1997 LAKE TAPPS SURVEY: THE WARMWATER FISH COMMUNITY OF A RESERVOIR MANAGED FOR HYDROPOWER

by

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INTRODUCTION AND BACKGROUND

Lake Tapps is a large reservoir (1,125 hectares at full capacity) which was created by flooding four smaller lakes with water diverted from the White River during the early 1900's. Numerous islands and peninsulas were formed, resulting in a complex, extended shoreline [length = 67.6 kilometers (km)]. The mean depth in Lake Tapps is 7.6 meters (m), whereas the maximum depth is 27.4 m. Given the colloidal nature of the lake, due to glacial silt from the White River, light penetration is low, resulting in low to moderate primary productivity and few, if any, aquatic plants.

Development on the lake is moderately high (average number of nearshore homes exceeds 8/km shoreline). There are 10 private neighborhood parks, and one private campground maintained by Puget Sound Energy (PSE). Public access includes the Lake Tapps County Park (Pierce County) at the north end of the lake, and the City of Bonney Lake's Allen York Park at the south end. Recreational activities include fishing, water skiing, jet skiing, and other small water-craft use.

Lake Tapps has been managed for hydropower generation for most of the 20th century. The lake experiences annual fluctuations in depth ('drawdowns') of up to 8.5 m, which undoubtedly contributes to the paucity of aquatic vegetation. Maximum drawdown occurs during late winter or early spring (elevation ~ 157 m). However, during peak recreational months (summer), the lake is maintained at full pool, or an elevation of 166 m. Hydraulic residence time at mean flow (949 cfs) is about 36 days. At maximum flow (2,000 cfs), hydraulic residence time decreases to about 17 days (PSPLC 1983). The short residence time and reduced light penetration probably account for the low to moderate primary productivity in the lake.

In 1990, the Washington Department of Fish and Wildlife (WDFW), then Washington Department of Wildlife, and PSE, then Puget Sound Power & Light Company (PSPLC), agreed to develop a resident fisheries enhancement plan for the reservoir. The Lake Tapps fisheries enhancement plan was developed as a condition for the Federal Energy Regulatory Commission (FERC) hydropower license. The license was issued on December 17, 1997, and has been appealed by several parties. Currently, the resident fisheries enhancement plan is under abeyance pending the status of the license issued to PSE by the FERC to operate the hydroelectric project at Lake Tapps. The plan includes a salmonid stocking program, warmwater fish habitat improvements, and follow-up studies by both organizations to monitor the success of these efforts. The first aspect consists of a plan to stock thousands of kokanee (*Oncorhynchus nerka*) fry and fingerling rainbow trout (*O. mykiss*) into the lake, whereas the second consists of a plan to deploy several artificial reef structures along the 7.6 m depth contour at locations selected by WDFW. Still, no recent information exists regarding the resident fish community at the lake. Therefore, in an effort to assess the warmwater fishery at the lake, especially given the warmwater fish component of the enhancement plan, personnel from WDFW's Warmwater Enhancement Program conducted a fisheries survey at Lake Tapps in fall 1997.

MATERIALS AND METHODS

Lake Tapps was surveyed by a three-person team during October 6 - 9, 1997. Fish were captured using two sampling techniques: electrofishing and gill netting. The electrofishing unit consisted of a 5.5 m Smith-Root 5.0 GPP ‘shock boat’ using a DC current of 120 cycles/sec at 3 to 4 amps power. Experimental gill nets (45.7 m long × 2.4 m deep) were constructed of four sinking panels (two each at 7.6 m and 15.2 m long) of variable-size (1.3, 1.9, 2.5, and 5.1 cm stretched) monofilament mesh.

Given the complexity of the lake’s shoreline (Figure 1), sampling locations were selected by dividing the surface area of the lake into a grid pattern with 55 consecutively numbered sections of about 1.2 km^2 each (determined visually from a map). Using the random numbers table from Zar (1984), nine of these sections were then randomly selected as sampling locations. While electrofishing, the boat was maneuvered through the shallows (depth range: 0.2 - 1.5 m), adjacent to the shoreline, at a rate of approximately 18.3 m/minute (linear distance covered over time). Gill nets were set perpendicular to the shoreline. The small-mesh end was attached onshore while the large-mesh end was anchored offshore.

Sampling occurred during evening hours to maximize the type and number of fish captured. Nighttime electrofishing occurred along 2.4% (~ 1.6 km) of the available shoreline, whereas gill nets were set overnight at six locations around the lake (Figure 1). In order to reduce bias between techniques, the sampling time for each gear type was standardized so that the ‘ratio’ of electrofishing to gill netting was 1:1 (Fletcher et al. 1993). Total electrofishing time was 5,409 seconds (‘pedal-down’ time), or roughly three standard units of 0.5 hours each; total gill netting time was 87 hours, or roughly three standard units of 24 hours each.

With the exception of sculpin (family Cottidae), all fish captured were identified to the species level. Each fish was measured to the nearest millimeter (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. However, if a sample included several hundred young-of-year or small juveniles (< 100 mm TL) of a given species, then a sub-sample (N ~ 100 fish) was measured and the remainder counted overboard. The length frequency distribution of the sub-sample was then applied to the total number collected. When possible, up to 10 fish from each size class were weighed to the nearest gram (g). Furthermore, scales were removed from these fish for aging. Scale samples (up to six per size class) were mounted and pressed, and the fish aged according to Jearld (1983) and Fletcher et al. (1993). However, salmonid and non-game fish were not aged.

Water quality data was collected during midday from three locations on October 9, 1997 (Figure 1). Using a Hydrolab® probe and digital recorder, information was gathered on dissolved oxygen, redox, temperature, pH, and conductivity. Secchi disc readings were recorded in feet and then converted to m (Table 1).

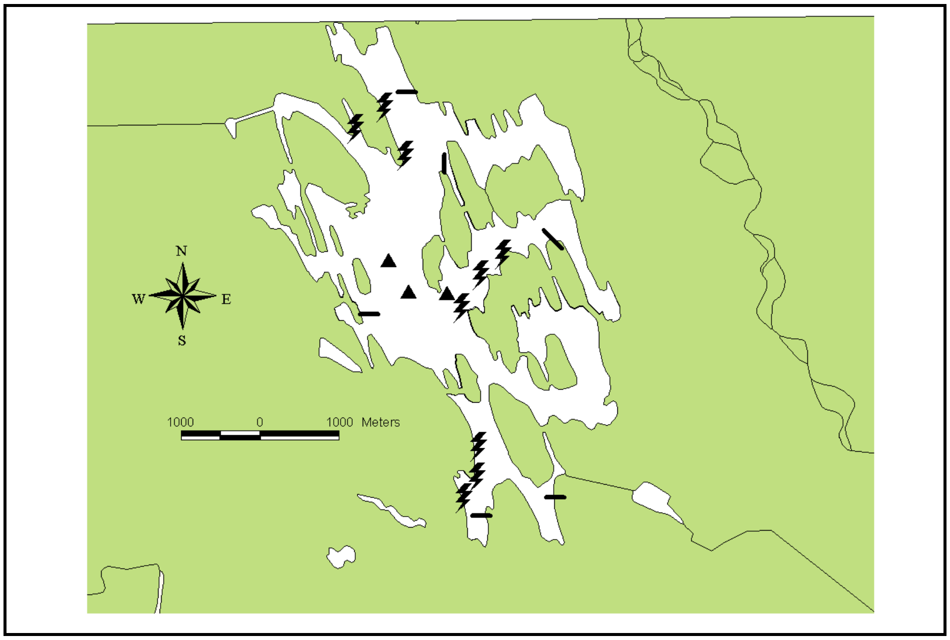


Figure 1. Map of Lake Tapps (Pierce County) showing sampling locations. Bolts indicate sections of shoreline where electrofishing occurred. Bars extending into lake indicate placement of gill nets. Triangles indicate water quality stations.

Table 1. Water quality from three locations (nearshore, offshore, and mid-lake) at Lake Tapps (Pierce County). Samples were collected midday on October 9, 1997.

		Parameter					
Location	Secchi (m)	Depth (m)	DO	Temp (°C)	pH	Conductivity	Redox
Nearshore	---	1	9.3	12.8	7.1	58	426
		2	9.3	12.8	7.1	57	427
Offshore	0.5	1	9.4	12.9	7.1	56	432
		3	9.2	12.9	7.2	57	434
		5	9.2	12.9	7.2	56	433
		7.6	9.3	12.9	7.1	60	437
Mid-lake	---	1	9.4	13.0	7.3	59	430
		3	9.2	13.0	7.3	56	431
		5	9.3	13.0	7.2	52	434
		10	9.4	12.1	7.1	60	442
		15	8.0	11.0	6.8	68	466
		20	5.6	8.7	6.5	62	485

Data analysis

The species composition by number of fish captured was determined using procedures outlined in Fletcher et al. (1993). Species composition by weight (kg) of fish captured was determined using procedures adapted from Swingle (1950). Percentage of the aggregate biomass for each species provided useful information regarding the balance and productivity of the community (Swingle 1950; Bennett 1962). Only fish estimated to be at least one year old were used to determine species composition. These were inferred from the length frequency distributions described below, in conjunction with the results of the aging process. Young-of-year or small juveniles were not considered because large fluctuations in their numbers may cause distorted results (Fletcher et al. 1993). For example, the length frequency distribution of yellow perch (*Perca flavescens*) may suggest successful spawning during a given year, as indicated by a preponderance of fish in the smallest size classes. However, most of these fish would be subject to natural attrition during their first winter, resulting in a different size distribution by the following year.

The catch per unit effort (CPUE) of electrofishing for each warmwater species was determined by dividing the number of fish captured in each size class by the total electrofishing time (Reynolds 1983). The CPUE of gill netting was determined similarly, except that the number of fish captured in each size class was divided by the total soak time of all nets deployed (Royce 1972). These proportions (fish/hour) were then used to make length frequency histograms to evaluate the size structure of the warmwater fish species and their relative abundance in the lake. Furthermore, since it is standardized, the CPUE is useful for comparing stocks between lakes.

A relative weight (W_r) index was used to evaluate the condition (plumpness or robustness) of fish in the lake. A W_r value of 100 generally indicates that a fish is in good condition when compared to the national average for that species. Furthermore, relative weights are 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 warmwater fish species, including the minimum length recommendations for their application, are listed in Anderson and Neumann (1996). With the exception of smallmouth bass (*Micropterus dolomieu*) and rock bass (*Ambloplites rupestris*), the W_r values from this study were compared to the Washington State average (Scott Bonar, WDFW, unpublished data) and national standard (W_r = 100) for each species. Since average W_r values for smallmouth bass and rock bass were lacking, their condition was compared to the national standard only.

Age and growth of warmwater fish in Lake Tapps were evaluated according to Fletcher et al. (1993). 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. Mean back-calculated lengths at age n for each species were presented in tabular form for easy comparison between year classes. Differences in growth between the Lake Tapps fish and the state average for the same species (listed in Fletcher et al. 1993) were compared by plotting their overall mean back-calculated lengths versus age *n*.

RESULTS

Species composition

The dominant species in terms of biomass and number of fish captured was the largescale sucker (*Catostomus macrocheilus*). Two young-of-year largescale suckers were observed; one measured 55 mm TL, the other, 57 mm TL. Although less abundant, common carp (*Cyprinus carpio*) and kokanee accounted for nearly 40% of the biomass captured. Approximately 30% of the fish captured (N=331) were of the warmwater variety; however, these accounted for less than 10% of the total biomass (99.8 kg).

Table 2. Species composition (excluding young-of-year) by weight (kg) and number of fish captured at Lake Tapps (Pierce County) during a fall 1997 survey of warmwater fish.

	Species composition		
Type of fish	by weight (kg)	by number	Size range (mm TL)
Largescale sucker (*Catostomus macrocheilus*)	48.2	117	90 - 468
Common carp (*Cyprinus carpio*)	21.9	17	310 - 561
Kokanee (*Oncorhynchus nerka*)	17.5	45	271 - 430
Smallmouth bass (*Micropterus dolomieu*)	3.6	5	81 - 450
Yellow perch (*Perca flavescens*)	3.2	38	97 - 231
Rock bass (*Ambloplites rupestris*)	1.7	28	70 - 199
Mountain whitefish (*Prosopium williamsoni*)	1.3	11	139 - 264
Black crappie (*Pomoxis nigromaculatus*)	1.2	25	56 - 284
Red-side shiner (*Richardsonius balteatus*)	0.6	34	82 - 153
Cutthroat trout (*Oncorhynchus clarki*)	0.3	1	338
Sculpin (*Cottus* sp.)	0.2	8	85 - 132
Bluegill (*Lepomis macrochirus*)	0.1	2	85 - 125
Total	99.8	331	

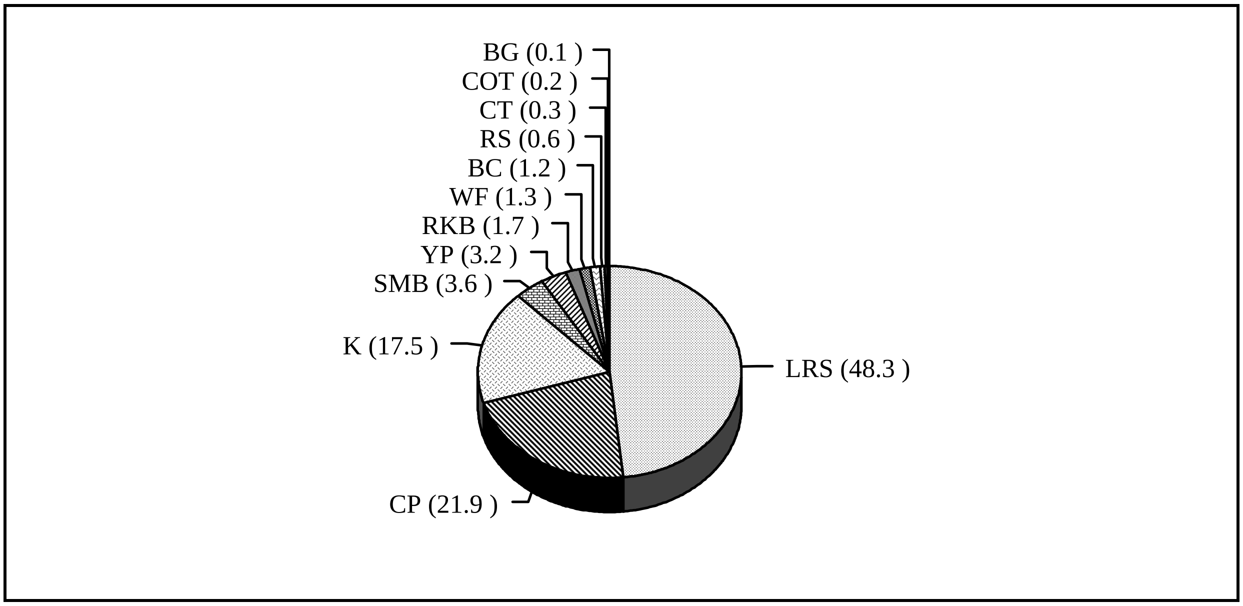


Figure 2. Species composition expressed as percent of total biomass captured (99.8 kg, excluding young-of-year) at Lake Tapps (Pierce County) during fall 1997. LRS = largescale sucker, CP = common carp, K = kokanee, SMB = smallmouth bass, YP = yellow perch, RKB = rock bass, WF = mountain whitefish, BC = black crappie, RS = red-sided shiner, CT = cutthroat trout, COT = sculpin (Cottidae), and BG = bluegill.

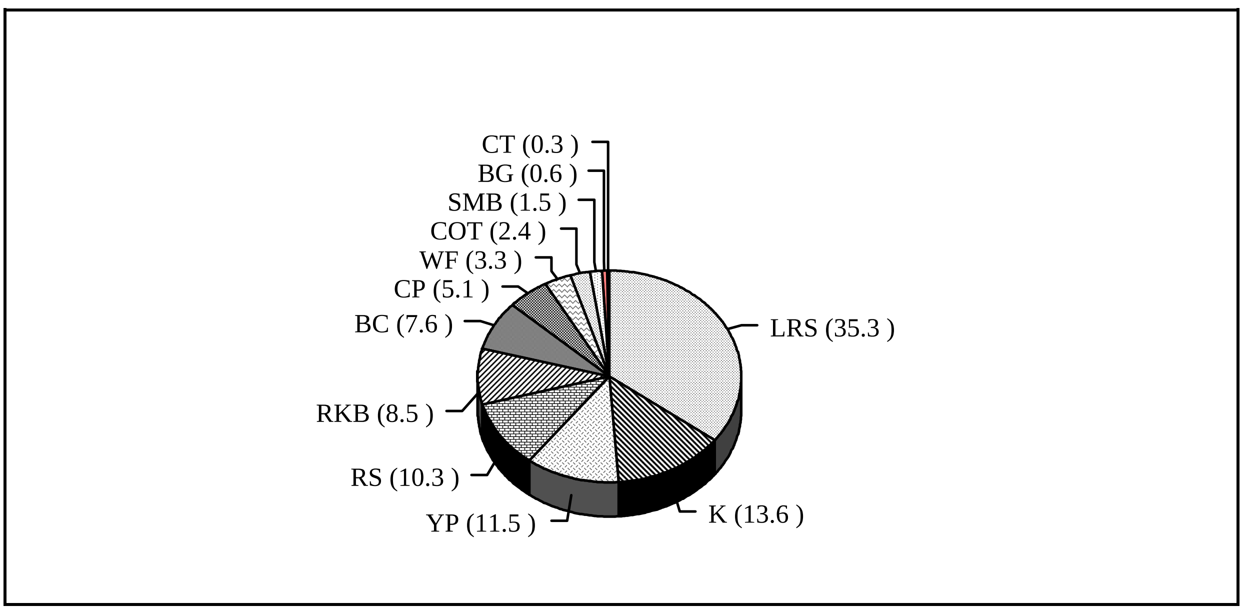


Figure 3. Species composition expressed as percent of total number captured (N = 331, excluding young-of-year) at Lake Tapps (Pierce County) during fall 1997. LRS = largescale sucker, K = kokanee, YP = yellow perch, RS = red-sided shiner, RKB = rock bass, BC = black crappie, CP = common carp, WF = mountain whitefish, COT = sculpin (Cottidae), SMB = smallmouth bass, BG = bluegill, and CT = cutthroat trout.

Smallmouth bass

Lake Tapps smallmouth bass ranged from 53 to 450 mm TL (age 0+ to 10+). Only one fish was captured while gill netting; it measured 152 mm TL and weighed 43 g. Although three young-of-year were observed (53 - 64 mm TL), several year classes were conspicuously absent (Table 3; Figures 4 and 5). Still, three of the eight fish captured were of quality size ($\geq$ 279 mm TL). Quality size varies by species, and is defined as the minimum size which most anglers would like to catch (Anderson 1980 cited in Fletcher et al. 1993). Growth of Lake Tapps smallmouth bass was slow when compared to fish statewide (Table 3; Figure 6), yet condition (expressed as W_r) increased with length or age (Figure 7). The largest fish captured weighed 1,445 g.

Table 3. Age and growth of smallmouth bass (*Micropterus dolomieu*) captured at Lake Tapps (Pierce County) during fall 1997. Values are mean back-calculated lengths at annulus formation.

		Mean length (mm) at age									
Year class	# fish	1	2	3	4	5	6	7	8	9	10
1997	1	55.0									
1996	0										
1995	0										
1994	1	58.3	86.1	106.4	139.3						
1993	0										
1992	0										
1991	0										
1990	1	72.3	101.2	141.7	202.4	245.8	283.4	309.4	332.5		
1989	1	73.8	113.5	167.5	215.7	283.9	326.5	380.4	411.6	425.8	
1988	1	82.8	141.7	192.7	218.2	269.3	303.3	348.6	379.8	408.2	428.0
Overall mean		68.3	110.7	152.1	193.9	266.3	304.4	346.1	374.7	417.0	428.0
State average		70.4	146.3	211.8	268.0	334.0	356.1	392.7	413.8	423.9	---

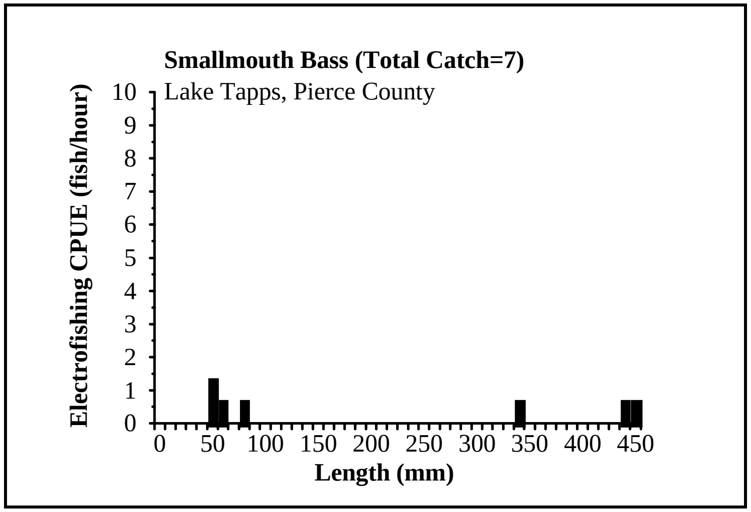
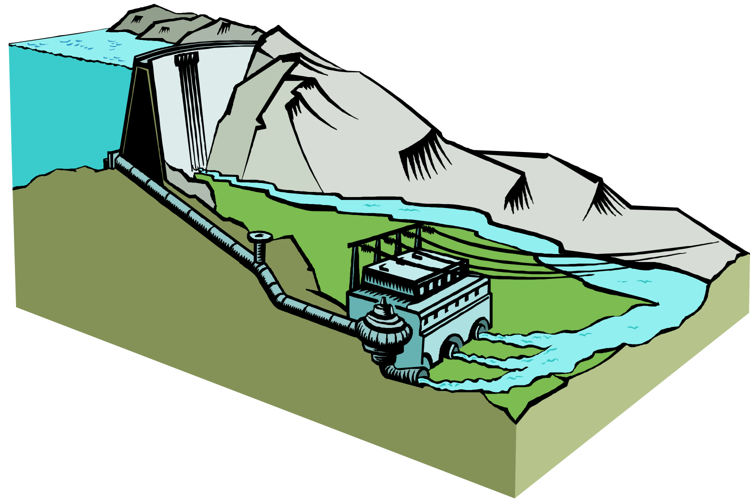


Figure 4. Relationship between total length and catch per unit effort of electrofishing for smallmouth bass (*Micropterus dolomieu*) at Lake Tapps (Pierce County) during fall 1997.



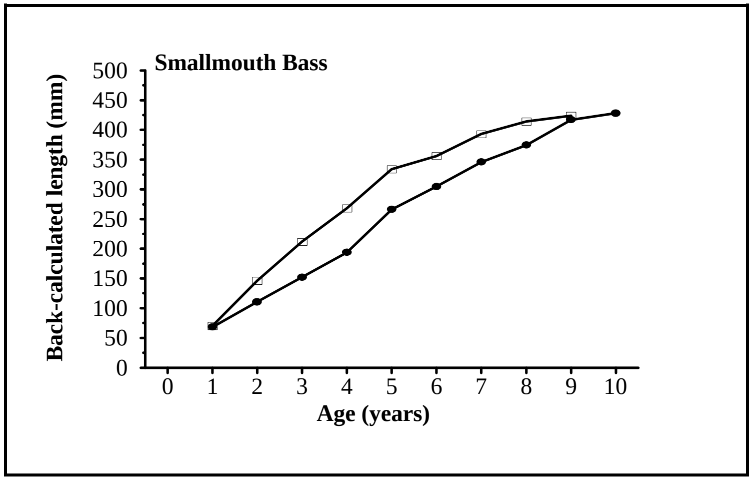


Figure 6. Growth of smallmouth bass (*Micropterus dolomieu*) from Lake Tapps, Pierce County (closed, black circles), compared to the Washington State average (open, clear rectangles). Values are mean back-calculated lengths at age.

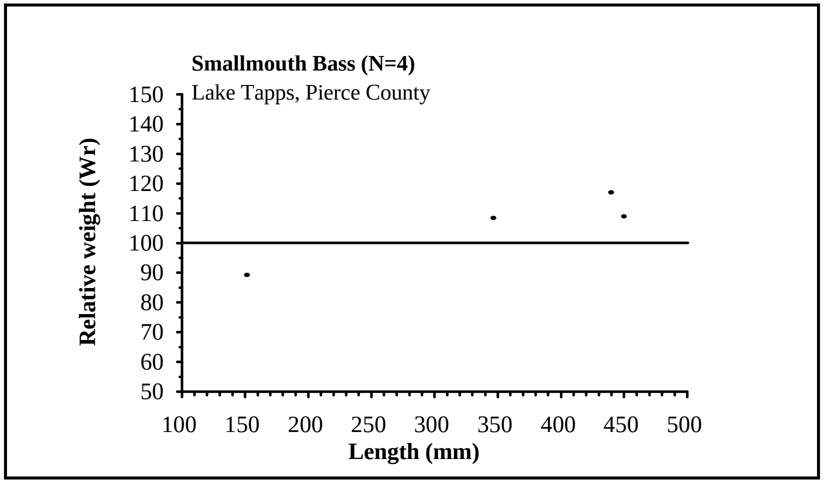


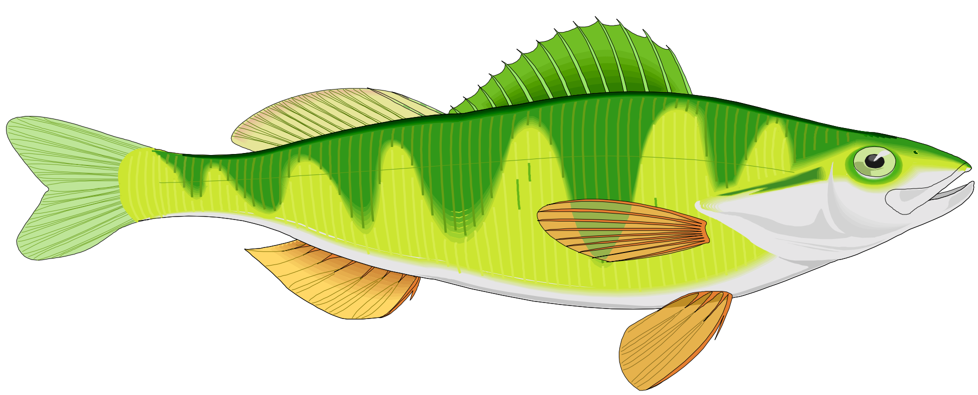
Figure 7. Relationship between total length and relative weight (W_r) of smallmouth bass (*Micropterus dolomieu*) from Lake Tapps, Pierce County (closed, black circles), compared to the national standard (horizontal line at 100).

Yellow perch

Size of yellow perch ranged from 46 to 231 mm TL (age 0+ to 7+). Young-of-year (46 - 70 mm TL) and large (≥ 180 mm TL), older (≥ age 6) fish were dominant, whereas intermediate ages (or sizes) were lacking, including the 1994 year class (Table 4; Figures 8 and 9). Although 50% of the fish captured (N=38, excluding young-of-year) were of quality size (≥ 203 mm TL), growth and condition of Lake Tapps yellow perch were below average (Table 4; Figures 10 and 11).

Table 4. Age and growth of yellow perch (*Perca flavescens*) captured at Lake Tapps (Pierce County) during fall 1997. Values are mean back-calculated lengths at annulus formation.

		Mean length (mm) at age						
Year class	# fish	1	2	3	4	5	6	7
1997	1	72.1						
1996	5	56.3	86.6					
1995	3	51.0	84.8	110.5				
1994	0							
1993	1	59.5	102.9	132.7	160.1	171.6		
1992	6	60.1	94.7	124.7	151.6	173.0	190.7	
1991	7	51.1	86.3	120.0	144.2	166.5	184.8	203.9
	Overall mean	55.8	89.2	120.7	148.5	169.7	187.6	203.9
	State average	59.7	119.9	152.1	192.5	206.0	---	---



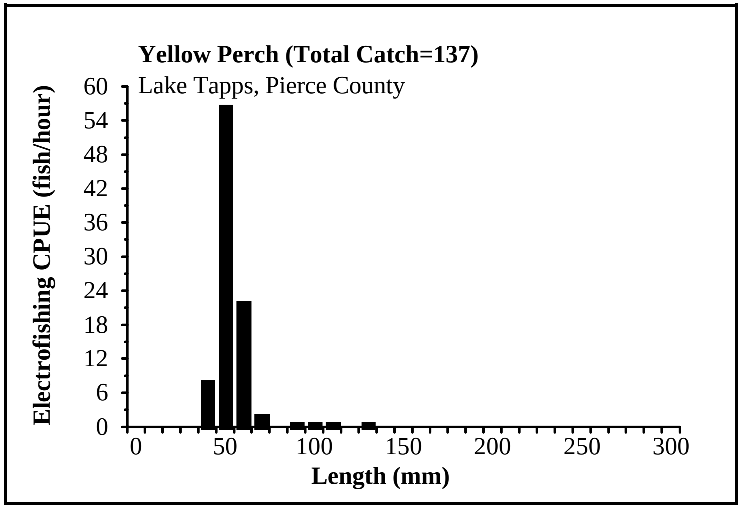


Figure 8. Relationship between total length and catch per unit effort of electrofishing for yellow perch (*Perca flavescens*) at Lake Tapps (Pierce County) during fall 1997.

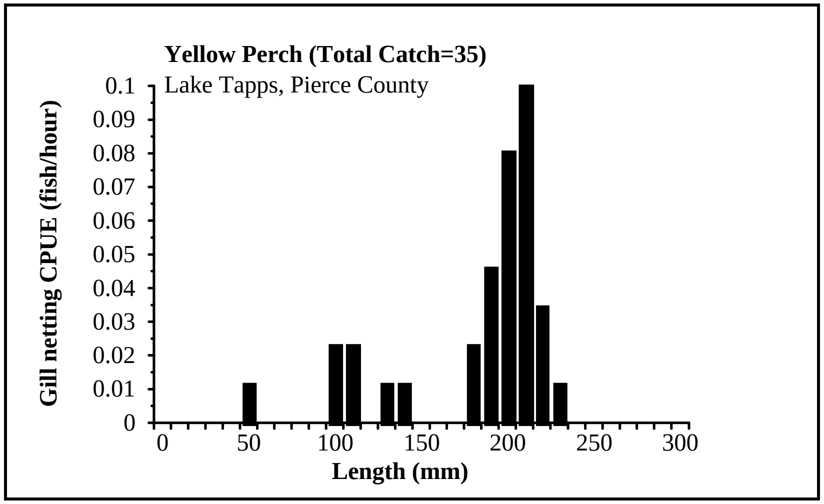


Figure 9. Relationship between total length and catch per unit effort of gill netting for yellow perch (*Perca flavescens*) at Lake Tapps (Pierce County) during fall 1997.

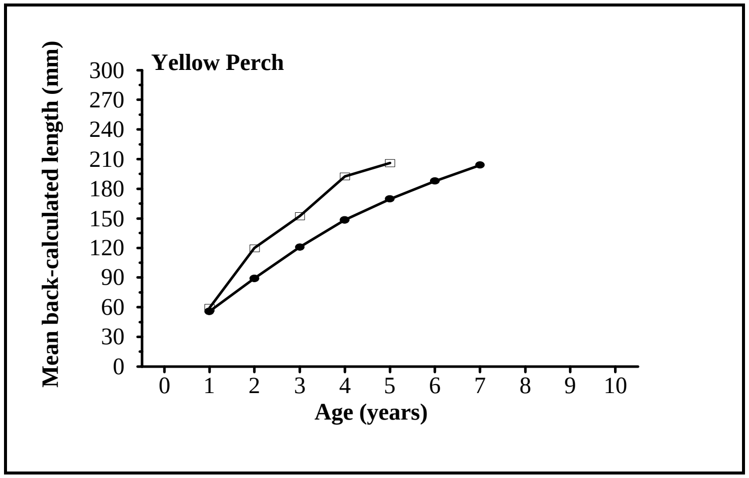


Figure 10. Growth of yellow perch (*Perca flavescens*) from Lake Tapps, Pierce County (closed, black circles), compared to the Washington State average (open, clear rectangles). Values are mean back-calculated lengths at age.

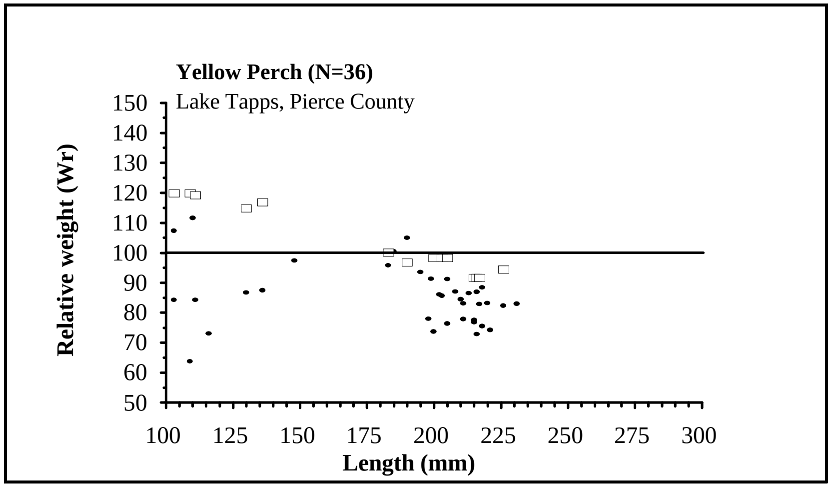


Figure 11. Relationship between total length and relative weight (W_r) of yellow perch (*Perca flavescens*) from Lake Tapps, Pierce County (closed, black circles), compared to the Washington State average (open, clear rectangles) and national standard (horizontal line at 100).

Rock bass

Lake Tapps rock bass ranged from 70 to 199 mm TL (age 2+ to 9+). Intermediate size/age fish (~ 120 to 160 mm TL; age 5+ to 7+) were dominant, whereas no juveniles or young-of-year were observed. Furthermore, the 1994 and 1997 year classes were missing (Table 5; Figures 12 and 13). Growth of the Lake Tapps fish was slow when compared to rock bass statewide (Figure 14), and their condition was poor by national standards (Figure 15). Less than 11% of the fish captured were of quality size ($\geq$ 178 mm TL).

Table 5. Age and growth of rock bass (*Ambloplites rupestris*) captured at Lake Tapps (Pierce County) during fall 1997. Values are mean back-calculated lengths at annulus formation.

		Mean length (mm) at age								
Year class	# fish	1	2	3	4	5	6	7	8	9
1997	0									
1996	1	36.5	62.7							
1995	1	47.7	66.4	78.4						
1994	0									
1993	4	38.4	60.1	75.6	93.1	113.4				
1992	2	34.9	54.4	73.8	108.7	128.2	138.3			
1991	7	31.3	53.7	78.5	102.3	120.4	135.3	147.2		
1990	1	32.4	72.8	98.7	134.3	158.6	169.9	181.2	190.9	
1989	1	23.5	50.5	74.0	104.5	122.2	138.6	150.4	166.8	182.1
Overall mean		34.3	57.5	78.2	103.0	122.2	139.3	151.3	178.9	182.1
State average		29.0	69.6	117.6	151.6	178.1	192.8	202.7	---	---

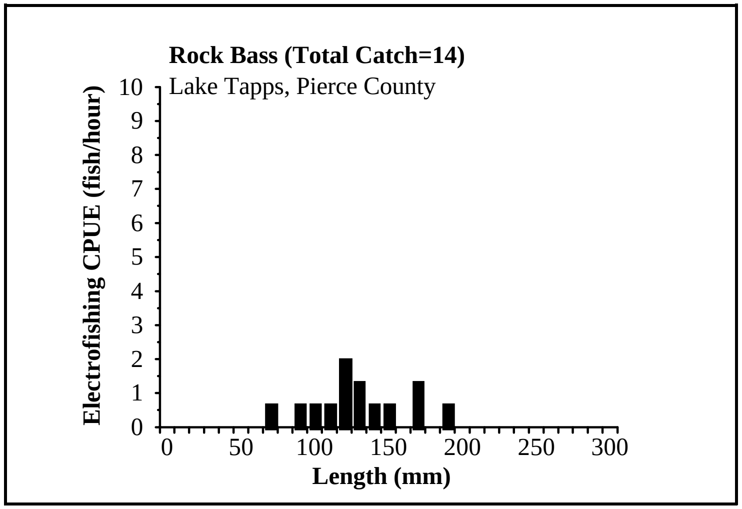


Figure 12. Relationship between total length and catch per unit effort of electrofishing for rock bass (*Ambloplites rupestris*) at Lake Tapps (Pierce County) during fall 1997.

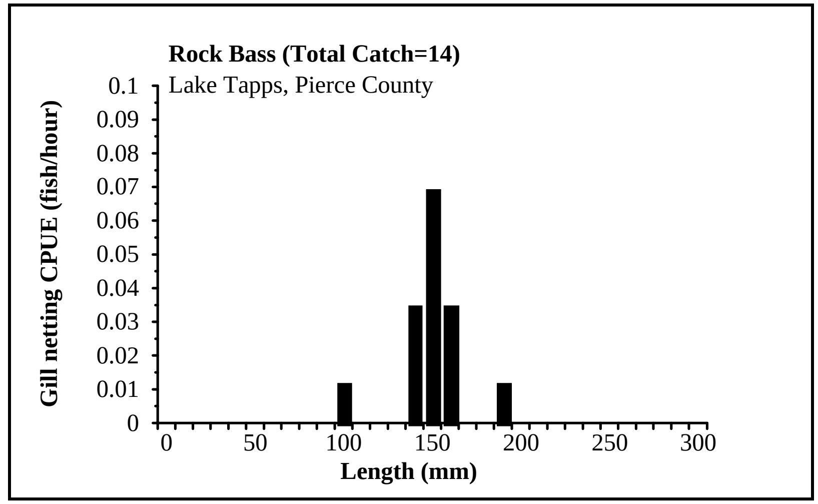


Figure 13. Relationship between total length and catch per unit effort of gill netting for rock bass (*Ambloplites rupestris*) at Lake Tapps (Pierce County) during fall 1997.

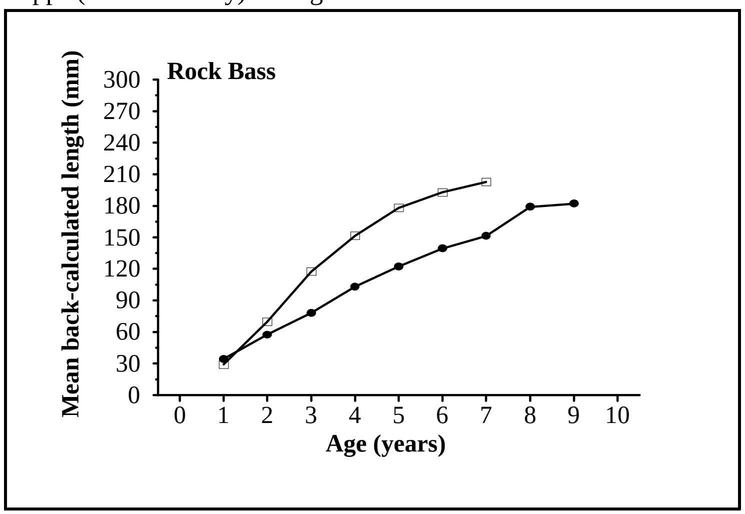


Figure 14. Growth of rock bass (*Ambloplites rupestris*) from Lake Tapps, Pierce County (closed, black circles), compared to the Washington State average (open, clear rectangles). Values are mean back-calculated lengths at age.

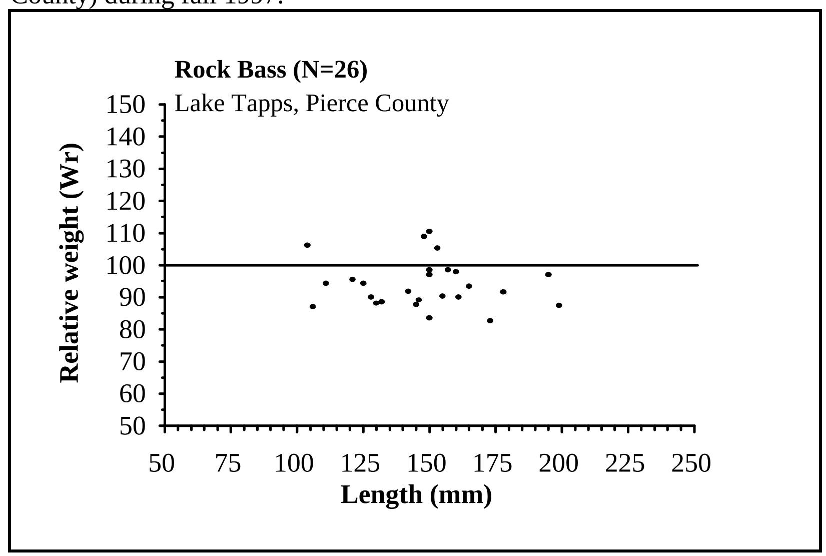


Figure 15. Relationship between total length and relative weight (W_r) of rock bass (*Ambloplites rupestris*) from Lake Tapps, Pierce County (closed, black circles), compared to the national standard (horizontal line at 100).

Black crappie

Size range of black crappie was 56 to 284 mm TL (age 1+ to 6+). Age 1+ fish (56 - 78 mm TL) were dominant, whereas several year classes were conspicuously absent. Only 12% of the fish captured (N=25, excluding young-of-year) were of quality size ($\geq$ 203 mm TL). Gill netting proved to be the best sampling method for larger black crappie (Table 6; Figures 16 and 17). Growth and condition of the Lake Tapps fish were below average when compared to black crappie statewide (Figures 18 and 19).

Table 6. Age and growth of black crappie (*Pomoxis nigromaculatus*) captured at Lake Tapps (Pierce County) during fall 1997. Values are mean back-calculated lengths at annulus formation.

		Mean length (mm) at age								
Year class	# fish	1	2	3	4	5	6	7	8	9
1997	3	53.2								
1996	0									
1995	0									
1994	1	35.0	52.5	96.2	129.5					
1993	1	43.7	65.6	107.3	141.1	153.1				
1992	0									
1991	0									
1990	1	48.2	61.9	86.0	123.8	153.1	180.6	204.7	240.1	
1989	1	44.4	71.0	99.4	133.1	159.7	195.2	227.2	248.5	264.5
Overall mean		47.3	62.8	97.2	131.9	155.3	187.9	215.9	244.6	264.5
State average		46.0	111.2	156.7	183.4	220.0	224.0	261.1	293.6	

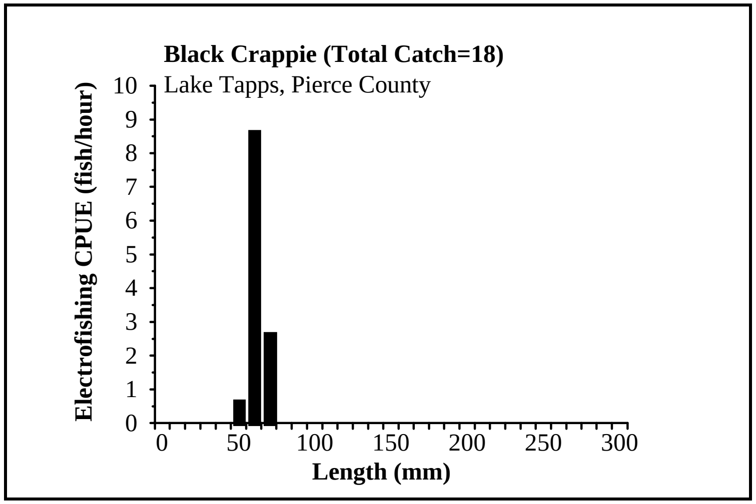


Figure 16. Relationship between total length and catch per unit effort of electrofishing for black crappie (*Pomoxis nigromaculatus*) at Lake Tapps (Pierce County) during fall 1997.

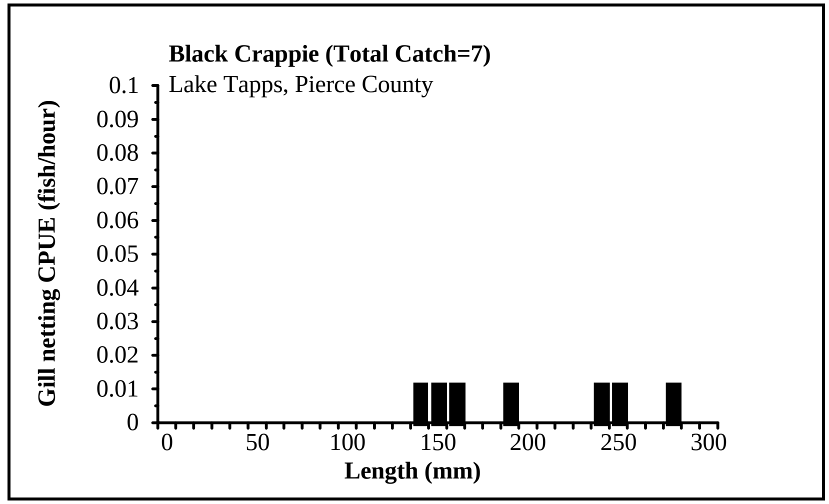


Figure 17. Relationship between total length and catch per unit effort of gill netting for black crappie (*Pomoxis nigromaculatus*) at Lake Tapps (Pierce County) during fall 1997.

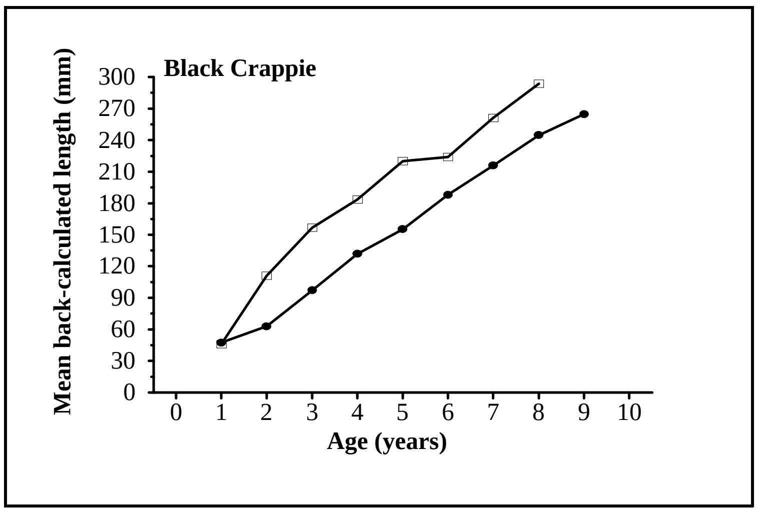


Figure 18. Growth of black crappie (*Pomoxis nigromaculatus*) from Lake Tapps, Pierce County (closed, black circles), compared to the Washington State average (open, clear rectangles). Values are mean back-calculated lengths at age.

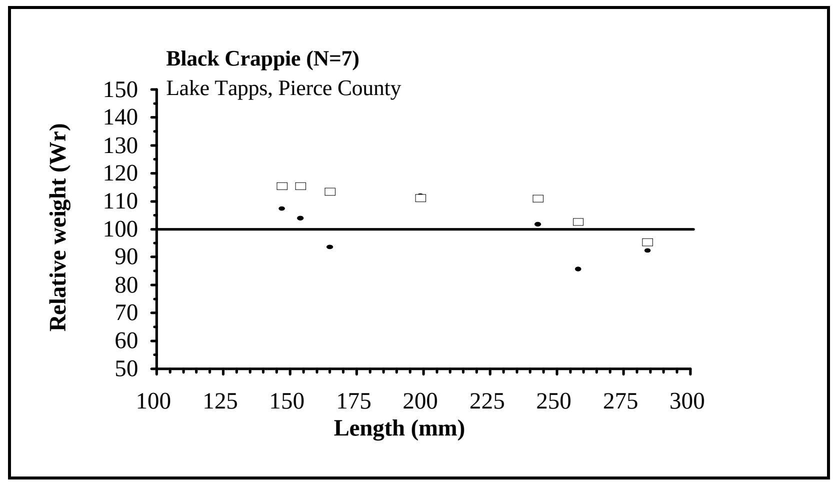


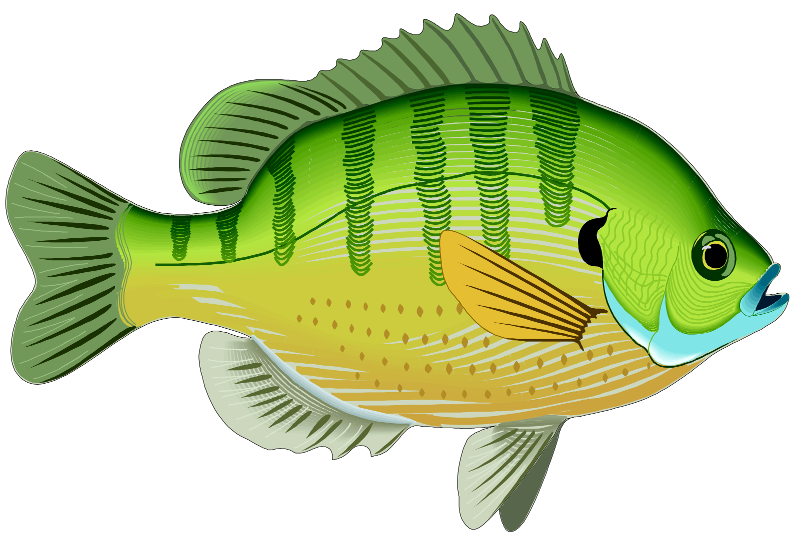
Figure 19. Relationship between total length and relative weight (W_r) of black crappie (*Pomoxis nigromaculatus*) from Lake Tapps, Pierce County (closed, black circles), compared to the Washington State average (open, clear rectangles) and national standard (horizontal line at 100)

Bluegill

Two bluegill were captured at Lake Tapps; one measured 85 mm TL and weighed 9 g, the other, 125 mm TL and 41 g (age 2+ and 4+, respectively). No juveniles or young-of-year were observed. No quality size ($\geq$ 152 mm TL) fish were captured. Furthermore, the 1995 and 1997 year classes were missing. Growth of the two fish was slow when compared to bluegill statewide (Table 7). The relative weight, or condition, of the smaller fish was below average (W_r = 85 vs. 118), whereas the relative weight of the larger fish was similar to the state average (W_r = 108 vs. 118).

Table 7. Age and growth of bluegill (*Lepomis macrochirus*) captured at Lake Tapps (Pierce County) during fall 1997. Values are mean back-calculated lengths at annulus formation.

		Mean length (mm) at age			
Year class	# fish	1	2	3	4
1997	0				
1996	1	37.2	65.5		
1995	0				
1994	1	42.8	61.6	87.3	116.4
	Overall mean	42.8	63.6	87.3	116.4
	State average	37.3	96.8	132.1	148.3



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 size structure, growth, and condition (W_r) provide useful information on the adequacy of the food supply (Kohler and Kelly 1991) and balance within a body of water. Characteristics of unbalanced populations include poor growth or condition, and low recruitment (Swingle 1950, 1956; Kohler and Kelly 1991; Masser *undated*).

During fall 1997, Lake Tapps showed indications of having an unbalanced fish community. For example, in terms of biomass, the lake was clearly dominated by largescale suckers and common carp. The size structure, growth pattern, and condition of smallmouth bass suggest that these predators were unable to reproduce and grow to control overproduction of the dominant non-game fish in the lake. The remaining warmwater fish species exhibited either below average growth, condition, or both. Furthermore, few quality size fish were captured, and several year classes were lacking or altogether absent.

Causes for the variation described above are complex and difficult to isolate from a single survey; however, some inferences can be drawn from previous studies. For example, the conditions observed during fall 1997 resemble those described by Swingle (1956) and Masser (*undated*) for populations experiencing inter- and intraspecific competition because of crowding. According to Swingle (1956), crowding in fish populations results in slow growth (less food per individual) and reduced or inhibited reproduction. This was evident in the warmwater forage fish populations at Lake Tapps. Like smallmouth bass, their size structure, growth pattern, and condition suggest that these fish were not able to feed effectively, possibly due to overcrowding and competition with the dominant largescale suckers and common carp.

However, besides the prolific non-game fish, another likely cause of unbalance in the fish community is the cold 'sterile' environment of the lake itself, the result of its use for hydropower generation. Annual drawdowns and refills affect both biological and physical characteristics of the reservoir. For example, little, if any, submersed aquatic vegetation (an important source of food and shelter for most warmwater fish) was detected in Lake Tapps during the study. Temperatures did not exceed 13° C throughout the water column (cool temperatures result in slow fish growth). Furthermore, because of the colloidal nature of the water, secchi disc readings did not exceed 0.5 m (negligible light penetration affects primary productivity, aquatic plant growth, as well as foraging efficiency of fish).

MANAGEMENT OPTIONS

Given its limiting physical and biological characteristics (bathymetry, cooler year-round temperatures, poor to moderate primary productivity, and lack of aquatic vegetation) and use for hydropower (fluctuating water levels, relatively short hydraulic residence time), Lake Tapps is better suited for pelagic, coldwater species (e.g., kokanee) than warmwater species. For example, the water temperature at the bottom of the reservoir's shallow embayments (the likely habitat for most warmwater fish) rarely exceeds 14° C (Figure 20). Still, if warmwater recreational fishing is to be improved, the following options should be considered.

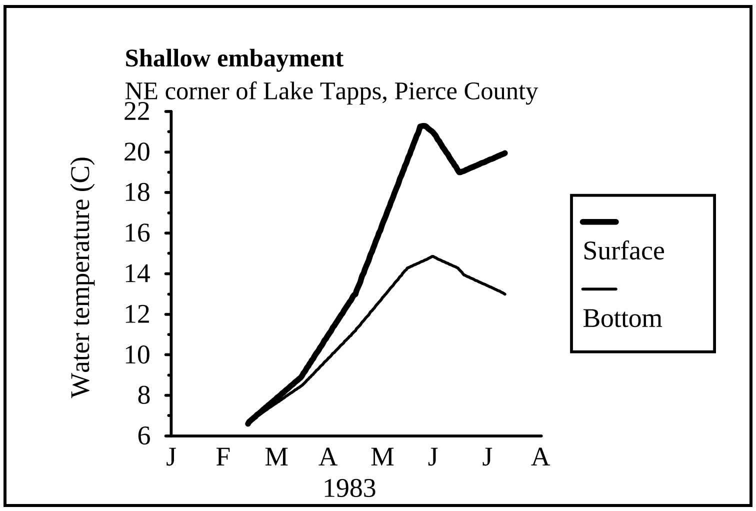


Figure 20. Seasonal water temperature changes at the surface and bottom of a shallow embayment located in the northeast corner of Lake Tapps (redrawn from PSPLC 1983).

Stabilize lake elevation before warmwater fish spawning period

The water level in Lake Tapps is typically at its lowest elevation (~ 157 m) during March - April (Robert Barnes, PSE, personal communication). Given the seasonal water temperature profile of the reservoir (Figure 20), the warmwater fish probably reproduce during May when surface temperatures reach 16 - 21° C. With the exception of yellow perch, these species are likely to build nests and spawn in water less than 1 m deep. The males will defend the nests and guard the young for days unless disturbed (Table 8). However, during this time, the reservoir is filled to full pool, or an elevation of 166 m, where it remains throughout the summer (Robert Barnes, PSE, personal communication). Consequently, spawning grounds established before June would be subject to excessive siltation and temperature or depth changes during the refilling process. According to Becker (1983), the two most common reasons for reproductive failure in established smallmouth bass populations are excessive siltation and fluctuations in water level during spawning. Since spawning may be inhibited by changes in water level and temperature (Henderson and Foster 1956; Royce 1972; Montgomery et al. 1980), precautions should be taken to refill the reservoir no later than April 15 each year.

Table 8. Reproductive habits of five species of warmwater fish (from Breder and Rosen 1966) captured at Lake Tapps (Pierce County) during fall 1997.				
Fish type	Spawning period	Temperature	Depth	Parental care
Smallmouth bass (*Micropterus dolomieu*)	May - July	15.6 - 18.3° C	0.6 - 3.7 m; average 0.9 m	♂ builds and defends nest; guards eggs/fry
Yellow perch (*Perca flavescens*)	March - May	6.7 - 12.2° C	variable	none
Rock bass (*Ambloplites rupestris*)	April - July	not reported	to 1.2 m	♂ builds and defends nest; guards eggs/fry
Black crappie (*Pomoxis nigromaculatus*)	April - July	17.8 - 20.0° C	0.1 - 0.6 m; occasionally to 6.1 m	♂ builds and defends nest; guards eggs/fry
Bluegill (*Lepomis macrochirus*)	April - October	20.0 - 27.8° C	0.2 - 0.6 m	♂ builds and defends nest; guards eggs/fry

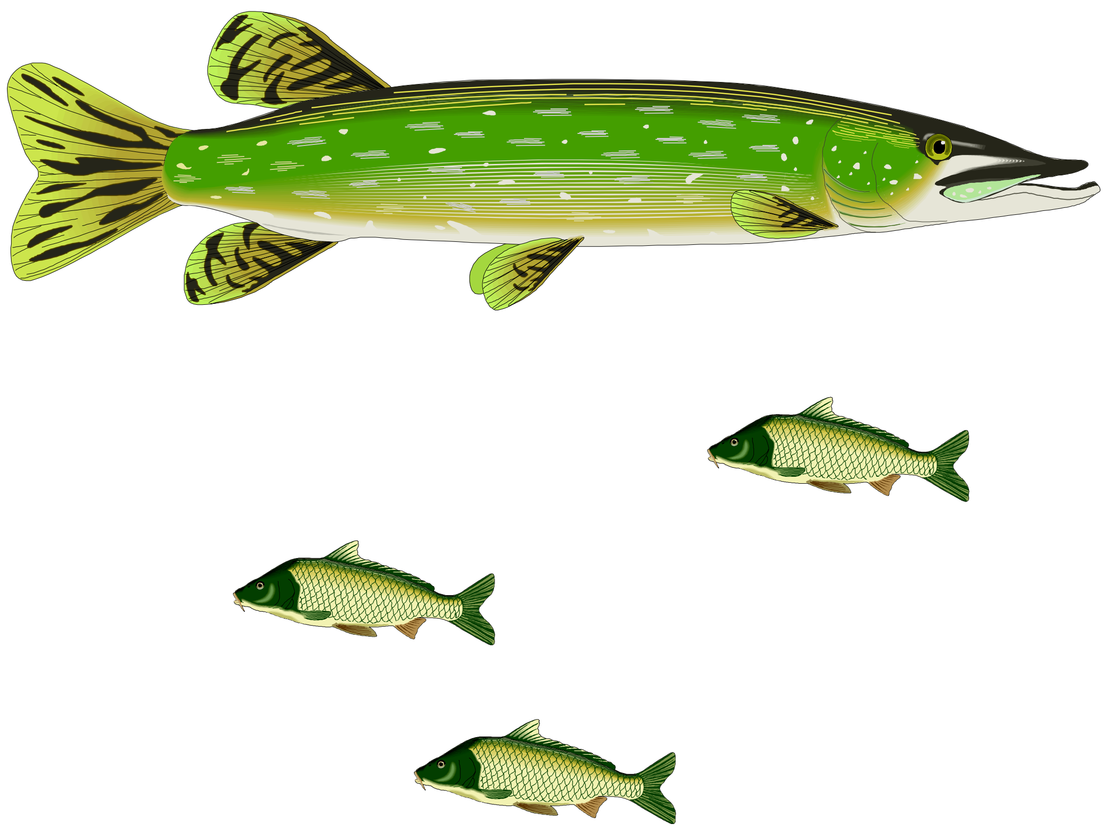
Change existing fishing rules to alter size structure of smallmouth bass

Currently, anglers are allowed to retain five smallmouth bass daily at Lake Tapps. Although there is no minimum size limit, no more than three of these fish can measure over 381 mm TL (15"). The size structure of smallmouth bass observed during fall 1997 showed that intermediate size classes, those fish needed to maintain balance within Lake Tapps, were lacking. The few smallmouth bass that were captured were either small juveniles or large adults. Implementing catch-and-release fishing might allow more smallmouth bass to realize their full growth potential.

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

Control non-game fish populations with 'super predator'

Besides implementation of new rules to alter the size structure of smallmouth bass, the balance within Lake Tapps may be restored by stocking a sufficient number of 'super predators' to reduce the dominant, non-game fish populations. This technique has been used with varied degrees of success for years (Bennett 1962; Noble 1981; Wahl and Stein 1988; Boxrucker 1992; Bolding et al. 1997). For example, stocking a relatively low number (≤ 1,500) of sterile, yearling tiger musky (*Esox masquinongy* × *E. lucius*) may improve the density and growth of warmwater fish species through predation of the overabundant largescale suckers and common carp. Although tiger musky generally fare well irrespectively of the forage base (Kohler and Kelly 1991), the predator prefers fusiform, soft-rayed prey, such as minnows, over deep-bodied, spiny-rayed prey, such as bluegill (Tomcko et al. 1984; Wahl and Stein 1988). Moreover, tiger musky grow rapidly in Washington (WDFW 1996). Therefore, in addition to improving balance, stocking tiger musky may also provide a trophy fishing opportunity at Lake Tapps (Storck and Newman 1992).



LITERATURE CITED

Anderson, R.O. 1980. Proportional stock density (PSD) and relative weight (W_r): interpretive indices for fish populations and communities. Pages 27-33 *in* Gloss, S., and B. Shupp (eds.), Practical fisheries management: more with less in the 1980's, Proceedings of the First Annual Workshop of the New York Chapter American Fisheries Society. New York Cooperative Fishery Research Unit, Ithaca, NY.

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.

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison, WI.

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

Bolding, B., S.A. Bonar, M. Divens, D. Fletcher, and E. Anderson. 1997. Stocking walleye to improve growth and reduce abundance of overcrowded panfish in a small impoundment. Washington Department of Fish and Wildlife, Research Report # RAD97-05, 27 p.

Boxrucker, J. 1992. Results of concomitant predator and prey stockings as a management strategy in combating stunting in an Oklahoma crappie population. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 46: 327-336.

Breder, C.M., and D.E. Rosen. 1966. Modes of Reproduction in Fishes. Natural History Press, Garden City, NY (reprinted by T.F.H. Publications, Jersey City, NJ).

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.

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.

Henderson, C., and R.F. Foster. 1956. Studies of smallmouth black bass (*Micropterus dolomieu*) in the Columbia River near Richland, Washington. Transactions of the American Fisheries Society 86: 112-127.

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

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.

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

Montgomery, J.C., D.H. Fickeisen, and C. Dale Becker. 1980. Factors influencing smallmouth bass production in the Hanford area, Columbia River. Northwest Science 54: 296-305.

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.

Noble, R.L. 1981. Management of forage fishes in impoundments of the southern United States. Transactions of the American Fisheries Society 110: 738-750.

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.

PSPLC (Puget Sound Power and Light Company). 1983. White River Project. Application for License, Major Project at Existing Dam, Before the Federal Energy Regulatory Commission (FERC Project No. 2494).

Reynolds, J.B. 1983. Electrofishing. Pages 147-163 *in* Nielsen, L.A., and D.L. Johnson (eds.), Fisheries Techniques. American Fisheries Society, Bethesda, MD.

Royce, W.F. 1972. Introduction to the Fishery Sciences. Academic Press, New York, NY.

Storck, T.W., and D.L. Newman. 1992. Contribution of tiger muskellunge to the sport fishery of a small, centrarchid-dominated impoundment. North American Journal of Fisheries Management 12: 213-221.

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.

Tomcko, C.M., R.A. Stein, and R.F. Carline. 1984. Predation by tiger muskellunge on bluegill: effects of predator experience, vegetation, and prey density. Transactions of the American Fisheries Society 113: 588-594.

Wahl, D.H., and R.A. Stein. 1988. Selective predation by three esocids: the role of prey behavior and morphology. Transactions of the American Fisheries Society 117: 142-151.

WDFW (Washington Department of Fish and Wildlife). 1996. Warmwater fish in Washington. Washington Department of Fish and Wildlife, Report # FM93-9, 15 p.

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

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