1997 American Lake Survey: The Warmwater Fish Community Before Stocking Smallmouth Bass

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

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Introduction and Background

American Lake is the largest (surface area = 446 ha), natural body of freshwater in Pierce County. The lake, which is located 24 km south of the City of Tacoma, consists of two basins separated by a distinct, narrow channel. The southern basin is relatively small (31 ha) and shallow (12 m maximum depth), whereas the northern basin is considerably larger (415 ha) and deeper (27 m maximum depth) (Figure 1). American Lake is primarily fed by groundwater. However, some inflow occurs through Murray Creek from the east, precipitation, and stormwater runoff. Surface water exits the lake mostly through groundwater seepage, some evaporation and, during times of high water (elevation > 71 m), a box culvert overflow channel at the south end of the lake (Bortelson et al. 1976; KCM 1993).

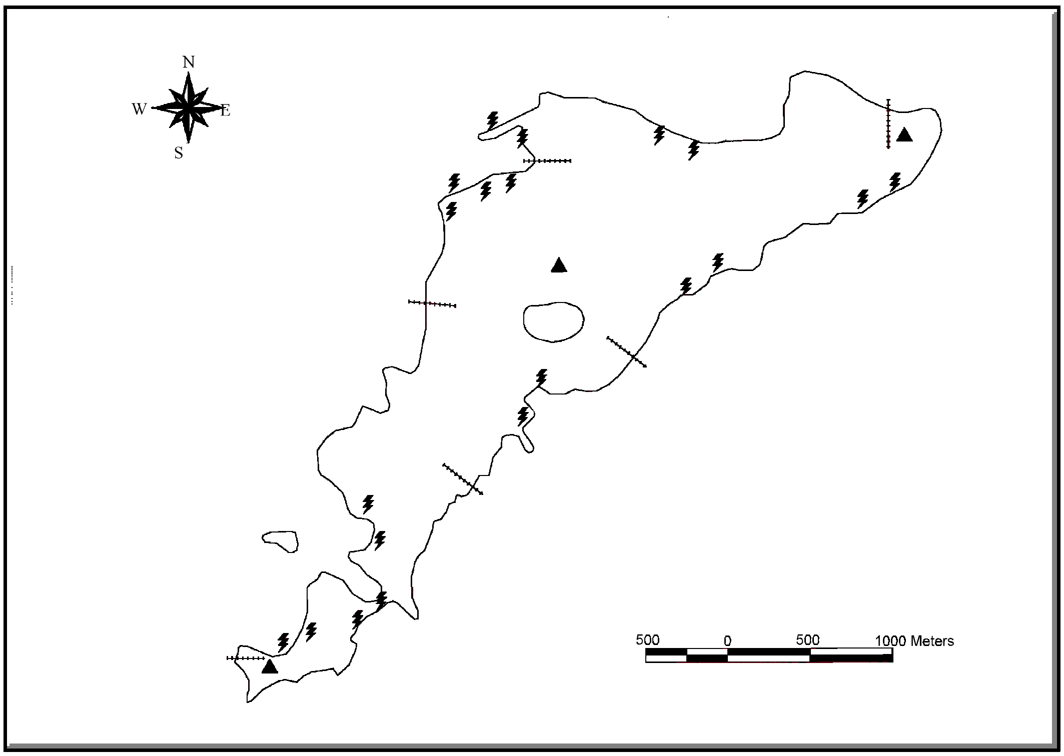

Figure 1. Map of American Lake (Pierce County) showing sampling locations. Bolts indicate sections of shoreline where electrofishing occurred. Hatched lines extending into lake indicate placement of gillnets whereas triangles indicate water quality stations.

Moderate to steep slopes comprised of gravel characterize the near-shore habitat of American Lake. The aquatic plant community consists of a variety of pondweeds (*Potamogeton* sp.), muskwort (*Chara* sp.), common elodea (*Elodea canadensis*), stonewort (*Nitella* sp.), common naiad (*Najas flexilis*), and water celery (*Vallisneria americana*). However, emergent and submersed aquatic vegetation cover no more than 10% of the littoral zone [Bortelson et al. 1976; KCM 1993; Jenifer Parsons, Washington Department of Ecology (WDE), unpublished data].

Land use around American Lake is mostly urban. Nearly 300 residences are within 100 m of the lake. Furthermore, the Fort Lewis Military Reservation comprises over 30% of the shoreline, Camp Murray, 12%, with the remainder being privately held, including the Tacoma Country and Golf Club along the northwestern shore (KCM 1993).

Surrounding land uses in the American Lake watershed affect its water quality. For example, groundwater studies revealed that the aquifer supplying the lake contains excessive concentrations of nutrients such as phosphorus and nitrate. According to KCM (1993), American Lake is "a moderately productive lake that is exhibiting tendencies to increased eutrophy. The lake's progression to a more eutrophic state is characterized by intermittent algal blooms, oxygen-depleted bottom waters (e.g., see Table 1), hypolimnetic buildup of phosphorus, an impoverished benthic invertebrate community, and phosphorus-rich surface sediments. The occurrence of toxic blue-green algal blooms is of particular concern for reasons of both public health and lake ecology." Furthermore, during 1990 through 1992, over one-third of the swimmers itch (an annoying skin condition caused by a small, free-swimming parasite) reports to the Tacoma-Pierce County Health Department were from American Lake (KCM 1993).

Because of its proximity to the City of Tacoma, Fort Lewis, and McChord Air Force Base, American Lake receives high recreational use. Pierce County Parks and Recreation operates two parks along the northern and eastern shores, while the Washington Department of Fish and Wildlife (WDFW) maintains a public boat launch near the mouth of Murray Creek. Two private marinas rent a variety of watercraft for pleasure, exercise, and fishing. Furthermore, several private swimming areas rim the shoreline, whereas the only seaplane base in Pierce County is located along the northern shore (Bortelson et al. 1976; KCM 1993).

Historically, WDFW managed American Lake as a salmonid-only fishery. To this end, in 1957, WDFW, acting as the Washington Department of Game (WDG), rehabilitated the lake with the natural piscicide, rotenone, in order to eliminate warmwater species, such as largemouth bass (*Micropterus salmoides*) and yellow perch (*Perca flavescens*), and roughfish, such as common carp (*Cyprinus carpio*). However, within a few years of its rehabilitation, American Lake supported a thriving population of rock bass (*Ambloplites rupestris*). Since the early 1980's, WDFW has stocked several thousand rainbow trout (*Oncorhynchus mykiss*), cutthroat trout (*O. clarki*), and kokanee (*O. nerka*) annually into the lake to bolster recreational angling opportunities. Nevertheless, a small-scale fisheries survey by KCM (1993) revealed that warmwater species such as rock bass, yellow perch, and pumpkinseed (*Lepomis gibbosus*) dominated the shallows of American Lake in 1991.

Because of its trophic status, American Lake is well suited for warmwater fishes (KCM 1993; Table 1). Given the relatively steep morphometry of the lake, the ubiquitous gravel substrate, and the abundant forage fish as a possible prey base, the introduction of smallmouth bass (*Micropterus dolomieu*) into American Lake was proposed in 1997 (Steve Jackson, WDFW, personal communication). Subsequently, on August 19, 1998, several thousand (n = 8,211) juvenile smallmouth bass were released into the lake by WDFW personnel. The approximate total length (TL) and weight of each fish was 102 mm (4”) and 6.5 g (0.2 oz), respectively. Moreover, dozens (n = 179) of adult-size (> 203 mm or 8” TL) smallmouth bass weighing approximately 227 g (8 oz) each were stocked into American Lake on November 2, 1998 (WDFW, management files). Still, no recent information exists concerning the warmwater fish community at the lake. In an effort to assess its warmwater fishery and suitability for smallmouth bass, personnel from WDFW’s Warmwater Enhancement Program conducted a fisheries survey during early fall 1997. Since it was gathered before stocking smallmouth bass, the baseline information presented here will be useful when monitoring the success of the introduction of a new sport fish into American Lake.

Table 1. Water quality from three locations (south end, mid-lake, and north end) at American Lake (Pierce County). Samples were collected midday on September 5, 1997.

Location	Secchi depth (m)	Parameter					
		Depth (m)	DO	Temp (°C)	pH	Specific conductance	Redox
South end	7.0	1	8.98	22.39	8.26	103	365
		3	9.16	22.30	8.37	98	361
		5	9.22	22.14	8.30	102	365
		7	5.53	19.48	7.05	108	423
		8 (bottom)	1.57	16.75	6.86	112	433
Mid-lake	6.4	1	8.62	22.06	8.14	101	387
		3	8.80	22.04	8.21	105	387
		5	8.90	21.99	8.21	105	386
		7	8.97	21.80	8.21	105	386
		9	17.50	16.64	9.50	115	351
		11	5.66	11.52	7.40	120	432
		13	1.24	9.94	6.70	107	462
		15	0.70	9.52	6.60	109	459
North end	6.6	1	8.50	22.33	8.11	104	361
		3	8.64	22.37	8.21	107	359
		5	8.74	22.36	8.17	104	360
		7	8.90	22.15	8.18	104	362
		9	16.79	17.12	9.44	104	328
		11	9.30	11.45	7.88	107	389
		13	2.22	10.02	6.93	109	422
		15	1.35	9.21	6.69	100	393
		17 (bottom)	0.91	8.88	6.60	107	371

Materials and Methods

American Lake was surveyed during September 2 - 5, 1997 by a three-person team consisting of one biologist and two scientific technicians. Fish were captured using two sampling techniques: electrofishing and gillnetting. The electrofishing unit consisted of a 5.5 m Smith-Root 5.0 GPP 'shock boat' set to 3 to 4 amp DC (120 cycles/sec). Experimental gillnets (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 86 consecutively numbered sections of about 200 m each (determined visually from a map). Using the random numbers table from Zar (1984), 15 of these sections were then randomly selected as sampling locations. Sampling occurred during evening hours to maximize the type and number of fish captured. 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. Nighttime electrofishing occurred along 9.3% (~ 1.8 km) of the available shoreline (9 sections at 600 sec each). Gillnets were set perpendicular to the shoreline. The small-mesh end was attached onshore while the large-mesh end was anchored offshore. Gillnets were set overnight at 6 locations (= 6 'net nights') (Figure 1).

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, salmonid and non-game fish were not aged.

Water quality data was collected during midday from three locations on September 5, 1997 (Figure 1). Secchi depth transparencies were recorded in m. Using a Hydrolab® probe and digital recorder, information was gathered on dissolved oxygen, redox, temperature, pH, and specific conductance (Table 1).

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).

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 salmonids and non-game fish were 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 ± $t_{(\alpha, N\text{-}1)} \times SE$, 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 ≥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 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 ≥ specified length/number of fish ≥ stock length × 100. For example, RSD P was the percentage of stock length fish that also were longer than preferred length, RSD M, the percentage of stock length fish that also were longer than memorable length, and so on. Eighty-percent confidence intervals for PSD and RSD were selected from tables in Gustafson (1988).

Table 2. Length categories for cold- and warmwater fish species used to calculate stock density indices (PSD and RSD; Gabelhouse 1984) of fish captured at American Lake (Pierce County) during early fall 1997. Measurements are minimum total lengths (mm) for each category (Anderson and Neumann 1996).

Type of fish	Size				
	Stock	Quality	Preferred	Memorable	Trophy
Cutthroat trout	200	350	450	600	750
Largemouth bass	200	300	380	510	630
Pumpkinseed	80	150	200	250	300
Rainbow trout	250	400	500	650	800
Rock bass	100	180	230	280	330
Yellow perch	130	200	250	300	380

Age and growth of warmwater fishes in American 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 American 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 and kokanee. 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. Anderson and Neumann (1996) as well as Timothy J. Bister and David W. Willis (South Dakota State University, unpublished data) have compiled the parameters of the Ws equations for many cold- and warmwater fish species, including the minimum length recommendations for their application. With the exception of non-game fish and kokanee, 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 early fall 1997, rock bass and yellow perch, both in terms of biomass and abundance dominated our catch. In fact, nearly half of the fish captured (n = 857) were rock bass (Table 3). Pumpkinseed comprised 18.6% of the catch by number yet only 8.2% by weight. Other fishes comprised 8.3% of the catch by number and 13.3% by weight. Of these, sculpin was dominant in terms of abundance (4.4%), whereas kokanee was dominant in terms of biomass (6.9%) (Table 3).

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 the 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 2). Although many of these fish would be subject to natural attrition during their first winter (Chew 1974), resulting in a different size distribution by the following year, their presence in the system relates directly to fecundity and interspecific and intraspecific competition at lower trophic levels (Olson et al. 1995).

Table 3. Species composition by weight (kg) and number of fish captured at American Lake (Pierce County) during an early fall 1997 survey of warmwater fish.					
	Species composition				
Type of fish	**by weight**		**by number**		**Size range (mm TL)**
	(kg)	**(%)**	**(#)**	**(%)**	
Cutthroat trout (*Oncorhynchus clarki*)	1.943	2.467	9	0.517	224 - 347
Kokanee (*Oncorhynchus nerka*)	5.440	6.908	19	1.092	210 - 410
Largemouth bass (*Micropterus salmoides*)	1.339	1.700	29	1.667	61 - 256
Pumpkinseed (*Lepomis gibbosus*)	6.458	8.201	324	18.621	36 - 129
Rainbow trout (*Oncorhynchus mykiss*)	3.394	4.310	11	0.632	197 - 480
Rock bass (*Ambloplites rupestris*)	35.288	44.810	857	49.253	41 - 235
Sculpin (*Cottus* sp.)	1.751	2.223	76	4.368	88 - 160
Yellow perch (*Perca flavescens*)	23.138	29.381	415	23.851	42 - 292
Total	78.751		1,740		

CPUE

While electrofishing, catch rates were highest for stock-size pumpkinseed and rock bass. For species other than the warmwater variety, electrofishing catch rates were highest for sculpin. No stock-size salmonids were captured while electrofishing (Table 4). Conversely, while gillnetting, catch rates were highest for stock-size rock bass and yellow perch. For species other than the warmwater variety, gillnetting catch rates were highest for kokanee and cutthroat trout (Table 4). The low catch rates for salmonids can probably be attributed to seasonal influences and gear-related biases (Pope and Willis 1996).

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, salmonids, and non-game fish collected from American Lake (Pierce County) while electrofishing and gillnetting during early fall 1997.				
	Gear type			
Type of fish	**Electrofishing (# fish/hour)**	**Shock sites**	**Gillnetting (# fish/net night)**	**Net nights**
Cutthroat trout	None captured	9	1.50 ± 0.79	6
Kokanee	None captured	9	3.17 ± 2.82	6
Largemouth bass	0.66 [a]	9	None captured	6
Pumpkinseed	156.61 ± 63.28	9	7.50 ± 2.64	6
Rainbow trout	None captured	9	1.00 ± 0.88	6
Rock bass	142.28 ± 25.75	9	61.83 ± 27.22	6
Sculpin	49.13 ± 18.61	9	0.17 [a]	6
Yellow perch	1.97 ± 1.26	9	29.00 ± 16.66	6
[a] Sample size was insufficient to calculate confidence intervals				

Stock Density Indices

During early fall 1997, the gillnetting PSD values for rock bass and yellow perch (Table 5) were within the stock density index range (PSD values of 50 to 80) for a body of water managed for panfish (Gabelhouse 1984; Willis et al. 1993). The PSD and RSD values for other species (Table 5) 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). For example, only one stock-length largemouth bass was captured which measured 256 mm TL.

Table 5. Traditional stock density indices, including 80% confidence intervals, for cold- and warmwater fishes collected from American Lake (Pierce County) while electrofishing and gillnetting during early fall 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, GN = gillnetting.

Type of fish	Gear type	# Stock length fish	PSD	RSD-P	RSD-M	RSD-T
Cutthroat trout	EB	0	0	0	0	0
	GN	9	0	0	0	0
Largemouth bass	EB	1	0	0	0	0
	GN	0	0	0	0	0
Pumpkinseed	EB	237	0	0	0	0
	GN	45	0	0	0	0
Rainbow trout	EB	0	0	0	0	0
	GN	6	17 [a]	0	0	0
Rock bass	EB	216	20 ± 3	1 [a]	0	0
	GN	371	48 ± 3	1 [a]	0	0
Yellow perch	EB	3	0	0	0	0
	GN	174	79 ± 4	3 ± 2	0	0

[a] Sample size was insufficient to calculate confidence intervals

Size Structure

Length frequencies are generally reported by gear type because selectivity of gear types biases species catch based on body form and behavior, and size classes within species (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, which can be interpreted independently.

Largemouth Bass

American Lake largemouth bass ranged from 61 to 256 mm TL (age 0+ to 2+). Of these, the 1996 year-class was dominant (Table 6) with fish measuring ~ 80 to 150 mm TL (Figure 2). The growth and relative weights of American Lake largemouth bass were high (Table 6, Figure 3). Only one stock-length largemouth bass was captured (Figure 2). The fish measured 256 mm TL and weighed 317 g. Its growth and relative weight were high as well (Table 6, Figure 3). The growth and condition of American Lake largemouth bass were characteristic of a low-density predator population with an abundant forage base (Blackwell et al. *in press*).

Table 6. Age and growth of largemouth bass (*Micropterus salmoides*) captured at American Lake (Pierce County) during early fall 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
1996	23	78.1	
		86.7	
1995	1	97.4	214.0
		109.8	217.3
Overall mean		87.7	214.0
Weighted mean		87.7	217.3
State Average		60.4	145.5

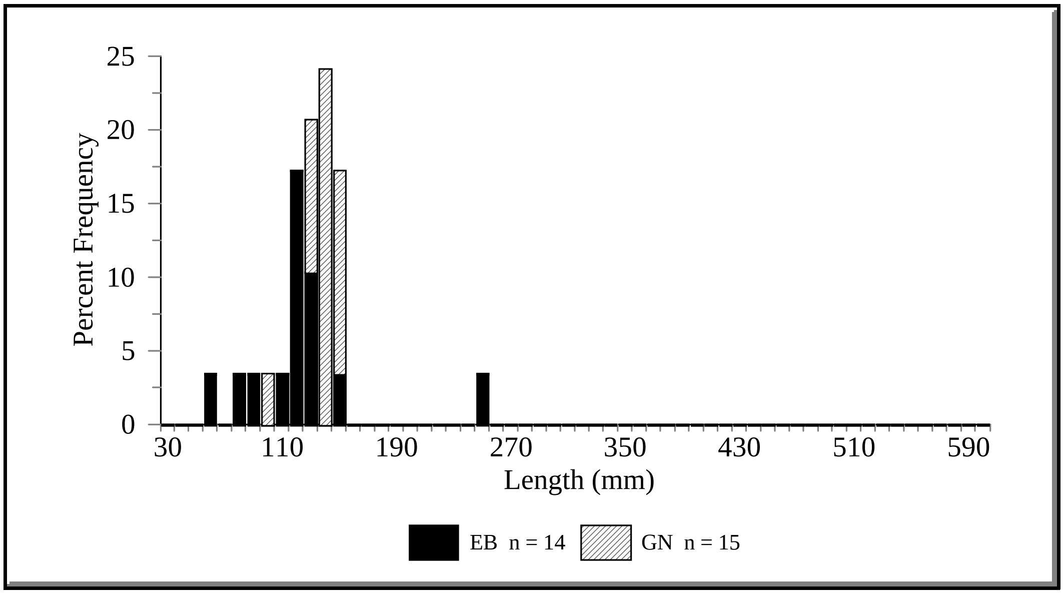

Figure 2. Length frequency histogram of largemouth bass sampled from American Lake (Pierce County) in early fall 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gillnetting.

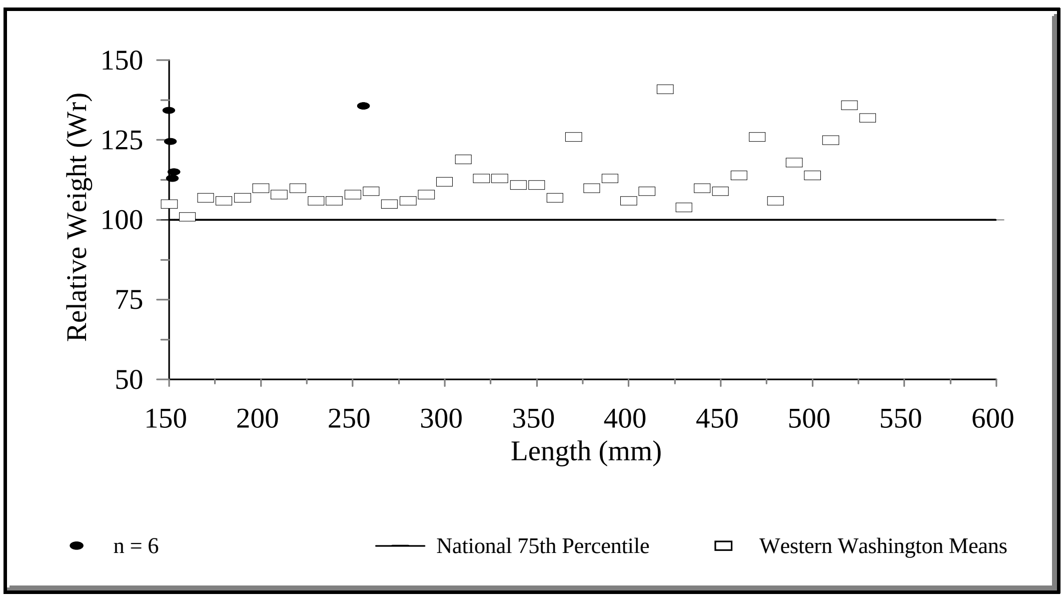

Figure 3. Relationship between total length and relative weight (W_r) of largemouth bass from American Lake (Pierce County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Pumpkinseed

Pumpkinseed in American Lake ranged from 36 to 129 mm TL (age 0+ to 4+). During their first year, American Lake pumpkinseed experienced above average growth. However, after age 2, growth was consistent with pumpkinseed statewide (Table 7). The 1994 year-class was dominant (~ 90 mm TL), which was reflected in the length frequency histogram (Figure 4). With few exceptions, the relative weights of pumpkinseed were high (Figure 5) suggesting ample forage for this species as well.

Table 7. Age and growth of pumpkinseed (*Lepomis gibbosus*) captured at American Lake (Pierce County) during early fall 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
1996	7	35.6			
		50.2			
1995	7	35.4	77.2		
		52.0	83.9		
1994	13	35.4	63.3	93.3	
		52.1	73.6	96.6	
1993	4	35.0	72.7	101.9	120.8
		53.1	83.2	106.6	121.7
Overall mean		35.4	71.1	97.6	120.8
Weighted mean		51.8	78.2	98.9	121.7
State average		23.6	72.1	101.6	122.7

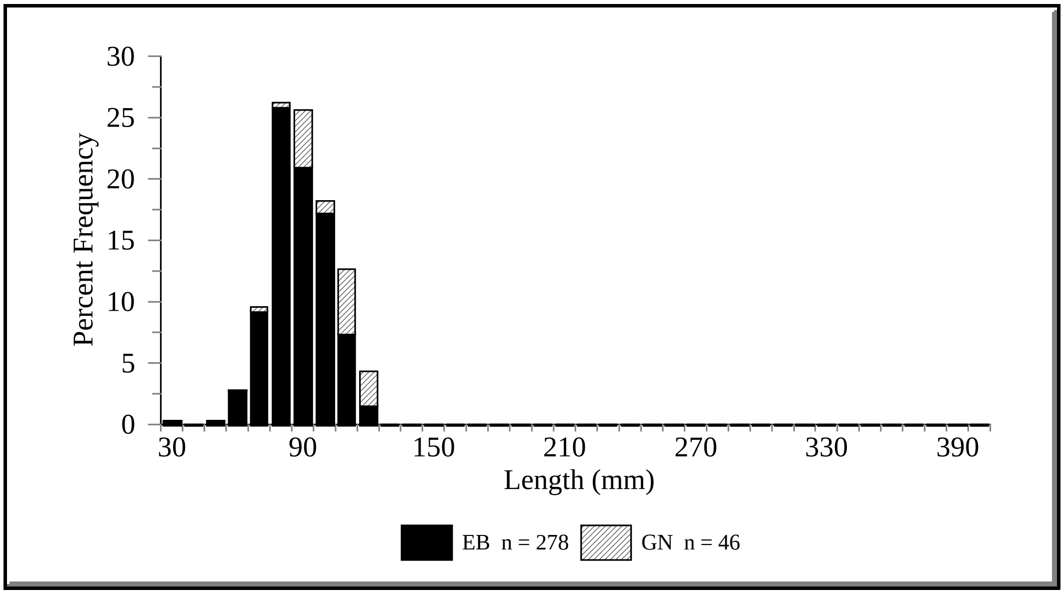

Figure 4. Length frequency histogram of pumpkinseed sampled from American Lake (Pierce County) in early fall 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gillnetting.

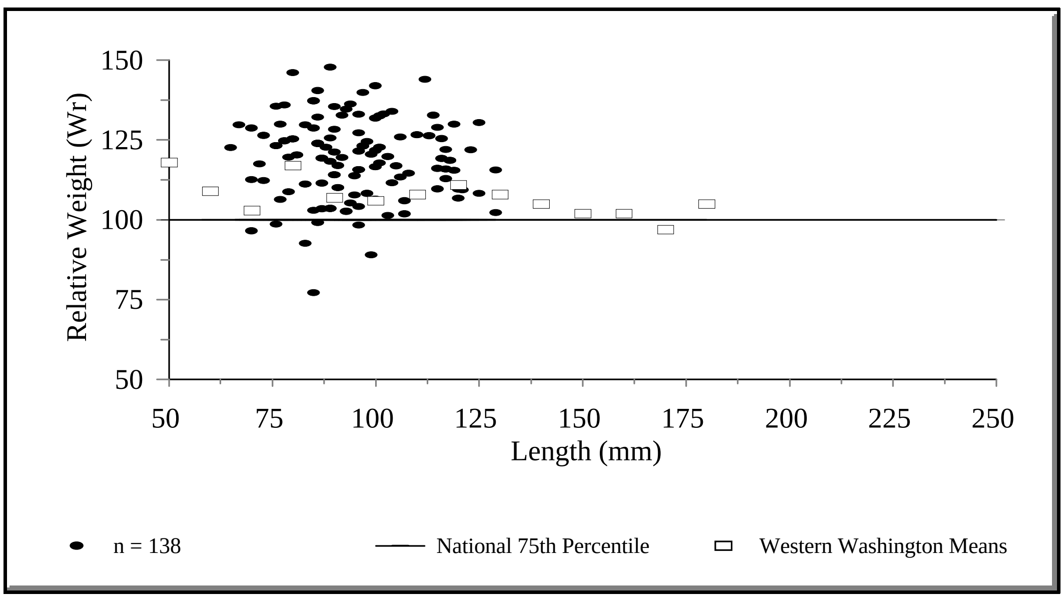

Figure 5. Relationship between total length and relative weight (W_r) of pumpkinseed from American Lake (Pierce County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Rock Bass

The rock bass population at American Lake is thriving. Sizes ranged from 41 to 235 mm TL, while ages ranged from 1+ to 7+. The 1992 and 1995 year-classes were dominant, with most fish measuring about 90 and 150 mm TL, respectively (Figure 6, Table 8). Growth of American Lake rock bass was high when compared to rock bass statewide (Table 8), whereas relative weights were generally consistent with the means from up to 25 western Washington lakes (Figure 7).

Table 8. Age and growth of rock bass (*Ambloplites rupestris*) captured at American Lake (Pierce County) during early fall 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
1996	0							
1995	26	35.9	84.0					
		52.3	88.8					
1994	7	30.2	79.2	118.1				
		49.8	89.9	121.9				
1993	19	37.3	80.1	114.5	147.6			
		56.5	92.7	121.7	149.6			
1992	12	39.7	90.3	129.4	156.7	173.5		
		59.3	102.9	136.8	160.4	174.9		
1991	5	40.0	95.1	144.4	172.8	195.0	213.7	
		60.5	109.3	153.1	178.3	198.0	214.6	
1990	1	45.6	103.7	138.2	174.2	197.7	218.4	232.2
		65.8	117.6	148.5	180.6	201.6	220.2	232.5
Overall mean		38.1	88.7	128.9	162.8	188.7	216.0	232.2
Weighted mean		55.2	94.3	130.0	157.8	182.8	215.5	232.5
State average		29	69.6	117.6	151.6	178.1	192.8	202.7

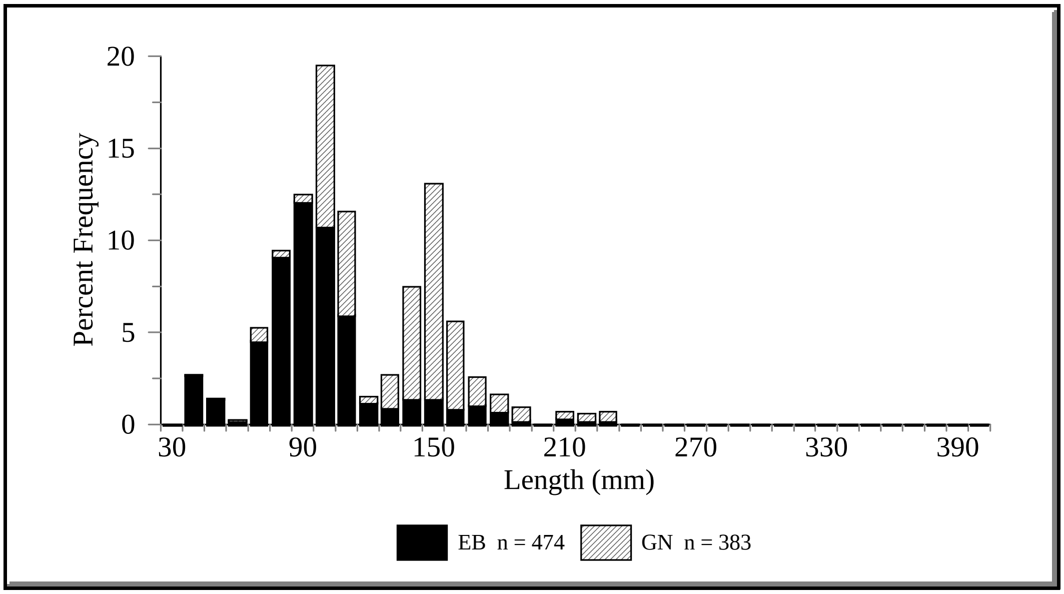

Figure 6. Length frequency histogram of rock bass sampled from American Lake (Pierce County) in early fall 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gillnetting.

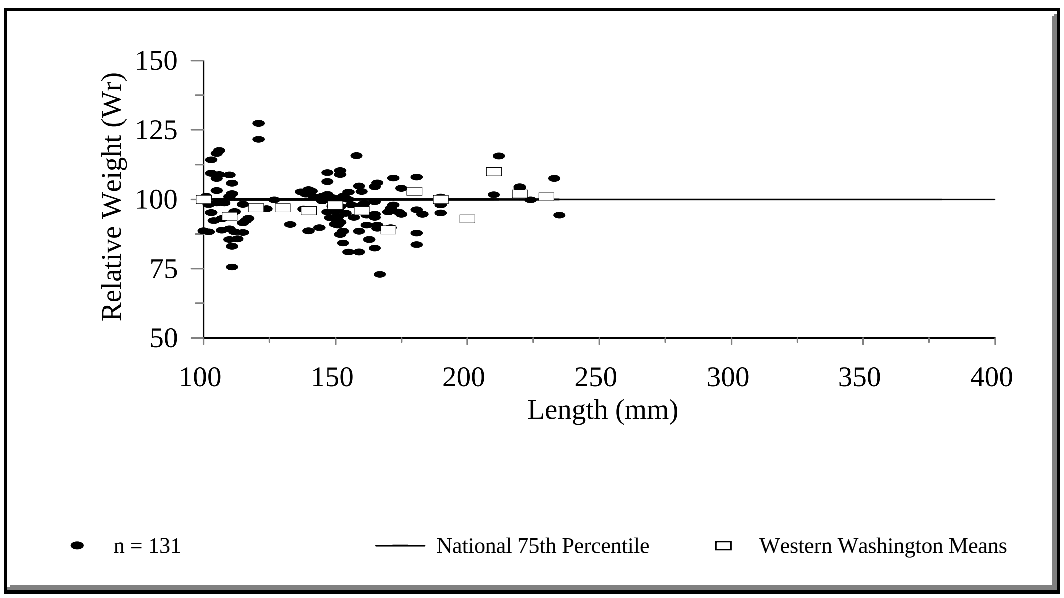

Figure 7. Relationship between total length and relative weight (W_r) of rock bass from American Lake (Pierce County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Yellow Perch

American Lake yellow perch ranged from 42 to 292 mm TL (age 0+ to 7+). The 1996 and 1992/1993 year-classes were dominant, which was reflected in the length frequency histogram (Figure 8). During their first two years, yellow perch growth was consistent with the state average; however, after age 3+, growth was relatively high (Table 9). Like pumpkinseed, the relative weights of American Lake yellow perch were high when compared to yellow perch statewide (Figure 9) indicating ample forage.

Table 9. Age and growth of yellow perch (*Perca flavescens*) captured at American Lake (Pierce County) during early fall 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
1996	5	69.7						
		77.3						
1995	17	59.5	130.1					
		78.2	135.4					
1994	19	59.1	132.4	172.8				
		79.9	141.7	175.8				
1993	15	60.1	108.4	163.7	203.1			
		82.1	123.9	171.8	206.0			
1992	5	63.8	97.5	148.7	191.5	225.3		
		85.8	115.2	160.1	197.5	227.2		
1991	1	58.6	87.9	142.3	217.7	251.2	265.8	
		82.1	108.1	156.5	223.5	253.3	266.3	
1990	1	52.9	105.8	143.9	186.2	230.6	253.9	275.1
		77.5	124.9	159.1	197.1	236.9	257.8	276.8
Overall mean		60.5	110.3	154.3	199.6	235.7	259.9	275.1
Weighted mean		80.2	132.1	171.6	204.4	232.3	262.1	276.8
State average		59.7	119.9	152.1	192.5	206.0		

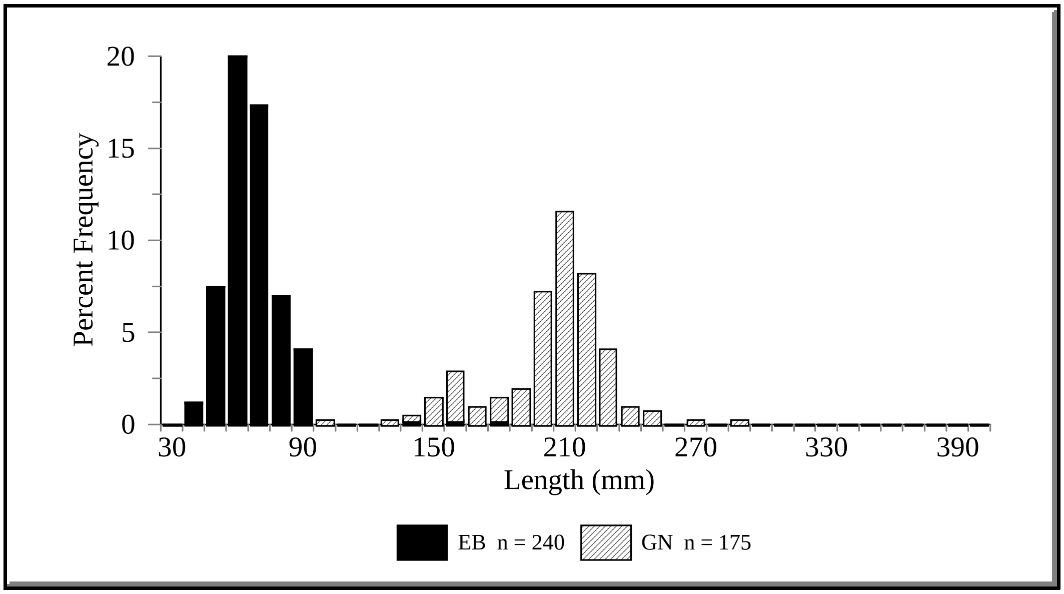

Figure 8. Length frequency histogram of yellow perch sampled from American Lake (Pierce County) in early fall 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gillnetting.

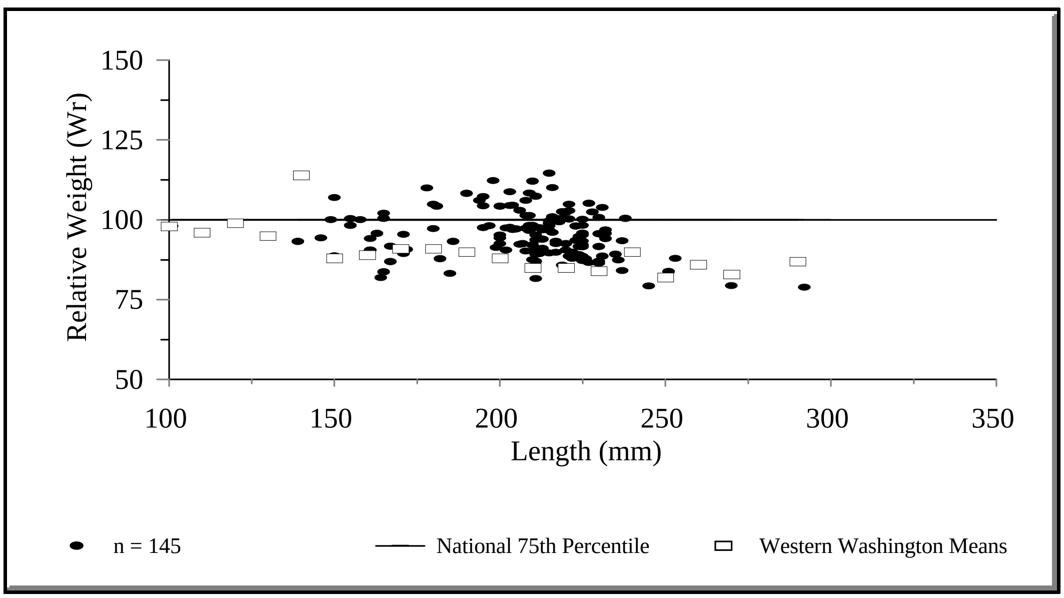

Figure 9. Relationship between total length and relative weight (W_r) of yellow perch from American Lake (Pierce County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Members of the Family Salmonidae and Non-game Fish

During early fall 1997, kokanee was the dominant salmonid in our catch (Table 3). American Lake kokanee ranged in size from 210 to 410 mm TL (Figure 10) and were captured in the northern basin only. The catch rates for cutthroat and rainbow trout were similar (Table 4). American Lake cutthroat trout ranged from 224 to 347 mm TL (Figure 11), whereas rainbow trout ranged from 197 to 480 mm TL (Figure 13). Except for large rainbow trout, relative weights for both species were generally below the national standard. Ostensibly, cutthroat trout relative weights decreased with size, whereas those of rainbow trout increased with size (Figures 12 and 14).

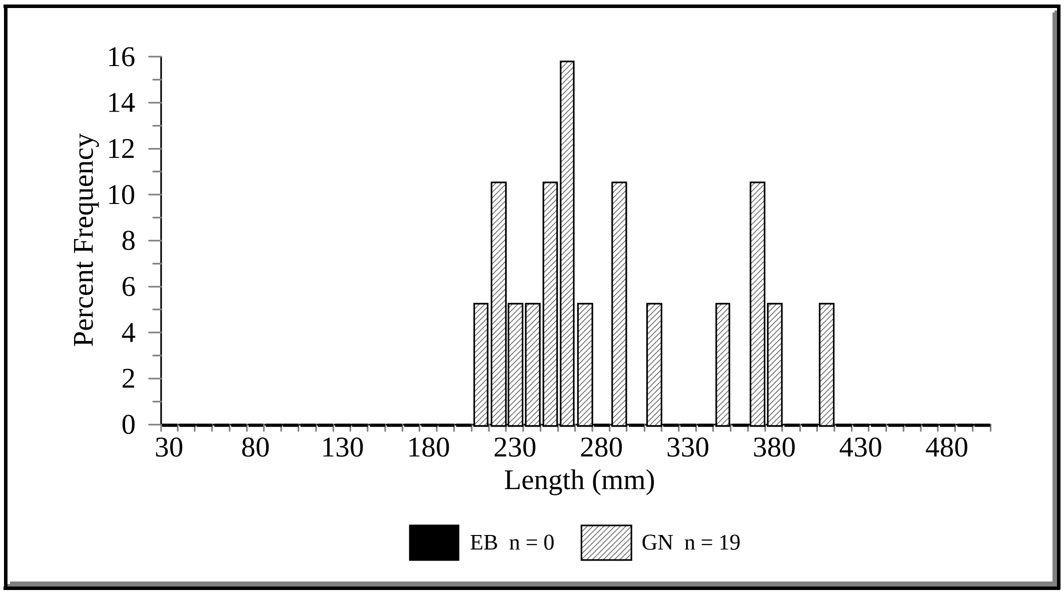

Figure 10. Length frequency histogram of kokanee sampled from American Lake (Pierce County) in early fall 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gillnetting.

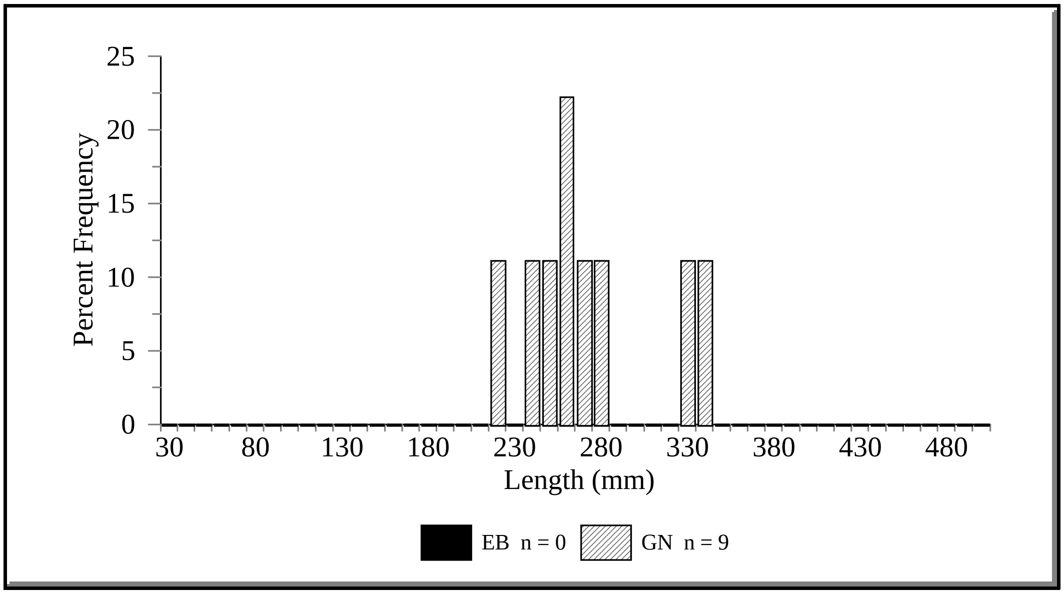

Figure 11. Length frequency histogram of cutthroat trout sampled from American Lake (Pierce County) in early fall 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gillnetting.

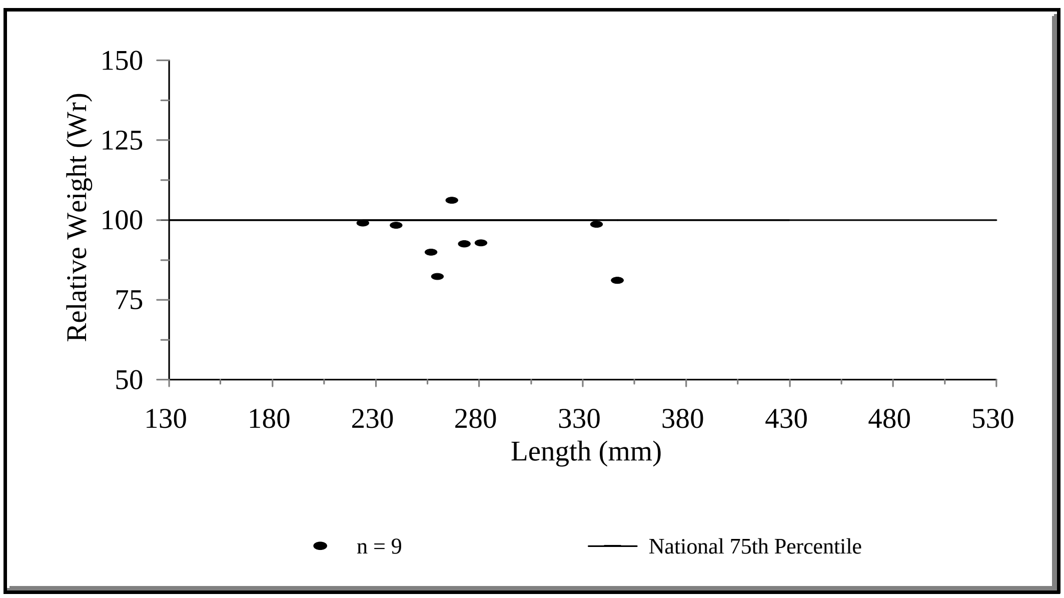

Figure 12. Relationship between total length and relative weight (W_r) of cutthroat trout from American Lake (Pierce County) compared with the national 75th percentile.

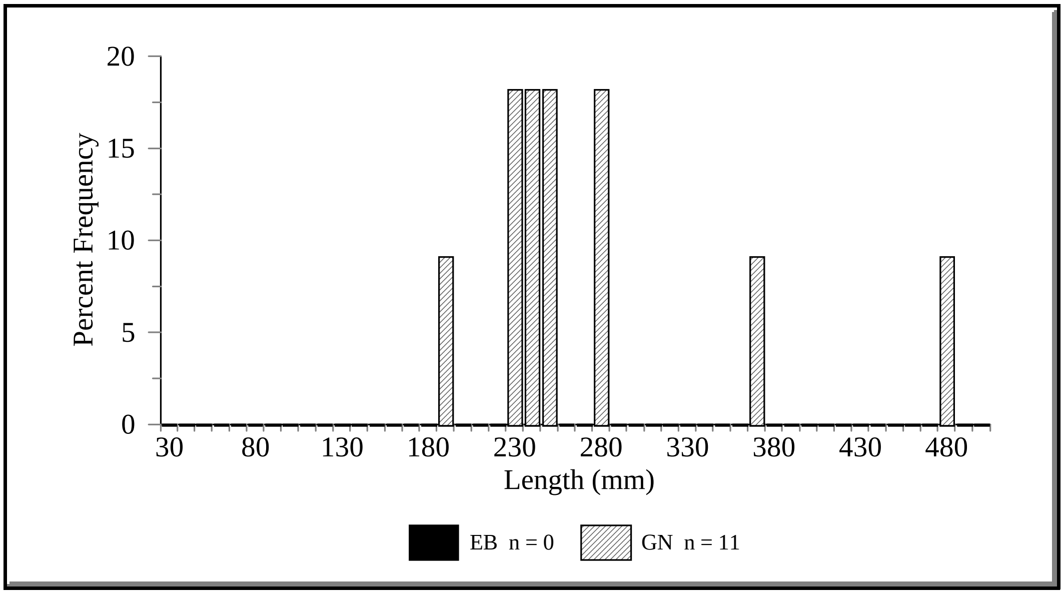

Figure 13. Length frequency histogram of rainbow trout sampled from American Lake (Pierce County) in early fall 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gillnetting.

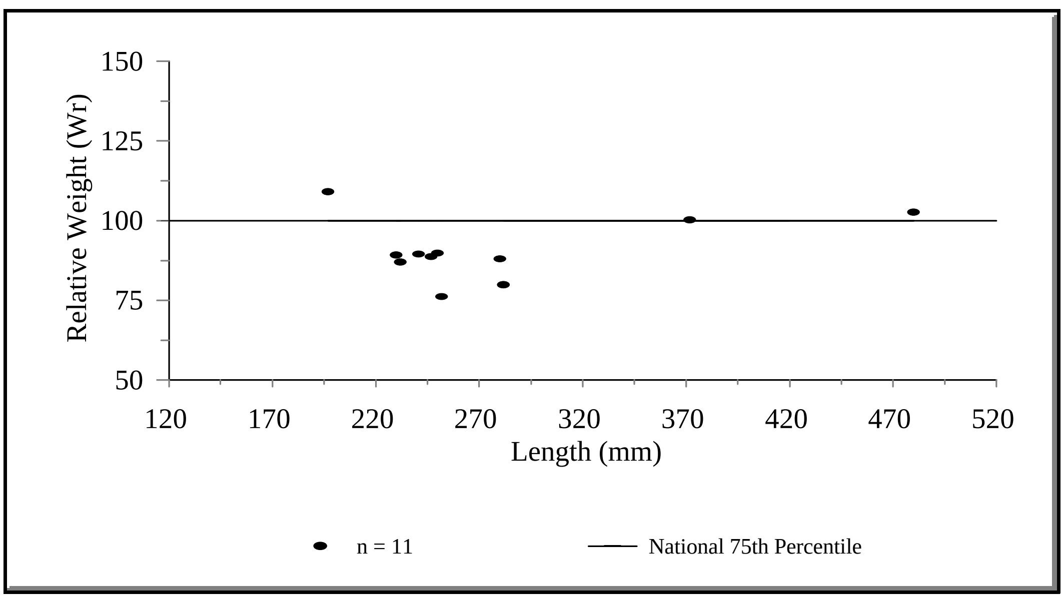

Figure 14. Relationship between total length and relative weight (W_r) of rainbow trout from American Lake (Pierce County) compared with the national 75th percentile.

Sculpin were the only non-game fish captured during early fall 1997. Except for pumpkinseed and rock bass, the electrofishing catch rate for sculpin was high when compared to those of other species (Table 4). American Lake sculpin ranged in size from 88 to 160 mm TL (Figure 15). Besides the abundant panfish of American Lake (i.e., rock bass, yellow perch, and pumpkinseed), sculpin should provide some forage for the newly introduced smallmouth bass (Pflug and Pauley 1984).

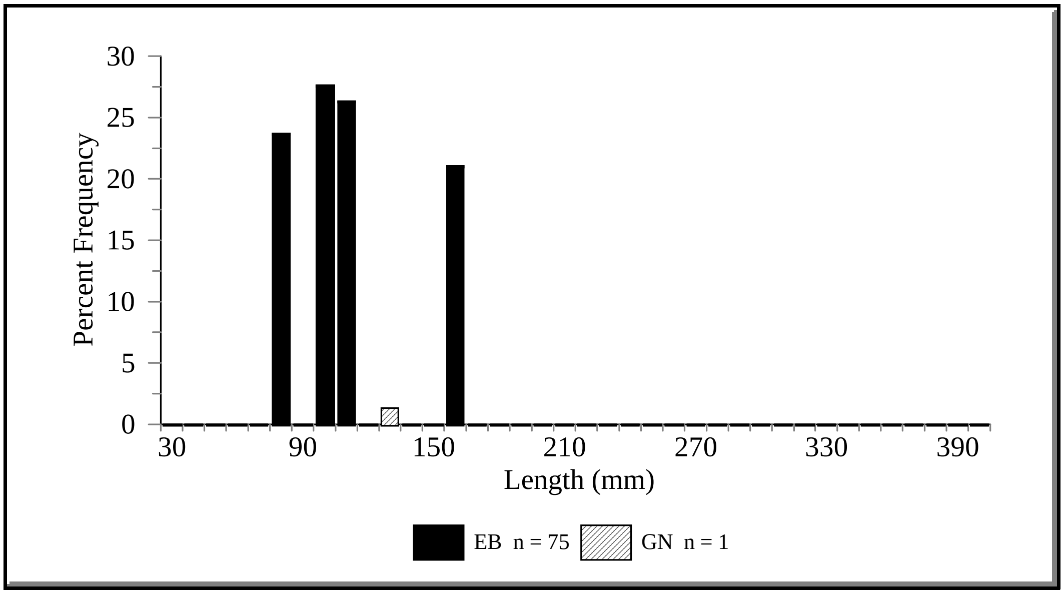

Figure 15. Length frequency histogram of sculpin (*Cottus* sp.) sampled from American Lake (Pierce County) in early fall 1997. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gillnetting.

Warmwater Enhancement Options

The rock bass population at American Lake is thriving. Since rock bass and smallmouth bass prefer similar overall habitats, but separate within habitat types (George and Hadley 1979; Probst et al. 1984), the latter should adapt well to conditions at American Lake. High relative weights observed among panfish indicate an abundant food supply for the newly introduced juvenile smallmouth bass, while abundant forage fish should provide an adequate prey base for the adult-size smallmouth bass. Management strategies that might improve the warmwater fishery at American Lake include, but are not limited to, the following:

Change Existing Fishing Rules to Protect Smallmouth and Largemouth Bass

Currently, American Lake anglers are allowed to retain five fish daily of any combination of smallmouth and largemouth bass. Although there is no minimum size limit, no more than three fish can measure over 381 mm (15”) TL. During early fall 1997, the electrofishing PSD and RSD values revealed that largemouth bass recruitment is very low in American Lake (i.e., no stock-size fish were captured). A minimum length limit might benefit this species and the newly introduced smallmouth bass (Lucas 1986; Willis 1989). Under this type of regulation, fish below a designated length must be released. For example, a minimum length limit of 457 mm TL (18”) with a reduced bag limit (e.g., one fish daily) should allow more smallmouth and largemouth bass to reach their full growth potential while protecting the resource (Lucas 1986; Willis 1989; Maceina et al. 1998; Slipke et al. 1998).

Gillnetting PSD and RSD values suggest that a panfish fishery has evolved at American Lake. One way of creating or protecting a panfish fishery is implementing a minimum length rule on predators (Willis 1989). Thus, the potential exists for the minimum length rule to serve dual purposes at American Lake. Still, a minimum length rule might result in little or no change in smallmouth and largemouth bass size structures several years after implementation (Mueller 1999). A simpler alternative would be to implement catch-and-release fishing. Under this rule, all smallmouth and largemouth bass captured must be released back into American Lake alive. Catch-and-release fishing would at least ensure the likelihood of some individuals reaching larger size classes.

Implementing a 305-432 mm (12-17") slot limit for smallmouth and largemouth bass might succeed should the current rule fail to protect the predator populations. The main objective of a slot limit is to improve the size structure of smallmouth and 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). If the fishing rules are changed to protect American Lake smallmouth and largemouth bass, clear and concise multilingual posters or signs should be placed at the lake describing the new regulations. Press releases should be sent to local papers, magazines, and sport fishing groups detailing the changes to, and purpose of, the rules. Furthermore, if necessary, increasing the presence of WDFW enforcement personnel at American Lake should reduce non-compliance.

Conduct Study of Distribution, Abundance, and Habitat Use by Crayfish

Crayfish are an essential component in the diet of Washington smallmouth bass (Pflug and Pauley 1984; Downen 1999). Despite its importance, little is known about the distribution, abundance, and habitat use of this prey item in American Lake. A study should be conducted to determine if smallmouth bass and crayfish abundances at American Lake are related (*sensu* Mather and Stein 1991). For example, underwater survey methods developed by WDFW for stock assessment of marine invertebrates (Goodwin and Pease 1991; Pfister and Bradbury 1996) can be used to determine how crayfish density varies according to smallmouth bass abundance, depth, and habitat type. An understanding of how biotic and abiotic factors influence their distribution should lead to better ways of managing predator and preys species alike.

Quantify, Analyze, and Monitor Habitat with Geographic Information Systems (GIS)

Large bodies of water, such as American Lake, often exhibit patches of distinct habitats with different assemblages of fish depending on such factors as life stage, species, and seasonality (Hayes et al. 1996). During early fall 1997, we observed a number of distinct habitat types and associated assemblages of fish species. For example, kokanee were captured in the northern basin only, whereas largemouth bass were captured mostly in the southern basin. Furthermore, rock bass, yellow perch, and pumpkinseed were ubiquitous throughout the lake, yet cutthroat and rainbow trout were patchily distributed.

GIS would be an effective tool for managing and analyzing such data since it can link data by location. Analyses of proximity, quantity (e.g., length or area of disturbed shoreline), spatial autocorrelation, and temporal change can then can allow the resource manager to predict future dynamics in fish populations and assess risks associated with human activity. Effective management of the fish populations in American Lake would benefit from an inventory and quantification of important habitats as well as disturbances likely to impact these habitats. For example, despite American Lake’s large volume, prime nursery habitat for warmwater species is restricted to a few shallow embayments. The importance of this habitat is apparent, but its extent has not been quantified. Future development (e.g., bulkheading or pile driving) of spawning, nursery, and foraging habitats throughout the lake could have direct influences on recruitment of both native fishes and introduced warmwater species and subsequent numbers of harvestable fish. However, causal relationships cannot be effectively argued without a means of quantifying habitat and disturbance and determining the extent of their spatial and temporal overlap.

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