1997 Lacamas Lake Survey: The Warmwater Fish Community of a Highly Eutrophic Lowland Lake

by

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Table of Contents

List of Tables

List of Figures

Introduction and Background

Lacamas Lake is a narrow, moderately deep (mean and maximum depth = 7.1 and 19.8 m, respectively) body of water located in Clark County just north of the City of Camas and 16.1 km east of the City of Vancouver, Washington. The lake is fed by Lacamas Creek from the north and runoff from the surrounding foothills. Surface water exits Lacamas Lake at the southern end, through Round Lake via Lacamas Creek, eventually discharging into the Washougal River. Although the lake's origin is natural, it was enlarged (present surface area = 123.3 ha) during the latter part of the 19^{th} century with the construction of two downstream dams. Since 1936, the outflow from Lacamas and Round Lakes has been controlled and regulated by the Fort James Corporation (formerly Crown Zellerbach), which operates the dams and a paper mill at the south end of Round Lake (Beak/SRI 1985).

Lacamas Lake is highly eutrophic and has experienced water quality problems for years. Heavy nutrient loads (nitrogen and phosphorous) from farms and failed sewage systems along Lacamas Creek and its tributaries contribute to nuisance algal blooms by species that favor the eutrophic conditions. Nutrient concentrations and algal growth rates cause extreme diurnal swings in pH which can be harmful to fish. Furthermore, during the warmer spring and summer months, the lake readily stratifies. Consequently, decomposition of plankton creates a hypoxic, inhospitable environment for fish and other aquatic animals in the lake's hypolimnion (Beak/SRI 1985; ESEC 1998). Past proposals to rectify the situation included implementation of improved waste disposal and handling techniques, and hypolimnetic aeration (Beak/SRI 1985). In recent years, agricultural best management practices sponsored by the Clark County Public Works' Lacamas Lake Restoration Program were successful in reducing the nutrient input to Lacamas Creek (Bachert and Hutton 1995), whereas limited resources and, to a lesser degree, water safety issues, precluded installing a hypolimnetic aerator at Lacamas Lake (Jeff Schnabel, Clark County Public Works, personal communication).

Although the Lacamas Lake Restoration Program has been effective in improving the water quality of Lacamas Creek, recent studies and a review of the program's activities suggest that there has been no improvement in the lake's water quality since the mid-1980's (ESEC 1998). According to ESEC (1998), the Lacamas Lake Restoration Program should be "redirected to focus on improving and maintaining conditions in the lake that will support appropriate beneficial uses desired by the community rather than striving for some historical pristine condition." Fishing has been identified as the main use of Lacamas Lake (Beak/SRI 1985). Other recreational activities include water skiing and jet skiing. For 60 years, the Washington Department of Fish and Wildlife (WDFW; formerly Washington Department of Game) has managed the lake as a trout fishery. Rainbow trout (*Oncorhynchus mykiss*) have been stocked intermittently since 1938, whereas brown trout (*Salmo trutta*) were first stocked in 1980 (John Weinheimer, WDFW, unpublished data). However, a previous study by WDFW (Fletcher 1981) indicated that Lacamas Lake was well suited for warmwater fish species. Therefore, in an effort to assess the warmwater fishery of the lake, as well as to monitor the success of the restoration plan, personnel from WDFW's Warmwater Enhancement Program conducted a fisheries survey at Lacamas Lake in summer 1997.

Materials and Methods

Lacamas Lake was surveyed by a three-person team during July 21 - 23, 1997. Fish were captured using two sampling techniques: electrofishing and gill netting. The electrofishing unit consisted of a 5.5 m Smith-Root 5.0 GPP ‘shock boat’ using a DC current of 120 cycles/sec at 3 to 4 amps power. 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.

Sampling locations were selected by dividing the shoreline into 27 consecutively numbered sections of about 305 m each (determined visually from a map). Using the random numbers table from Zar (1984), 9 of these sections were then randomly selected as sampling locations. While electrofishing, the boat was maneuvered through the shallows (depth range: 0.2 - 1.5 m), adjacent to the shoreline, at a rate of approximately 18.3 m/minute. Gill nets were set perpendicular to the shoreline. The small-mesh end was attached onshore while the large-mesh end was anchored offshore. Sampling occurred during evening hours to maximize the type and number of fish captured. Nighttime electrofishing occurred along 22.2% (~ 1.8 km) of the available shoreline, whereas gill nets were set overnight (~ 12 hours) at four locations (= 4 ‘net nights’) around the lake (Figure 1).

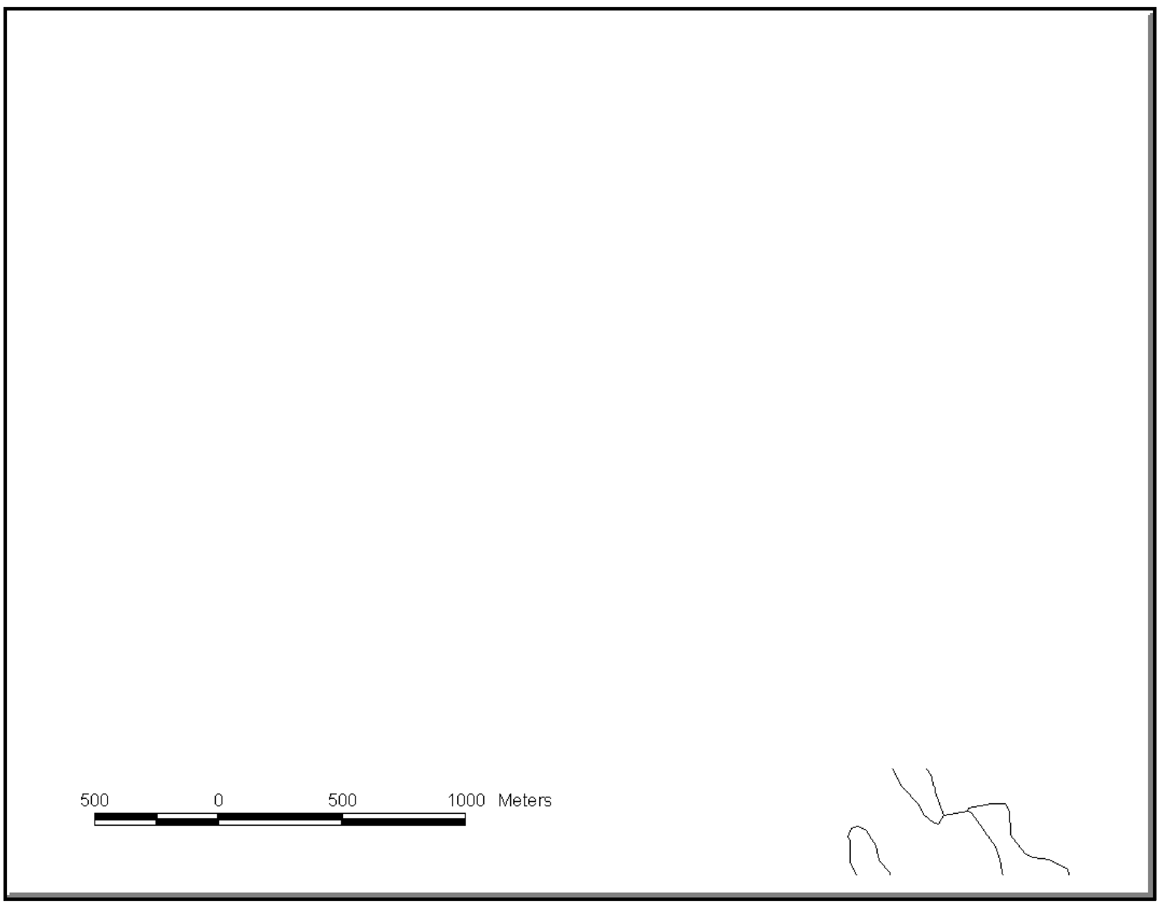

Figure 1. Map of Lacamas Lake (Clark County) showing sampling locations. Bolts indicate sections of shoreline where electrofishing occurred. Bars extending into lake indicate placement of gillnets. Triangles indicate water quality stations.

With the exception of sculpins (family Cottidae), 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 10 fish from each size class were weighed to the nearest 1 g. However, if a sample included several hundred individuals of a given species, then a sub-sample (n ± 100 fish) was measured and weighed while the remainder was counted overboard. The length frequency distribution of the sub-sample was then applied to the total number collected. Weights of individuals counted overboard were estimated using a simple linear regression of $\log_{10}$-length on $\log_{10}$-weight of fish from the sub-sample. Scales were removed from up to 10 fish from each size class for aging. Scale samples were mounted, pressed, and the fish aged according to Jearld (1983) and Fletcher et al. (1993). However, a lack of technical resources precluded aging members of the family Ictaluridae (catfish). Furthermore, given the narrow scope of this study, salmonid and non-game fish were not aged.

Water quality data was collected during midday from three locations on July 22, 1997 (Figure 1). Using a Hydrolab® probe and digital recorder, information was gathered on dissolved oxygen, redox, temperature, pH, and specific conductance. Secchi disc readings were recorded in feet and then converted to m (Table 10).

Data Analysis

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

Species composition by weight (kg) 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. With the exception of sculpin, red-side shiner (*Richardsonius balteatus*), and cutthroat trout (*Oncorhynchus clarki*), size structures were evaluated by constructing length frequency histograms (number of fish captured in each size class by gear type divided by the total number of fish captured by all gear types × 100) that showed the relative contribution of each gear type to the total catch.

Catch per unit effort (CPUE) by gear type was determined for each warmwater fish species (number of fish/hour electrofishing and number of fish/net night). Only stock size fish and larger were used to determine CPUE. Stock length, which varies by species (see Table 1 and discussion below), refers to the minimum size of fish having recreational value. Since sample locations were randomly selected, which might introduce high variability due to habitat differences within the lake, 80% confidence intervals (CI) were determined for each mean CPUE by species and gear type. CI was calculated as the mean ± $t_{(\alpha, N\text{-}1)} \times SE$, where t = Student's t for α confidence level with N-1 degrees of freedom (twotailed) and *SE* = standard error of the mean. Since it is standardized, CPUE is a useful index for comparing relative abundance of stocks between lakes.

Table 1. Length categories for warmwater fish species captured at Lacamas Lake (Clark County) during summer 1997. Measurements are minimum total lengths (mm) for each category (Willis et al. 1993).

	Size				
Type of fish	**Stock**	**Quality**	**Preferred**	**Memorable**	**Trophy**
Yellow perch	130	200	250	300	380
Brown bullhead	150	230	---	---	---
Bluegill	80	150	200	250	300
Pumpkinseed	80	150	200	250	300
Largemouth bass	200	300	380	510	630
Black crappie	130	200	250	300	380

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±quality length/number of fish±stock length × 100, is a numerical descriptor of length frequency data that provides useful information about population dynamics. Stock and quality lengths, which vary by species, are based on percentages of world-record lengths. Again, stock length (20-26% of world-record length) refers to the minimum size fish with recreational value, whereas quality length (36-41% of world-record length) refers to the minimum size fish most anglers like to catch.

The relative stock density (RSD) of each 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 1). 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).

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

A relative weight (W_r) index was used to evaluate the condition of all species except non-game fish. 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 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). With the exception of brown bullhead (*Ameiurus nebulosus*) and members of the family Salmonidae, the W_r values from this study were compared to the national standard ($W_r = 100$) and the average W_r values from up to 25 western Washington warmwater lakes sampled during 1997 and 1998 (Steve Caromile, WDFW, unpublished data). Since average W_r values for brown bullhead, brown trout, and cutthroat trout were lacking, their W_r values were compared to the national standard only.

Differences in the warmwater fish community before and after implementation of the restoration plan were evaluated by comparing the size structure, condition, and growth of fishes from Fletcher (1981) with this study.

Results and Discussion

Species Composition

Some changes have occurred in the structure of the fish community at Lacamas Lake; Fletcher (1981) showed that largemouth bass (*Micropterus salmoides*) comprised 49% of the number of fish captured, whereas in 1997, the predator accounted for only 17%. Furthermore, Fletcher (1981) found that yellow perch (*Perca flavescens*) accounted for only 5% of the number of fish captured in 1981 but had increased to 39% by number in 1997. Lacamas Lake continues to be dominated by warmwater species (Table 2) consistent with Fletcher's (1981) results. Together, yellow perch, brown bullhead, and bluegill (*Lepomis macrochirus*) accounted for about 50% of the biomass and number captured. Species other than the warmwater variety comprised about 40% of the biomass captured and only 8% by number (Table 2). Of these, largescale sucker (*Catostomus macrocheilus*) and brown trout were dominant, which supports Fletcher's (1981) findings as well.

Table 2. Species composition by weight (kg) and number of fish captured at Lacamas Lake (Clark County) during a summer 1997 survey of warmwater fish.

Type of fish	Species composition by weight (kg)	by weight (%)	by number (#)	by number (%)	Size range (mm TL)
Yellow perch (*Perca flavescens*)	20.14	31.03	248	39.18	45 - 226
Brown bullhead (*Ameiurus nebulosus*)	5.72	8.82	25	3.95	167 - 325
Bluegill (*Lepomis macrochirus*)	4.87	7.50	182	28.75	44 - 161
Pumpkinseed (*Lepomis gibbosus*)	0.33	0.51	10	1.58	71 - 134
Largemouth bass (*Micropterus salmoides*)	6.56	10.10	110	17.38	42 - 422
Brown trout (*Salmo trutta*)	6.91	10.65	30	4.73	231 - 375
Sculpin (*Cottus* sp.)	0.01	0.02	2	0.32	85 - 91
Largescale sucker (*Catostomus macrocheilus*)	19.67	30.30	15	2.37	222 - 551
Cutthroat trout (*Oncorhynchus clarki*)	0.13	0.20	1	0.16	242
Black crappie (*Pomoxis nigromaculatus*)	0.56	0.87	9	1.42	95 - 210
Red-side shiner (*Richardsonius balteatus*)	---	---	1	0.16	132
Total	64.90		633		

C P U E

While electrofishing, catch rates were highest for stock-size bluegill and yellow perch, whereas a relatively low number of stock-size largemouth bass were captured (Table 3). With the exception of yellow perch, the catch rates for stock-size fish were much lower with gill netting compared to electrofishing (Table 3).

Table 3. 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 collected from Lacamas Lake (Clark County) while electrofishing and gill netting during summer 1997.

Type of fish	Gear type			
	Electrofishing (# fish/hour)	Shock sites	Gill netting (# fish/net night)	Net nights
Yellow perch	68.5 ± 29.1	5	34.0 ± 25.9	4
Brown bullhead	13.4 ± 6.1	5	1.3 ± 1.2	4
Bluegill	85.6 ± 22.4	5	4.8 ± 4.0	4
Pumpkinseed	6.0 ± 3.8	5	0.3 [a]	4
Largemouth bass	5.2 ± 2.9	5	None captured	4
Black crappie	2.2 ± 1.2	5	0.8 ± 0.3	4

[a] sample size was insufficient to calculate confidence interval.

Stock Density Indices

Except for yellow perch and brown bullhead, few quality or preferred size warmwater fish were captured. No memorable length fish were captured (Table 4). However, the PSD and RSD for pumpkinseed (*Lepomis gibbosus*), largemouth bass, and black crappie (*Pomoxis nigromaculatus*) 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 4. Traditional stock density indices, including 80% confidence intervals, for warmwater fishes collected from Lacamas Lake (Clark County) while electrofishing and gill netting during summer 1997. 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).

Electrofishing					
Type of fish	Number of stock length fish captured	Stock density index			
		PSD	RSD P	RSD M	RSD T
Yellow perch	91	33 ± 6	0	0	0
Brown bullhead	20	70 ± 13	10 ± 9	0	0
Bluegill	114	6 ± 3	0	0	0
Pumpkinseed	8	0	0	0	0
Largemouth bass	8	13 [a]	13 [a]	0	0
Black crappie	3	67 [a]	0	0	0
Gill netting					
Type of fish	Number of stock length fish captured	Stock density index			
		PSD	RSD P	RSD M	RSD T
Yellow perch	136	15 ± 4	0	0	0
Brown Bullhead	5	0	0	0	0
Bluegill	19	0	0	0	0
Pumpkinseed	1	0	0	0	0
Largemouth bass	0	0	0	0	0
Black crappie	3	0	0	0	0

[a] sample size was insufficient to calculate confidence intervals.

Yellow Perch

Lacamas Lake yellow perch ranged from 45 to 226 mm TL (age 0+ to 6+). Few small, young fish were captured, whereas individuals measuring ~ 180 to 190 mm TL (age 4+ to 5+) were dominant (Figure 2). Growth of yellow perch in Lacamas Lake was slow when compared to Fletcher's (1981) work, and below average after age 3+ when compared to yellow perch statewide (Table 5). Still, their relative weights were high when compared to the averages for yellow perch from 17 western Washington warmwater lakes, and consistent with the national standard for the species (Figure 3).

Table 5. Age and growth of yellow perch (*Perca flavescens*) captured at Lacamas Lake (Clark County) during summer 1996. 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 length (mm) at age					
Year class	# fish	1	2	3	4	5	6
1996	0						
1995	2	78.3	111.9				
		91.2	117.4				
1994	4	76.5	120.6	152.9			
		93.2	129.6	156.2			
1993	14	75.1	115.5	140.0	169.5		
		92.8	126.6	147.1	171.8		
1992	8	83.6	119.7	149.6	173.0	182.6	
		101.1	131.8	157.2	177.2	185.4	
1991	3	73.2	107.1	147.2	172.7	191.1	202.4
		92.9	122.0	156.4	178.3	194.2	203.8
Unweighted mean		77.3	115.0	147.4	171.7	186.9	202.4
Weighted mean		94.9	127.3	152.1	174.3	187.8	203.8
Data from Fletcher (1981)		89.9	197.1	209.5	---	---	---
Unweighted state mean		59.7	119.9	152.1	192.5	206.0	---

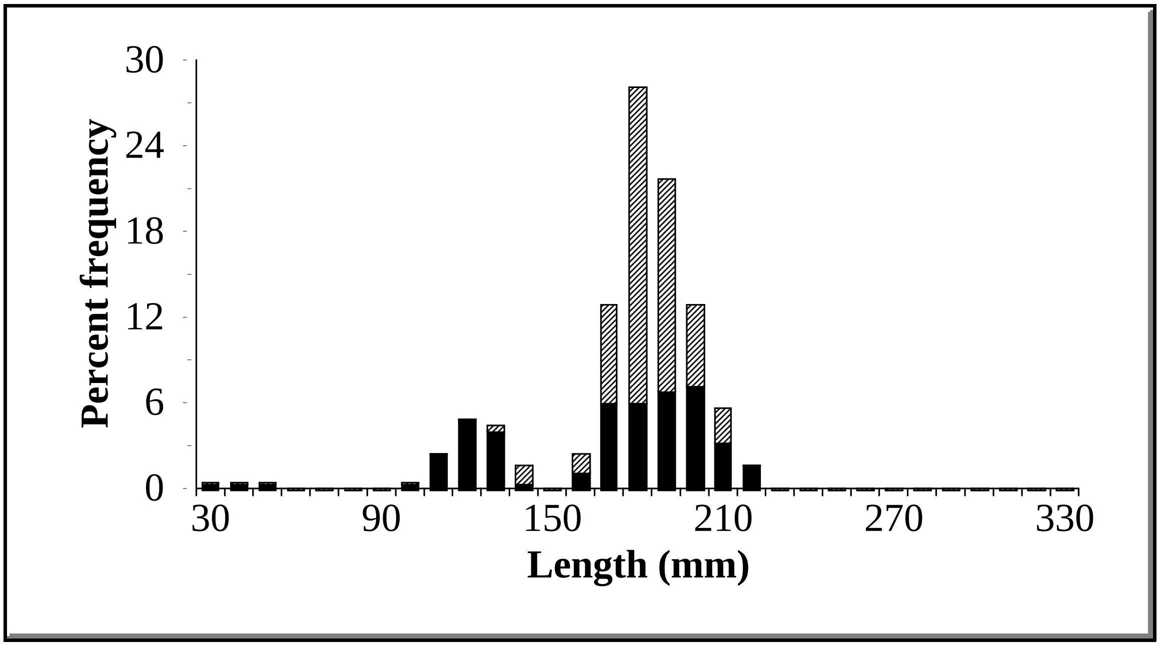

Figure 2. Length frequency distribution of yellow perch (*Perca flavescens*) at Lacamas Lake (Clark County) during summer 1997. Stacked bars show relative contribution of each gear type (electrofishing = black, gill netting = hatched) to total catch (n = 249).

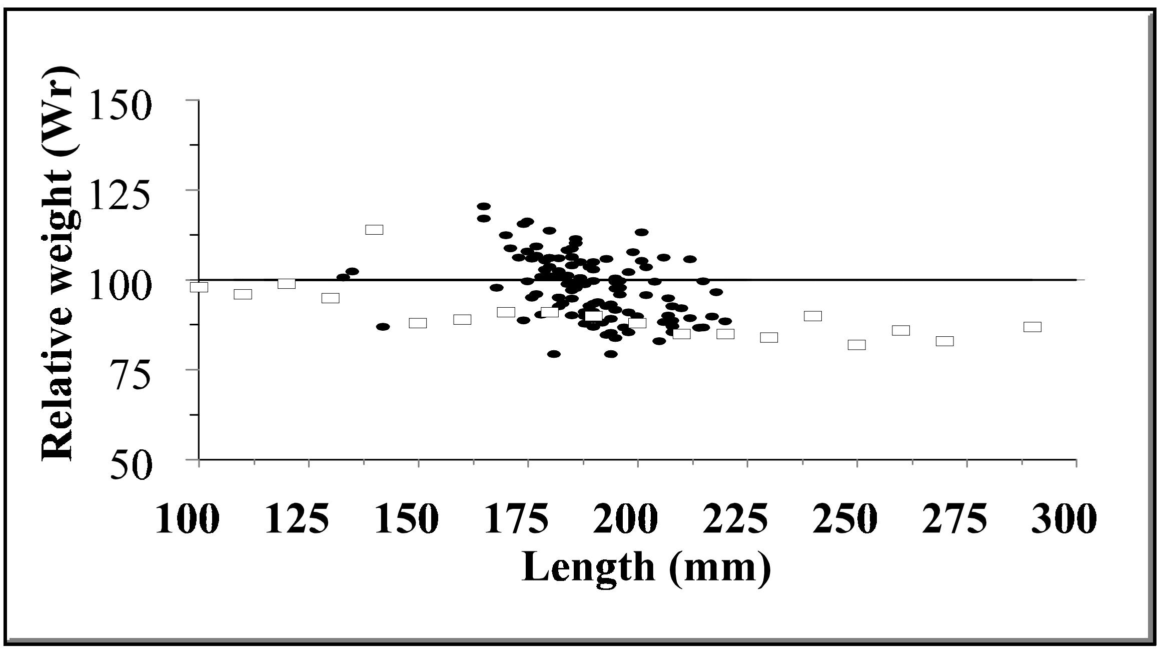

Figure 3. Relationship between total length and relative weight (W_r) of yellow perch, *Perca flavescens* (n = 119), from Lacamas Lake, Clark County (closed, black circles), compared to the average W_r from 17 western Washington warmwater lakes (open, clear rectangles) and the national standard (horizontal line at 100).

Brown Bullhead

Brown bullhead in Lacamas Lake ranged from 167 to 325 mm TL. The dominant size classes were about 190 and 280 mm TL (Figure 4). These fish were not aged. The relative weights were low by national standards, but fish larger than 280 mm TL generally exceeded the standards (Figure 5).

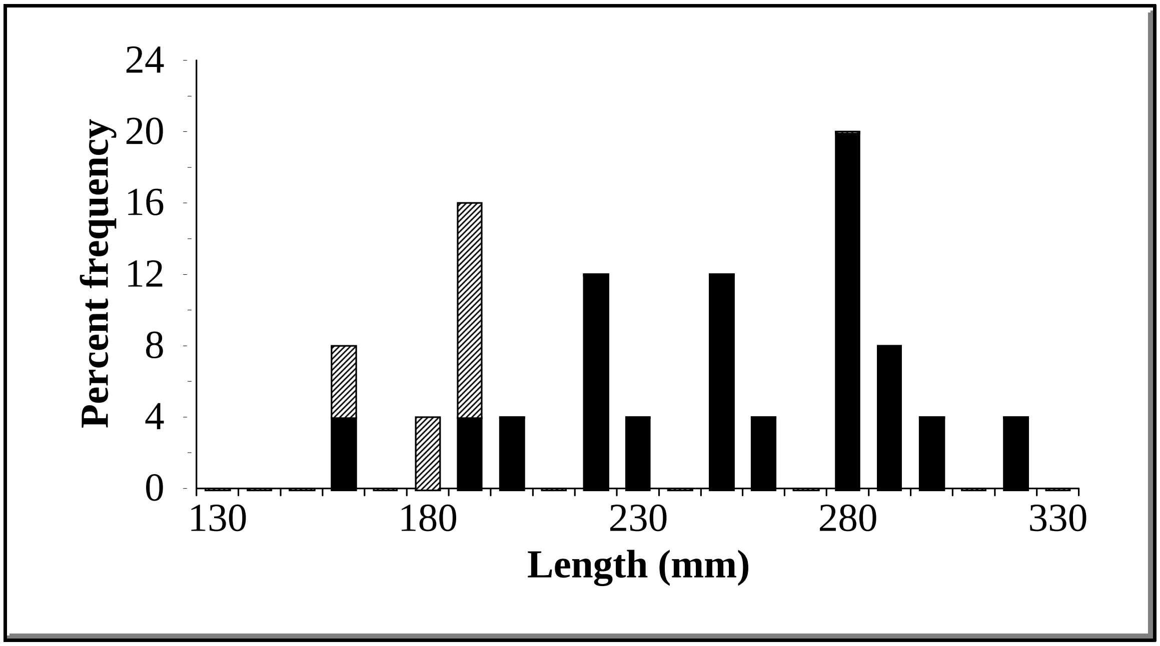

Figure 4. Length frequency distribution of brown bullhead (*Ameiurus nebulosus*) at Lacamas Lake (Clark County) during summer 1997. Stacked bars show relative contribution of each gear type (electrofishing = black, gill netting = hatched) to total catch (n = 25).

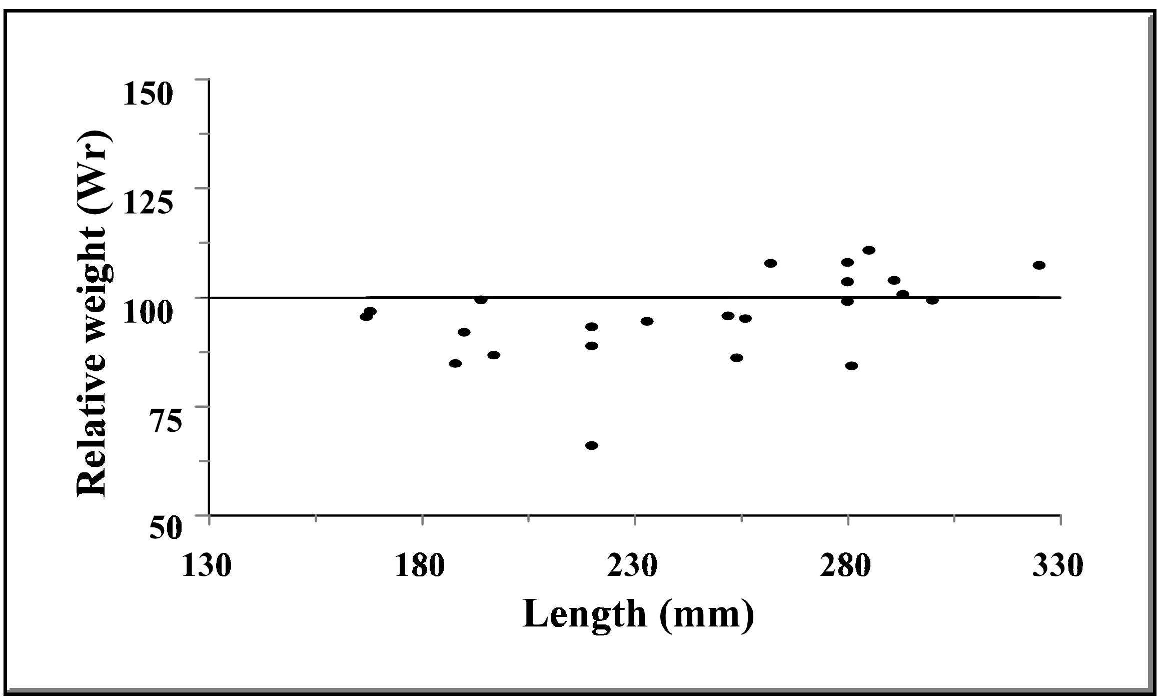

Figure 5. Relationship between total length and relative weight (W_r) of brown bullhead, *Ameiurus nebulosus* (n = 23), from Lacamas Lake, Clark County (closed, black circles), compared to the national standard (horizontal line at 100).

Bluegill

Bluegill ranged from 44 to 161 mm TL (age 0+ to 6+). The 1993, 1994, and 1996 year-classes were dominant (Table 6), which was reflected in the length frequency distribution (Figure 6). After age 2+ (~ 80 mm TL), growth of Lacamas Lake bluegill was slow when compared to Fletcher's (1981) study and bluegill statewide (Table 6). Like yellow perch, the relative weights of these fish were high when compared to the averages for bluegill from 12 western Washington warmwater lakes (Figure 7).

Table 6. Age and growth of bluegill (*Lepomis macrochirus*) captured at Lacamas Lake (Clark County) during summer 1997. 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 length (mm) at age					
Year class	**# fish**	**1**	**2**	**3**	**4**	**5**	**6**
1996	14	48.5					
		54.6					
1995	3	48.9	76.5				
		58.2	79.7				
1994	16	51.4	74.4	92.6			
		61.5	80.1	94.8			
1993	13	51.2	75.5	97.5	117.1		
		63.3	83.8	102.5	119.1		
1992	7	52.9	73.3	92.8	115.5	134.3	
		65.6	83.3	100.1	119.6	135.9	
1991	2	45.0	73.4	97.3	120.0	131.9	144.0
		59.0	83.6	104.3	124.0	134.3	144.8
Unweighted mean		49.6	74.6	95.0	117.5	133.1	144.0
Weighted mean		60.4	82.0	98.9	119.7	135.5	144.8
Data from Fletcher (1981)		43.7	81.3	125.7	140.0	169.9	184.1
Unweighted state mean		37.3	96.8	132.1	148.3	169.9	200.9

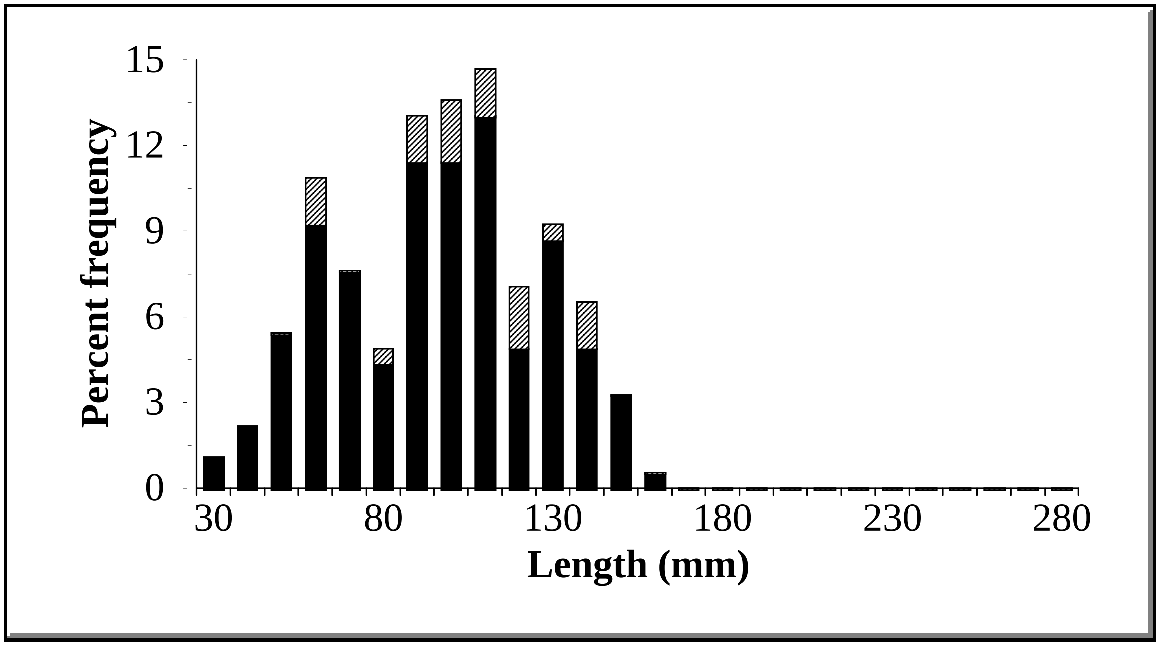

Figure 6. Length frequency distribution of bluegill (*Lepomis macrochirus*) at Lacamas Lake (Clark County) during summer 1997. Stacked bars show relative contribution of each gear type (electrofishing = black, gill netting = hatched) to total catch (n = 184).

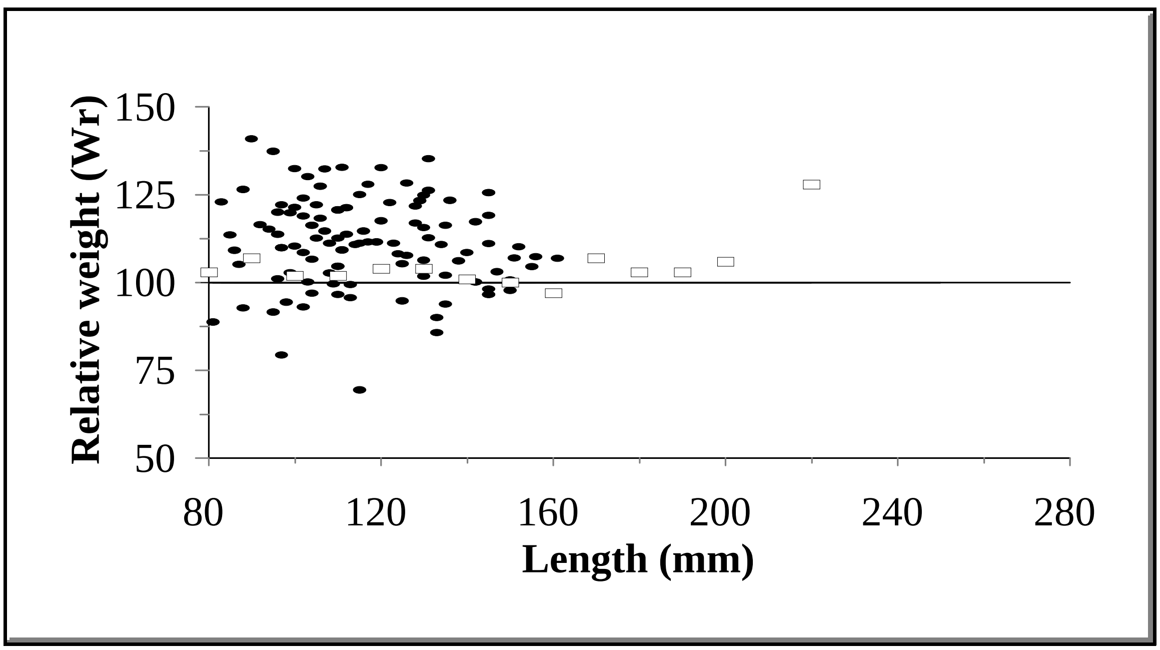

Figure 7. Relationship between total length and relative weight (W_r) of bluegill, *Lepomis macrochirus* (n = 121), from Lacamas Lake, Clark County (closed, black circles), compared to the average W_r from 12 western Washington warmwater lakes (open, clear rectangles) and the national standard (horizontal line at 100).

Pumpkinseed

Lacamas Lake pumpkinseed ranged from 71 to 134 mm TL (age 1+ to 5+). Older (> age 3+), larger fish (~ 110 to 130 mm TL) were dominant (Figure 8). After age 2+, growth of Lacamas Lake pumpkinseed was slow compared to Fletcher (1981) and the state average (Table 7). However, these results should be viewed with caution given the low number of pumpkinseed used in the age analysis. Relative weights were generally above the national standard, yet consistent with, or above, the average relative weights of pumpkinseed from 17 western Washington warmwater lakes (Figure 9).

Table 7. Age and growth of pumpkinseed (*Lepomis gibbosus*) captured at Lacamas Lake (Clark County) during summer 1997. 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 length (mm) at age				
Year class	**# fish**	**1**	**2**	**3**	**4**	**5**
1996	1	54.3				
		60.2				
1995	1	48.7	73.1			
		59.7	77.1			
1994	1	41.2	66.5	79.2		
		55.3	74.0	83.3		
1993	2	45.1	67.9	88.9	105.6	
		60.4	78.3	94.8	107.9	
1992	2	43.2	66.7	80.9	99.8	120.0
		60.1	79.1	90.7	106.1	122.4
Unweighted mean		46.5	68.5	83.0	102.7	120.0
Weighted mean		59.5	77.6	90.9	107.0	122.4
Data from Fletcher (1981)		18.1	63.7	115.1	127.0	---
Unweighted state mean		23.6	72.1	101.6	122.7	139.4

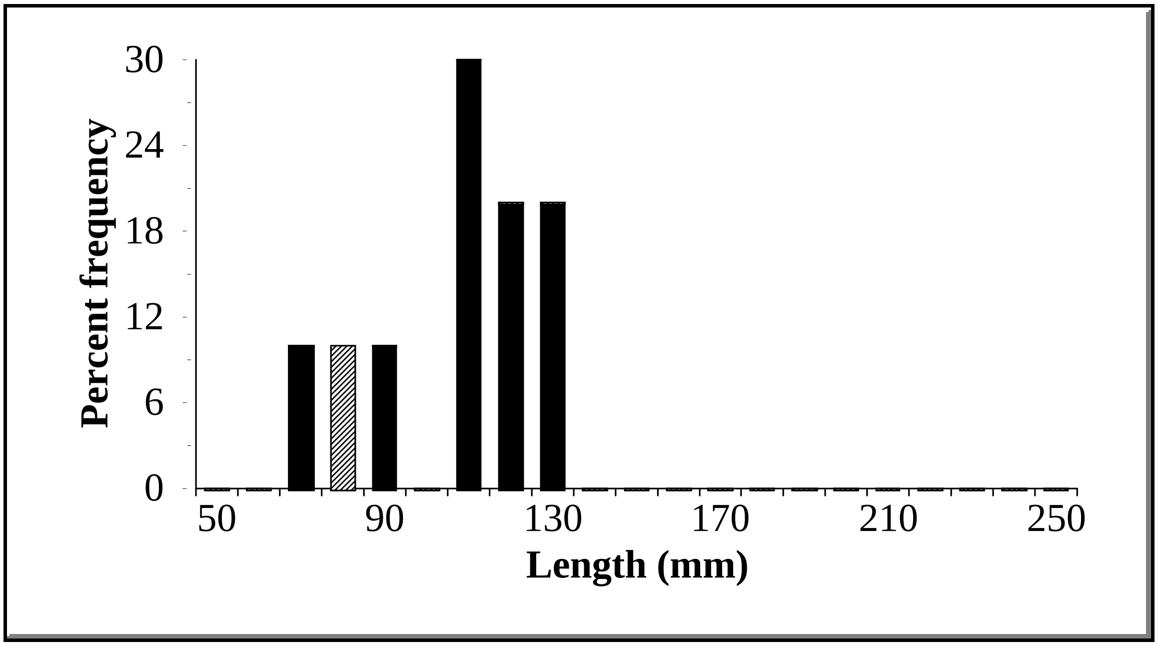

Figure 8. Length frequency distribution of pumpkinseed (*Lepomis gibbosus*) at Lacamas Lake (Clark County) during summer 1997. Stacked bars show relative contribution of each gear type (electrofishing = black, gill netting = hatched) to total catch (n = 10).

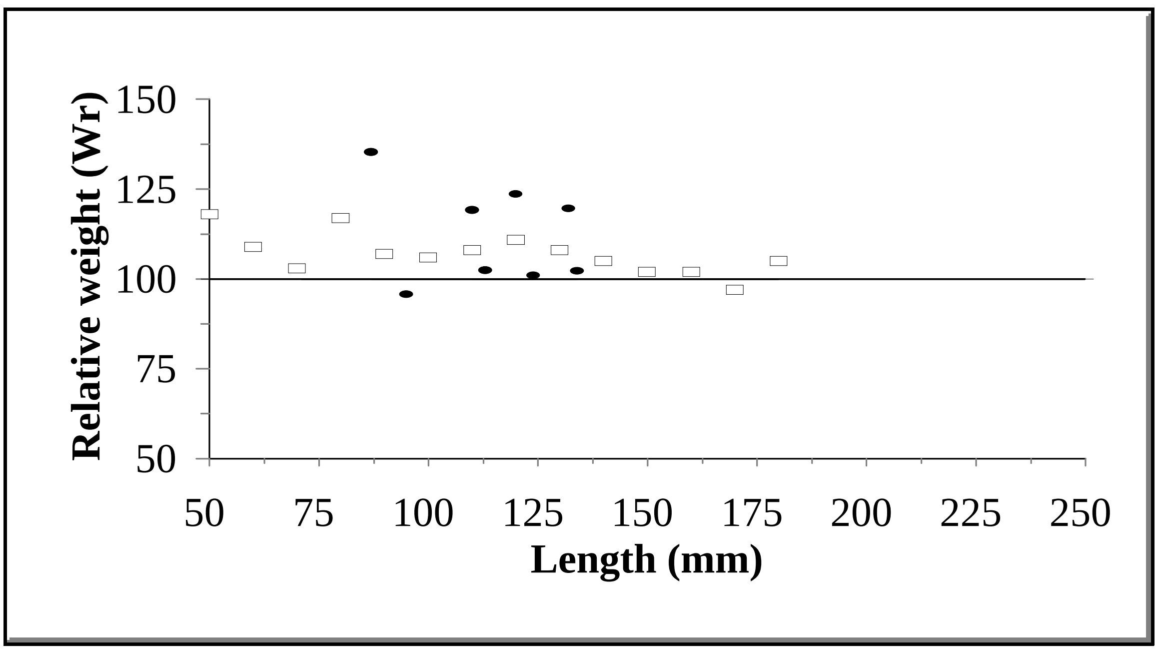

Figure 9. Relationship between total length and relative weight (W_r) of pumpkinseed, *Lepomis gibbosus* (n = 9), from Lacamas Lake, Clark County (closed, black circles), compared to the average W_r from 17 western Washington warmwater lakes (open, clear rectangles) and the national standard (horizontal line at 100).

Largemouth Bass

Largemouth bass in Lacamas Lake ranged from 42 to 422 mm TL (age 0+ to 8+). The size structure of largemouth bass captured in 1997 (Figure 10) was remarkably similar to Fletcher (1981). Small (~ 90 to 140 mm TL), young ($\geq$ age 3+) fish were dominant, whereas only 8 quality size ($\geq$ 200 mm TL) fish were observed (Figure 10). With the exception of age 1+ fish, growth of largemouth bass was slow when compared to Fletcher (1981) and the average growth of other western Washington largemouth bass (Table 8). The relative weights of fish below 225 mm TL were low when compared to the average relative weights of largemouth bass from 20 western Washington warmwater lakes and the national standard (Figure 11). However, larger fish exceeded national standards and were comparable to average relative weights for western Washington.

Table 8. Age and growth of largemouth bass (*Micropterus salmoides*) captured at Lacamas Lake (Clark County) during summer 1997. 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 length (mm) at age							
Year class	**# fish**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1996	8	59.2							
		67.0							
1995	16	65.6	98.4						
		74.8	102.2						
1994	17	70.0	99.0	125.4					
		80.3	105.2	127.9					
1993	4	68.8	106.0	130.6	156.7				
		81.0	113.9	135.7	158.8				
1992	5	71.8	101.7	127.0	157.0	180.4			
		84.6	111.5	134.3	161.3	182.4			
1991	1	68.9	101.1	126.4	160.9	188.4	204.5		
		82.6	111.7	134.7	166.0	191.0	205.6		
1990	1	86.8	127.6	160.8	201.7	229.7	252.7	268.0	
		100.8	138.9	169.8	207.8	233.9	255.3	269.6	
1989	2	78.4	109.1	133.2	161.5	190.1	226.5	242.4	256.2
		92.5	121.0	143.3	169.5	196.0	229.8	244.5	257.2
Unweighted mean		71.2	106.1	133.9	167.6	197.1	227.9	255.2	256.2
Weighted mean		78.0	107.2	132.7	165.7	192.1	230.1	252.8	257.2
Data from Fletcher (1981)		73.9	141.5	190.0	220.7	284.5	329.9	372.4	---
Unweighted western Washington mean		60.4	145.5	222.2	261.1	289.3	319.0	367.8	396.0

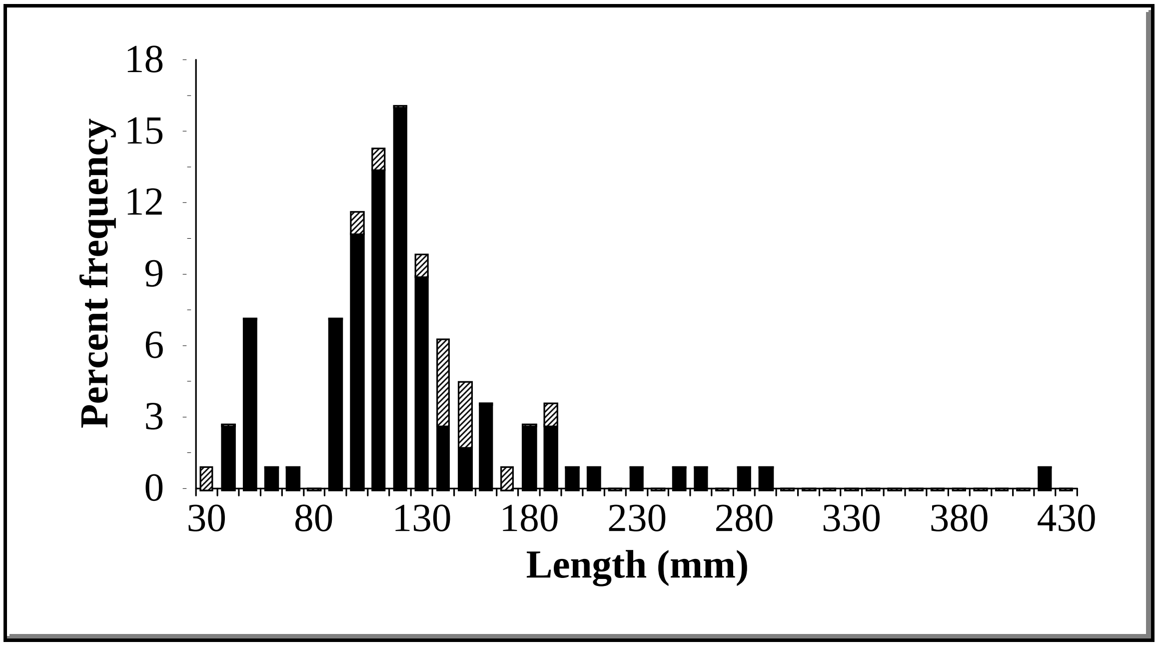

Figure 10. Length frequency distribution of largemouth bass (*Micropterus salmoides*) at Lacamas Lake (Clark County) during summer 1997. Stacked bars show relative contribution of each gear type (electrofishing = black, gill netting = hatched) to total catch (n = 112).

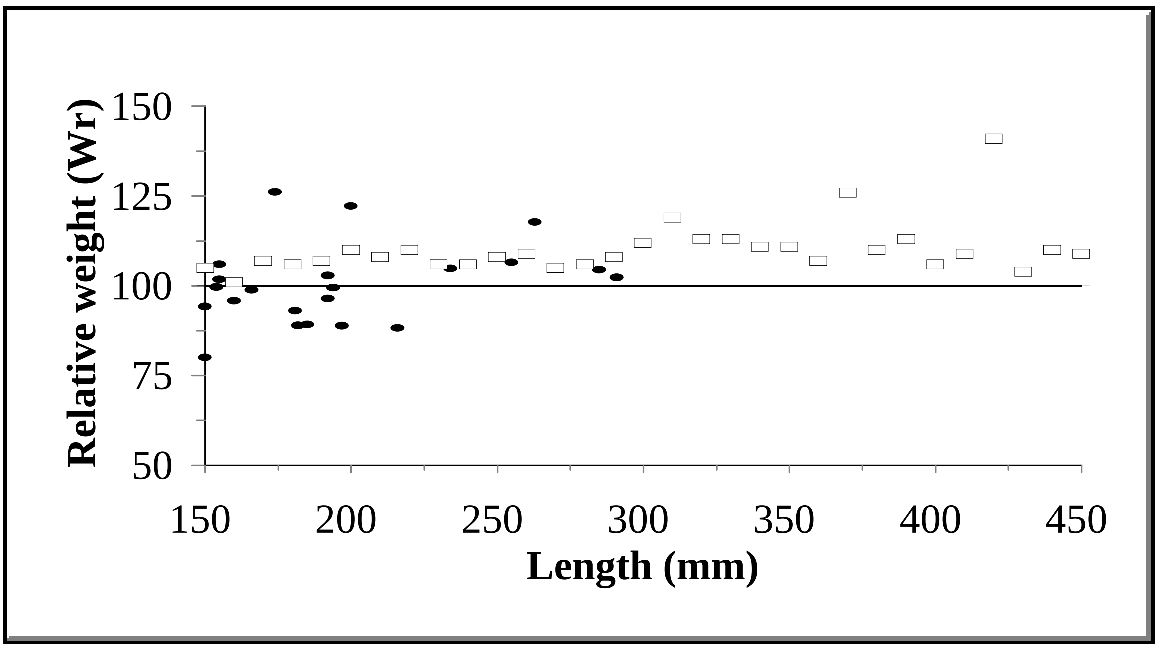

Figure 11. Relationship between total length and relative weight (W_r) of largemouth bass, *Micropterus salmoides* (n = 23), from Lacamas Lake, Clark County (closed, black circles), compared to the average W_r from 20 western Washington warmwater lakes (open, clear rectangles) and the national standard (horizontal line at 100).

Black Crappie

Black crappie ranged from 95 to 210 mm TL (Figure 12) and were aged 2+ to 7+. Black crappie showed variable year class strength. For example, the 1990 and 1995 year-classes were dominant, whereas the 1993 and 1996 year-classes were not observed (Table 9). With the exception of age 1+ fish, growth of black crappie was slow compared to Fletcher (1981) and the average growth of black crappie statewide (Table 9). However, these results should be viewed with caution given the low number of black crappie used in the age analysis. Relative weights of Lacamas Lake black crappie were variable and consistent with, or below, the average relative weights of black crappie from nine western Washington warmwater lakes (Figure 13).

Table 9. Age and growth of black crappie (*Pomoxis nigromaculatus*) captured at Lacamas Lake (Clark County) during summer 1997. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

Year class	# fish	Mean length (mm) at age						
		1	2	3	4	5	6	7
1996	0							
1995	4	63.1	89.8					
		78.2	96.6					
1994	1	61.3	86.5	111.7				
		82.4	102.0	121.5				
1993	0							
1992	1	53.0	91.4	124.3	155.4	175.5		
		78.4	109.8	136.7	162.1	178.5		
1991	1	55.0	75.0	125.0	156.7	178.3	191.7	
		80.4	96.9	138.1	164.3	182.1	193.1	
1990	2	55.0	77.6	113.7	129.0	156.4	175.2	191.1
		80.5	99.2	129.0	141.7	164.3	179.9	193.1
Unweighted mean		57.5	84.1	118.7	147.0	170.1	183.4	191.1
Weighted mean		79.5	99.3	130.9	152.4	172.3	184.3	193.1
Data from Fletcher (1981)		39.1	98.8	156.2	196.3	215.9	---	---
Unweighted state mean		46.0	111.2	156.7	183.4	220.0	224.0	261.1

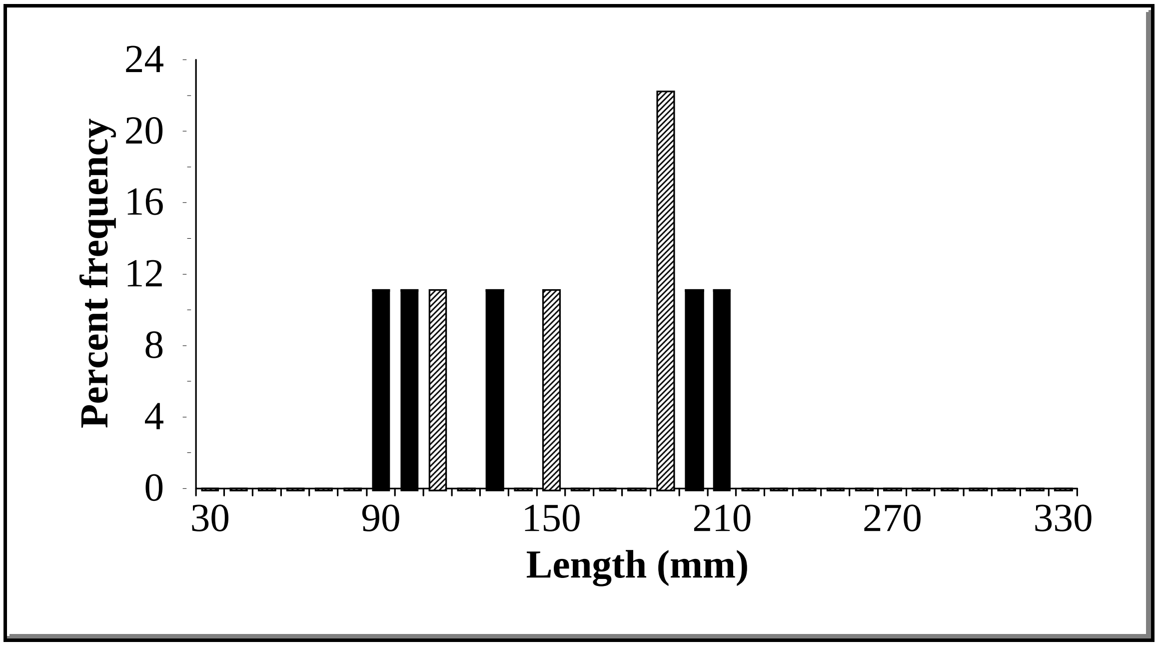

Figure 12. Length frequency distribution of black crappie (*Pomoxis nigromaculatus*) at Lacamas Lake (Clark County) during summer 1997. Stacked bars show relative contribution of each gear type (electrofishing = black, gill netting = hatched) to total catch (n = 9).

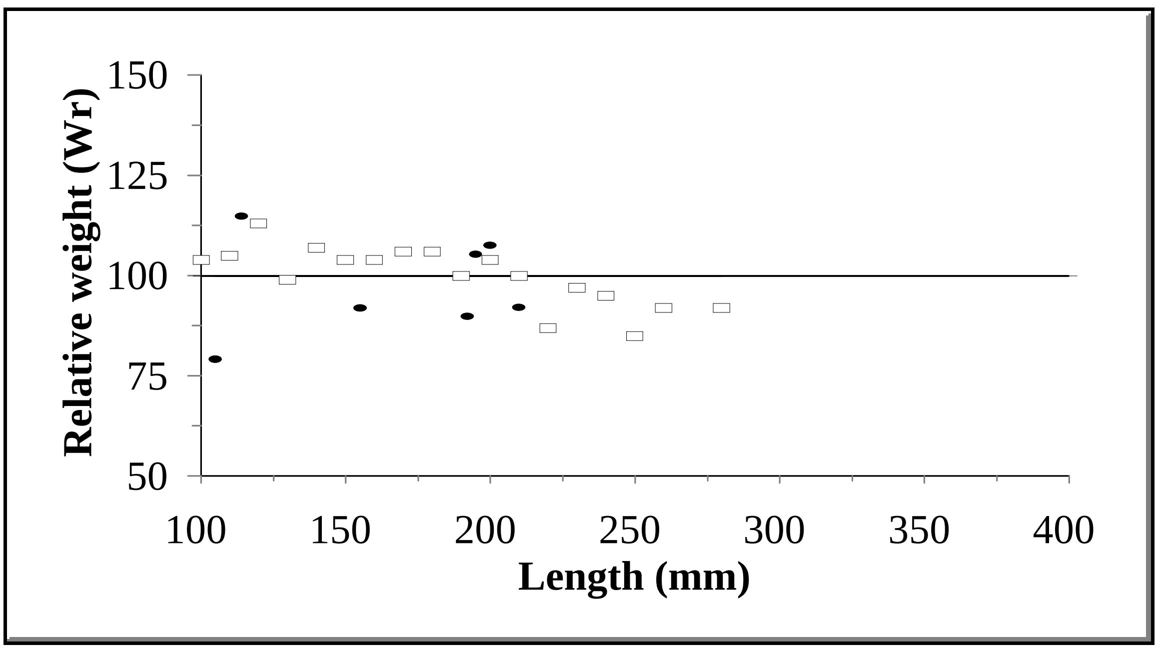

Figure 13. Relationship between total length and relative weight (W_r) of black crappie, *Pomoxis nigromaculatus* (n = 7), from Lacamas Lake, Clark County (closed, black circles), compared to the average W_r from nine western Washington warmwater lakes (open, clear rectangles) and the national standard (horizontal line at 100).

Non-game Fish and Members of the Family Salmonidae

Largescale sucker comprised 30% of the biomass captured at Lacamas Lake but less than 3% by number (Table 2). Several year-classes of largescale sucker were evident from their length frequency distribution (Figure 14); however, these fish were not aged. The smaller fish were captured while electrofishing only, whereas the larger fish were captured using both gear types (Figure 14). In addition to the above, two sculpin, *Cottus* sp. (85 and 91 mm TL), and one red-side shiner (132 mm TL) were captured while electrofishing.

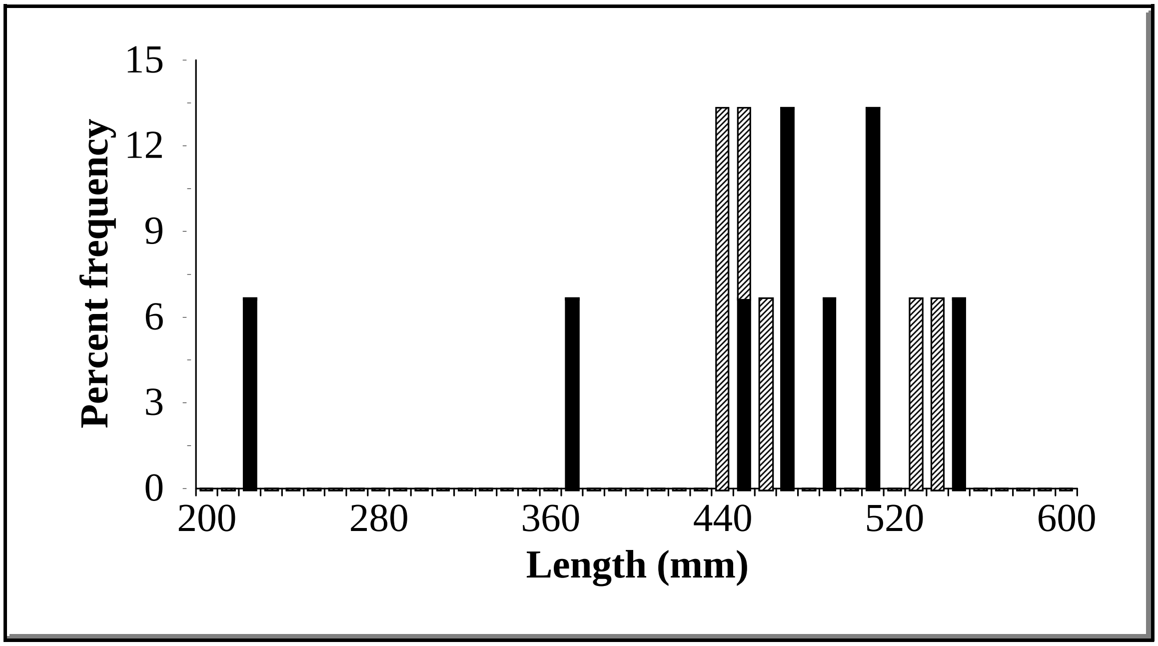

Figure 14. Length frequency distribution of largescale sucker (*Catostomus macrocheilus*) at Lacamas Lake (Clark County) during summer 1997. Stacked bars show relative contribution of each gear type (electrofishing = black, gill netting = hatched) to total catch (n = 15).

Brown trout ranged from 231 to 375 mm TL (Figure 15) and comprised nearly 11% of the biomass captured at Lacamas Lake, but less than 5% by number (Table 2). However, in terms of abundance, a four-fold increase in brown trout has occurred since Fletcher's (1981) survey. This is not surprising since the number of catchable fish stocked annually increased from 16,212 in 1981 to 30,586 in 1997. In 1999, 33,000 brown trout were stocked into Lacamas Lake (John Weinheimer, WDFW, unpublished data). The relative weights of brown trout in 1997 were below the national standard but increased with length (Figure 16). One cutthroat trout was captured while gill netting. It measured 242 mm TL and weighed 134 g. The relative weight of the cutthroat trout was 92.

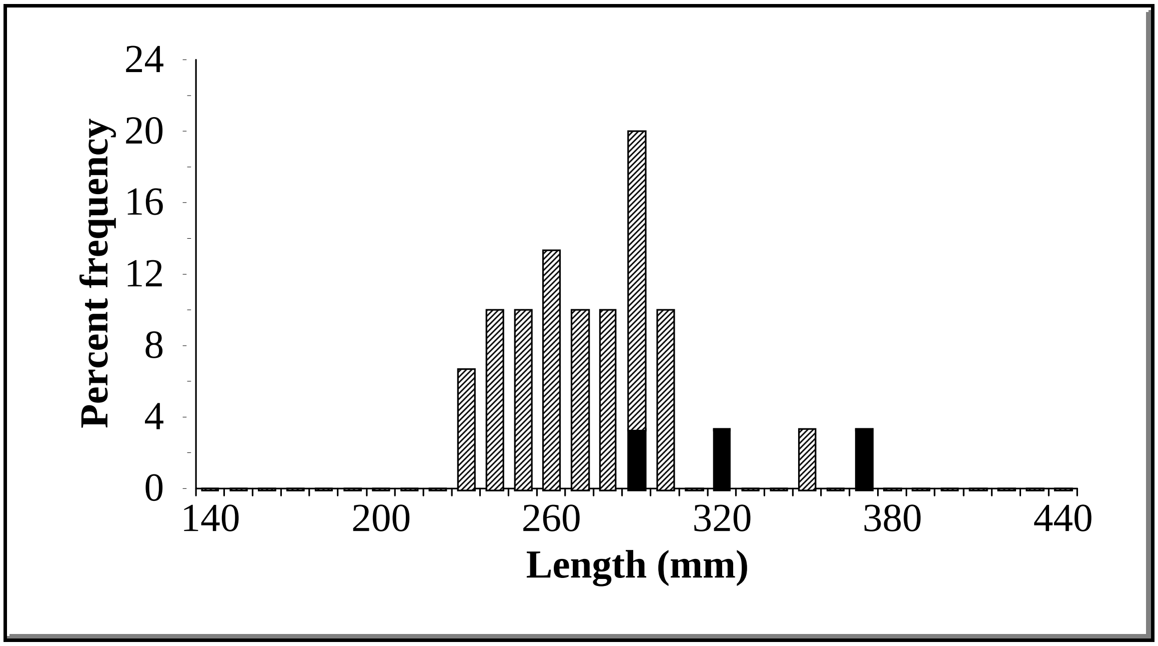

Figure 15. Length frequency of brown trout (*Salmo trutta*) at Lacamas Lake (Clark County) during summer 1997. Stacked bars show relative contribution of each gear type (electrofishing = black, gill netting = hatched) to total catch (n = 30).

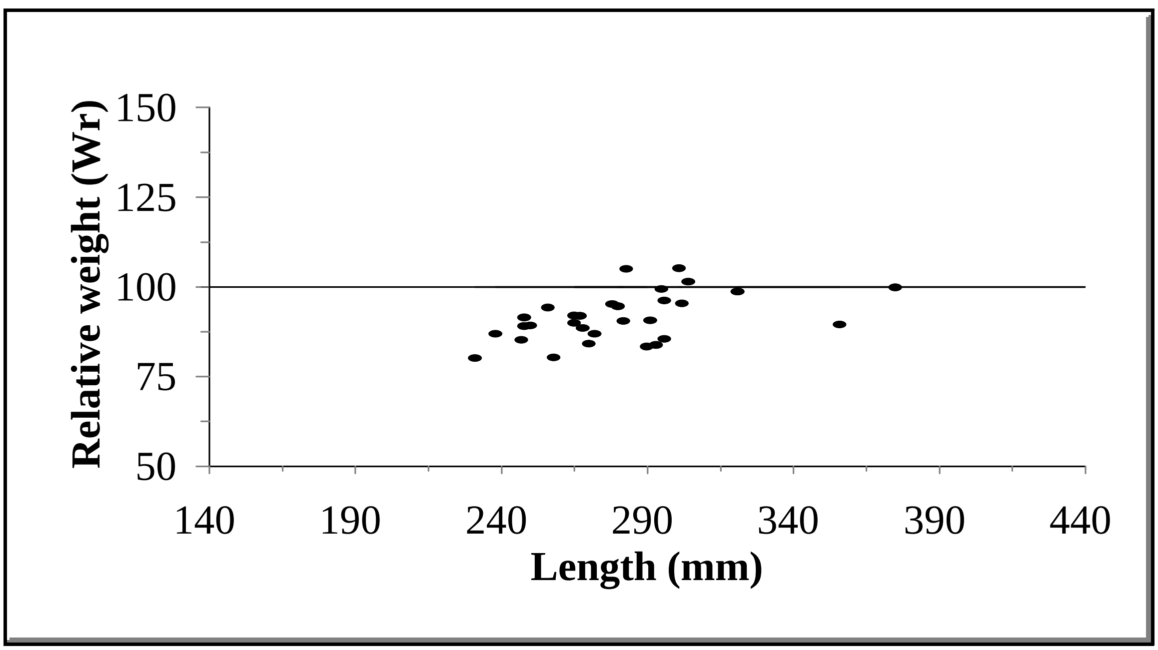

Figure 16. Relationship between total length and relative weight (W_r) of brown trout, *Salmo trutta* (n = 30), from Lacamas Lake, Clark County (closed, black circles), compared to the national standard (horizontal line at 100).

Warmwater Enhancement Options

Lacamas Lake showed some indications of having an unbalanced fish community. Characteristics of unbalanced populations include slow growth, poor condition, and low recruitment (Swingle 1950, 1956; Kohler and Kelly 1991; Masser *undated*). Lacamas Lake was clearly dominated by small, slow-growing yellow perch, bluegill, and largemouth bass. Few quality size fish were captured, and some year-classes were scant or absent. Moreover, the intermediate size classes (203 - 305 mm or 8 - 12" TL) of largemouth bass, those fish needed to maintain balance within Lacamas Lake, were lacking. The size structure and growth pattern of largemouth bass suggest that these predators were unable to reach an adequate size to control overproduction of yellow perch and bluegill.

Causes for the variation described above are complex and difficult to isolate from a single survey; however, some inferences can be drawn from previous studies. For example, the conditions observed in 1997 resemble those described by Swingle (1956) and Masser (*undated*) for populations experiencing inter- and intraspecific competition because of crowding. According to Swingle (1956), crowding in fish populations results in slow growth (less food per individual) and reduced or inhibited reproduction, as evident in the warmwater fish at Lacamas Lake. Prey fish size structures and growth patterns suggest that these fishes were not able to forage effectively, possibly due to overcrowding and competition with the dominant yellow perch and bluegill. Paradoxically, the majority of yellow perch and bluegill captured had relative weights that exceeded those of similar fish throughout western Washington, which suggests that food was not limited during summer 1997, and that other exogenous factors were responsible for their slow growth. Heavy algal blooms, variable pH, and low dissolved oxygen (DO) levels affect the foraging ability, growth, and metabolism of fish (Stuber et al. 1982 and references therein). Thus, perhaps the main impediment to improved growth rates of warmwater fishes at Lacamas Lake is poor water quality (Table 10). Management strategies that might improve the warmwater fishery at Lacamas Lake include, but are not limited to, the following:

Destratify Lake with Aerator

Fletcher (1981) attributed the poor growth and condition of fish in Lacamas Lake to poor water quality and supported aeration of the lake. The WDFW routinely aerates a number of lakes throughout the state to improve or maintain water quality during warm periods. For example, during the early 1980's, an aerator was installed along the shore of Anderson Lake in Jefferson County. Before using the aerator, the lake was subject to periodic fish die-offs because of low DO levels when the lake was stratified. Today, the Anderson Lake aerator runs continuously during summer and, since installed, no fish die-offs have occurred (Dan Collins, WDFW, personal communication).

Aerating Lacamas Lake will reduce crowding of warmwater fish by increasing the area considered hospitable to most fish (i.e., DO $\geq$ 5 mg/l). Moreover, as fish densities decrease and DO levels improve, fish growth should increase.

Table 10. Water quality from three locations (near shore, offshore, and mid-lake) at Lacamas Lake (Clark County). Samples were collected midday on July 22, 1997.

		Parameter					
Location	**Secchi (m)**	**Depth (m)**	**DO**	**Temp (°C)**	**pH**	**Conductance**	**Redox**
Near shore	1.6 m	1	12.4	24.1	9.0	88	384
		3	9.4	18.1	7.4	87	454
		5	4.6	15.4	6.6	84	486
Offshore	1.6 m	1	11.9	23.3	9.1	86	392
		3	9.7	18.3	7.8	92	453
		5	5.4	15.8	6.9	88	490
		7	2.0	13.5	6.5	90	507
		9	1.1	12.0	6.3	75	412
Mid-lake	1.6 m	1	12.4	23.1	9.1	85	385
		3	10.3	18.6	7.7	92	435
		5	4.8	15.7	6.7	90	481
		7	1.4	13.4	6.4	86	494
		9	0.8	11.9	6.2	75	462
		11	0.6	10.6	6.2	68	412
		13	0.4	9.9	6.1	64	414
		15	0.4	9.6	6.1	68	420

Change Existing Fishing Rules to Alter Size Structure of Largemouth Bass

Currently, Lacamas Lake anglers are allowed to retain five largemouth bass daily with no more than three over 381 mm TL (15"). The size structure of largemouth bass observed in 1997 suggests that the predator is not reaching its full growth potential under the existing rule. For example, over 90% of the largemouth bass captured measured less than 203 mm TL (8"); the CPUE for stock length fish was low. Moreover, growth was slow and PSD values were poor irrespective of sampling method.

Implementing a 305 - 381 mm (12 - 15") slot limit for largemouth bass at Lacamas Lake might succeed where the original rule failed. Under this type of regulation, only fish less than 305 or greater than 381 mm TL may be kept. Adjusting the daily creel limit so that only one fish can exceed 381 mm TL would stimulate harvest of small fish while still protecting large fish. A reduction of small fish may improve growth and production of predator and prey species alike (McHugh 1990).

Manage Lacamas Lake for Panfish

The panfish populations at Lacamas Lake are thriving. Therefore, the simplest management strategy might be developing the panfish fishery at the lake. Minimum length limits on predators, such as largemouth bass, are often used to develop quality panfish fisheries (Willis 1989). Under a minimum length rule, all fish below a designated length must be released. A minimum length limit of 381 mm (15") TL on largemouth bass in Lacamas Lake should increase the number of predators in the 203 - 381 mm (8 – 15") TL range. Consequently, these fish would then thin out the overabundant, slow-growing yellow perch and bluegill ‘making room’ for the remaining forage fish to achieve their full growth potential.

However, the success of any rule changes depends upon angler compliance. Reasons for non-compliance include lack of angler knowledge of the rules for a particular lake, a poor understanding of the purpose of the rules, and inadequate enforcement (Glass 1984). Therefore, clear and concise multilingual posters or signs should be placed at Lacamas Lake describing the fishing rules for the lake. Press releases should be sent to local papers, magazines, and sport fishing groups detailing the changes to, and purpose of, the rules. Furthermore, non-compliance may be reduced by increasing the presence of WDFW enforcement personnel at Lacamas Lake during peak harvest periods.

Promote Juvenile Fishing Derby for Yellow Perch and Other Panfish

Besides increased predation by largemouth bass, panfish numbers might be reduced by tournament anglers. Yellow perch and bluegill can provide hours of enjoyment for eager, young anglers. Although significant control of these prolific fishes is nominal from such events, the opportunity for increased angler awareness and recreation is excellent.

Review Proposals to Control Aquatic Vegetation

Lacamas Lake supports a diverse aquatic plant community (Jenifer Parsons, Washington Department of Ecology, personal communication), including several varieties of floating leaf pondweed (*Potamogeton* sp.), but mostly a hybrid of the large-leaf pondweed (*Potamogeton amplifolius*). Submersed vegetation includes common elodea (*Elodea canadensis*) and the exotic Brazilian elodea (*Egeria densa*). Emergent vegetation includes spatter-dock or yellow waterlilly (*Nuphar polysepala*), watershield (*Brasenia schreberi*), and narrow-leaf burreed (*Sparganium anustifolium*). A previous study showed that the growth of aquatic vegetation in Lacamas Lake was extensive. In fact, practically all of the substrate within lighted depths was found to be colonized by aquatic macrophytes (Beak/SRI 1985). Because of concerns about the spread of aquatic vegetation in Lacamas Lake, implementation of an aquatic plant management plan remains a viable option in the restoration process (ESEC 1998).

A healthy aquatic plant community is essential for the well-being of many warmwater fish species, which are more likely to be found in areas with aquatic plants than in areas without them (Killgore et al. 1989). Submersed 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 (Wiley et al. 1984) as well as the structure of the fish community itself (Bettoli et al. 1993). For these reasons, it is important to carefully review all proposals to limit or control the growth and spread of aquatic vegetation in Lacamas Lake.

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