1997 Black Lake Survey: A Coastal Warmwater Fish Community Before the Introduction of Grass Carp

by

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

January 2000

Acknowledgments

We thank John Pahutski, Steve Anderson, and Bob Warinner of the Washington Department of Fish and Wildlife (WDFW) for their unfailing, invaluable assistance in the field and lab. Bill Zook provided technical assistance, encouragement and support, whereas Scott Bonar, Bruce Bolding, and Marc Divens (WDFW) provided helpful advice. We also thank Kathy Hamel and Jenifer Parsons of Washington Department of Ecology, Malcolm McPhail of Cranmac Farm, Inc., and Debra Gore of the City of Ilwaco for providing useful background information. Steve Jackson, Bill Freymond, and John Linth (WDFW) provided thoughtful criticism of the original draft of the manuscript, whereas Darrell Pruett and Peggy Ushakoff (WDFW) designed the cover. Lauren Munday, Walt Cooper, Everett Latch, and Ted Morton (WDFW) proved indispensable when preparing and printing the final report. This project was funded by the Warmwater Enhancement Program, which is providing greater opportunities to fish for and catch warmwater fish in Washington.

Table of Contents

List of Tables

List of Figures

Introduction and Background

Black Lake is a shallow (mean and maximum depth = 4.0 and 9.8 m, respectively), L-shaped body of water (surface area = 13.3 ha) located north of the City of Ilwaco on the Long Beach Peninsula in Pacific County, Washington. Precipitation and groundwater feed the lake, whereas surface water flows out a drainage channel at the north end, through Tarlett Slough, eventually discharging into Willapa Bay. Nearshore residential development at Black Lake is minimal; however, Highway 101 runs along the west shore, while a cranberry farm located along the north shore occasionally draws water from the lake for irrigation and harvest purposes. Much of the eastern shoreline consists of a park with primitive boat launch and trail system that allows public access to the lake. Not long ago, a public pier was constructed over the lake off Highway 101. Recreational activities include fishing for warmwater species and trout (the lake is stocked annually with rainbow trout, *Oncorhynchus mykiss*) and small watercraft use. No motorboats are allowed on Black Lake.

In recent years, the aquatic plant community of Black Lake has become dominated by invasive Brazilian elodea (*Egeria densa*). In 1999, exotic Eurasian watermilfoil (*Myriophyllum spicatum*) was discovered at the primitive boat launch along the east shore. Other aquatic plants include ribbon-leaf pondweed (*Potamogeton epihydrus*), yellow water-lily (*Nuphar polysepala*), and a variety of emergent types that rim the shoreline (Jenifer Parsons, Washington Department of Ecology, personal communication).

Concern about the invasion of Brazilian elodea led the City of Ilwaco to explore management options available to control the errant vegetation in Black Lake. The city settled on the use of sterile, triploid grass carp (*Ctenopharyngodon idella*) as a way of reducing the standing crop of Brazilian elodea. Since the mid-1980's, it has been shown that grass carp can be a cost-effective aquatic plant management tool in the Pacific Northwest (Pauley et al. 1994). In Washington, public satisfaction concerning the use of grass carp has been moderate to high (Bonar et al. 1996). On July 22, 1997, the Washington Department of Fish and Wildlife (WDFW) issued a permit to the City of Ilwaco to stock sterile, triploid grass carp into Black Lake. During September-October 1997, 150 grass carp measuring 229 to 254 mm (9 to 10") total length each were released into the lake at a density of 11 fish per hectare.

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). A diverse, thriving 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). For these reasons, it is important to gather baseline information and carefully review all proposals to limit or control aquatic vegetation for a given lake, especially when the lake supports a popular fishery. In an effort to assess its warmwater fishery, personnel from

WDFW's Warmwater Enhancement Program conducted a fisheries survey at Black Lake in late summer 1997. Since it was gathered before the introduction of grass carp, the baseline information presented here will be useful when monitoring the long-term effects of grass carp herbivory at the lake.

Materials and Methods

Black Lake was surveyed by a three-person team during August 18 - 22, 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 pulsed 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 14 consecutively numbered sections of about 183 m each (determined visually from a map). Using the random numbers table from Zar (1984), 10 of these sections were then randomly selected as sampling locations (Figure 1). Sampling occurred during evening hours to maximize the type and number of fish captured. Nighttime electrofishing occurred along 45.5% (~ 1.1 km) of the available shoreline. While electrofishing, the boat was maneuvered through the shallows (depth range: 0.2 - 1.5 m), adjacent to the shoreline, at a rate of 18.3 m/minute. Gill nets were set overnight at four locations (= 4 ‘net nights’). The small-mesh end was attached onshore while the large-mesh end was anchored offshore perpendicular to the shoreline.

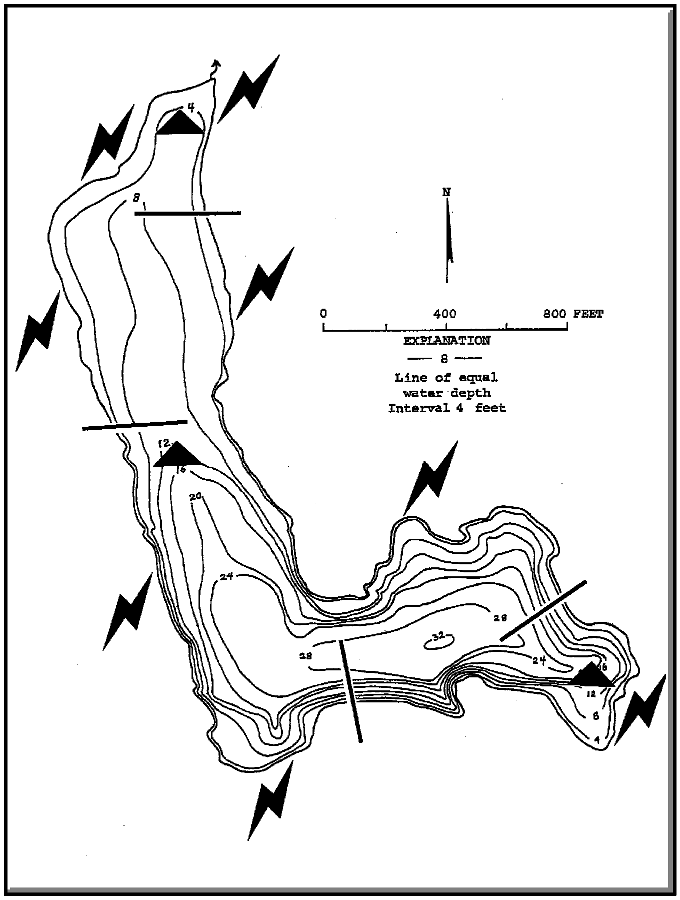

Figure 1. Map of Black Lake (Pacific County) showing sampling locations. Bolts indicate sections of shoreline where electofishing occurred. Bars extending into lake indicate placement of gill nets whereas triangles indicate water quality stations.

With the exception of sculpin (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 ($n \geq 100$ 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 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, because the focus of our study was the characteristics of the warmwater fish community, non-game fish were not aged.

Water quality data was collected during midday from three locations on August 21, 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 1).

Table 1. Water quality from three locations (north end, mid-lake, and southeast end) at Black Lake (Pacific County). Samples were collected midday on August 21, 1997.

		Parameter					
Location	**Secchi (m)**	**Depth (m)**	**DO**	**Temp (°C)**	**pH**	**Conductance**	**Redox**
North end	—	1 (bottom)	7.35	19.60	7.50	151	412
Mid-lake	2.6 m	1	7.21	22.20	6.95	145	445
		2	7.44	21.25	6.98	146	445
		3	7.37	20.72	6.97	146	448
		3.7 (bottom)	3.99	19.74	6.77	149	455
Southeast end	2.3 m	1	6.60	21.63	6.73	145	456
		2	6.15	21.15	6.67	144	460
		3	6.21	20.82	6.66	144	464
		4	1.60	19.10	6.43	145	479
		5 (bottom)	0.85	14.85	6.29	165	383

Data Analysis

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.

The size structure of each species captured was evaluated by constructing stacked length frequency histograms. By using this chart style, we were able to show the relative contribution of each gear type to the total catch (number of fish captured in each size class by gear type divided by the total number of fish captured by all gear types × 100). Since selectivity of gear types not only biases species catch based on body form and behavior, but also size classes within species, length frequencies are generally reported by gear type (Willis et al. 1993). However, differences in size selectivity of gear types can sometimes result in offsetting biases (Anderson and Neumann 1996). Therefore, we chose to report the length frequency of each species based on the total catch from combined gear types broken down by the relative contribution each gear type made to each size class. This changed the scale, but not the shape, of the length frequencies by gear type. If concern arises that pooled gear does not represent the least biased assessment of length frequency for a given species, then the shape of the gear type-specific distributions is still represented on the graphs, and these may be interpreted independently.

Catch per unit effort (CPUE) by gear type was determined for all species (number of fish/hour electrofishing and number of fish/net night). Only stock size fish and larger were used to determine CPUE for the warmwater species, whereas CPUE for non-game fish was calculated for all sizes. Stock length, which varies by species (see Table 2 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 $\pm\ t_{(\alpha,N\text{-}1)} \times SE$, where t = Student's t for α confidence level with N-1 degrees of freedom (two-tailed) and SE = standard error of the mean. Since it is standardized, CPUE is a useful index for comparing relative abundance of stocks between lakes.

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 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 2). 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$\geq$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 2. Length categories for warmwater fish species used to calculate stock density indices (PSD and RSD; Gabelhouse 1984) of fish captured at Black Lake (Pacific County) during late summer 1997. Measurements are minimum total lengths (mm) for each category (Anderson and Neumann 1996).

	Size				
Type of fish	**Stock**	**Quality**	**Preferred**	**Memorable**	**Trophy**
Black crappie	130	200	250	300	380
Bluegill	80	150	200	250	300
Brown bullhead [a]	130	200	280	360	430
Largemouth bass	200	300	380	510	630
Yellow perch	130	200	250	300	380

[a] T. J. Bister and D. W. Willis, South Dakota State University, unpublished data.

Age and growth of warmwater fishes in Black 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 Black 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 non-game fish, the W_r values from this study were compared to the national standard ($W_r = 100$) and, where available, the mean W_r values from up to 25 western Washington warmwater lakes sampled during 1997 and 1998 (Steve Caromile, WDFW, unpublished data).

Results and Discussion

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

During late summer 1997, the fish community of Black Lake was dominated by largemouth bass (*Micropterus salmoides*) and yellow perch (*Perca flavescens*) both in terms of biomass and abundance. However, in terms of abundance, the lake was clearly dominated by yellow perch (Table 3). Black crappie (*Pomoxis nigromaculatus*) comprised about 7% of the catch in terms of biomass and abundance, whereas brown bullhead (*Ameiurus nebulosus*) and bluegill (*Lepomis macrochirus*) comprised less than 2% of the catch. Species other than the warmwater variety comprised less than 7% of the biomass captured and less than 3% by number. Of these, peamouth (*Mylocheilus caurinus*) was dominant (Table 3).

Table 3. Species composition by weight (kg) and number of fish captured at Black Lake (Pacific County) during a late summer 1997 survey of warmwater fish.

	Species composition				
	by weight		by number		
Type of fish	(kg)	(%)	(#)	(%)	Size range (mm TL)
Black crappie (*Pomoxis nigromaculatus*)	2.439	7.343	78	7.632	35 - 212
Bluegill (*Lepomis macrochirus*)	0.019	0.056	2	0.196	37 - 96
Brown bullhead (*Ameiurus nebulosus*)	0.587	1.767	3	0.294	212 - 294
Largemouth bass (*Micropterus salmoides*)	21.519	64.779	142	13.894	37 - 491
Peamouth (*Mylocheilus caurinus*)	2.149	6.469	20	1.957	101 - 250
Sculpin (*Cottus* sp.)	0.015	0.044	4	0.391	66 - 77
Yellow perch (*Perca flavescens*)	6.491	19.541	773	75.636	45 - 196
Total	33.220		1,022		

Young-of-year or small juveniles are often not considered when analyzing species composition because large fluctuations in their numbers may distort results (Fletcher et al. 1993). However, we chose to include them since their relative contribution to total biomass captured was small (Table 3). 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 (e.g., Figure 6). Although many young-of-year and small juveniles are subject to high mortality during their first winter (Chew 1974), resulting in a different size distribution come spring, the presence of these fish in the system relates directly to fecundity and inter- and intraspecific competition at lower trophic levels (Olson et al. 1995).

CPUE

While electrofishing, catch rates were highest for stock-size yellow perch and largemouth bass, whereas a moderate number of stock-size black crappie were captured (Table 4). While gill netting, catch rates were similar for stock-size largemouth bass and black crappie, whereas few stock-size yellow perch were captured using this method. Peamouth were captured almost exclusively with gill nets (Table 4).

Table 4. 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 and non-game fish collected from Black Lake (Pacific County) while electrofishing and gill netting during late summer 1997.

Type of fish	Gear type			
	Electrofishing (# fish/hour)	Shock sites	Gill netting (# fish/net night)	Net nights
Black crappie	12.62 ± 3.66	6	3.50 ± 1.11	4
Bluegill	0.50 [a]	6	None captured	4
Brown bullhead	2.33 ± 1.92	6	None captured	4
Largemouth bass	21.73 ± 10.31	6	3.00 ± 0.52	4
Peamouth	0.99 [a]	6	4.75 ± 4.54	4
Sculpin	2.66 [a]	6	None captured	4
Yellow perch	52.83 ± 31.49	6	0.75 ± 0.61	4

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

Stock Density Indices

Except for largemouth bass and black crappie, few quality or preferred size warmwater fish were captured (Table 5). No memorable length fish were captured; yet the PSD and RSD-P values for largemouth bass were within the stock density index ranges for a body of water managed for a balance between predator and prey species. For largemouth bass, the generally accepted stock density index ranges for balanced fish populations are PSD values of 40 to 70 and RSD-P values of 10 to 40 (Gabelhouse 1984; Willis et al. 1993). The PSD values for black crappie and brown bullhead captured while electrofishing 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 5. Traditional stock density indices, including 80% confidence intervals, for warmwater fishes collected from Black Lake (Pacific County) while electrofishing and gill netting during late 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). EB = electrofishing and GN = gill netting.

Type of fish	Gear type	# Stock length fish	PSD	RSD-P	RSD-M	RSD-T
Black crappie	EB	16	6 [a]	0	0	0
	GN	14	14 ± 12	0	0	0
Bluegill	EB	1	0	0	0	0
	GN	0	0	0	0	0
Brown bullhead	EB	3	33 [a]	0	0	0
	GN	0	0	0	0	0
Largemouth bass	EB	24	38 ± 13	13 ± 9	0	0
	GN	12	67 ± 17	25 ± 16	0	0
Yellow perch	EB	67	0	0	0	0
	GN	3	0	0	0	0

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

Black Crappie

Black Lake black crappie ranged from 35 to 212 mm TL (age 0+ to 5+). The 1996 year-class (~ 50 mm TL) was dominant, followed by the 1993 and 1994 year-classes (~ 160 and 180 mm TL, respectively) (Table 6, Figure 2). Growth of black crappie in Black Lake was slow when compared to black crappie statewide (Table 6), and their relative weights were consistent with or below the averages for black crappie from up to 25 western Washington warmwater lakes (Figure 3).

Table 6. Age and growth of black crappie (*Pomoxis nigromaculatus*) captured at Black Lake (Pacific County) during late 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 total length (mm) at age				
Year class	**# fish**	**1**	**2**	**3**	**4**	**5**
1996	7	53.6				
		69.2				
1995	3	43.9	86.8			
		67.7	99.6			
1994	12	44.6	90.9	142.9		
		70.5	107.3	148.9		
1993	13	41.3	70.3	112.8	159.4	
		68.1	91.4	125.5	162.9	
1992	1	39.5	71.8	131.0	170.5	201.0
		67.9	94.8	144.2	177.1	202.5
	Overall mean	44.6	79.9	128.9	165.0	201.0
	Weighted mean	69.1	98.9	137.0	163.9	202.5
	State average	46.0	111.2	156.7	183.4	220.0

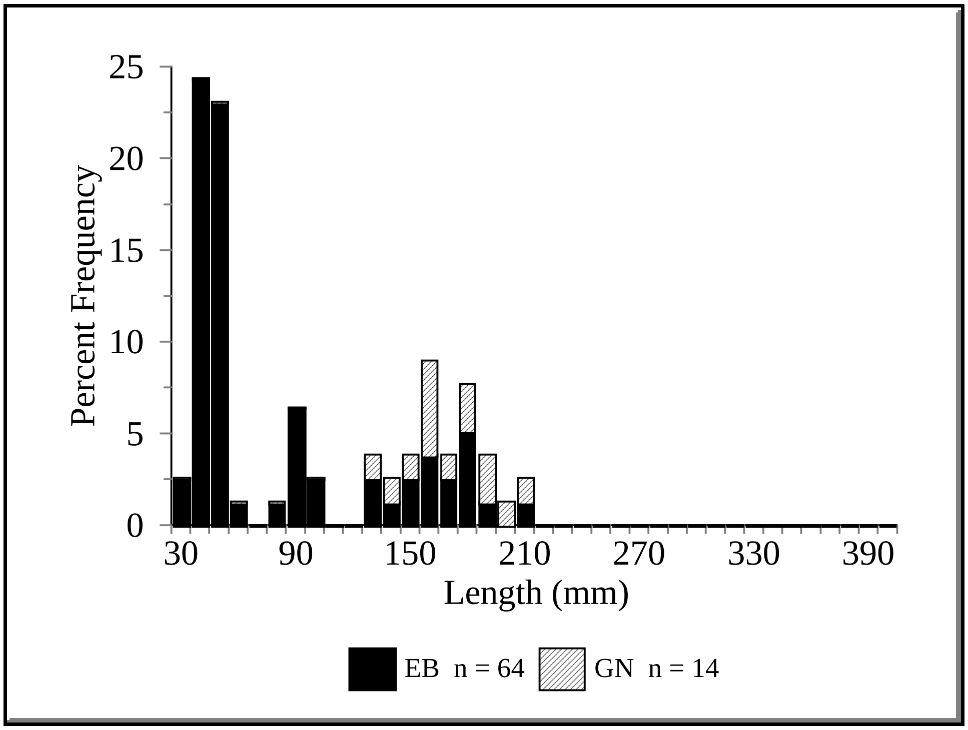

Figure 2. Length frequency histogram of black crappie sampled from Black Lake (Pacific County) in late summer 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing and GN = gill netting.

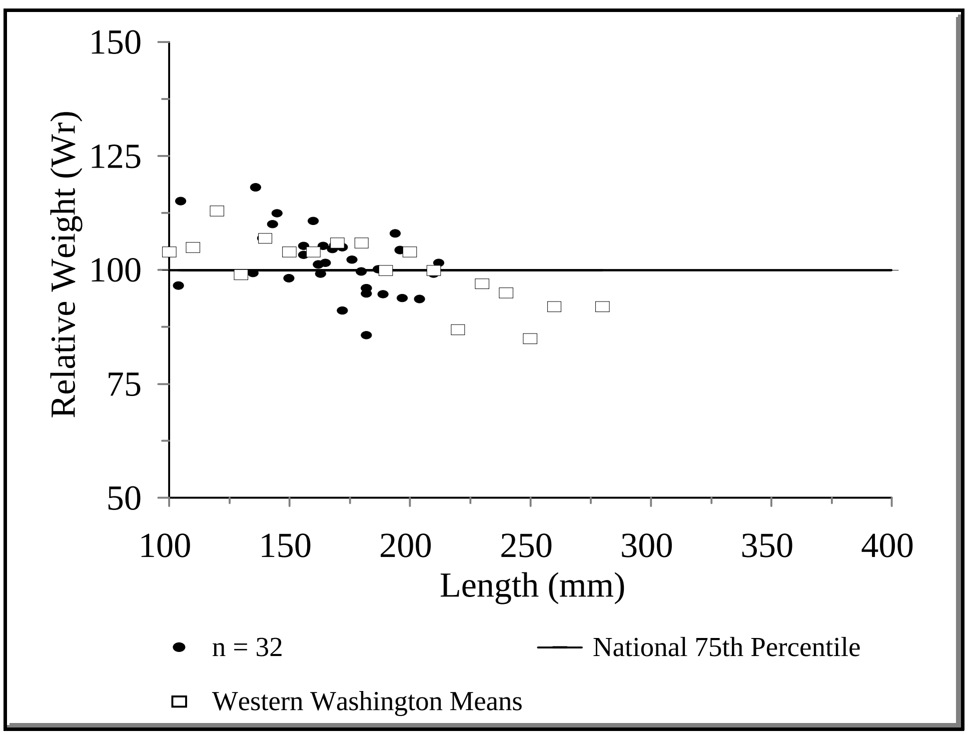

Figure 3. Relationship between total length and relative weight (Wr) of black crappie from Black Lake (Pacific County) compared with means from up to 25 western Washington lakes and the national 75^{th} percentile.

Bluegill

Only two bluegill were captured at Black Lake during late summer 1997. One measured 37 mm TL and was aged 0+ or young-of-year. The other measured 96 mm TL and weighed 18 g. Its relative weight was 114, which was high when compared to the average for bluegill from up to 25 western Washington warmwater lakes (Steve Caromile, WDFW, unpublished data). The larger bluegill was aged 1+. Using Lee's modification of the direct proportion method (Carlander 1982), the fish measured 61.0 mm at first annulus formation. Using the direct proportion method (Fletcher et al. 1993), the fish measured 51.8 mm. This was high when compared to the state average (37.3 mm using the direct proportion method) for the species.

Brown Bullhead

Only three brown bullhead were captured during late summer 1997. These fish ranged from 212 to 294 mm TL. Two year-classes were evident from the length frequency histogram (Figure 4); however, these fish were not aged. The relative weights of Black Lake brown bullhead were low by national standards (Figure 5).

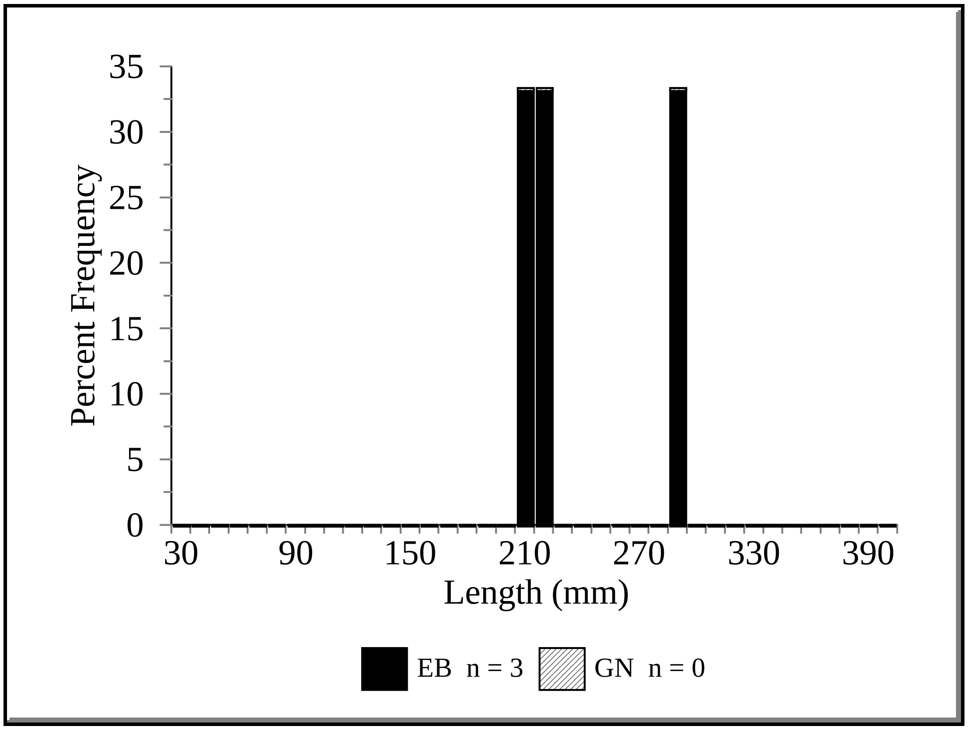

Figure 4. Length frequency histogram of brown bullhead sampled from Black Lake (Pacific County) in late summer 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing and GN = gill netting.

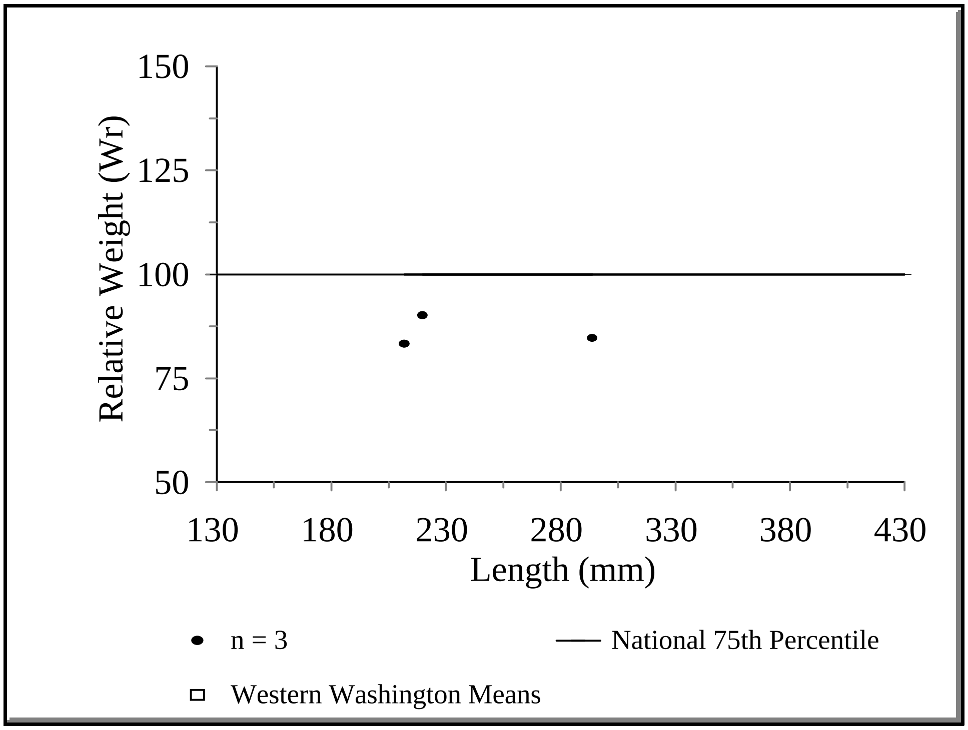

Figure 5. Relationship between total length and relative weight (Wr) of brown bullhead from Black Lake (Pacific County) compared with the national 75th percentile.

Largemouth Bass

Black Lake largemouth bass ranged from 37 to 491 mm TL (age 0+ to 13+) (Figure 6). The size structure of largemouth bass, as indicated by their PSD and RSD-P values (Table 5), suggests a balanced condition in the lake (Gabelhouse 1984; Willis et al. 1993); however, the 1990 and 1991 year-classes were not observed in our sample. With the exception of their first year, growth of Black Lake largemouth bass was slow when compared to other western Washington fish (Table 7), and relative weights were consistent with or below the average for largemouth bass from up to 25 western Washington warmwater lakes (Figure 7).

Table 7. Age and growth of largemouth bass (*Micropterus salmoides*) captured at Black Lake (Pacific County) during late 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 total length (mm) at age												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1996	8	62.6												
		72.9												
1995	32	55.1	114.5											
		68.1	119.8											
1994	5	45.7	104.7	161.9										
		60.6	113.0	163.7										
1993	5	50.5	100.6	168.7	215.8									
		66.1	111.8	174.0	216.9									
1992	12	52.9	101.1	143.8	188.0	222.4								
		68.4	112.6	151.7	192.2	223.8								
1991	0													
1990	0													
1989	1	38.8	75.6	120.2	178.4	217.2	261.8	287.0	323.8					
		56.6	91.3	133.3	188.2	224.7	266.8	290.5	325.2					
1988	4	42.2	97.3	128.4	184.3	234.5	257.7	289.5	314.0	330.9				
		59.7	111.6	140.9	193.6	240.9	262.7	292.7	315.7	331.6				
1987	4	52.1	101.3	137.3	176.3	207.7	246.0	282.9	307.5	333.5	349.8			
		69.2	115.7	149.7	186.6	216.2	252.3	287.2	310.4	334.9	350.4			
1986	3	45.1	97.0	135.3	165.6	203.9	234.6	262.2	293.6	326.2	344.6	368.0		
		62.8	111.8	148.1	176.8	213.1	242.2	268.3	298.0	328.9	346.3	368.5		
1985	3	53.1	101.1	135.7	173.0	212.5	244.6	274.6	302.9	329.8	354.7	376.3	390.6	
		70.5	116.1	148.9	184.4	221.8	252.4	280.9	307.7	333.3	356.9	377.4	391.0	
1984	2	61.6	121.5	193.3	230.9	259.1	289.3	319.5	351.9	380.3	406.5	430.5	439.9	452.4
		79.0	136.3	205.1	241.1	268.1	297.0	325.9	356.9	384.2	409.2	432.2	441.2	453.2
Overall mean		50.9	101.5	147.2	189.0	222.5	255.7	286.0	315.6	340.2	363.9	391.6	415.3	452.4
Weighted mean		67.7	116.4	156.6	196.0	226.9	259.1	288.8	315.3	338.8	360.8	387.8	411.1	453.2
Western WA average		60.4	145.5	222.2	261.1	289.3	319.0	367.8	396.0	439.9	484.6	471.7	495.6	—

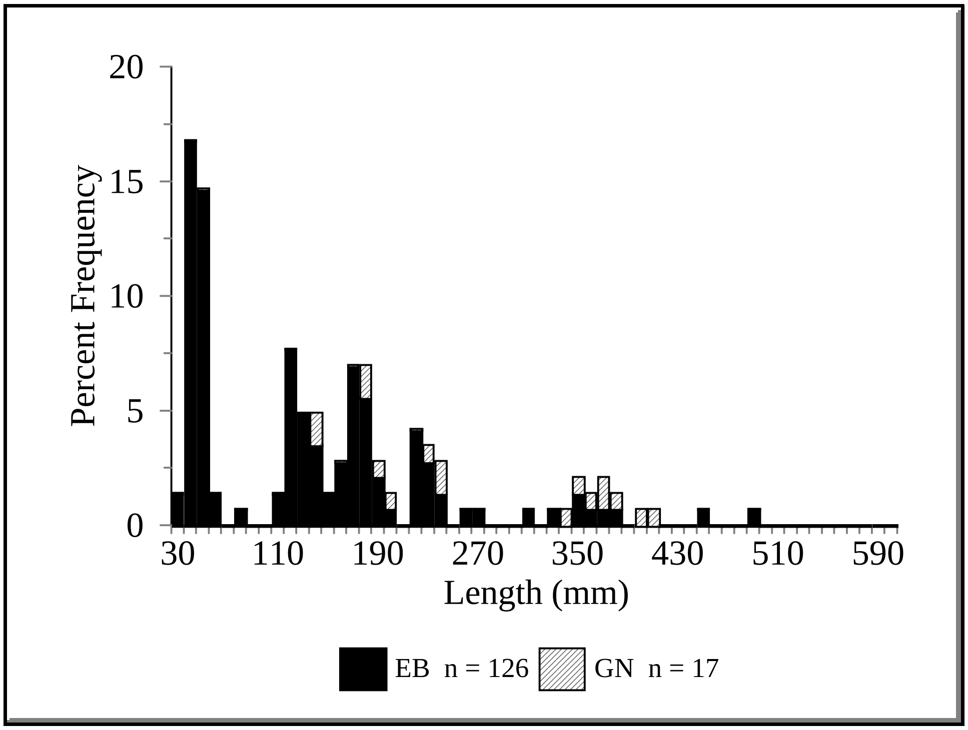

Figure 6. Length frequency histogram of largemouth bass sampled from Black Lake (Pacific County) in late summer 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing and GN = gill netting.

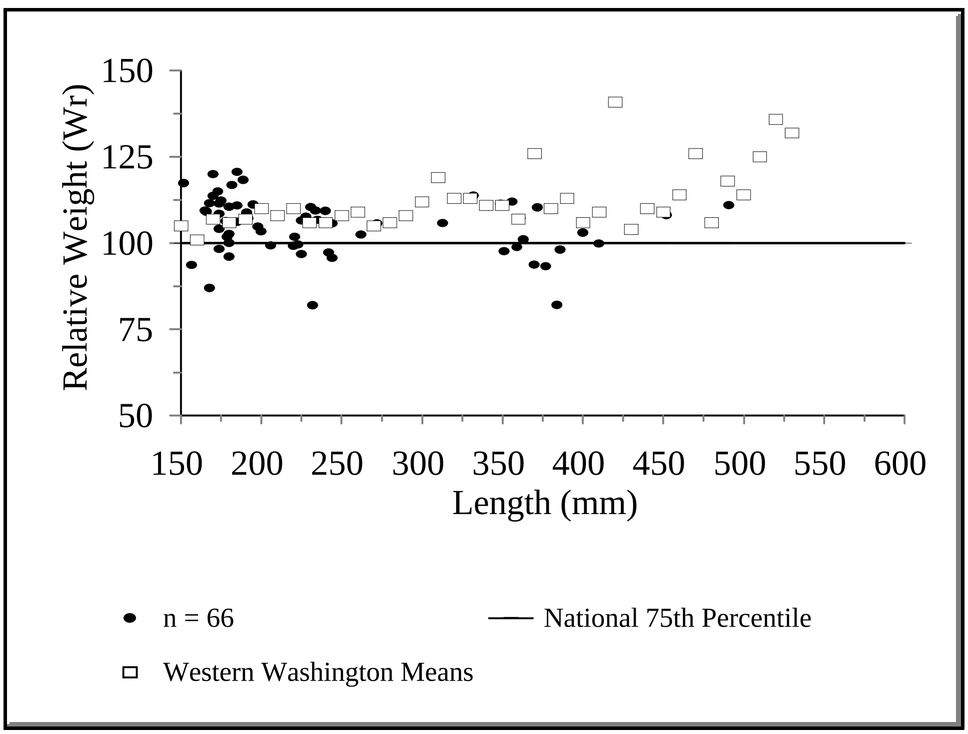

Figure 7. Relationship between total length and relative weight (Wr) of largemouth bass from Black Lake (Pacific County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Yellow Perch

Yellow perch ranged from 45 to 196 mm TL (age 0+ to 5+). Young-of-year and age 1+ fish were dominant (Table 9), as indicated by the length frequency distribution (Figure 8). Up to age 3+, growth of Black Lake yellow perch was consistent with yellow perch statewide; however, after their third year, growth was below average (Table 8). Relative weights were generally well below the national standard and average for yellow perch from up to 25 western Washington warmwater lakes (Figure 9).

Table 8. Age and growth of yellow perch (*Perca flavescens*) captured at Black Lake (Pacific County) during late 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 total length (mm) at age				
Year class	**# fish**	**1**	**2**	**3**	**4**	**5**
1996	17	67.6				
		77.6				
1995	19	69.8	121.7			
		85.3	126.4			
1994	14	63.7	119.2	149.8		
		82.1	127.4	152.6		
1993	2	59.8	112.2	151.5	176.6	
		80.2	124.2	157.2	178.2	
1992	1	76.9	138.9	161.3	181.1	188.6
		95.1	147.7	166.6	183.4	189.7
Overall mean		67.6	123.0	154.2	178.8	188.6
Weighted mean		82.0	127.3	153.9	180.0	189.7
State average		59.7	119.9	152.1	192.5	206.0

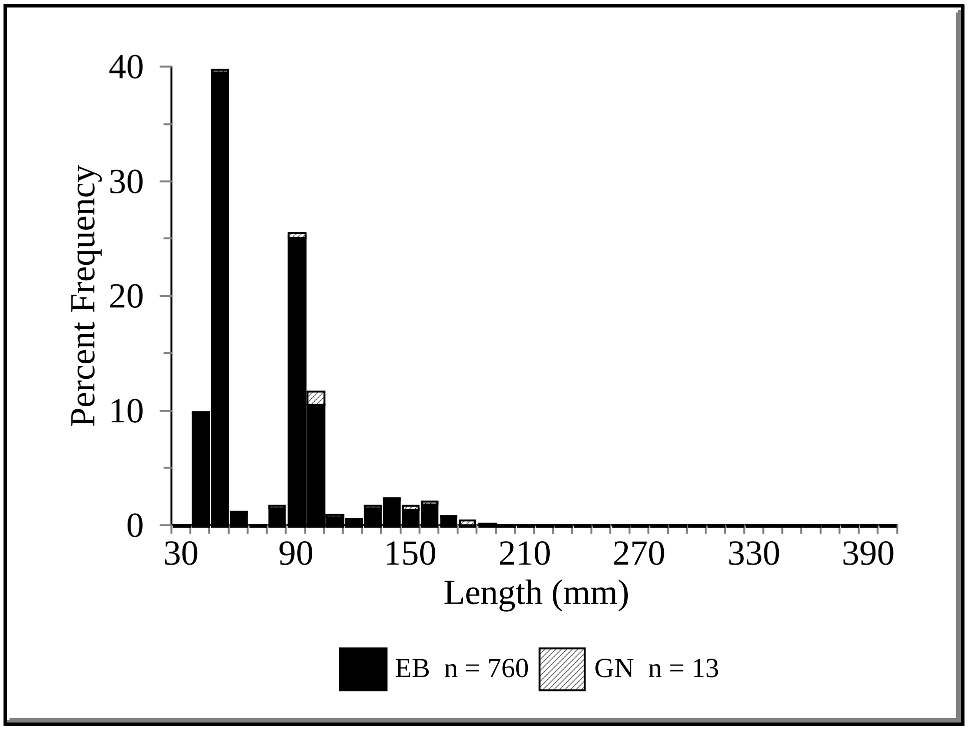

Figure 8. Length frequency histogram of yellow perch sampled from Black Lake (Pacific County) in late summer 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing and GN = gill netting.

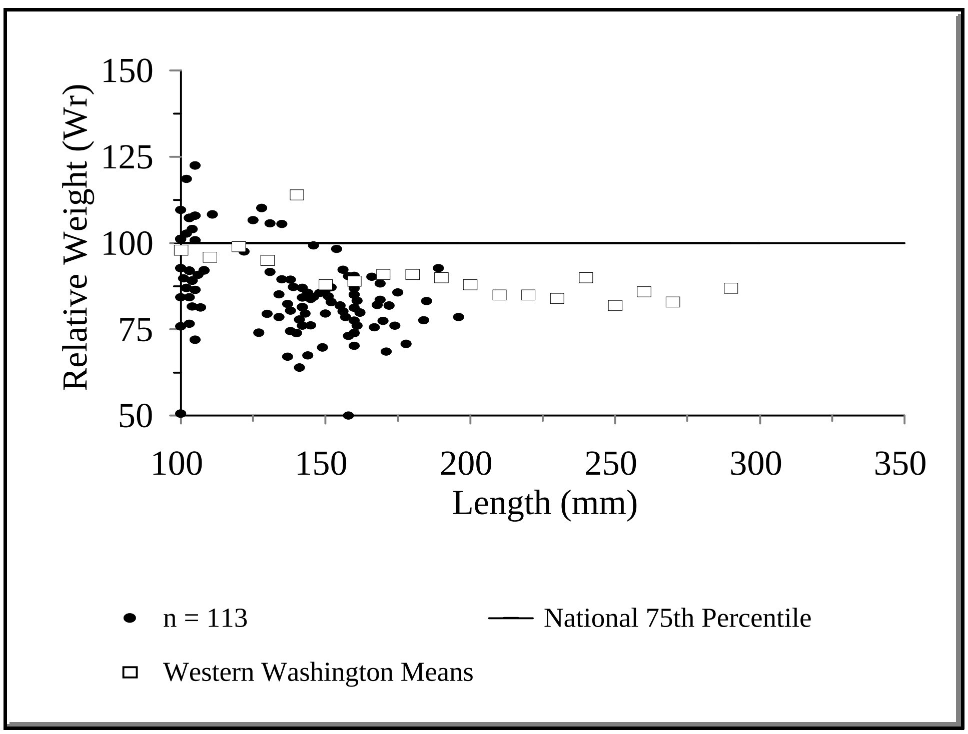

Figure 9. Relationship between total length and relative weight (Wr) of yellow perch from Black Lake (Pacific County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Non-game Fish

Peamouth comprised about 6.5% of the biomass captured at Black Lake and 2% by number (Table 3). At least three year-classes of peamouth were evident from their length frequency distribution (Figure 10); however, these fish were not aged. The smallest fish was captured while electrofishing, whereas the larger fish were captured while gill netting (Figure 10). Sculpin ranged from 66 to 77 mm TL (Figure 11) and comprised less than 0.5% of the biomass and number of fish captured at Black Lake (Table 3). Sculpin were captured while electrofishing only (Figure 11).

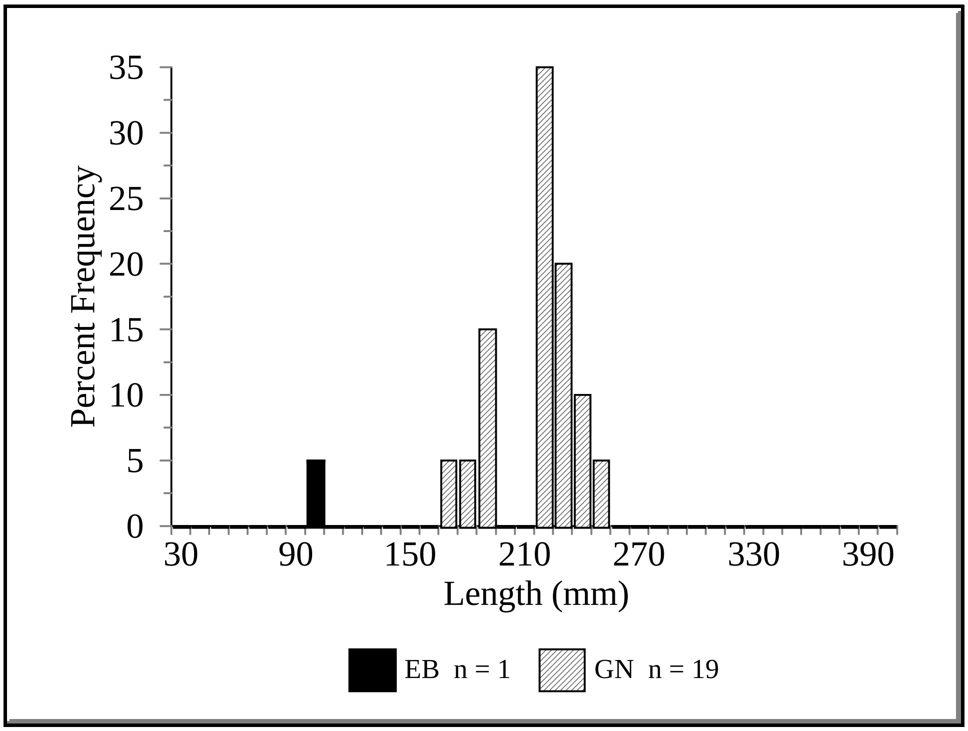

Figure 10. Length frequency histogram of peamouth (*Mylocheilus caurinus*) sampled from Black Lake (Pacific County) in late summer 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing and GN = gill netting.

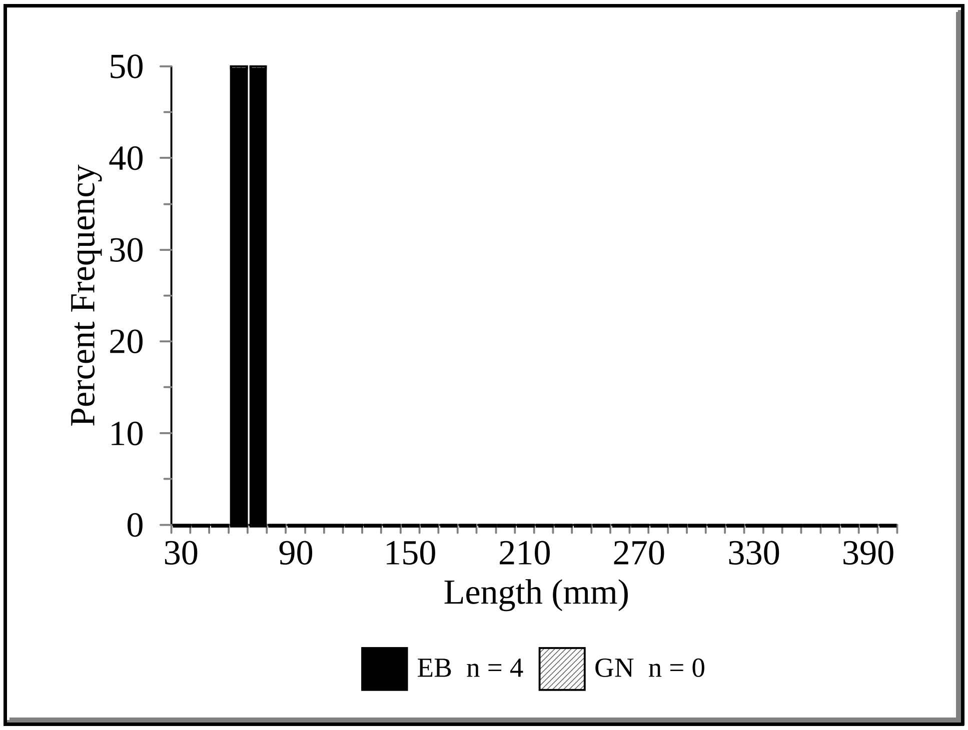

Figure 11. Length frequency histogram of sculpin (*Cottus* sp.) sampled from Black Lake (Pacific County) in late summer 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing and GN = gill netting.

Warmwater Enhancement Options

During late summer 1997, the warmwater fishes of Black Lake showed signs of impaired growth and condition. This was probably due to the extensive aquatic plant cover. For example, Hoyer and Canfield (1996) showed an inverse relationship between macrophyte abundance and growth of one- and two-year old largemouth bass. As macrophyte density increases, predator foraging efficiency decreases because of increased refuge available to prey. The increased survival of prey leads to greater population density (crowding) and more competition among these fish (Olson et al. 1998 and references therein). Thus, crowding of fish populations can result in slow growth as well (Swingle 1956). This was evident in the largemouth bass, black crappie, and larger, older yellow perch at Black Lake. Their size structures and growth patterns suggest that these fishes were not able to forage effectively, possibly due to the dense vegetation, overcrowding, and competition with the dominant yellow perch. However, cooler coastal temperatures cannot be ruled out as another contributing factor.

Elimination of aquatic vegetation can affect the growth and condition of individuals, as well as the balance of a fish community. Recent studies (Olson et al. 1998; Unmeth et al. 1999) showed that growth rates of certain age classes of largemouth bass and bluegill increased substantially by the mechanical removal of up to 20% of the aquatic macrophytes from the littoral zone. Other studies (Colle and Shireman 1980; Maceina et al. 1991) showed increases in growth and condition of warmwater fish species after removal of aquatic vegetation by grass carp (*Ctenopharyngodon idella*). Conversely, Silver Lake (Cowlitz County, Washington) yellow perch showed little difference in growth and condition before and after the total elimination of submersed aquatic vegetation by grass carp, whereas bluegill (*Lepomis macrochirus*) growth and condition decreased (Mueller 1998). However, removal of too much cover may shift the balance in a lake toward the predators by reducing prey refuge. In the short term, we would expect to see an increase in the number of large predators with a subsequent increase in production. In the long term, the result would be an unbalanced fish community with abundant, small predators and few, large prey fish (Swingle 1956; Davies and Rwangano 1991).

Most researchers agree that a low or moderate level of aquatic vegetation is better than no vegetation or too much (Savino and Stein 1982; Durocher et al. 1984; Wiley et al. 1984; Killgore et al. 1989; Davies and Rwangano 1991). For example, Wiley et al. (1984) showed a positive correlation between the concentration of aquatic plants and the production of both epiphytic invertebrates and forage fish such as bluegill, whereas largemouth bass production was reduced at both high and low concentrations of aquatic plants. If grass carp herbivory results in negative impacts to the warmwater fishery at Black Lake, because of the reduction or elimination of submersed aquatic vegetation, then remedial action by WDFW may be necessary. Management strategies that might improve the warmwater fishery at Black Lake include, but are not limited to, the following:

Conduct Follow-up Fisheries Survey

If the introduction of grass carp into Black Lake is successful, the subsequent changes in the aquatic plant community will undoubtedly affect the fish community. Whether this impacts the fisheries of Black Lake positively or negatively remains to be seen (see discussion above). Our results provide some baseline information necessary to monitor the long-term effects of grass carp herbivory at Black Lake. However, without follow-up study, any impacts from the introduction of grass carp will remain enigmatic.

If Necessary, Change Existing Fishing Rules to Alter Size Structure of Largemouth Bass

Currently, Black Lake anglers are allowed to harvest five largemouth bass daily, including no more than three over 381 mm (15”) TL. The PSD and RSD-P values of largemouth bass suggest that a balanced condition exists in the lake (Gabelhouse 1984; Willis et al. 1993). Changes in the size structure of largemouth bass, resulting from the reduction or elimination of aquatic vegetation in Black Lake, may require implementing corrective length and bag limits on largemouth bass (sensu Willis 1989) to restore the population to its pre-treatment balance.

Implementing a 305 – 432 mm (12 – 17”) slot limit for largemouth bass might succeed should the current rule fail to maintain the balance in Black Lake after reducing the standing crop of aquatic vegetation. The main objective of a slot limit is to improve the size structure of largemouth bass. Under this rule, only fish less than 305 or greater than 432 mm TL may be kept. Decreasing the creel limit of harvestable large fish from three fish over 381 mm TL to one fish over 432 mm TL would stimulate harvest of small fish while still protecting large fish. A reduction of small fish may improve growth and production of predator and prey species alike (McHugh 1990).

The success of any rule change, though, depends upon angler compliance. Reasons for non-compliance include lack of angler knowledge of the rules for a particular lake, a poor understanding of the purpose of the rules, and inadequate enforcement (Glass 1984). Therefore, clear and concise multilingual posters or signs should be placed at Black 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 Black Lake during peak harvest periods.

Modify Existing Barrier at Outlet to Prevent the Escape of Grass Carp

A prerequisite of stocking grass carp in Washington waters is the construction of barriers that would prevent their migration out of lakes (Loch and Bonar 1997). The existing barrier at the outlet of Black Lake consists of a net panel set ~ 3 m in front of a series of removable weir boards. The latter are used to adjust the elevation of the lake. Fouling of this system by aquatic vegetation is a recurring problem (Malcolm McPhail, Cranmac Farms, Inc., personal communication). Furthermore, given the grass carp's nomadic nature (Guillory and Gasaway 1978) and propensity for jumping over nets (Bonar et al. 1993), it is possible that fish have escaped from Black Lake into Tarlett Slough. The existing barrier should be inspected and, if necessary, modified or upgraded (*sensu* Maceina et al. 1999) to prevent fouling and escapement of grass carp.

Literature Cited

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

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

Bettoli, P.W., M.J. Maceina, R.L. Noble, and R.K. Betsill. 1993. Response of a reservoir fish community to aquatic vegetation removal. North American Journal of Fisheries Management 13: 110-124.

Bonar, S.A., A. Vecht, C.R. Bennett, G.B. Pauley, and G.L. Thomas. 1993. Capture of grass carp from vegetated lakes. Journal of Aquatic Plant Management 31: 168-174.

Bonar, S.A., B. Bolding, and M. Divens. 1996. Management of aquatic plants in Washington State using grass carp: effects on aquatic plants, water quality and public satisfaction (1990-1995). Washington Department of Fish and Wildlife, Inland Fish Division Research Report No. IF96-05, 28 p.

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

Chew, R.L. 1974. Early life history of the Florida largemouth bass. Florida Game and Fresh Water Fish Commission, Fishery Bulletin No. 7, 76 p.

Colle, D.E., and J.V. Shireman. 1980. Coefficients of condition for largemouth bass, bluegill, and redear sunfish in Hydrilla-infested lakes. Transactions of the American Fisheries Society 109: 521-531.

Davies, W.D., and F. Rwangano. 1991. Farm pond fish populations in the Willamette Valley, Oregon: assessment and management implications. Pages 143-148 in Proceedings of the Warmwater Fisheries Symposium I, June 4-8, 1991, Scottsdale, Arizona. USDA Forest Service, General Technical Report RM-207.

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

Durocher, P.P., W.C. Provine, and J.E. Kraai. 1984. Relationship between abundance of largemouth bass and submerged vegetation in Texas reservoirs. North American Journal of Fisheries Management 4: 84-88.

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

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

Guillory, V., and R.D. Gasaway. 1978. Zoogeography of the grass carp in the United States. Transactions of the American Fisheries Society 107: 105-112.

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

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

Hoyer, M.V., and D.E. Canfield. 1996. Largemouth bass abundance and aquatic vegetation in Florida lakes: an empirical analysis. Journal of Aquatic Plant Management 34: 23-32.

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

Killgore, K.J., R.P. Morgan II, and N.B. Rybicki. 1989. Distribution and abundance of fishes associated with submersed aquatic plants in the Potomac River. North American Journal of Fisheries Management 9: 101-111.

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

Loch, J.J., and S.A. Bonar. 1997. Occurrence of grass carp in the lower Columbia and Snake Rivers. Washington Department of Fish and Wildlife, Research Report No. RAD97-07, 13 p.

Maceina, M.J., P.W. Bettoli, W.G. Klussmann, R.K. Betsill, and R.L. Noble. 1991. Effect of aquatic macrophyte removal on recruitment and growth of black crappies and white crappies in Lake Conroe, Texas. North American Journal of Fisheries Management 11: 556-563.

Maceina, M.J., J.W. Slipke, and J.M. Grizzle. 1999. Effectiveness of three barrier types for confining grass carp in embayments of Lake Seminole, Georgia. North American Journal of Fisheries Management 19: 968-976.

Masser, M. *Undated*. Recreational fish pond management for Alabama. Auburn University, Alabama Cooperative Extension Service Technical Report, 32 p.

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

Mueller, K.W. 1998. 1997 Silver Lake Survey: The Forage Fish Community After Removal of Aquatic Vegetation by Grass Carp. Washington Department of Fish and Wildlife, Warmwater Enhancement Program, June 1998 Technical Report, 32 p.

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

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

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

Olson, M.H., S.R. Carpenter, P. Cunningham, S. Gafny, B.R. Herwig, N.P. Nibbelink, T. Pellett, C. Storlie, A.S. Trebitz, and K.A. Wilson. 1998. Managing macrophytes to improve fish growth: a multi-lake experiment. Fisheries 23(2): 6-12.

Pauley, G.B., G.L. Thomas, S.A. Bonar, J.D. Frodge, D.A. Marino, S.L. Thiesfeld, S. Vecht, K.L. Bowers, and H. Sehgal. 1994. An overview of the use and efficiency of triploid grass carp Ctenopharyngodon idella as a biological control of aquatic macrophytes in Oregon and Washington State lakes. Pages 46-54 *in* Proceedings of the Grass Carp Symposium, March 7-9, 1994, Gainesville, Florida. U.S. Army Corps of Engineers, Waterways Experimental Station, Vicksburg, VA.

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

Savino, J.F., and R.A. Stein. 1982. Predator-prey interaction between largemouth bass and bluegills as influenced by simulated, submersed vegetation. Transactions of the American Fisheries Society 111: 255-266.

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

Swingle, H.S. 1956. Appraisal of methods of fish population study - part IV: determination of balance in farm fish ponds. Pages 298-322 *in* Transactions of the 21st North American Wildlife Conference, March 5-7, 1956. Wildlife Management Institute, Washington D.C.

Unmeth, J.M.L., M.J. Hansen, and T.D. Pellett. 1999. Effects of mechanical harvesting of Eurasian watermilfoil on largemouth bass and bluegill populations in Fish Lake, Wisconsin. North American Journal of Fisheries Management 19: 1089-1098.

Wiley, M.J., R.W. Gordon, S.W. Waite, and T. Powless. 1984. The relationship between aquatic macrophytes and sport fish production in Illinois ponds: a simple model. North American Journal of Fisheries Management 4: 111-119.

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

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

Willis, D.W., D.O. Lucchesi, and B.G. Blackwell. 1997. Influence of Aquatic Vegetation on Natural Recruitment of Some Centrarchid, Esocid, and Percid Fishes: A Literature Review. South Dakota Department of Game, Fish and Parks, Special Report No. 97-4, 26 p.

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

The Washington Department of Fish and Wildlife will provide equal employment opportunities to all potential and existing employees without regard to race, creed, color, sex, sexual orientation, religion, age, marital status, national origin, disability, or Vietnam Era Veteran's Status. The Department is subject to Title VI of the Civil Rights Act of 1964 and Section 504 of the Rehabilitation Act of 1973, which prohibits discrimination on the basis of race, color, national origin or handicap. If you believe you have been discriminated against in any Department program, activity, or facility, or if you want further information about Title VI or Section 504, write to: Office of Equal Opportunity, U.S. Department of Interior, Washington D.C. 20240, or Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.