1999 Lake Sawyer Survey: The Warmwater Fish Community in a Popular, Unregulated Fishery

by

Mark R. Downen and Karl W. Mueller
Washington Department of Fish and Wildlife
Fish Program
Warmwater Enhancement Program
600 Capitol Way North
Olympia, Washington 98501-1091

May 2000

Acknowledgments

We thank Bob Warinner and Doug Fletcher of WDFW for their assistance in the field and lab. Bill Zook, and Jim Johnston provided technical assistance, support, and encouragement. Scott Bonar provided helpful advice, and Marc Divens contributed greatly to automating our analysis process. Steve Jackson provided a thoughtful review of the original manuscript, whereas Darrell Pruett and Peggy Ushakoff (WDFW) designed the cover. Colleen Desselle, Walt Cooper, Everett Latch, and Ted Morton (WDFW) proved indispensable when 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.

Abstract

The WDFW Warmwater Enhancement Program conducted a stock assessment of Lake Sawyer in fall 1999, because of its warmwater fishery history and suitability of habitat and environmental conditions for these species. Not surprisingly, warmwater fish species, especially yellow perch, dominated our catch. Growth of largemouth bass, smallmouth bass, black crappie, pumpkinseed and yellow perch was consistent with or above western Washington State averages. However, CPUE for largemouth bass, black crappie and pumpkinseed were below average, suggesting low abundance of larger individuals of these species. Obvious gaps in the length frequency distribution of largemouth bass may be due to weather–related year–class failure, competition with the abundant yellow perch, or overharvest of larger individuals. Similar factors may also be responsible for the absence of larger, older black crappie and other panfish. The smallmouth bass population in Lake Sawyer appears robust, as evidenced by rapid growth rates, strong PSD values, and CPUE rates consistent with other western Washington State waters. However, an unregulated fishery could jeopardize the structure and abundance of this population. Based on our assessment of the warmwater fish community in Lake Sawyer, enhancement options are discussed that include an assessment of usage and harvest and rule changes to improve the size structures of largemouth and smallmouth bass, and increase numbers of panfish.

Table of Contents

Abstract i

List of Tables iii

List of Figures v

Introduction and Background 1

Materials and Methods 3
  Data Analysis 5

Results And Discussion 10
  Species Composition 10
  CPUE 10
  Stock Density Indices 11
    Largemouth Bass 13
    Smallmouth Bass 15
    Black Crappie 17
    Bluegill 19
    Pumpkinseed 20
    Yellow Perch 22
    Brown Bullhead 24
    Members of the Family Salmonidae 25
    Non–Game Fish 25

Warmwater Enhancement Options 26
  Conduct a Standardized Creel Survey on the Lake 26
  Change Existing Fishing Rules to Protect and Improve Size Structures of Largemouth and Smallmouth Bass 27
  Change Existing Fishing Rules to Increase Abundance of Panfish Other Than Yellow Perch 28

Literature Cited 29

List of Tables

Table 1. Water quality from the deepest location on Lake Sawyer (King County) collected at mid–day on September 14, 1999. 5

Table 2. Mean catch per unit effort (number of fish/hour electrofishing and number of fish/ net night) for stock size fish collected from several western Washington Lakes while electrofishing, gill netting, and fyke netting during 1997 and 1998 6

Table 3. Length categories for warmwater fish species by Gabelhouse (1984) used to calculate stock density indices (PSD, RSD) for fish captured at Lake Sawyer (King County) during spring 1999 based on numbers from Anderson and Neumann (1996) and Bister et al. unpublished data 8

Table 4. Stock density index ranges for largemouth bass and bluegills under three commonly implemented management options 8

Table 5. Mean stock density indices for available warmwater fishes from western Washington lakes with the most effective sampling method for a given species during 1997 and 1998 8

Table 6. Species composition by weight (kg) and number of fish captured at Lake Sawyer (King County) during spring 1999 10

Table 7. Mean catch per unit effort (number of fish /hour electrofishing and number of fish/ net night), including 80% confidence intervals, for stock size fish collected from Lake Sawyer (King County) while electrofishing, gill netting, and fyke netting during fall 1999 11

Table 8. Traditional stock density indices, including 80% confidence intervals, for warmwater fishes collected from Lake Sawyer(King County) while electrofishing, gill netting, and fyke netting during spring 1999 12

Table 9. Age and growth of largemouth bass captured at Lake Sawyer (King County) during fall 1999 13

Table 10. Age and growth of smallmouth bass captured at Lake Sawyer (King County) during fall 1999 15

Table 11. Age and growth of black crappie captured at Lake Sawyer (King County) during fall 1999 17

Table 12. Age and growth of bluegill captured at Lake Sawyer (King County) during fall 1999 19

Table 13. Age and growth of pumpkinseed captured at Lake Sawyer (King County) during fall 1999 20

Table 14. Age and growth of yellow perch captured at Lake Sawyer (King County) during fall 1999 22

List of Figures

Figure 1. Hydrology, bathymetry, and 1999 sampling sites on Lake Sawyer (King County). . . 4

Figure 2. Length frequency histogram of largemouth bass sampled from Lake Sawyer in fall 1999 14

Figure 3. Relationship between total length and relative weight (W_r) of largemouth bass from Lake Sawyer (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile 14

Figure 4. Length frequency histogram of smallmouth bass sampled from Lake Sawyer in fall 1999 16

Figure 5. Relationship between total length and relative weight (W_r) of smallmouth bass from Lake Sawyer (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile 16

Figure 6. Length frequency histogram of black crappie sampled Lake Sawyer in fall 1999 . . 18

Figure 7. Relationship between total length and relative weight (W_r) of black crappie from Lake Sawyer (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile 18

Figure 8. Length frequency histogram of pumpkinseed sampled from Lake Sawyer in fall 1999 20

Figure 9. Relationship between total length and relative weight (W_r) of pumpkinseed from Lake Sawyer (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile 20

Figure 10. Length frequency histogram of yellow perch sampled from Lake Sawyer in fall 1999 23

Figure 11. Relationship between total length and relative weight (W_r) of yellow perch from Lake Sawyer (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile 23

Figure 12. Length frequency histogram of brown bullhead sampled from Lake Sawyer in fall 1999 24

Figure 13. Relationship between total length and relative weight (W_r) of brown bullhead from Lake Sawyer (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile 25

Introduction and Background

Lake Sawyer is one of the larger (121.4 ha), deeper (mean depth = 8 m, maximum depth = 17.7 m) lakes in King County, Washington. Located just east of the city of Kent, at an altitude of 156 m, Lake Sawyer receives surface and groundwater inputs from 43,800 ha of forested, fallow, urban, and rural residential lands. The lake is fed by two streams, Ravensdale Creek and Rock Creek, and drains from one surface outlet, Covington Creek. Subsurface flow from the lake charges local aquifers; this seepage is particularly important in summer and fall.

Shoreline configuration is complex due to a number of islands, arms and embayments. Approximately 80% of the shoreline supports residential development and nearly 75% is bulkheaded. Currently, 294 docks extend into the lake while natural, coarse, woody debris is sparse or absent from all but a few locations in the littoral zone. Sedimentary and metamorphic materials characterize basin geology and the lake substrate is a mixture of gravel and cobble overlain with detritus and silt.

Current development and prospects for future growth in the vicinity of Lake Sawyer have resulted in long–term studies of nutrient loading, water budgets, productivity, and aquatic vegetation. Existing whole–lake volume weighted total phosphorus concentrations of 36.6 ug/L indicate that Lake Sawyer is an upper mesotrophic lake (Carlson 1977). Water quality data collected over the past three decades has demonstrated a eutrophic trend in the lake. Stratification and subsequent hypolimnetic oxygen depletion encourage internal nutrient loading from the substrate and further increase the risk of eutrophication.

Productive conditions support an extensive aquatic plant community in Lake Sawyer. A recent plant survey described a diverse aquatic macrophyte assemblage comprising 24 species of floating, submergent, and emergent plants (King County SWMD 1995). Floating plant assemblages, including *Nuphar* sp.and *Nymphaea* sp., covered 3.6 ha of lake surface area with percent cover less than 25%. Submergent plant assemblages, including several *potamogeton* spp. and *Myriophyllum spicatum* (Eurasian watermilfoil) covered 26.6 ha with percent cover between 25 and 75%. Emergent vegetation, including *Typha* sp., and *Scirpus* sp., formed limited assemblages in rare, undeveloped segments of shoreline. As with a number of other highly developed lowland lakes in the region, anthropogenic processes of nutrient input, lake flushing, lake level regulation, and vegetation control now shape the physical environment for the fish community of Lake Sawyer.

Lake Sawyer supports a diverse assemblage of fish fauna. A late, winter–run of coho salmon (*Oncorhynchus kisutch*) migrates through the lake in January, bound for spawning grounds in upper Ravensdale Creek and, historically, in Rock Creek as well (Trotter et al 1996). Other native fishes include coastal cutthroat trout (*Oncorhynchus clarki*), northern pikeminnow (*Ptychocheilus oregonensis*), sculpin (*Cottus* sp.), three–spined stickleback (*Gasterosteus aculeatus*), peamouth (*Mylocheilus caurinus*), and largescale sucker (*Catostomus macrocheilus*).

For decades, the Washington Department of Fish and Wildlife (WDFW), formerly the Washington Department of Game (WDG), routinely stocked rainbow trout (*Oncorhynchus mykiss*), kokanee (*Oncorhynchus nerka*), and cutthroat trout (*Oncorhynchus clarki*). WDFW continues this practice today. Introduced warmwater game fish including largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), yellow perch (*Perca flavescens*), and brown bullhead (*Ameiurus nebulosus*) have been present in the lake since at least the 1930s (WDFW, unpublished data). Smallmouth bass (*Micropterus dolomieu*) were introduced by WDG in the early 1980s, during a period of widespread stocking of this species into western Washington Lakes. Due to its warmwater fishery history and suitability of habitat and environmental conditions for these species, the WDFW Warmwater Enhancement Program conducted a stock assessment in fall 1999. We assessed species composition, abundance, size structure, growth, and condition of fish in the lake. We also evaluated habitat, access, and the effects of current fishing rules, and outlined options for enhancing the fishery and fishing opportunity.

Materials and Methods

Two WDFW biologists and one scientific technician surveyed Lake Sawyer during September 14-17,1999. Fish were captured using three sampling techniques: electrofishing; gill netting; and fyke netting. The electrofishing unit consisted of a 4.9 m Smith-Root 5.0 GPP electrofishing boat set to a DC current of 120 cycles/second at 6 amps current. Experimental gill nets (45.7 m long × 2.4 m deep) were constructed of four sinking panels (two each at 7.6 m and 15.2 m long) of variable–size (13, 19, 25, and 51 mm stretched) monofilament mesh. Fyke nets were constructed of a single 30.4–m lead and two 15.2–m wings of 130 mm nylon mesh with the body of the nets stretched around four 1.2 m aluminum rings in each of two sections.

Sampling locations were selected by dividing the shoreline into 14 consecutively numbered sections of about 400 m each as determined from a 1:24,000 USGS map (Figure 1). A portion of the shoreline was sampled by electrofishing six randomly selected sections for a total of 3,600 seconds. While electrofishing, the boat was maneuvered through the shallows (depth range: 0.2-1.5 m), adjacent to the shoreline, at a rate of 18 m/minute. Four gill nets were set perpendicular to the shoreline with the small–mesh end attached onshore and the large–mesh end anchored offshore. Four fyke nets were set in water less than 3 meters deep, perpendicular to the shoreline with wings extended at 70° angles from the lead. Sampling occurred during evening hours to maximize the type and number of fish captured. In order to reduce bias between techniques and to standardize effort, the sampling time for each gear type was standardized to a ratio of 1:1:1 (Fletcher et al 1993). One unit of electrofishing time equal to three 600–second sections (actual pedal–down time) was applied for each 24 hour unit (= 2 net nights) of gill netting time and fyke netting time so that three sites were electrofished for every two sites of gill netting and fyke netting.

All fish captured were identified to species. Each fish was measured to the nearest millimeter and assigned to a 10–mm size class based on total length (TL). For example, a fish measuring 156 mm TL was assigned to the 150–mm size class for that species, a fish measuring 113 mm TL was assigned to the 110–mm size class, and so on. Fish were weighed to the nearest 0.5 g. If a sample included several hundred individuals of a given species, then a subsample (n $\geq$100 fish) was measured and weighed while the remainder was counted overboard. The length frequency distribution of the subsample was then applied to the total number collected. Weights of individuals counted overboard were estimated using the linear regression of $\log_{10}$-length on $\log_{10}$-weight of fish from the subsample. Scales were removed from up to five fish from each size class for aging. Scale samples were mounted, pressed, and the fish aged according to Jearld (1983) and Fletcher et al (1993). Scales were also measured for standard back–calculation of growth. However, a lack of technical resources precluded aging members of the Family *Ictaluridae* (catfish).

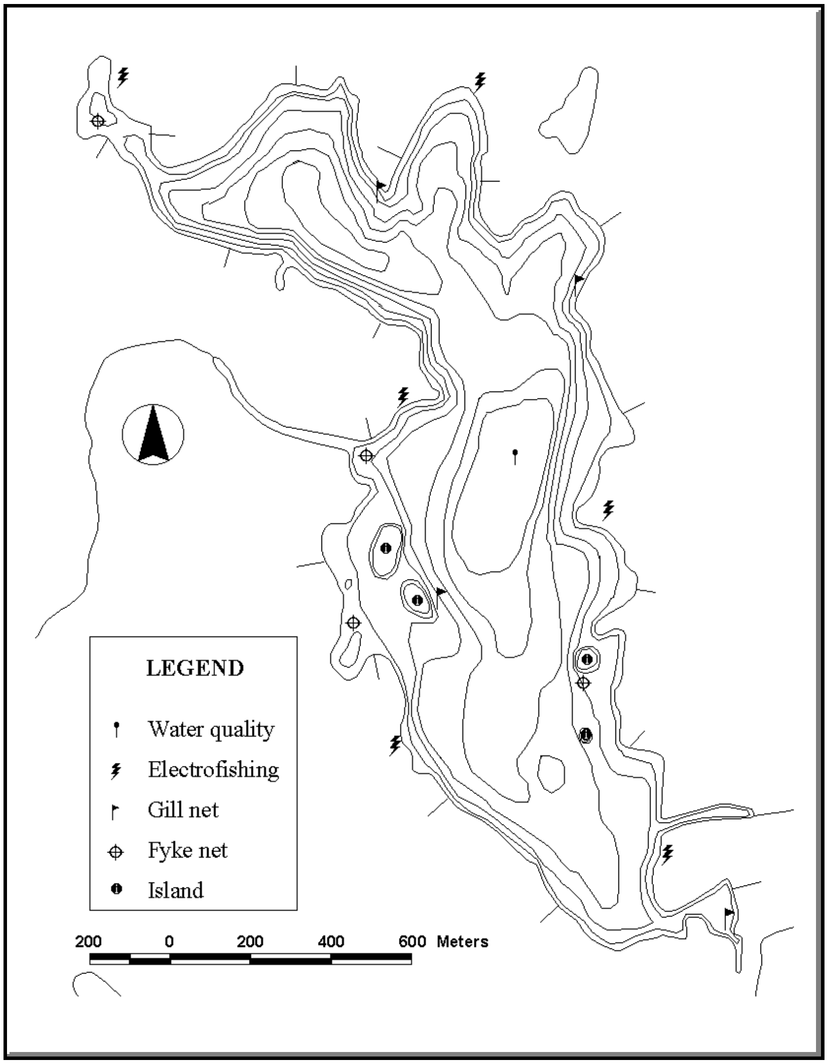

Figure 1. Hydrology, bathymetry, and 1999 sampling sites on Lake Sawyer (King County).

Water quality data was collected during mid–day from one site on September 14, 1999 using a Hydrolab® probe and digital recorder. We measured dissolved oxygen, total dissolved solids, temperature, pH, and specific conductance. Secchi disc readings were recorded in meters (Table 1).

Table 1. Water quality from the deepest location on Lake Sawyer (King County) collected at mid–day on September 14, 1999. Secchi depth = 4.6 m.

Depth (m)	Temp (EC)	DO (mg/L)	pH	Conductance (uS/cm)	TDS (g/L)
0	21.37	9.21	7.78	83.6	0.0536
1	19.86	9.13	7.86	83.1	0.0531
2	19.59	9.08	7.93	83.3	0.0530
3	19.34	9.05	7.95	83.0	0.0530
4	19.14	8.96	7.97	82.6	0.0530
5	18.31	8.39	7.86	82.2	0.0527
6	16.32	5.83	7.63	83.3	0.0534
7	13.68	1.30	7.35	83.9	0.0537
8	10.79	0.73	7.24	82.6	0.0530
9	9.47	0.68	7.19	83.3	0.0533
10	8.78	0.61	7.17	82.2	0.0527
11	8.43	0.57	7.12	82.3	0.0526
12	8.10	0.57	7.08	83.1	0.0534
13	8.08	0.53	7.06	83.6	0.0536
14	7.84	0.53	7.03	84.8	0.0541
15	7.62	0.51	6.99	88.1	0.0564
16	7.51	0.49	6.92	96.2	0.0616

Data Analysis

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

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

Catch per unit effort (CPUE) by gear type was determined for all fish species (number of fish/hour electrofishing and number of fish/net night). Only stock size fish and larger were used to determine CPUE for warmwater and other game species. Stock length, which varies by species (see Table 3 and discussion below), refers to the minimum size of fish having recreational value. Since sample locations were randomly selected, which can introduce high variability due to habitat differences within the lake, 80% confidence intervals (CI) were determined for each mean CPUE by species and gear type. CI was calculated as the mean ± $t_{(\alpha, N-1)} \times SE$, where t = Student's t for α confidence level with n -1 degrees of freedom (two–tailed) and SE = standard error of the mean. Since it is standardized, CPUE is a useful index for comparing relative abundance of stocks between lakes and the confidence intervals express the relative uniformity of species distributions throughout a given lake. CPUE values for Lake Sawyer were then compared to western Washington State averages compiled by the WDFW Inland Fisheries Research Unit (Table 2).

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

	Gear type					
Species	**Electrofishing (fish/hr)**	**n (lakes)**	**Gillnetting (fish/hr)**	**n (lakes)**	**Fyke netting (fish/hr)**	**n (lakes)**
Largemouth bass	41.6	12	1.9	8	0.3	1
Smallmouth bass	5.8	3	3.2	3	-	-
Black crappie	9.63	4	4.2	3	23.4	2
Bluegill	169.1	7	1.6	4	20.7	5
Pumpkinseed	70.8	11	3.8	9	7.9	4
Yellow perch	97.5	8	13.7	6	0.2	2
Brown bullhead	7.80	10	14.4	7	12.7	6

The size structure of each species captured was evaluated by constructing a stacked length frequency histogram (percent frequency of fish in a given size class captured by each gear type). Although length frequencies are generally reported by gear type, we report the length frequency of our catch with combined gear types which is then broken down by the relative contribution each gear type makes to each size class. Selectivity of gear types not only biases species catch based on body form, and behavior, but also based on size classes and subsequent habitat use within species (Willis et al. 1993). Therefore, an unbiased assessment of length frequency is unlikely under any circumstance. Our standardized 1:1:1 gear type ratio adjusts for differences in sampling effort between sampling times and locations. Furthermore, differences in size selectivity of gear types may in some circumstances result in offsetting biases (Anderson and Neumann 1996). Length frequency proportions for each gear type are divided by the total numbers of fish caught by all gear types for each size class. This changes the scale but not the shape of the length frequency percentages by gear type. If concern arises that pooled gear does not represent the least biased assessment of length frequency for a given species, then the shape of the gear type–specific distributions is still represented on the graphs, and these may be interpreted independently.

The proportional stock density (PSD) of each warmwater fish species was determined following procedures outlined in Anderson and Neumann (1996). PSD, which was calculated as the number of fish $\geq$quality length/number of fish $\geq$stock length×100, is a numerical descriptor of length frequency data that provides useful information about size class structure. Stock and quality lengths, which vary by species, are based on percentages of world–record lengths. Again, stock length (20-26% of world–record length) refers to the minimum size fish with recreational value, whereas quality length (36-41% of world–record length) refers to the minimum size fish most anglers like to catch.

The relative stock density (RSD) of each warmwater fish species was examined using the five–cell model proposed by Gabelhouse (1984). In addition to stock and quality length, Gabelhouse (1984) introduced preferred, memorable, and trophy length categories (Table 3). Preferred length (45-55% of world–record length) refers to the minimum size fish anglers would prefer to catch. Memorable length (59-64% of world–record length) refers to the minimum size fish most anglers are likely to remember catching, whereas trophy length (74-80% of world–record length) refers to the minimum size fish considered worthy of acknowledgment. Like PSD, RSD provides useful information regarding size class structure, but is more sensitive to changes in year–class strength. RSD was calculated as the number of fish $\geq$specified length/number of fish $\geq$stock length×100. For example, RSD P was the percentage of stock length fish that also were longer than preferred length, RSD M, the percentage of stock length fish that also were longer than memorable length, and so on. Eighty percent confidence intervals for PSD and RSD were selected from tables in Gustafson (1988).

Table 3. Length categories for warmwater fish species by Gabelhouse (1984) used to calculate stock density indices (PSD, RSD) for fish captured at Lake Sawyer (King County) during spring 1999 based on numbers from Anderson and Neumann (1996) and Bister et al. (unpublished data).*

	Total Length (mm)				
Species	**Stock**	**Quality**	**Preferred**	**Memorable**	**Trophy**
Largemouth bass	200	300	380	510	630
Smallmouth bass	180	280	350	430	510
Black crappie	130	200	250	300	380
Bluegill	80	150	200	250	300
Pumpkinseed	80	150	200	250	300
Yellow perch	130	200	250	300	380
Brown bullhead	130	200	280	360	430

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

PSD and RSD have become important tools for assessing size structures of warmwater fish populations and determining management options for warmwater fish communities (Willis et al. 1993). Three major management options commonly implemented for these communities include the panfish option, balanced predator–prey option, and big bass option and each of these has associated ranges of PSD and RSD values (Table 4).

Table 4. Stock density index ranges for largemouth bass and bluegills under three commonly implemented management options (from Willis et al. 1993).

	Largemouth bass			Bluegill	
Option	**PSD**	**RSD-P**	**RSD-M**	**PSD**	**RSD-P**
Panfish	20 – 40	0 – 10		50 – 80	10 – 30
Balanced	40 – 70	10 – 40	0 – 10	20 – 60	5 – 20
Big bass	50 – 80	30 – 60	10 – 25	10 – 50	0 – 10

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

Table 5. Mean stock density indices for available warmwater fishes from western Washington lakes with the most effective sampling method for a given species during 1997 and 1998 (WDFW Inland Fisheries Research Unit, unpublished data). PSD = proportional stock density, whereas RSD = relative stock density of preferred length fish (RSD P), memorable length fish (RSD M), and trophy length fish (RSD T). EB = electrofishing, GN = gill netting.

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

Age and growth of warmwater fishes in Lake Sawyer were evaluated using the direct proportion method (Jearld 1983; Fletcher et al. 1993) and Lee's modification of the direct proportion method (Carlander 1982). Using the direct proportion method, total length at annulus formation was back–calculated as $L_n = (A \times TL)/S$, where A is the radius of the fish scale at age n, TL is the total length of the fish captured, and S is the total radius of the scale at capture. Using Lee's modification, L_n was back–calculated as $L_n = a + A \times (TL - a)/S$, where a is the species–specific standard intercept from a scale radius–fish length regression. Mean back–calculated lengths at age n for each species were presented in tabular form for easy comparison of growth between year classes, as well as between Lake Sawyer fish and the Washington State average (listed in Fletcher et al 1993) for the same species. Instantaneous growth rates, G, were calculated according to Ricker (1975), by estimating weights from average total lengths using the linear regression of $\log_{10}$-length on $\log_{10}$-weight. Mean annual G was then compared to the state average, G_{avg}, derived from the data 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). Trends in the dispersion of points on the relative weight graph have been used to infer ecological dynamics of fish populations (Blackwell et al. *in press*). For example, a decrease in relative weight with increasing total length often occurs where competition is high among larger size classes. Conversely, low relative weights in small fish suggest competition and crowding among smaller size classes.

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 coldwater 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). Standard transformation failed to normalize the length data when testing the statistical significance of the relationship between total length and relative weight. Furthermore, no assumption was made that the relationship would be linear. Therefore, we used a non–parametric statistic, Spearman's Rho (Zar 1984), to assess the significance of correlation between total length and relative weight where relationships were suggested by the graphs.

Results And Discussion

Species Composition

Warmwater fish species made up 80% of our sample by weight and 92% by number (Table 6). Of these, yellow perch was dominant by weight (38%) and number (60%). Largemouth and smallmouth bass accounted for substantial percentages of the biomass, with 15 and 29%, respectively; however, smaller individuals of the former were sampled in greater numbers than the latter. Panfish comprised little of the biomass (1.7%) and number (4.4%). Salmonids made up less than 3% by weight and less than 1% by number, while non–game fish made up 10% by weight and 3% by number. Peamouth were fewer than panfish by number, yet more by weight, and may represent an important forage fish for larger predators. Sculpin may also be an important forage species, but these fish were sampled in low numbers.

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

	Species composition				
	by weight		by number		
Species	**(kg)**	**(%) weight**	**(#)**	**(%) n**	**Size range (mm TL)**
Largemouth bass (*Micropterus salmoides*)	9.703	15.076	203	20.0	30 - 512
Smallmouth bass (*Micropterus dolomieu*)	18.760	29.148	60	5.9	51 - 490
Black crappie (*Pomoxis nigromaculatus*)	0.743	1.154	52	5.1	25 - 225
Bluegill (*Lepomis macrochirus*)	0.011	0.016	1	0.1	87
Pumpkinseed (*Lepomis gibbosus*)	1.070	1.662	44	4.3	71 - 180
Yellow perch (*Perca flavescens*)	24.589	38.206	606	59.6	41 - 284
Brown bullhead (*Ameiurus nebulosus*)	1.433	2.227	6	0.6	85 - 396
Rainbow trout (*Oncorhynchus mykiss*)	0.530	0.823	1	0.1	350
Cutthroat trout (*Oncorhynchus clarki*)	0.757	1.175	3	0.3	272 - 295
Kokanee (*Oncorhynchus nerka*)	0.117	0.182	1	0.1	204
Largescale Sucker (*Catostomus macrocheilus*)	1.173	1.822	2	0.1	477 - 485
Peamouth Chub (*Mylocheilus caurinus*)	5.286	8.213	22	2.2	254 - 314
Sculpin (*Cottus* spp.)	0.190	0.296	16	1.6	37 - 152
Total	64.360		1,016		

CPUE

Catch rates for stock length yellow perch were three times the western Washington State average while electrofishing and consistent with state averages for other gear types. Catch rates for largemouth bass were very low for all gear types, and only one–fourth the state average while electrofishing. The CPUE for stock length smallmouth bass was above average while electrofishing and consistent with the state average while gill netting. Catch rates for black crappie, bluegill, and pumpkinseed were below average for all gear types. Both yellow perch and pumpkinseed were captured at higher than average rates with fyke nets. Brown bullhead were also captured at rates below the western Washington State average for all gear types (Table 7). Both rainbow trout and kokanee were sampled by electrofishing while cutthroat were only captured with gill nets. Peamouth and largescale sucker were sampled primarily with gill nets in areas where smallmouth bass also occurred.

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

	Gear type					
Species	**Electrofishing (fish/hr)**	**n (sites)**	**Gill Netting (fish/hr)**	**n (net nights)**	**Fyke Netting (fish/hr)**	**n (net nights)**
Largemouth bass	10.93±4.59	6	0.5[a]	4	0	4
Smallmouth bass	7.95±3.78	6	3.25± 1.42	4	0	4
Black crappie	2.99±2.61	6	1± 0.91	4	0	4
Bluegill	1[a]	6	0	4	0	4
Pumpkinseed	22.84±12.36	6	0.75± 0.32	4	4± 3.18	4
Yellow perch	335.04±123.35	6	11.75± 7.5	4	5.75± 4.63	4
Brown bullhead	3.97±3.22	6	0	4	0	4
Rainbow trout	0.99[a]	6	0	4	0	4
Cutthroat trout	0	6	0.75± 0.32	4	0	4
Kokanee	1[a]	6	0	4	0	4
Largescale sucker	0	6	0.5± 0.37	4	0	4
Peamouth chub	1[a]	6	5.25± 3.52	4	0	4
Sculpin	15.88±9.98	6	0	4	0	4

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

Stock Density Indices

Except for RSD-M, electrofishing stock density indices for largemouth bass were generally below the western Washington State average (Table 8). Missing size classes were apparent in the length frequency distribution as well (Figure 2). Smallmouth bass demonstrated high PSD and RSD values while gill netting, whereas similar PSD and RSD-P values for smallmouth bass sampled while electrofishing suggest a paucity of quality length (280-349 mm TL) fish. Black crappie, bluegill, and pumpkinseed all demonstrated stock density indices below the western Washington State average, while those of brown bullhead and yellow perch were considerably above average. Except for yellow perch, the stock density index values 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). No stock–length cutthroat or kokanee were sampled, and only one stock–length rainbow was sampled.

Table 8. Traditional stock density indices, including 80% confidence intervals, for warmwater fishes collected from Lake Sawyer(King County) while electrofishing, gill netting, and fyke netting during spring 1999. PSD = proportional stock density, whereas RSD = relative stock density of preferred length fish (RSD P), memorable length fish (RSD M), and trophy length fish (RSD T). EB = electrofishing, GN = gill netting, and FN = fyke netting.

Species	Gear type	n	PSD	RSD-P	RSD-M	RSD-T
Largemouth Bass	EB	11	18± 15	9[a]	9[a]	0
	GN	2	0	0	0	0
	FN	0	0	0	0	0
Smallmouth Bass	EB	8	25± 20	25± 20	13[a]	0
	GN	13	100	100	23± 15	0
	FN	0	0	0	0	0
Black Crappie	EB	3	33 [a]	0	0	0
	GN	4	25 [a]	0	0	0
	FN	0	0	0	0	0
Bluegill	EB	1	0	0	0	0
	GN	0	0	0	0	0
	FN	0	0	0	0	0
Pumpkinseed	EB	23	0	0	0	0
	GN	3	0	0	0	0
	FN	16	6[a]	0	0	0
Yellow Perch	EB	337	3± 1	1[a]	0	0
	GN	47	85± 7	9± 5	0	0
	FN	23	4[a]	4[a]	0	0
Brown Bullhead	EB	4	50± 32	25[a]	25 [a]	0
	GN	0	0	0	0	0
	FN	0	0	0	0	0
Rainbow trout	EB	0	0	0	0	0
	GN	1	100	0	0	0
	FN	0	0	0	0	0
Cutthroat Trout	EB	0	0	0	0	0
	GN	3	0	0	0	0
	FN	0	0	0	0	0

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

Largemouth Bass (*Micropterus salmoides*)

Largemouth bass ranged from 30 to 512 mm TL (age 1+ to 10+). The 1998 year–class was dominant followed by the 1997 year–class (Table 9). However, only three individuals older than 2+ were captured, and the 1990 through 1994 year–classes were not observed. Some gaps in length frequency distributions can occur due to slow growth in smaller age classes (Downen and Mueller 2000a). However, the growth of Lake Sawyer largemouth bass, as indicated by back–calculated lengths at annulus formation and instantaneous growth rates, was consistent with or above average; thus, in this case, instances of consecutive unsampled year classes explain the gap in the length frequency distribution (Figure 2). Relative weights for largemouth bass appear to be slightly below average with no apparent trend with increasing TL. The Spearman correlation coefficient, Rho, for largemouth bass length and relative weight was -0.21 (p = 0.866).

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

		Mean total length (mm) at age									
Year class	**# fish**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1998	39	66.0									
		78.4									
1997	6	72.0	169.1								
		84.9	173.1								
1996	1	58.9	142.3	248.6							
		74.4	151.6	249.9							
1995	1	60.1	185.2	221.9	275.3						
		76.1	192.9	227.2	277.1						
1994	0										
1993	0										
1992	0										
1991	0										
1990	0										
1989	1	93.1	155.2	227.6	289.6	346.5	398.2	439.6	460.3	486.1	501.7
		109.5	169.1	238.7	298.3	353.0	402.7	442.4	462.3	487.2	502.1
Overallmean		70.0	162.9	232.7	282.5	346.5	398.2	439.6	460.3	486.1	501.7
Weightedmean		79.8	172.5	238.6	287.7	353.0	402.7	442.4	462.3	487.2	502.1
Western WA Avg		60.4	145.5	222.2	261.1	289.3	319	367.8	396	439.9	484.6
	G	2.619	2.610	1.101	0.599	0.631	0.430	0.305	0.142	0.169	0.097
	G_{avg}	2.162	2.717	1.308	0.498	0.317	0.302	0.440	0.228	0.325	0.299

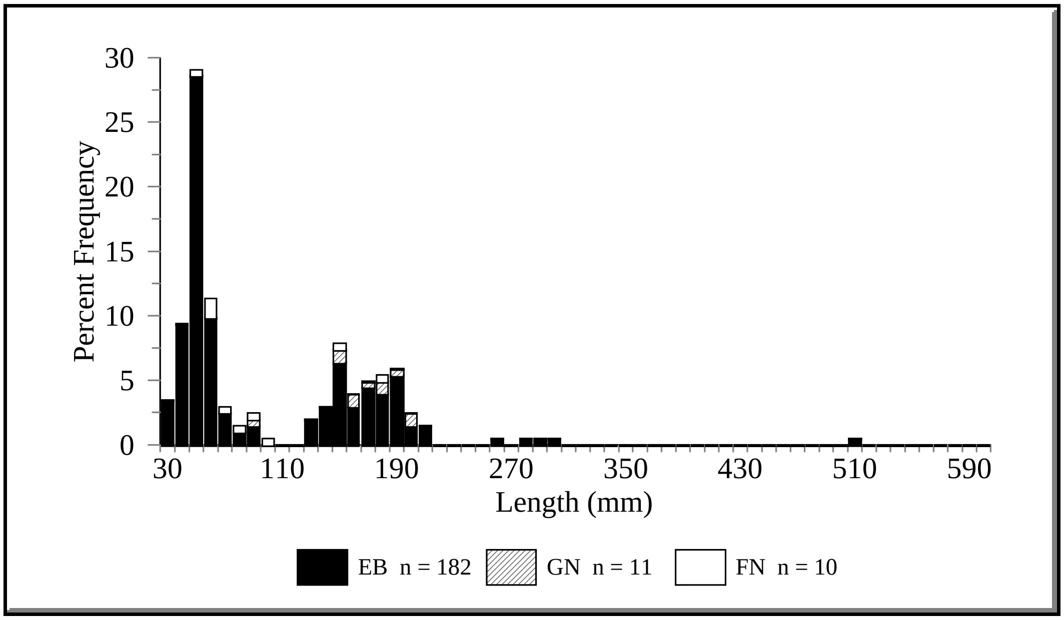

Figure 2. Length frequency histogram of largemouth bass sampled from Lake Sawyer in fall 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

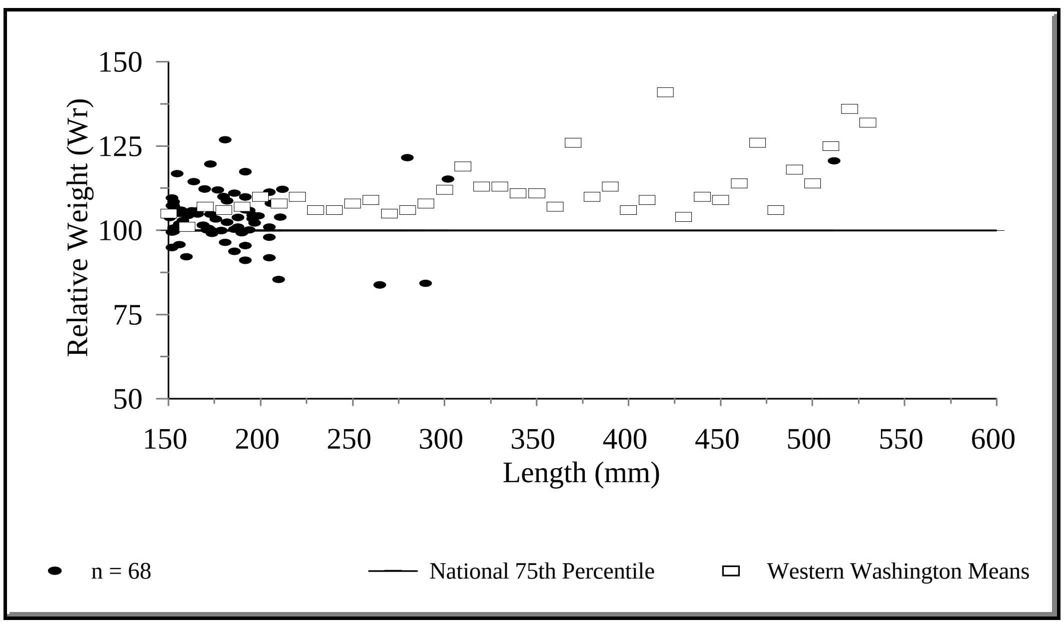

Figure 3. Relationship between total length and relative weight (W_r) of largemouth bass from Lake Sawyer (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Smallmouth Bass (*Micropterus dolomieu*)

Smallmouth bass ranged from 51 to 490 mm TL (0+ to 6+) (Figure 4). The 1998 year–class was the most abundant, but other year–classes were well represented and the 1993 year–class was particularly strong (Table 10). Growth of smallmouth bass in Lake Sawyer was below average through the first year, but generally above average thereafter. Relative weights were above average for 150 to 200 mm fish but declined significantly with increasing length (Figure 5). The Spearman correlation coefficient, Rho, of smallmouth bass length and relative weight was -0.421 ($p = 0.013$).

Table 10. Age and growth of smallmouth bass captured at Lake Sawyer (King County) during fall 1999. Unshaded values are mean back–calculated lengths at annulus formation using the direct proportion method (Fletcher et al 1993). Shaded values are mean back–calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age					
Year class	**# fish**	**1**	**2**	**3**	**4**	**5**	**6**
1998	24	56.5					
		77.8					
1997	5	45.5	154.1				
		73.4	165.7				
1996	1	82.9	140.7	196.7			
		105.9	155.3	203.1			
1995	2	45.2	118.3	224.5	332.7		
		76.0	142.1	238.3	336.4		
1994	4	42.0	111.3	207.1	287.2	355.2	
		73.1	136.0	223.1	295.9	357.6	
1993	7	48.6	145.9	234.3	325.6	374.5	408.4
		79.6	169.0	250.2	334.1	379.1	410.2
	Overall mean	53.4	134.1	215.6	315.2	364.9	408.4
	Weighted mean	77.7	157.7	237.4	322.7	371.3	410.2
	State Average	70.4	146.3	211.8	268	334	356.1
	G	1.785	2.841	1.469	1.173	0.453	0.348
	G_{avg}	2.636	2.260	1.143	0.727	0.680	0.198

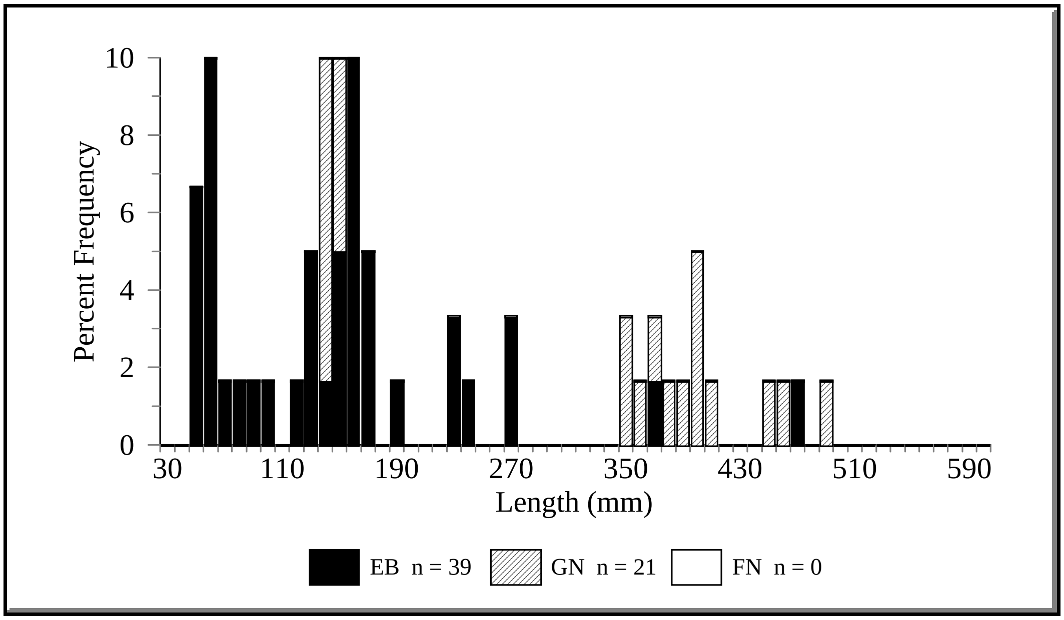

Figure 4. Length frequency histogram of smallmouth bass sampled from Lake Sawyer in fall 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

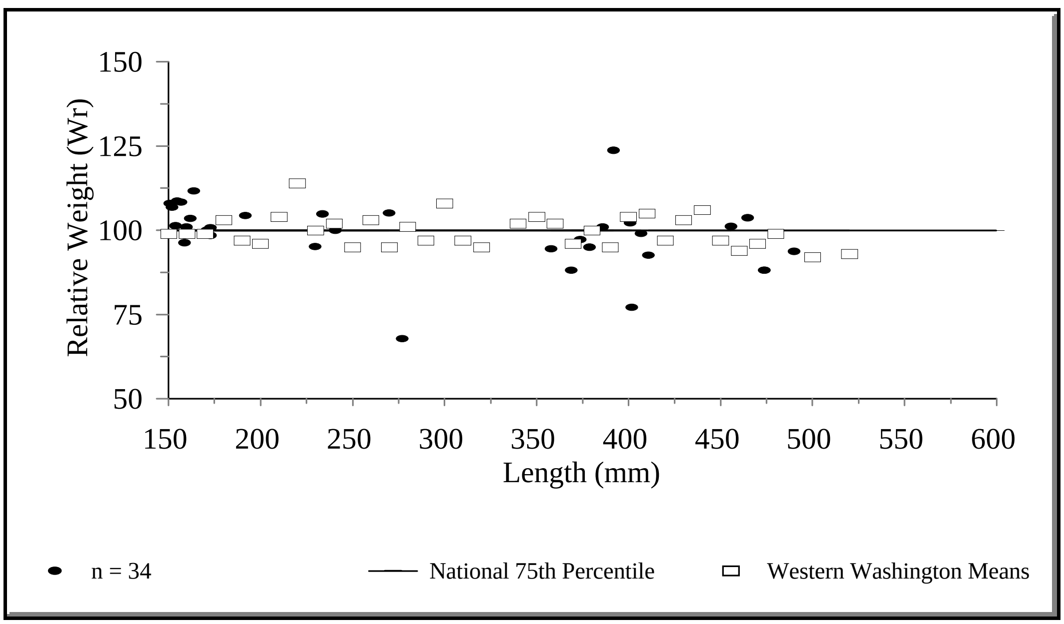

Figure 5. Relationship between total length and relative weight (W_r) of smallmouth bass from Lake Sawyer (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Black Crappie (*Pomoxis nigromaculatus*)

Black crappie ranged from 25 to 225 mm TL (age 1+ to 2+) (Figure 6). Only age 0+, 1+, and 2+ fish were sampled. Growth for these fish was considerably higher than the Washington State average. Relative weights for black crappie were generally above average and followed similar downward trend with increasing TL as is apparent in the Washington State averages. However, low sample size resulted in a nonsignificant relationship between relative weight and total length for Lake Sawyer black crappie (Figure 7). The Spearman correlation coefficient (Rho) for black crappie length and relative weight was -0.685 (p = 0.091).

Table 11. Age and growth of black crappie captured at Lake Sawyer (King County) during fall 1999. Unshaded values are mean back–calculated lengths at annulus formation using the direct proportion method (Fletcher et al 1993). Shaded values are mean back–calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age	
Year class	**# fish**	**1**	**2**
1998	5	49.2	
		73.2	
1997	2	55.0	175.6
		81.3	182.9
	Overall mean	52.1	175.6
	Weighted Mean	75.5	182.9
	State Average	46	111.2
	G	3.177	4.036
	G_{avg}	2.765	2.931

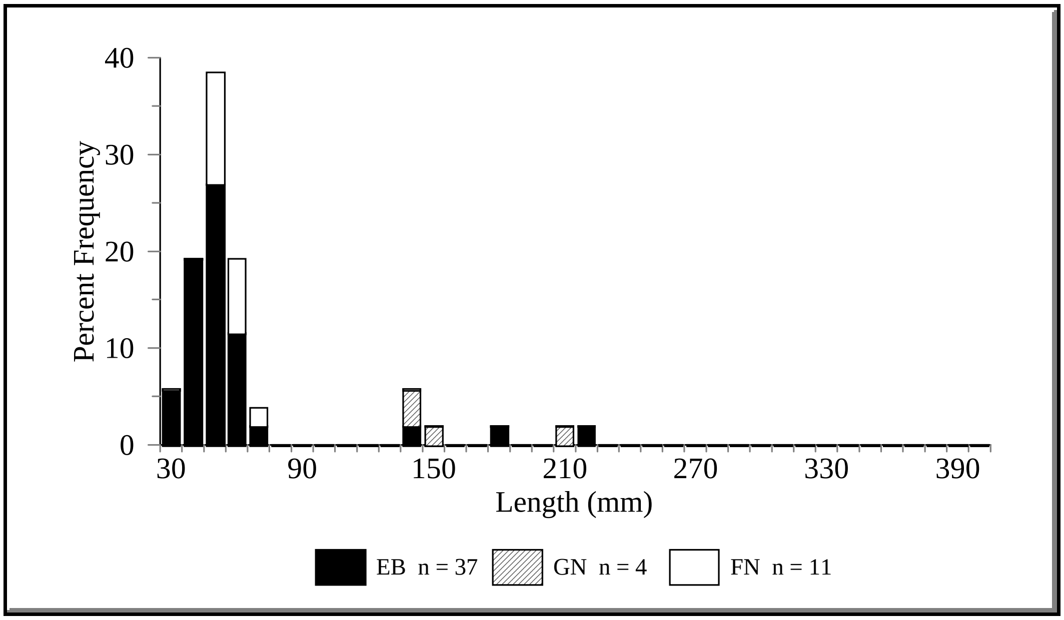

Figure 6. Length frequency histogram of black crappie sampled Lake Sawyer in fall 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

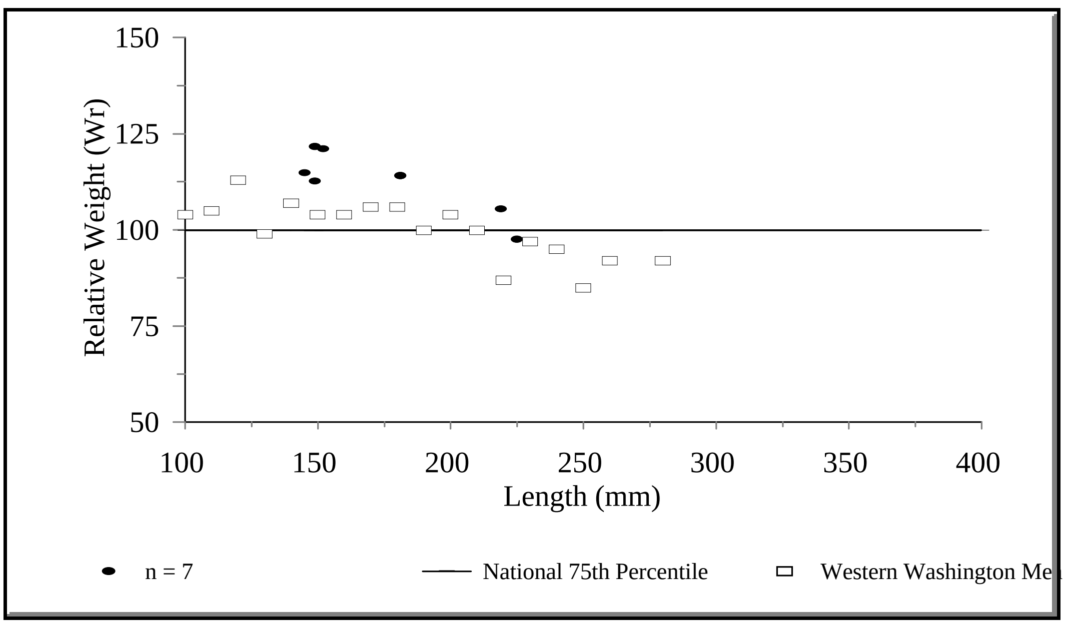

Figure 7. Relationship between total length and relative weight (W_r) of black crappie from Lake Sawyer (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Bluegill (*Lepomis macrochirus*)

Only one bluegill was sampled from Lake Sawyer measuring 87 mm TL and with a relative weight of 92. Growth for this age 1+ individual was below the Washington State average.

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

Year class	# fish	Mean total length (mm) at age 1
1998	1	23.0
		37.7
Overall mean		23.0
Weighted mean		37.7
State Average		37.3
G		0.47
G_{avg}		2.08

Pumpkinseed (*Lepomis gibbosus*)

Pumpkinseed ranged from 71 to 180 mm TL (Figure 8) (age 1+ to 4+). All the pumpkinseed sampled were age 1+ with the exception of one age 4+ individual (Table 13). Growth of pumpkinseed was above the Washington State average. Relative weights for pumpkinseed were generally consistent with the state average, with a slight upward trend with increasing TL (Figure 9). The Spearman correlation coefficient (Rho) for pumpkinseed length and relative weight was 0.288 (p = 0.071).

Table 13. Age and growth of pumpkinseed captured at Lake Sawyer (King County) during fall 1999. Unshaded values are mean back–calculated lengths at annulus formation using the direct proportion method (Fletcher et al 1993). Shaded values are mean back–calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age			
Year class	**# fish**	**1**	**2**	**3**	**4**
1998	24	28.4			
		46.4			
1997	0				
1996	0				
1995	1	27.1	105.9	158.8	171.8
		48.3	116.2	161.8	172.9
	Overall mean	27.7	105.9	158.8	171.8
	Weighted mean	46.5	116.2	161.8	172.9
	State Average	23.6	72.1	101.6	122.7
	G	0.984	4.032	1.220	0.236
	G_{avg}	0.498	3.362	1.032	0.568

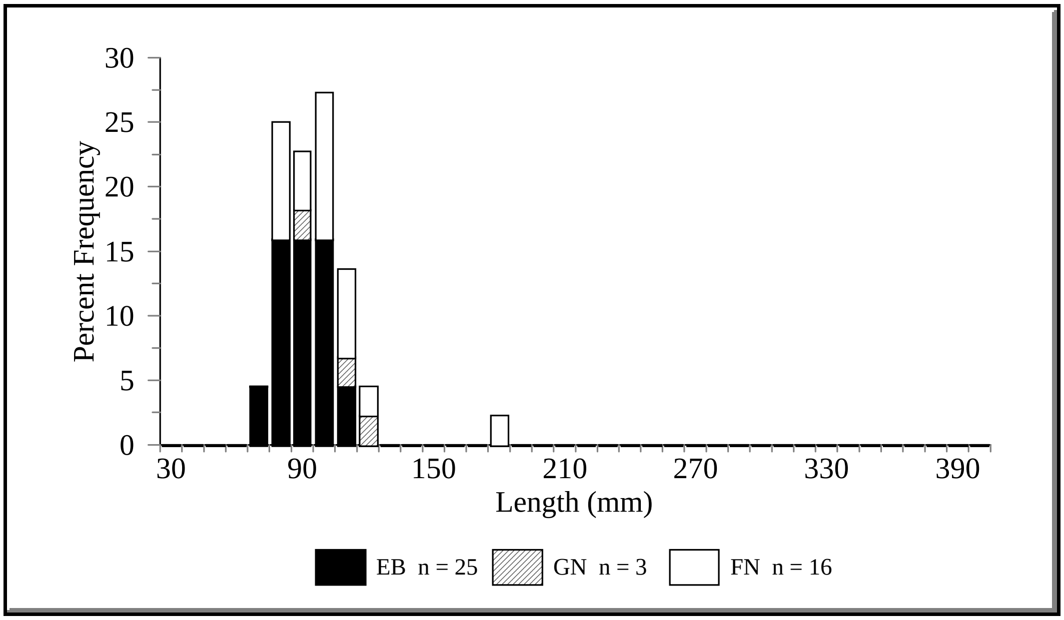

Figure 8. Length frequency histogram of pumpkinseed sampled from Lake Sawyer in fall 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

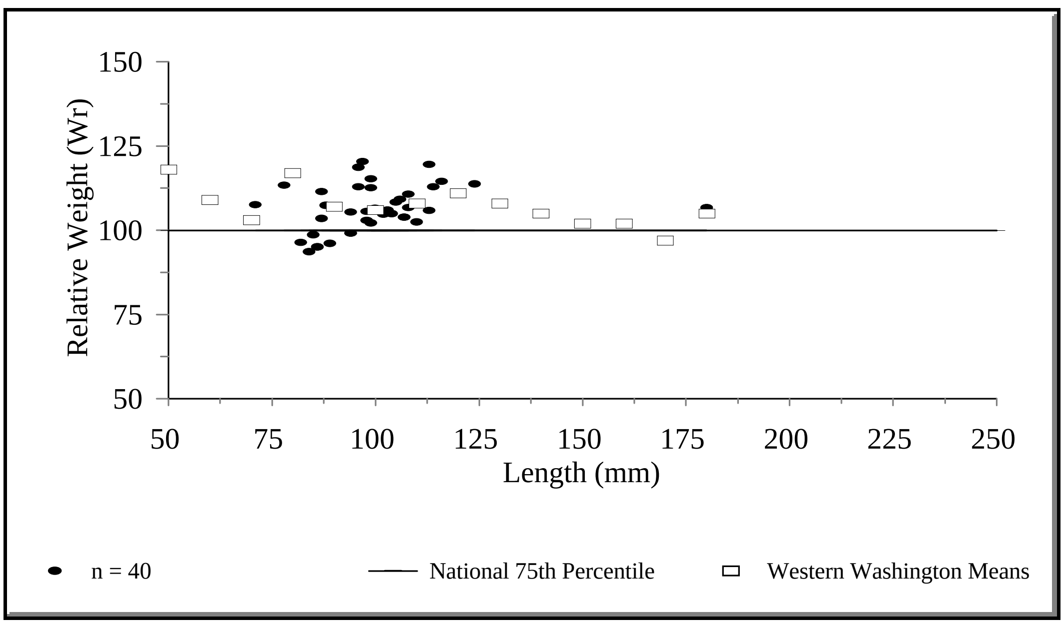

Figure 9. Relationship between total length and relative weight (W_r) of pumpkinseed from Lake Sawyer (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Yellow Perch (*Perca flavescens*)

Yellow perch ranged from 41 to 284 mm TL (Figure 10) (age 0+ to 4+). Except for the 1996 year–class, all ages were well represented. Age 1+ yellow perch were dominant. Growth of yellow perch was above the Washington State average for all age classes sampled. Relative weights of yellow perch were below the Washington State average for fish measuring less than 180 mm TL, yet consistent with averages thereafter. A slight, nonlinear downward trend appeared in the data with increasing TL. The Spearman correlation coefficient (Rho) for yellow perch length and relative weight was -0.279 ($p < 0.01$).

Table 14. Age and growth of yellow perch captured at Lake Sawyer (King County) during fall 1999. Unshaded values are mean back–calculated lengths at annulus formation using the direct proportion method (Fletcher et al 1993). Shaded values are mean back–calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age			
Year class	**# fish**	**1**	**2**	**3**	**4**
1998	42	67.0			
		83.2			
1997	15	69.4	169.6		
		89.5	175.4		
1996	4	63.6	152.2	200.2	
		85.4	162.4	204.1	
1995	14	57.4	135.0	195.6	231.4
		80.5	148.7	202.1	233.6
	Overall mean	64.3	152.2	197.9	231.4
	Weighted mean	84.1	162.5	202.6	233.6
	State Average	59.7	119.9	152.1	192.5
	G	3.751	2.764	0.842	0.502
	G_{avg}	3.510	2.238	0.764	0.756

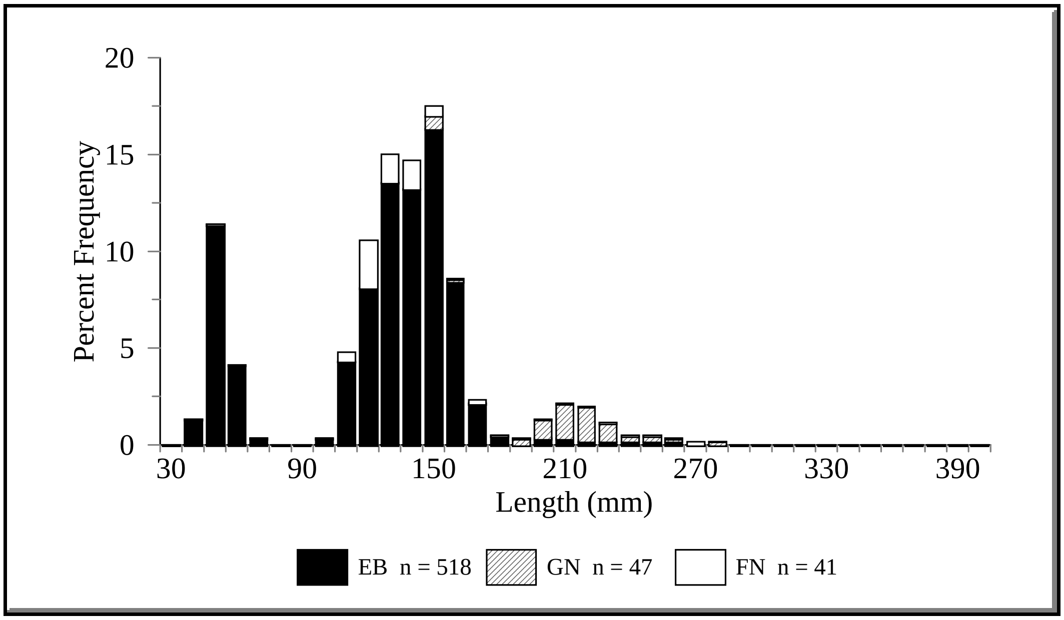

Figure 10. Length frequency histogram of yellow perch sampled from Lake Sawyer in fall 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

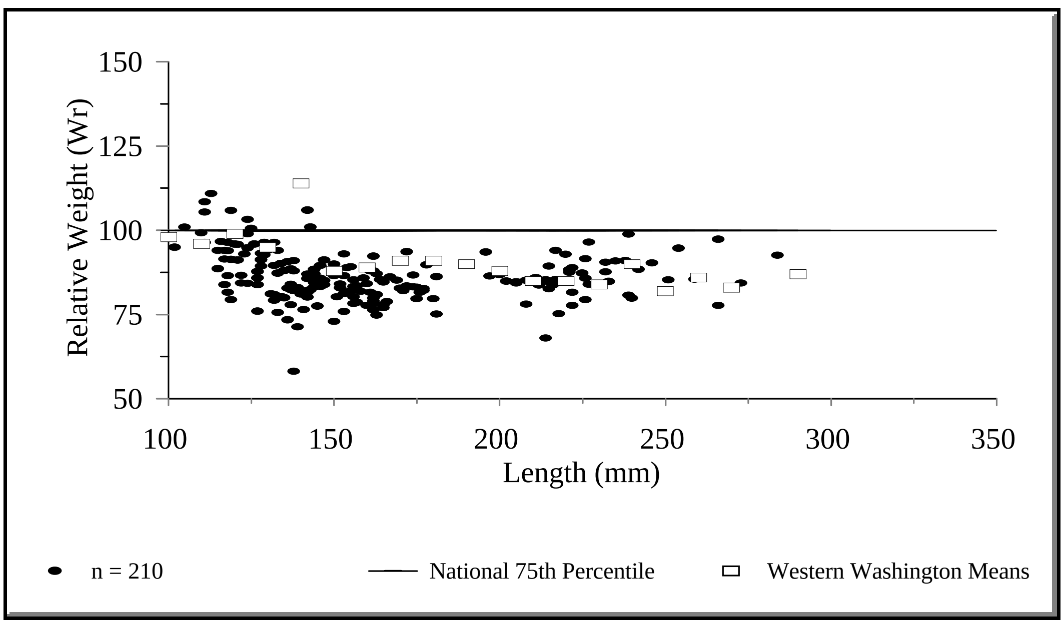

Figure 11. Relationship between total length and relative weight (W_r) of yellow perch from Lake Sawyer (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Brown Bullhead (*Ameiurus nebulosus*)

Brown bullhead ranged from 85 to 396 mm TL. YOY were represented in our sample (Figure 12). Relative weights for brown bullhead were consistent with the national 75th percentile for individuals measuring less than 230 mm TL, but generally below the 75th percentile for larger individuals. A slight downward trend appeared in the data with increasing total length, but was not significant due to low sample size. The Spearman correlation coefficient (Rho) for brown bullhead length and relative weight was -0.60 (p = 0.285).

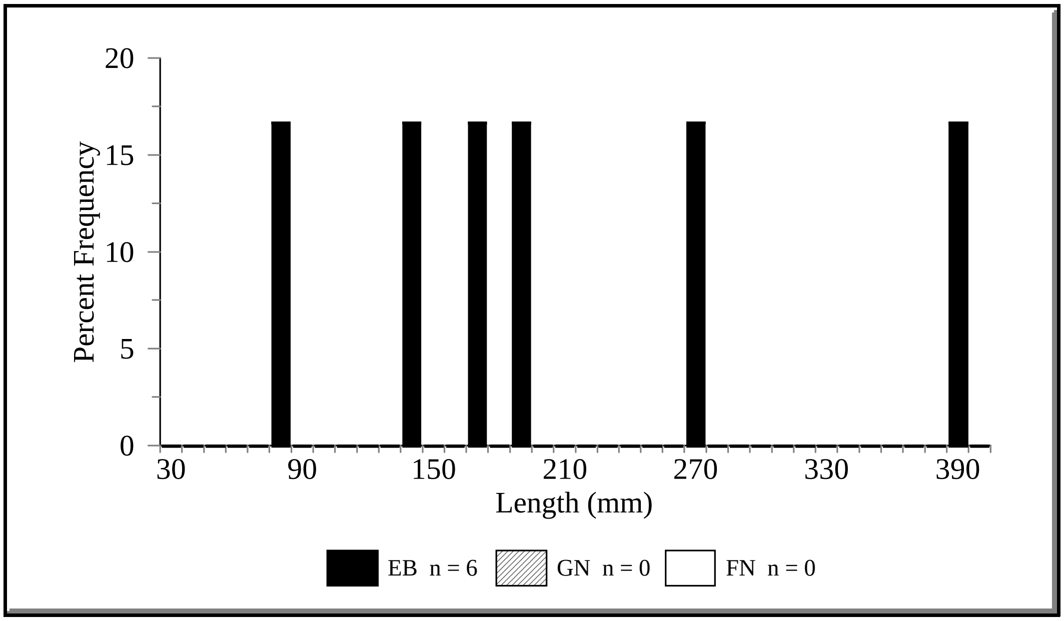

Figure 12. Length frequency histogram of brown bullhead sampled from Lake Sawyer in fall 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

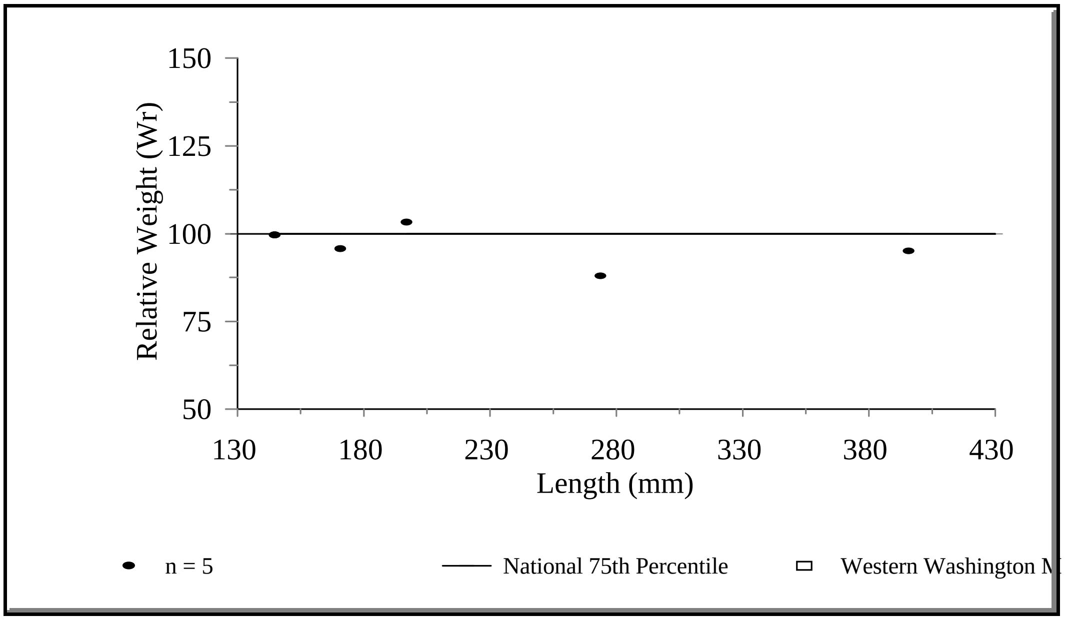

Figure 13. Relationship between total length and relative weight (W_r) of brown bullhead from Lake Sawyer (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Members of the Family Salmonidae

A number of salmonid species have been documented in the Lake Sawyer watershed. Coho salmon and sea–run cutthroat inhabited the system historically. In the last 50 years, WDFW and its predecessor, WDG, stocked thousands of kokanee, rainbow trout and cutthroat trout into the lake. Recently, coho salmon outmigrations have been monitored by King County Surface Water Division (Trotter et al 1996).

During our fall sampling effort we did not sample any anadromous salmonids. However, we did capture one kokanee measuring 204 mm TL (age 1+), one rainbow trout measuring 350 mm TL (age 2+) with a relative weight of 104, and three cutthroat trout measuring 272, 274, and 295 mm TL (all age 1+) with relative weights of 105, 129 and 97, respectively.

Non–Game Fish

Peamouth was the most abundant non–game fish in our sample; we captured 22 fish ranging from 254 to 314 mm TL. We determined the ages of four peamouth as follows: individuals with total lengths of 254, 269, 300, and 301 mm TL were aged 5+, 3+, 4+, and 5+, respectively. The second most abundant non–game fish was unidentified sculpin, 16 of which appeared in our sample. Two largescale suckers measuring 477 and 485 mm TL were estimated from scales to be age 2+ each.

Warmwater Enhancement Options

Warmwater fish species dominated our catch from Lake Sawyer in fall 1999. Growth of largemouth bass, smallmouth bass, black crappie, pumpkinseed and yellow perch was consistent with or above western Washington State averages. However, CPUE for largemouth bass, black crappie and pumpkinseed were below average, suggesting low abundance of larger individuals of these species. Obvious gaps in the length frequency distribution of largemouth bass may be due to weather–related year–class failure, competition with the abundant yellow perch, or overharvest of larger individuals. Similar factors may also be responsible for the absence of larger, older black crappie and other panfish. Low numbers of apex predators may exacerbate the apparent over abundance of yellow perch. The smallmouth bass population in Lake Sawyer appears robust, as evidenced by rapid growth rates, strong PSD values, and CPUE rates consistent with other western Washington State waters. However, an unregulated fishery could jeopardize the structure and abundance of this population. Based on our assessment of the warmwater fish community in Lake Sawyer, we suggest options for enhancing the fishery which include an assessment of usage and harvest, and rule changes to improve the size structures of largemouth and smallmouth bass as well as increase numbers of panfish. Management strategies that might improve the warmwater fishery at Lake Sawyer include, but are not limited to, the following:

Conduct a Standardized Creel Survey on the Lake

Historically, Lake Sawyer has been managed as a mixed–species fishery. More recently, the emphasis has shifted to warmwater species. No rigorous creel surveys have been conducted on Lake Sawyer since the 1970s. Yet even limited creel census data can be useful in helping fisheries managers make management decisions for the lake. Limitations on resources have prevented a formal creel census in recent years. With increasing public interest in warmwater fisheries, biologists have begun recommending standardized creels surveys on lakes where warmwater fishery enhancement options are practical (Mueller 1999; Downen and Mueller 2000a, b). A survey following the methods of Kraemer (1992) would allow resource managers to assess usage, target species, and harvest rates, and assess the impacts of fishing pressure on community and population characteristics of warmwater fish species. Standardized surveys also would allow for comparison of these parameters between lakes or between years, and strengthen correlations between rule changes and population size structures and abundance over time.

Change Existing Fishing Rules to Protect and Improve Size Structures of Largemouth and Smallmouth Bass

Currently, Lake Sawyer anglers are allowed to retain five fish daily of any combination of largemouth and smallmouth bass. Although there is no minimum size limit, no more than three fish can measure over 381 mm (15”) TL. During fall 1999, gill netting PSD and RSD values (Table 8) suggest that a trophy fishery is evolving for smallmouth bass (Gabelhouse 1984; Willis et al. 1993). One way of protecting and enhancing a trophy fishery is implementing a minimum length limit (Cornelius and Margenau 1999). Under this type of regulation, fish below a designated length must be released. A minimum length limit (e.g., 457 mm or 18” TL) with a reduced bag limit (e.g., one fish daily) should allow more fish to reach their full growth potential while protecting the resource (Maceina et al. 1998; Slipke et al. 1998). Since largemouth bass recruitment is very low in Lake Sawyer (i.e., few quality–size fish were captured), whether due to natural or anthropogenic factors (e.g., delayed mortality from catch–and–release [Wilde 1998] or overharvest), a minimum length limit should benefit this species as well (Lucas 1986; Willis 1989). However, it should be noted that a minimum length limit might result in little or no change in smallmouth and largemouth bass size structures several years after implementation (Mueller 1999).

Implementing a 305–432 mm (12–17") TL slot limit for largemouth and smallmouth bass might succeed where the original rule failed. The main objective of a slot limit is to improve the predators’ size structure. Under this rule, only fish less than 305 or greater than 432 mm TL may be kept. Decreasing the creel limit 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). Widening the slot limit to 254–457 mm TL (10–18") TL while reducing the creel limit from three to one fish above the slot and a daily limit of three fish, might allow more largemouth bass to realize their full growth potential in Lake Sawyer. A wide slot limit would protect largemouth bass for four to five years. In Arkansas, an outstanding largemouth bass fishery was developed by adjusting the slot and the creel limits to stimulate harvest of small fish while protecting large fish (Turman and Dennis 1998).

A simpler alternative to protect largemouth bass would be to implement catch–and–release fishing on the lake. Under this rule, all largemouth bass captured must be released back into Lake Sawyer alive. Increased numbers of larger fish would act as a control on the abundant yellow perch. Furthermore, since the rule is indisputable, it would be simpler to enforce.

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 Lake Sawyer 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, increasing the presence of WDFW Enforcement personnel at Lake Sawyer during peak harvest periods would encourage compliance.

Change Existing Fishing Rules to Increase Abundance of Panfish Other than Yellow Perch

Lake Sawyer falls under the statewide general freshwater fishing rules of no minimum size or daily limit on panfish. Low numbers of panfish in our samples were of some concern. Anecdotal reports of anglers retaining excessive numbers of Lake Sawyer panfish are common (Curt Kraemer, WDFW, personal communication). A deregulated fishery such as this, if highly exploited, will undoubtedly impact the resource resulting in an unbalanced fish community. In general, unbalanced fish communities fall into one of two categories with respect to predator and prey abundance: predator–crowded or prey–crowded (Swingle and Smith 1947). Rule changes are commonly implemented by fisheries managers in either of these situations to alter the numbers and size structures of predator species to achieve a balance between predator and prey fish (Anderson 1976, Novinger 1984). Bluegill and pumpkinseed are important forage species for largemouth bass (Carlander 1977). Low numbers of these fish in Lake Sawyer might be related to overharvest, competition with the dominant yellow perch, or weather–related year–class failure. Likewise, the paucity of larger, older black crappie in our samples suggests that this species be under pressure as well. Black crappie have long been a prized game fish in other regions of the U. S., and have been actively fished in Lake Sawyer for decades where they have attained total lengths and weights exceeding 305 mm (12") and 454 g (one pound), respectively. Therefore, we suggest changing the fishing rules to include a ten fish per day limit on panfish other than yellow perch to prevent harvest rates that might have long–term impacts on these and other species in the lake, particularly the largemouth and smallmouth bass.

Literature Cited

Anderson, R.O. 1976. Management of small warm water impoundments. Fisheries 7: 26-27.

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.

Blackwell, B.G., M.L. Brown, and D.W. Willis. *In press*. Relative weight (W_r) status and current use in fisheries assessment and management. South Dakota Agricultural Experiment Station, Journal Series # 3056, 00 p.

Bonar, S.A., Fletcher, D., and B. Bolding. 1994. Relationship between forage fish abundance in the diet of largemouth bass (*Micropterus salmoides*). Washington Department of Fish and Wildlife technical report no. 94-07. 22p.

Carlander, K.D. 1977. Handbook of freshwater fishery biology. Volume 2. Iowa State University Press, Armes, Iowa. 431 pp.

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.

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography 22: 361-369.

Cornelius, R.R., and T.L. Margenau. 1999. Effects of length limits on muskellunge in Bone Lake, Wisconsin. North American Journal of Fisheries Management 19: 300-308.

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

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

Downing, J.A., C. Plante, and S. Lalonde. 1990. Fish production correlated with primary productivity, not the morphedaphic index. Canadian Journal of Fisheries and Aquatic Sciences 47: 1929-36.

Downing, J.A., and C. Plante. 1993. Production of fish populations in lakes. Canadian Journal of Fisheries and Aquatic Sciences 50: 110-20.

Downen, M.R., and K.W. Mueller. 2000a. 1998 Lake Goodwin survey: Potential Trophy Largemouth Bass and Smallmouth Bass Fisheries in a Heavily Fished, Intensively Managed Western Washington Lake. Washington Department of Fish and Wildlife, Warmwater Enhancement Program, Technical Report # FPT00-02, 31 p.

Downen, M.R., and K.W. Mueller. 2000b. 1998 Twin Lakes (Gissburg Ponds) survey: Assessment and comparison of the warmwater fish communities in two small, heavily fished ponds. Washington Department of Fish and Wildlife, Warmwater Enhancement Program, Technical Report # FPT00-04, 33 p.

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.

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.

Jearld, A. 1983. Age determination. Pages 301-324 *In*: Nielson, L.A., and D.L. Johnson (eds.), Fisheries techniques. American Fisheries Society, Bethesda. MD.

Keast, A. 1979. Patterns of predation in generalist feeders. Pages 243-255 *in* H. Clepper, editor. Predator-Prey Systems in Fisheries Management. Sport Fishery Institute, Washington D.C.

King County. 1997. Lake Monitoring Report. King County, Seattle WA.

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.

Kraemer, C. 1992. 1991 Creel survey on Lake Goodwin, Snohomish County. Washington Department of Fish and Wildlife, Draft Technical Report.

King County Surface Water Management. 1995. Aquatic plant mapping for thirty-six King County lakes. King County, Seattle.

Lucas, B. 1986. Evaluation of the 14-inch minimum size limit on Silver Lake. Washington Department of Game, Fishery Management Report 86-19, 41 p.

Maceina, M.J., P.W. Bettoli, S.D. Finely, and V.J. DiCenzo. 1998. Analyses of the sauger fishery with simulated effects of a minimum size limit in the Tennessee River of Alabama. North American Journal of Fisheries Management 18: 66-75.

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. 1999. 1997 Lake Stevens survey: the warmwater fish community after implementation of a minimum length rule on largemouth and smallmouth bass. Washington Department of Fish and Wildlife, Warmwater Enhancement Program, April 1999 Technical Report, 26 p.

Murphy. B.R., D.W. Willis, and T.A. Springer. 1991. The relative weight index in fisheries management: status and needs. Fisheries 16: 30-38.

Novinger, G.D. 1984. Observations in the use of size limits for black basses in large impoundments. Fisheries 9: 2-6.

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.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Board of Canada 191: 382 pp.

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

Trotter, P.C., P.R. Olson, and K. Ludwa. 1996. Timing of juvenile coho salmon emigration from the Lake Sawyer drainage basin. King County Surface Water Management Division. King County, Seattle WA.

Turman, D., and C. Dennis. 1998. Review of largemouth bass minimum length and slot limits on Lake Columbia, Arkansas. American Fisheries Society, Fisheries Management Section Newsletter 17(1): 17.

Wilde, G.R. 1998. Tournament-associated mortality in black bass. Fisheries 23: 12-22.

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

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

Willis, D.W. 1999. Fisheries Management, Instruction Manual, FIS2103. US Fish and Wildlife Service National Conservation Training Center Branch of Aquatic Resources Training, Minneapolis, MN.

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