 100$ fish) was measured and weighed while the remainder was counted overboard. The length frequency distribution of the sub-sample was then applied to the total number collected. Weights of individuals counted overboard were estimated using the linear regression of $\log_{10}$-length on $\log_{10}$-weight of fish from the sub-sample. Scales were removed from up to five 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). Scales were also measured for standard back-calculation of growth. However, a lack of technical resources precluded aging members of the family Ictaluridae (catfish).

Water quality data was collected during midday from one site on 8 September 1999 using a Hydrolab® probe and digital recorder. We measured dissolved oxygen, total dissolved solids, temperature, pH, and specific conductance and recorded secchi disc readings in meters (Table 1).

Table 1. Water quality from the deepest location on Lake Campbell (Skagit County) collected at mid-day on 8 September 1999. Secchi depth = 1.8 m.

Depth (m)	Temp (°C)	DO (mg/L)	pH	Conductance (uS/cm)	TDS (g/L)
0	19.12	10.76	8.14	132.9	0.0850
1	19.08	8.98	8.15	133.2	0.0853
2	19.05	8.53	8.10	133.1	0.0853
3	18.55	8.30	8.05	133.2	0.0852
4	18.90	8.26	8.02	132.6	0.0854
5	18.75	8.00	7.99	132.6	0.0849
6	18.75	7.41	7.84	132.5	0.0855

Data Analysis

Balancing predator and prey fish populations is an important axiom of managing warmwater fisheries. According to Bennett (1962), the term ‘balance’ is used loosely to describe a system in which omnivorous forage fish or prey maximize food resources to produce harvestable-size stocks for fishermen while maintaining an adequate forage base for piscivorous fish or predators. Predators must reproduce and grow to control overproduction of both prey and predator species, as well as provide adequate fishing. To maintain balance, predator and prey fish must be able to forage effectively. Evaluations of species composition, size structure, growth, and condition (plumpness or robustness) of fish provide useful information on population age class structures, relative species abundances, the potential for species interactions, and the adequacy of the food supplies for various foraging niches (Ricker 1975; Kohler and Kelly 1991; Olson et al. 1995). Balance and productivity of the community may also be addressed based upon these evaluations (Swingle 1950, Bennett 1962).

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

Catch per unit effort (CPUE) by gear type was determined for all fish species (number of fish/hour electrofishing and number of fish/net night). Only stock size fish and larger were used to determine CPUE for warmwater and other game species. Stock length, which varies by species (see Table 3 and discussion below), refers to the minimum size of fish having recreational value. Since sample locations were randomly selected, which can 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 ± $t_{(\alpha, N-1)} \times SE$, where t = Student's t for α confidence level with n -1 degrees of freedom (two-tailed) and SE = standard error of the mean. Since it is standardized, CPUE is a useful index for comparing relative abundance of stocks between lakes and the confidence intervals express the relative uniformity of species distributions throughout a given lake. CPUE values for Lake Campbell were then compared to western Washington State averages compiled by the WDFW Inland Fisheries Research Unit (Table 2).

Table 2. Mean catch per unit effort (number of fish /hour electrofishing and number of fish/net night) for stock size fish collected from several western Washington Lakes while electrofishing, gill netting, and fyke netting during 1997 and 1998.

	Gear type					
Species	Electrofishing (fish/hr)	n (lakes)	Gillnetting (fish/hr)	n (lakes)	Fyke netting (fish/hr)	n (lakes)
Largemouth Bass	41.6	12	1.9	8	0.3	1
Black Crappie	9.63	4	4.2	3	23.4	2
Bluegill	169.1	7	1.6	4	20.7	5
Pumpkinseed	70.8	11	3.8	9	7.9	4
Yellow Perch	97.5	8	13.7	6	0.2	2
Brown Bullhead	7.8	10	14.4	7	12.7	6

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.

The proportional stock density (PSD) of each warmwater fish species was determined following procedures outlined in Anderson and Neumann (1996). PSD, which was calculated as the number of fish$\geq$quality length/number of fish$\geq$stock length$\times$100, is a numerical descriptor of length frequency data that provides useful information about size class structure. 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 warmwater 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. Memorable length (59-64% of world-record length) refers to the minimum size fish most anglers are likely to 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 size class structure, but is more sensitive to changes in year-class strength. RSD was calculated as the number of fish$\geq$specified length/number of fish$\geq$stock length$\times$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 warmwater fish species by Gabelhouse (1984) used to calculate stock density indices (PSD, RSD) for fish captured at Lake Campbell (Skagit County) during spring 1999 based on numbers from Anderson and Neumann (1996) and Bister et al. unpublished data.

	Total Length (mm)				
Species	Stock	Quality	Preferred	Memorable	Trophy
Largemouth bass	200	300	380	510	630
Black crappie	130	200	250	300	380
Bluegill	80	150	200	250	300
Pumpkinseed	80	150	200	250	300
Yellow perch	130	200	250	300	380
Brown bullhead	130	200	280	360	430

Bister et al. Dept. of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, South Dakota 57007.

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 bluegills under three commonly implemented management options (from Willis et al. 1993).

	Largemouth bass			Bluegill	
Option	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

We compared PSD and RSD values for warmwater species in Lake Campbell with western Washington State averages compiled by the WDFW Inland Fisheries Research Unit (Table 5).

Table 5. Mean stock density indices for available warmwater fishes from western Washington lakes with the most effective sampling method for a given species during 1997 and 1998 (WDFW Inland Fisheries Research Unit, unpublished data). 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.

Species	Gear type	n (lakes)	PSD	RSD-P	RSD-M	RSD-T
Largemouth Bass	EB	12	29	13	0	0
Black crappie	EB	3	100	5	0	0
Bluegill	EB	9	16	0	0	0
Pumpkinseed	EB	12	8	0	0	0
Yellow Perch	GN	12	53	1	0	0

Age and growth of warmwater fishes in Lake Campbell were evaluated using the direct proportion method (Jearld 1983; Fletcher et al. 1993) and Lee's modification of the direct proportion method (Carlander 1982). Using the direct proportion method, total length at annulus formation was back-calculated as $L_n = (A \times TL)/S$, where A is the radius of the fish scale at age n, TL is the total length of the fish captured, and S is the total radius of the scale at capture. Using Lee's modification, L_n was back-calculated as $L_n = a + A{\times}(TL - a)/S$, where a is the species-specific standard intercept from a scale radius-fish length regression. Mean back-calculated lengths at age n for each species were presented in tabular form for easy comparison of growth between year classes, as well as between Lake Campbell fish and the western Washington State average (listed in Fletcher et al. 1993) for the same species. Annual average instantaneous growth rates, G, were calculated according to Ricker (1975) by estimating weights from average total length using the linear regression of $\log_{10}$-length on $\log_{10}$-weight.

A relative weight (W_r) index was used to evaluate the condition of fish in the lake. A W_r value of 100 generally indicates that a fish has a condition value equal to the national standard (75th percentile) for that species. Furthermore, W_r is useful for comparing the condition of different size classes within a single population to determine if all sizes are finding adequate forage (ODFW 1997). Following Murphy et al. (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 for the W_s equations of many cold- and warmwater fish species, including the minimum length recommendations for their application, are listed in Anderson and Neumann (1996). The W_r values from this study were compared to the national standard ($W_r = 100$) and where available, with mean W_r values from up to 25 western Washington warmwater lakes sampled during 1997 and 1998 (Steve Caromile, WDFW, unpublished data). Trends in the dispersion of points on the relative weight graph have been used to infer ecological dynamics of fish populations (Willis 1999). For example, a decrease in relative weight with increasing total length often occurs where competition is high among larger size classes. Conversely, lower relative weights occurring with smaller fish suggests competition and crowding for these fish. Testing the statistical significance of the relationship between total length and relative weight, standard transformation failed to normalize the length data. Moreover, we make no assumption that relationships would be linear. We therefore used a nonparametric correlation, Spearman's Rho (Zar 1984), to assess the significance of correlations between total length and relative weight where relationships were suggested by the graphs.

Results and Discussion

Species Composition

Largemouth bass was the dominant species in our sample from Lake Campbell by biomass (39%) while bluegill was the dominant species by number (41%). Yellow perch accounted for nearly the same percentage of the sample by biomass and number at 24% and 20 %, respectively. Pumpkinseed and black crappie were relatively rare compared to other warmwater species both by biomass and number (Table 6). While brown bullhead only accounted for 5.7% of our sample by number, they had up 15% of our sample by biomass. Although channel catfish have been stocked in Lake Campbell in recent years, we did not sample them during this survey.

Table 6. Species composition by weight (kg) and number of fish captured at Lake Campbell (Skagit County) during spring 1999.

Species	(kg)	(%) weight	(#)	(%) n	Size range (mm)
Largemouth Bass (*Micropterus salmoides*)	37.323	38.972	392	26.133	32 -510
Black Crappie (*Pomoxis nigromaculatus*)	0.750	0.783	18	1.200	19 -171
Bluegill (*Lepomis macrochirus*)	16.189	16.904	621	41.400	24 -184
Pumpkinseed (*Lepomis gibbosus*)	2.623	2.738	65	4.333	76 -154
Yellow Perch (*Perca flavenscens*)	24.178	25.247	315	21.000	62 -252
Brown Bullhead (*Ameiurus nebulosus*)	14.663	15.311	85	5.667	36 -372
Sculpin (*Cottus* spp.)	0.043	0.045	4	0.267	94 -105
Total	95.768		1500		

C P U E

Catch rates for stock length largemouth bass and yellow perch were consistent with the western Washington state average while electrofishing. Although catch rates for largemouth bass while gill netting were also consistent with the state average, catch rates for yellow perch while gill netting were high. Catch rates were also high for bluegill for these gear types while catch rates for pumpkinseed and black crappie were low (Table 7).

Table 7. Mean catch per unit effort (number of fish /hour electrofishing and number of fish/net night), including 80% confidence intervals, for stock size fish collected from Lake Campbell (Skagit County) while electrofishing, gill netting, and fyke netting during spring 1999.

Species	Gear type					
	Electrofishing (fish/hr)	n (sites)	Gill netting (fish/hr)	n (net nights)	Fyke netting (fish/hr)	n (net nights)
Largemouth Bass	40.33 ± 9.88	6	2.25 ± 0.81	4	0	4
Black Crappie	0	6	3.75 ± 2.88	4	0	4
Bluegill	363.49 ± 119.14	6	8.75 ± 4.72	4	2 ± 0.91	4
Pumpkinseed	34.51 ± 20.32	6	4.5 ± 1.85	4	2.25 ± 0.61	4
Yellow Perch	91.24 ± 30.05	6	48.5 ± 16.23	4	3.75	4
Brown Bullhead	5.87 ± 6.16	6	8.5 ± 5.4	4	1.25 ± 1.21	4
Sculpin	0	6	0	4	1 ± 0.91	4

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

Stock Density Indices

Proportional stock indices for largemouth bass were generally above the western Washington state average while electrofishing. However, the PSD for largemouth bass was low in relation to the RSD-P due to a paucity of quality fish that were not also preferred length. This missing size class is also apparent in the length frequency distribution. A somewhat more diverse size structure was sampled with gill netting but these indices should be viewed with caution due to low sample size (Divens 1998). No quality length or greater black crappie were sampled. Bluegill, pumpkinseed, and yellow perch all demonstrate stock density indices below the western Washington state averages while those for brown bullhead were considerably above average (Table 8).

Table 8. Traditional stock density indices, including 80% confidence intervals, for warmwater fishes collected from Lake Campbell (Skagit County) while electrofishing, gill netting, and fyke netting during spring 1999.

Species	Gear type	n	PSD	RSD-P	RSD-M	RSD-T
Largemouth Bass	EB	41	34 ± 9	32 ± 9	2[a]	0
	GN	9	56 ± 21	44 ± 21	0	0
	FN	0	0	0	0	0
Black Crappie	EB	0	0	0	0	0
	GN	15	0	0	0	0
	FN	0	0	0	0	0
Bluegill	EB	369	8 ± 2	0	0	0
	GN	35	3[a]	0	0	0
	FN	8	63 ± 22	0	0	0
Pumpkinseed	EB	35	3[a]	0	0	0
	GN	18	6[a]	0	0	0
	FN	9	22 ± 18	0	0	0
Yellow Perch	EB	93	4 ± 3	0	0	0
	GN	194	26 ± 4	1[a]	0	0
	FN	15	0	0	0	0
Brown Bullhead	EB	6	67 ± 25	33 ± 25	0	0
	GN	34	74 ±10	35 ± 11	0	0
	FN	5	100	0	0	0

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

Largemouth Bass

Largemouth bass ranged from 32 to 510 mm TL (age 1+ to 11+). The 1998 year-class was dominant but the 1995 year-class was also strong (Table 9). Although the 1993 year-class was not sampled, there were no instances of consecutive unsampled year classes that would explain the gap in the length frequency distribution (Figure 4). However, a substantial increase in growth beginning at age 4+ and slowing again at age 7+ suggests fish grow rapidly through the gap. Despite slower than average growth rates at smaller sizes, relative weights were generally consistent with western Washington State averages across the entire range of size classes during the sampling period (Figure 5).

Table 9. Age and growth of largemouth bass captured at Lake Campbell (Skagit County) during Fall 1999. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age										
Year class	# fish	1	2	3	4	5	6	7	8	9	10	11
1998	29	53.4										
		65.7										
1997	8	50.0	101.4									
		64.0	109.4									
1996	6	45.2	97.0	144.6								
		60.4	106.6	149.1								
1995	19	39.6	81.8	133.6	177.1							
		55.8	94.0	140.8	180.1							
1994	6	39.2	76.2	116.6	165.4	199.1						
		55.7	89.4	126.3	170.9	201.7						
1993	0											
1992	1	84.8	178.1	237.4	318.0	373.1	385.8	407.0				
		100.8	189.7	246.2	323.0	375.5	387.6	407.8				
1991	5	61.2	116.3	180.2	231.5	295.8	326.4	370.9	401.0			
		78.3	130.8	191.7	240.6	301.9	331.1	373.4	402.1			
1990	7	54.3	103.2	154.4	187.5	232.2	263.2	325.7	360.6	390.3		
		71.7	118.1	166.8	198.3	240.7	270.3	329.6	362.8	391.0		
1989	5	57.9	117.0	167.6	208.2	249.9	273.5	317.2	351.8	379.0	401.6	
		75.2	131.5	179.6	218.3	258.0	280.7	322.2	355.2	381.0	402.5	
1988	1	88.3	156.9	210.9	250.1	313.8	348.2	411.9	431.5	461.0	485.5	495.3
		104.8	170.8	222.6	260.3	321.5	354.5	415.8	434.6	462.9	486.4	495.9
Overall mean		57.4	114.2	168.2	219.7	277.3	319.4	366.5	386.2	410.1	443.5	495.3
1978 Survey		58.7	152.6	238.8	302.5	352.5	378.7	402.3	384.0			
Weighted mean		64.9	109.2	156.4	198.0	255.7	299.6	347.8	375.6	392.7	416.5	495.9
State Average		60.4	145.5	222.2	261.1	289.3	319	367.8	396	439.9	484.6	471.7
Annual G		2.00	2.13	1.20	0.83	0.72	0.44	0.43	0.16	0.19	0.24	0.34
Statewide annual G		2.16	2.72	1.31	0.50	0.32	0.30	0.44	0.23	0.32	0.30	-0.08

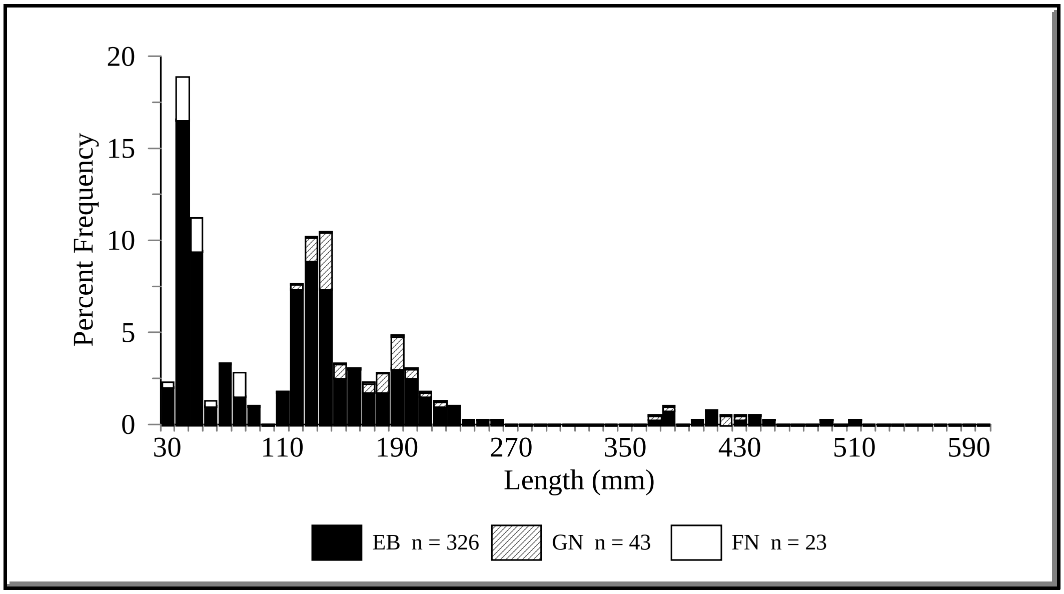

Figure 4. Length frequency histogram of largemouth bass sampled from Lake Campbell in Fall 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

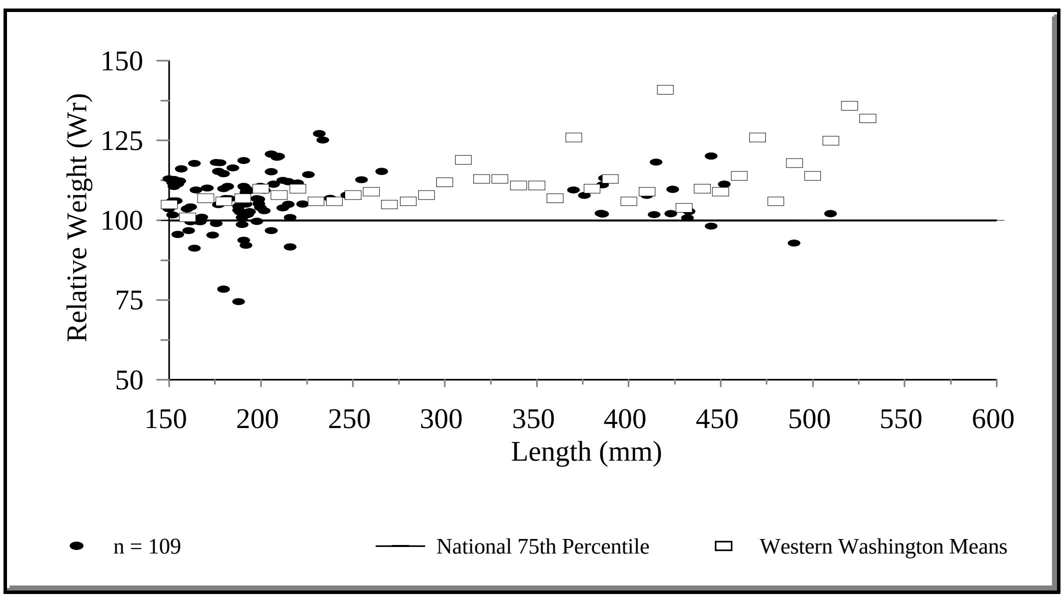

Figure 5. Relationship between total length and relative weight (W_r) of largemouth bass from Lake Campbell (Skagit County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Black Crappie

Black crappie ranged from 19 to 171 mm TL (age 1+ to 2+). All black crappie were taken with gill nets and fish older than 2+ were not taken in our sample. Growth for these fish were below the western Washington State average. However, relative weights were generally above average during the sampling period.

Table 10. Age and growth of black crappie captured at Lake Campbell (Skagit County) during Fall 1999. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age	
Year Class	# fish	1	2
1998	9	37.1	
		62.8	
1997	3	32.9	71.4
		59.8	88.7
	Overall mean	35.0	71.4
	Weighted Mean	62.0	88.7
	State Average	46.0	111.2
	Annual G	1.86	2.36
	Statewide annual G	2.77	2.93

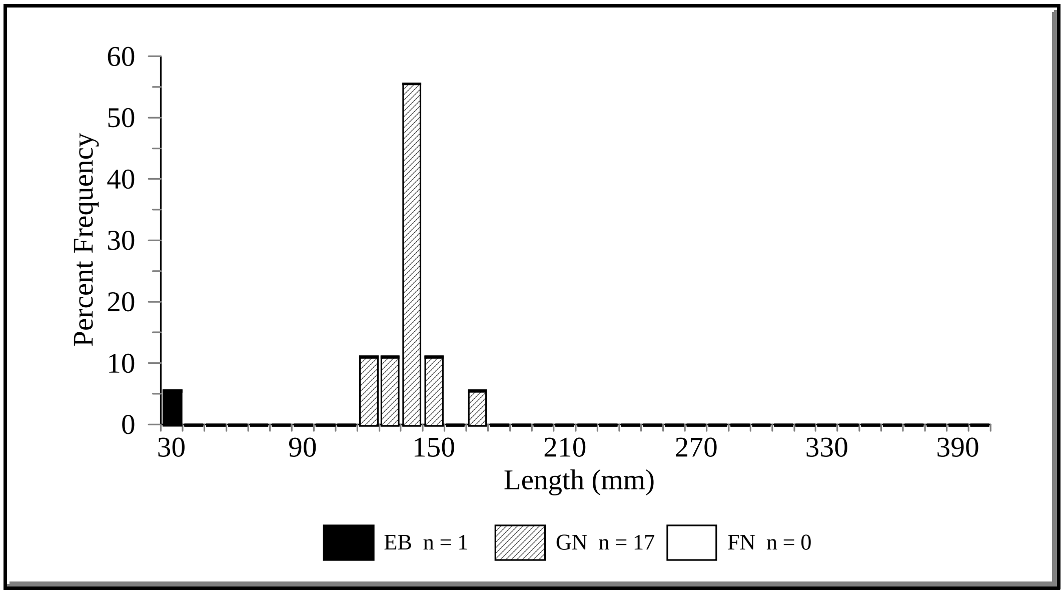

Figure 6. Length frequency histogram of black crappie sampled from Lake Campbell in Fall 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

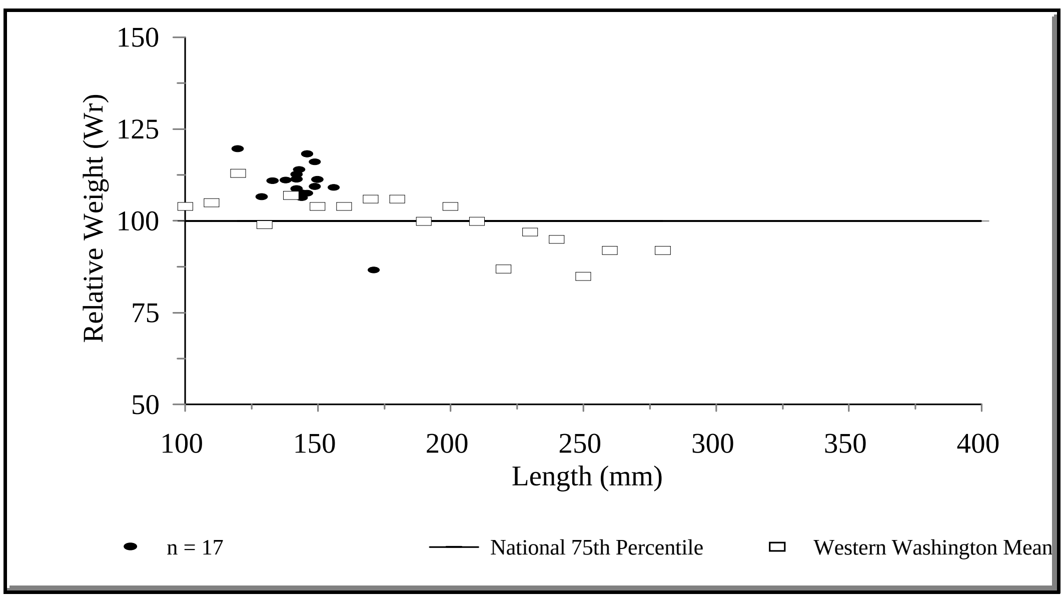

Figure 7. Relationship between total length and relative weight (W_r) of black crappie from Lake Campbell (Skagit County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Bluegill

Bluegill ranged from 24 to 184 mm TL (age 1+ to 8+). Initial growth rates for bluegill in Lake Campbell were very low but increased after age 2+. However, above average growth from age 2+ through 5+ did not overcome the impacts of initial low growth on the average lengths. Relative weights for bluegill were generally consistent with the western Washington State averages with a subtle downward trend with increasing TL.

Table 11. Age and growth of bluegill captured at Lake Campbell (Skagit County) during Fall 1999. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age							
Year Class	# fish	1	2	3	4	5	6	7	8
1998	30	23.3							
		37.7							
1997	20	18.3	63.4						
		35.4	73.4						
1996	4	23.3	72.5	117.6					
		40.0	82.0	120.4					
1995	2	11.3	54.2	86.3	122.2				
		29.7	66.3	93.8	124.5				
1994	7	36.2	70.5	100.9	131.3	151.0			
		51.9	82.0	108.8	135.6	152.9			
1993	2	16.9	56.1	88.4	114.5	139.5	160.6		
		34.9	69.5	98.0	121.1	143.2	161.8		
1992	0								
1991	1	13.5	50.8	88.0	110.6	124.2	138.8	146.7	163.7
		32.1	65.3	98.5	118.6	130.7	143.8	150.8	165.9
Overall mean		20.4	61.3	96.2	119.6	138.3	149.7	146.7	163.7
Weighted mean		38.2	75.2	107.8	129.9	148.8	155.8	150.8	165.9
State Average		37.3	96.8	132.1	148.3	169.9	200.9	195.8	
Annual G		0.07	3.67	1.51	0.73	0.48	0.27	-0.07	
Statewide annual G		2.08	3.19	1.04	0.39	0.45	0.56	-0.09	

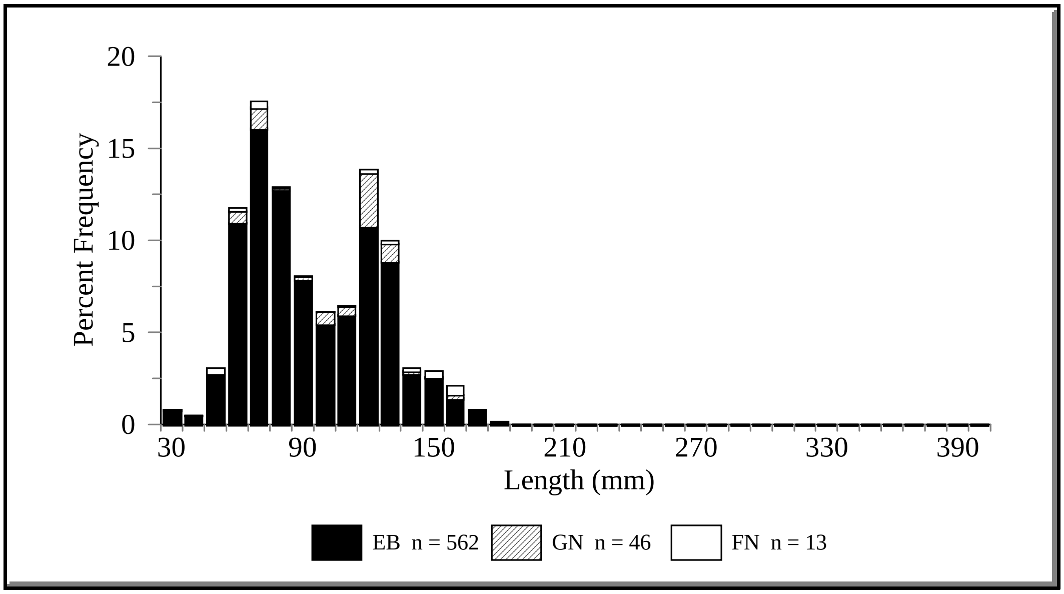

Figure 8. Length frequency histogram of bluegill sampled from Lake Campbell in Fall 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

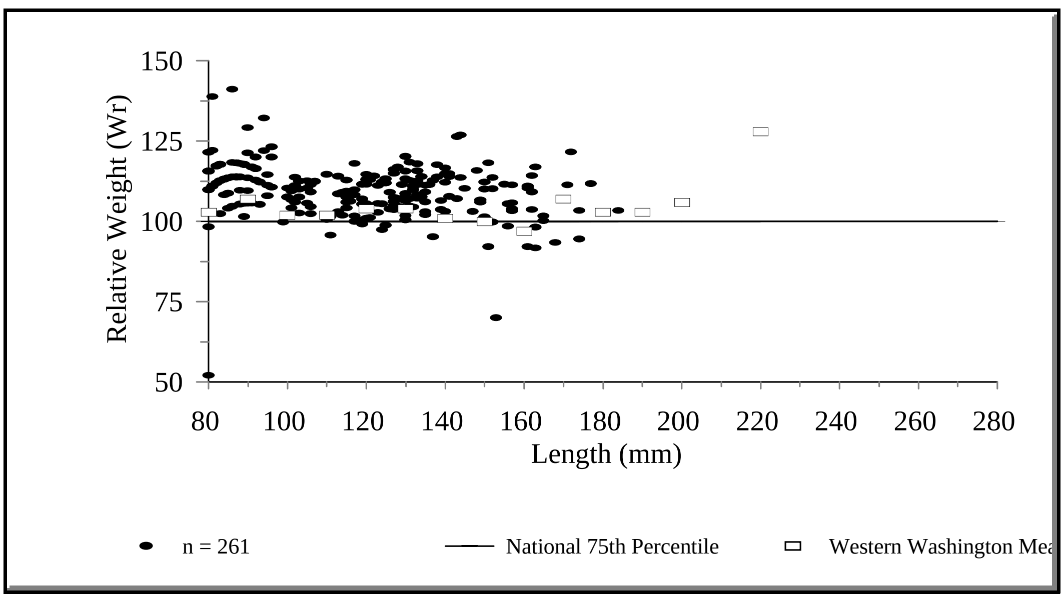

Figure 9. Relationship between total length and relative weight (W_r) of bluegill from Lake Campbell (Skagit County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Pumpkinseed

Pumpkinseed ranged from 76 to 154 mm TL (age 1 to 6). Although growth for pumpkinseed was below the western Washington average during the two years, it rose after age 2+ and was above average thereafter. But, like bluegill, increased growth rates did not eliminate the impact of initial slow growth on average TL for subsequent age classes. Relative weights for pumpkinseed were slightly below the western Washington State average with a slight downward trend with increasing TL.

Table 12. Age and growth of pumpkinseed captured at Lake Campbell (Skagit County) during Fall 1999. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age					
Year Class	# fish	1	2	3	4	5	6
1998	12	29.6					
		46.1					
1997	4	19.9	52.6				
		40.4	65.6				
1996	11	23.0	59.1	83.7			
		43.2	71.7	91.1			
1995	5	20.6	51.0	81.9	106.0		
		41.9	66.7	91.9	111.6		
1994	8	22.5	56.2	81.5	104.5	122.3	
		43.6	71.4	92.3	111.2	125.9	
1993	2	23.6	55.8	73.5	91.0	120.9	133.5
		44.6	71.4	86.2	100.7	125.5	135.9
Overall mean		23.2	54.9	80.2	100.5	121.6	133.5
Weighted mean		43.7	69.9	91.3	110.0	125.9	135.9
State Average		23.6	72.1	101.6	122.7	139.4	
Annual G		0.45	2.59	1.14	0.68	0.57	
Statewide Annual G		0.50	3.36	1.03	0.57	0.38	

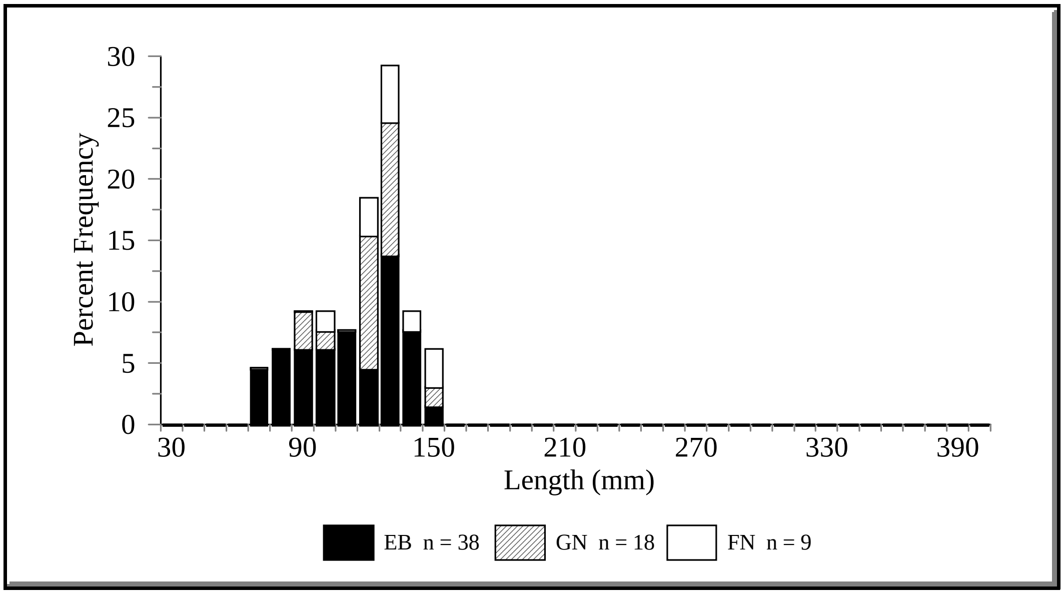

Figure 10. Length frequency histogram of pumpkinseed sampled from Lake Campbell in Fall 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

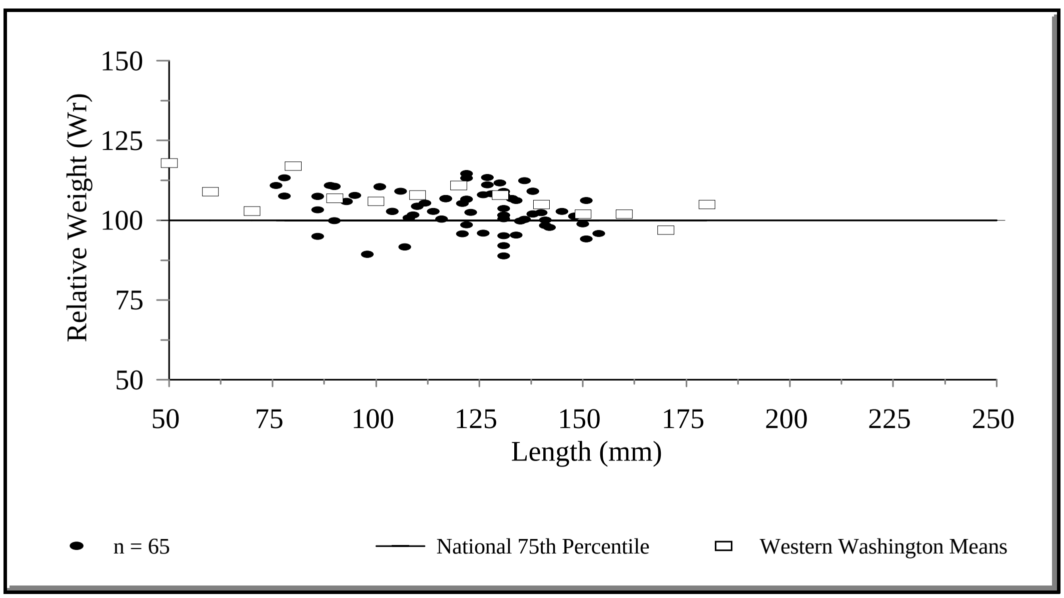

Figure 11. Relationship between total length and relative weight (W_r) of pumpkinseed from Lake Campbell (Skagit County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Yellow Perch

Yellow perch ranged from 62 to 252 mm TL (age 1+ to 5+). Age 1+, 2+ and 3+ yellow perch were relatively abundant. Growth for yellow perch varied from slightly below the western Washington State average for the first two years to slightly above for age 2+ and 4+, and was generally consistent with average overall. Relative weights for yellow perch were above the western Washington State average with an upward trend with increasing TL.

Table 13. Age and growth of yellow perch captured at Lake Campbell (Skagit County) during Fall 1999. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age				
Year Class	# fish	1	2	3	4	5
1998	27	56.1				
		75.0				
1997	14	63.5	136.8			
		83.8	146.0			
1996	16	62.3	115.3	167.7		
		83.9	129.8	175.2		
1995	5	65.3	115.5	148.4	180.6	
		86.2	129.4	157.7	185.4	
1994	3	44.9	93.7	129.5	156.7	183.3
		68.5	110.4	141.2	164.6	187.4
	Overall mean		115.3	148.6	168.7	183.3
	Weighted mean		134.2	167.3	177.6	187.4
	State Average		119.9	152.1	192.5	206.0
	Annual G		2.18	0.81	0.41	0.27
	Statewide annual G		2.24	0.76	0.76	0.22

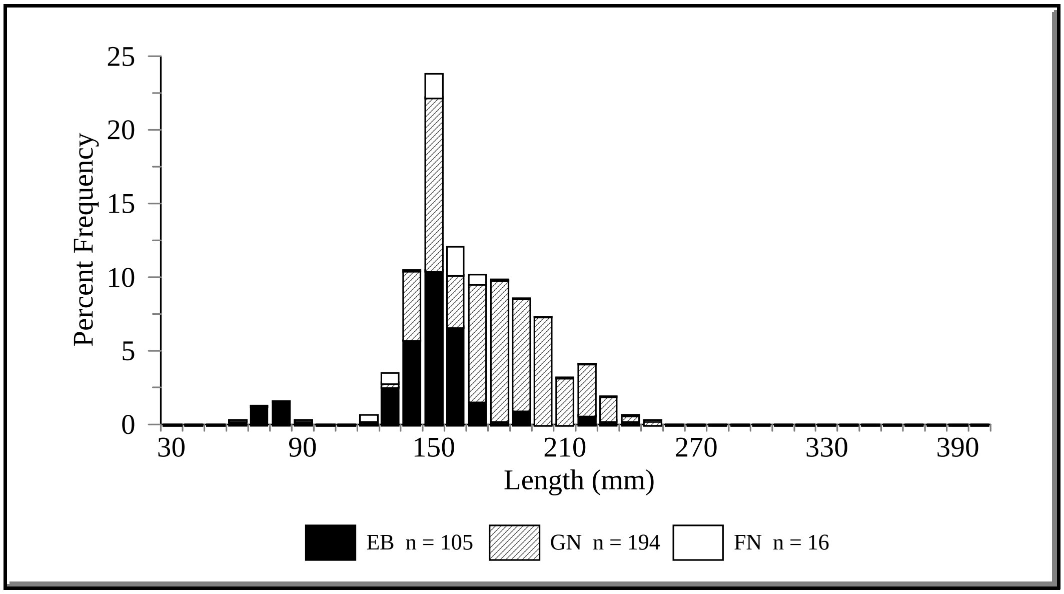

Figure 12. Length frequency histogram of yellow perch sampled from Lake Campbell in Fall 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

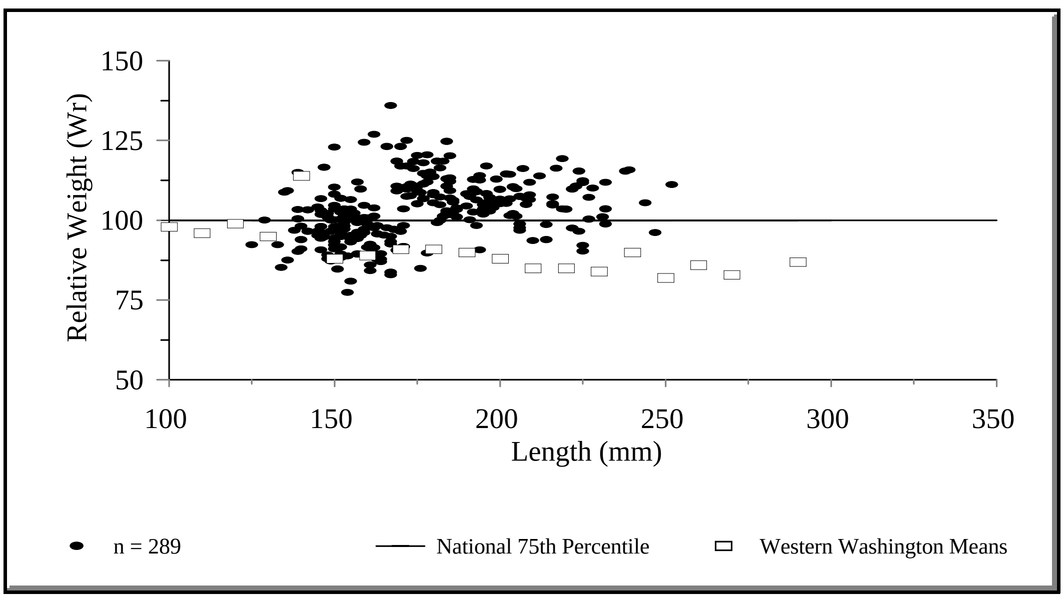

Figure 13. Relationship between total length and relative weight (W_r) of yellow perch from Lake Campbell (Skagit County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Brown Bullhead

Brown bullhead ranged from 36 to 372 mm TL. Young of year were well represented in our sample. Relative weights for brown bullhead were below the national 75th percentile for individuals measuring less than 280 mm TL but generally above the 75th percentile for larger individuals.

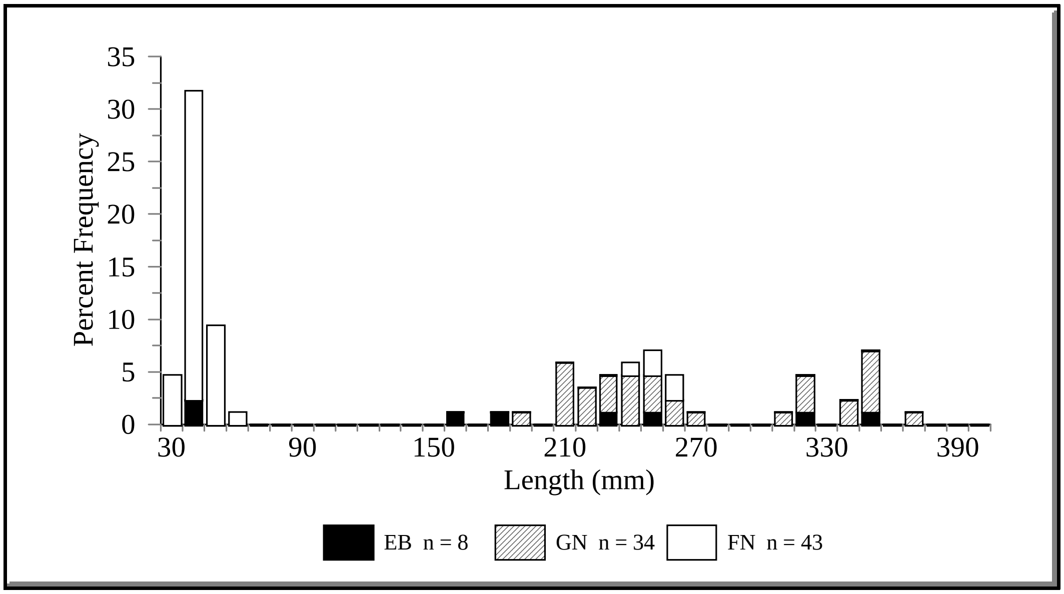

Figure 14. Length frequency histogram of largemouth bass sampled from Lake Campbell in Fall 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

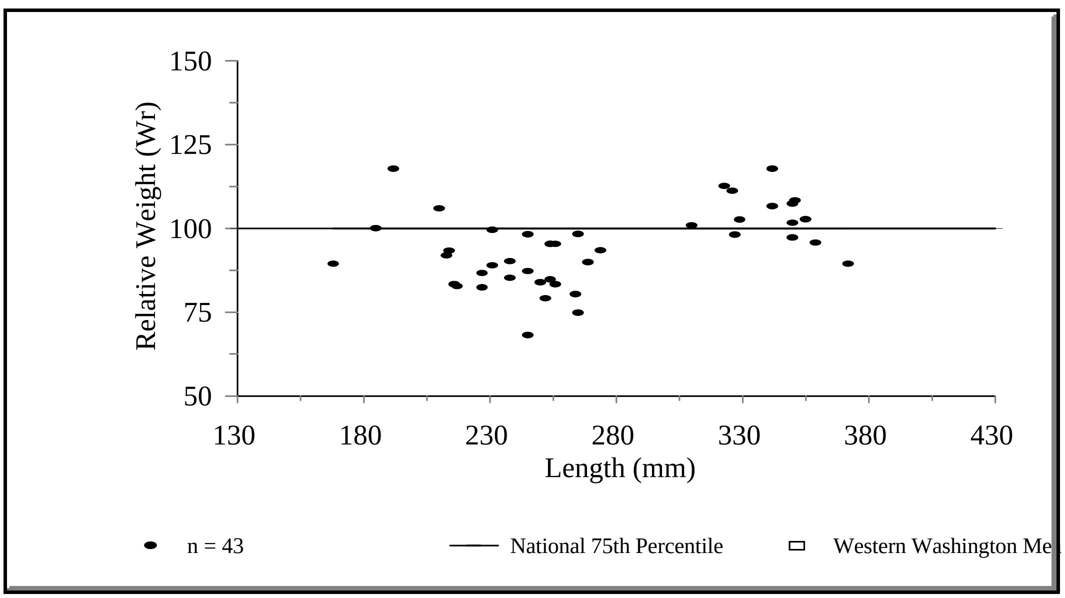

Figure 15. Relationship between total length and relative weight (W_r) of largemouth bass from Lake Campbell (Skagit County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Warmwater Enhancement Options

Improve Fishing Access

The only public access to Lake Campbell is gained through a WDFW boat launch on the north shore of the lake. There is currently little opportunity for shore fishing. Access to this fishery could be greatly enhanced by installing a pier adjacent to the WDFW boat launch.

Aquatic Vegetation Control

Much of the littoral zone (65 to 90 %) of Lake Campbell is densely or moderately vegetated with submerged, floating, and emergent plants (Jenifer Parsons, Washington Department of Ecology, unpublished data). Dense plant communities of yellow water lily, pondweed, Eurasian watermilfoil, and coontail present in Lake Campbell may inhibit foraging by larger largemouth bass and black crappie while providing too great of a refugia for forage fish such as bluegill, pumpkinseed and yellow perch (Wiley et al.1984).

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). Dense vegetation reduces foraging efficiency of many predatory warmwater fish species (Wiley et al. 1984). 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 Lake Campbell. Grass carp (*Ctenopharyngodon idella*) would provide an economical biological control. However, current regulations require screening the outlet of Lake Campbell before implementing this option. 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 from Lake Campbell is already being implemented on the lake and might continue to be a final option if fish introduction or herbicide were impractical. However, mechanical removal has been cited by DOE as a possible means of spreading Eurasian milfoil throughout the lake.

Change Existing Fishing Rules to Alter Size Structure of Largemouth Bass

Currently, a 305 – 381 mm (12 – 15 inch) slot limit makes it illegal to retain largemouth bass between 305 and 381 mm from Lake Campbell. Of the fish retained outside the slot, no more than three of the five fish allowed per person per day can measure over 381 mm TL. Although the slot and creel limits are intended to protect fish required for a balance within the lake, the low abundance of large largemouth bass and paucity of size classes within the slot observed during late summer 1999 suggests the rule is not working as intended. In one of the only available studies of harvest rates of largemouth bass in western Washington waters, Kraemer (1992) estimated a harvest rate of 5% for largemouth bass within the slot on Lake Goodwin (Snohomish County) in 1991 that was substantially lower than for outside the slot. However, the length frequency distribution and age class for Lake Campbell largemouth bass in 1999 suggest some reduced numbers of 270 to 370 mm. This may result in lack of recruitment into larger size classes in future years. Delayed mortality from catch and release angling may be a factor (Wilde 1998). Overharvest prior to or within the slot may be another factor.

Widening the slot limit to 254 – 457 mm TL (10 – 18 inches) while reducing the creel limit from three to one fish above the slot (while still maintaining the daily limit of five fish), might allow more largemouth bass to realize their full growth potential. This limit would protect these fish for four to five years where their growth rates rise above the western Washington State average. In Arkansas, an outstanding largemouth bass fishery was developed by adjusting the slot and the creel limits to stimulate harvest of small fish while protecting large fish (Turman and Dennis 1998). A reduction in small fish may improve growth and production of predator and prey species (McHugh 1990).

The success of any rule on the lake will depend upon angler compliance with the rules. Reasons for illegal harvest include lack of angler knowledge of the rules for a particular lake, a poor understanding of the purpose of the rules, and inadequate enforcement (Glass 1984). Public access to Lake Campbell is gained through WDFW access on the north shore of the lake. Rules and their purpose should be posted there to inform and encourage anglers in the active management of their resource. The presence of WDFW enforcement personnel during peak harvest periods might also lessen any illegal harvest that is occurring.

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