1998 Lake Goodwin Survey: Potential Trophy Largemouth Bass and Smallmouth Bass Fisheries in a Heavily Fished, Intensively Managed Western Washington Lake

by

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Introduction and Background

Lake Goodwin is located north of Everett in a region of Snohomish County known as the Seven Lakes area. This area contains a cluster of lakes with watersheds forming chains. The largest chain is comprised of Lake Loma, Lake Crabapple, Lake Goodwin, and Lake Shoecraft (listed in downstream order). This chain drains into Tulalip Creek which flows through Weallup Lake, and finally into Possession Sound. Lake Goodwin is comprised of three basins with a total surface area of 224 hectares and a volume of 12.3 million cubic meters. Its maximum and mean depths are 15.2 and 5.4 meters, respectively (Williams et al. 1999).

Historically, the watershed and lakeshore of Lake Goodwin were heavily wooded but trees have been steadily removed in recent decades to accommodate residential development. Today the Lake Goodwin watershed is about 40% developed and the lake's shoreline is almost completely developed, predominantly with single family housing (Williams et al. 1999). Moreover, the lake shoreline is approximately 42% bulkheaded with 290 docks. Most of the littoral zone is devoid of natural coarse woody debris and is patchily vegetated with largeleaf pondweed (*Potamogeton amplifolius*), naid (*Najas flexilis*), brittlewort (*Nitella sp.*), stonewort (*Chara sp.*), and invasive Eurasian watermilfoil (*Myriophyllum spicatum*).

Extensive development and heavy recreational use of Lake Goodwin have resulted in intensive management of the lake in several respects. Fluctuations in regulated water levels have been an ongoing issue of concern with residents. While some residents have reported property damage due to high lake levels in the spring, others have been unable to use their docks during low levels in summer. Increasing use of the lake by boaters, water-skiers, and personal watercraft has resulted in heavy traffic on the lake during summer months and subsequent regulation of these activities. The invasion of Eurasian watermilfoil during the late 1980's or early 1990's has resulted in active management of littoral vegetation by the Snohomish County Surface Water Management Division. In 1996 Snohomish County received a grant from the Washington State Department of Ecology to control the Eurasian watermilfoil due to concern that this aquatic plant could potentially colonize large areas of Lake Goodwin's littoral zone. By placing burlap barriers over dense watermilfoil colonies and hand-pulling plants in scattered locations divers have eradicated up to 95% of the Eurasian watermilfoil in the lake. However, regular year-to-year efforts have been recommended for management of this non-native plant (Williams et al. 1999).

Despite rapid development in recent years, water quality in Lake Goodwin remains good with only occasional algae blooms occurring (Williams et al. 1999). A Seven Lakes restoration analysis, carried out between 1982 and 1984 found Lake Goodwin to be a mesotrophic lake, well oxygenated throughout most of the year (Entranco Engineers 1984). This monitoring and analysis led to the conclusion that comprehensive in-lake restoration measures were not necessary, and that preventive measures would be the best strategy for meeting long term water quality goals.

The popularity of Lake Goodwin as a sport fishery has resulted in intensive management of its fish populations. Historically the lake harbored populations of sculpin (Family Cottidae), chub (Family Cyprinidae), suckers (Family Catastomidae), and cutthroat trout(*Oncorhynchus clarki*). Mackinaws (*Salvelinus namaycush*) were stocked in 1921 and eastern brook trout (*Salvelinus fontinalis*), rainbow trout (*Oncorhynchus mykiss*), kokanee (*Oncorhynchus nerka*), and cutthroat trout were stocked throughout the 1950's, 60's, and 70's. The Washington Department of Game (WDG) expended considerable resources surveying trout populations, water quality, zooplankton populations, and fishing pressure (WDG, unpublished data). During these decades illegally introduced populations of largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), pumpkinseed (*Lepomis gibbosus*), and brown bullhead (*Ameiurus nebulosus*) also became established but were periodically controlled through lake rehabilitation with the piscicide, rotenone. However, data suggesting that Lake Goodwin did not provide optimum conditions for salmonid fishes and increasing interest in fishing for warmwater species led to the management of the lake as a mixed species fishery (WDG, unpublished data). In the early 1980's smallmouth bass (*Micropterus dolomieu*) were introduced into Lake Goodwin and throughout the 1980's and early 1990's interest in warmwater species continued to develop. An extensive creel survey by Kraemer (1992) originally undertaken to measure angler recovery of stocked trout, found substantial pressure on largemouth bass, yellow perch, and other introduced species as well (Figure 1, Table 1).

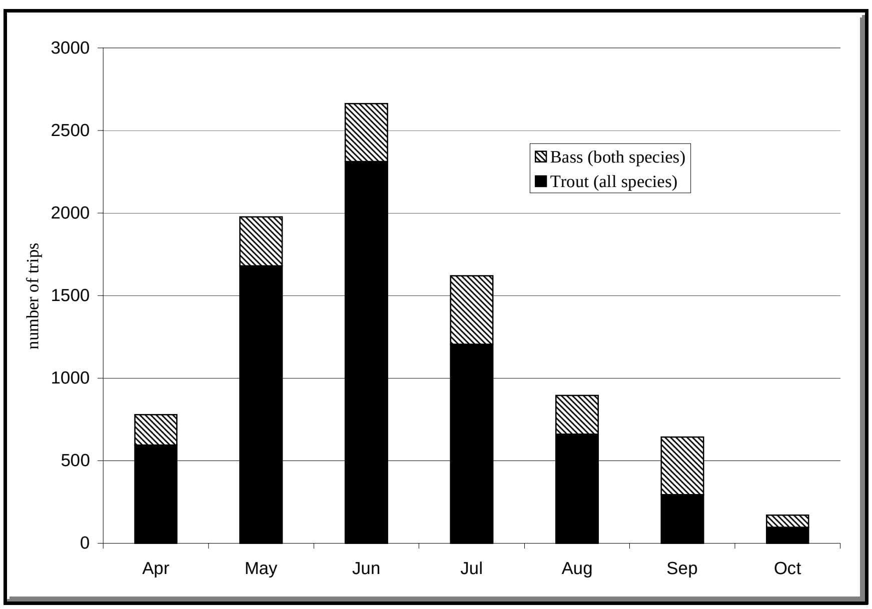

Figure 1. Angler effort for trout and bass on Lake Goodwin between April and October 1991 (Kraemer 1992).

Table 1. Total effort for fish by species for Lake Goodwin (Snohomish County) by anglers between April and October 1991 (Kraemer 1992).

Species	Angler trips	Fish captured	Fish retained	Min length (mm)	Max Length (mm)
Trout	6,837	13,120	11,784		
Largemouth bass	1906*	4,899	501	127	495.3
Smallmouth bass		450	165	107.95	438.15
Black crappie	30	38	38	82.55	342.9
Yellow perch	928	11,377	8,831	107.95	317.5
Pumpkinseed	34	4,947	1,503	88.9	190.5
Any species	2,659				

* Angler trips for bass were not differentiated by species.

The potential for increased warmwater angling opportunity and anecdotal information that angler interest in bass fishing in Lake Goodwin has increased dramatically since 1991 (Curtis Kraemer, WDFW, personal communication) led the Washington Department of Fish and Wildlife Warmwater Enhancement Program to survey the lake in late summer of 1998. We sought to evaluate concerns that forage fish populations might be expanding and stunting, that fishing pressure might be adversely impacting largemouth bass and smallmouth bass populations, and that these phenomena might be related.

Materials and Methods

Two WDFW biologists and one scientific technician surveyed Lake Goodwin during 14 through 16 September 1998. 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/sec 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 fourteen consecutively numbered sections of about 400 m each as determined from a 1:24,000 USGS map (Figure 2). A portion of the shoreline was sampled by electrofishing nine randomly selected sections for a total of 5,400 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. Six gill nets were set perpendicular to the shoreline with the small-mesh end attached onshore and the large-mesh end anchored offshore. Six fyke nets were set in water less than three 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 with the exception of sculpin which were identified to family. 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. However, if a sample included several hundred individuals of a given species, then a sub-sample ($n \geq 100$ fish) was measured and weighed while the remainder was counted overboard. The length frequency distribution of the sub-sample was then applied to the total number collected. Weights of individuals counted overboard were estimated using the linear regression of $\log_{10}$-length on $\log_{10}$-weight of fish from the sub-sample. 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). Furthermore, given the emphasis of this study on warmwater species, growth was not assessed for salmonid and non-game fish.

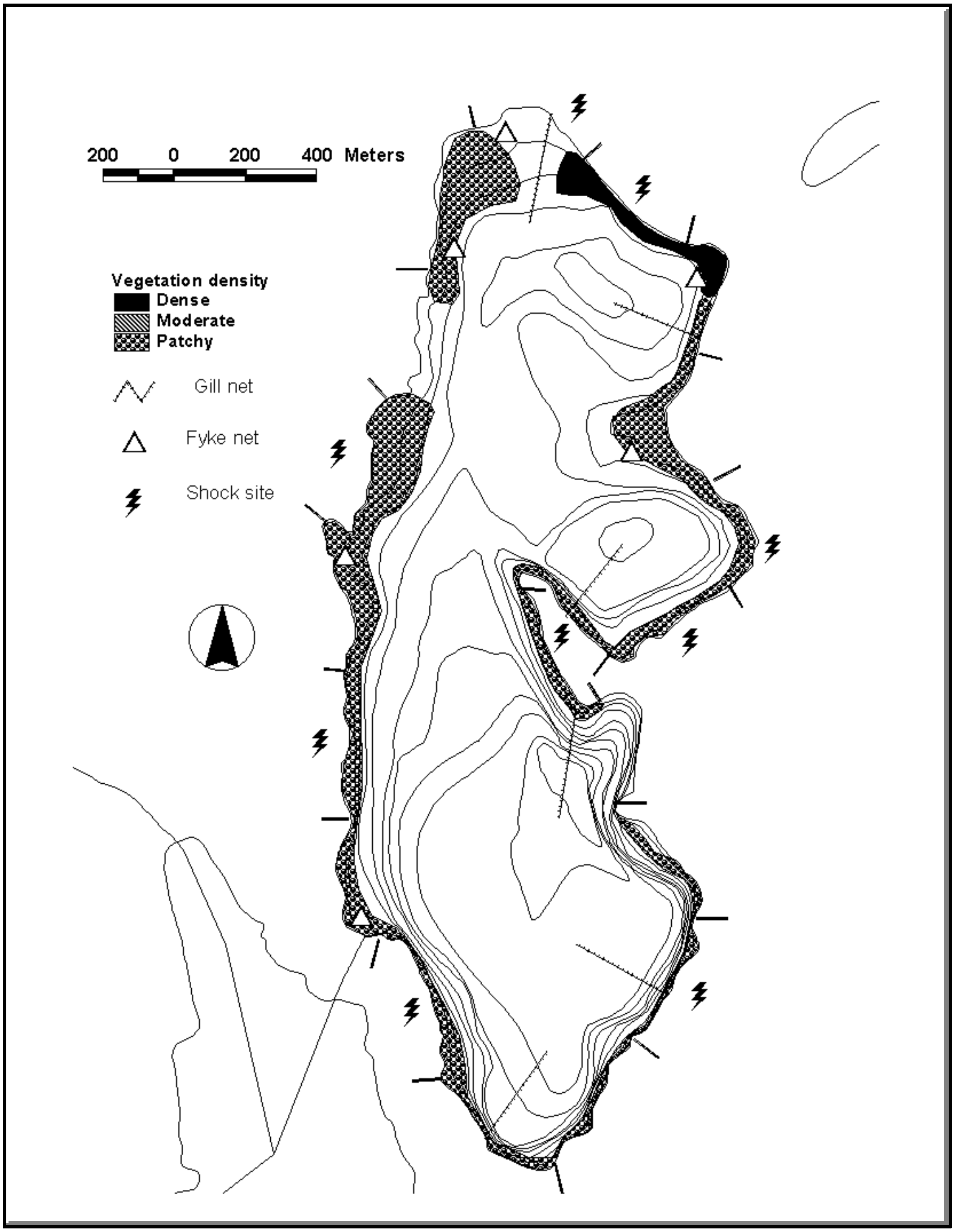

Figure 2. Hydrology, bathymetry, aquatic macrophyte distribution, and 1998 sampling sites on Lake Goodwin (Snohomish Co.).

Water quality data was collected during midday from three sites on 14 September 1998 using a Hydrolab® probe and digital recorder. We measured dissolved oxygen, total dissolved solids, temperature, pH, and specific conductance and recorded secchi disc readings in meters (Table 2).

Table 2. Water quality from three basins on Lake Goodwin (Snohomish County). Samples were collected midday on 14 September 1998.

		Parameter					
Basin	Secchi (m)	Depth (m)	Temp (°C)	DO (mg/L)	pH	Conductance (uS/cm)	TDS (g/L)
North basin	4.9	1	20.70	8.27	8.93	79.5	0.0512
		2	20.64	8.49	8.56	80.3	0.0520
		3	20.48	8.49	8.37	80.8	0.0520
		4	20.27	7.99	8.3	81.0	0.0518
		5	20.25	7.85	8.14	81.3	0.0520
Middle	4.9	1	21.04	8.37	8.30	81.3	0.0523
		2	20.94	8.23	8.11	80.3	0.0520
		3	20.88	8.27	7.99	81.2	0.0521
		4	20.86	8.23	7.97	81.2	0.0522
		5	20.84	8.28	7.92	81.6	0.0520
		6	20.76	8.04	7.89	81.7	0.0521
		7	20.74	8.04	7.86	81.5	0.0521
South	5.2	1	21.10	8.45	8.04	82.0	0.0522
		2	20.99	8.35	7.9	81.8	0.0522
		3	20.93	8.28	7.88	81.7	0.0524
		4	20.89	8.28	7.91	81.9	0.0523
		5	20.86	8.28	7.86	81.8	0.0522
		6	20.84	8.25	7.86	82.2	0.0524
		7	20.66	8.02	7.81	81.9	0.0524
		8	18.23	5.00	7.41	80.7	0.0516
		9	15.92	0.35	7.13	82.4	0.0521
		10	13.53	0.23	6.91	84.9	0.0542
		11	12.05	0.15	6.86	86.0	0.0548
		12	11.38	0.12	6.67	106.5	0.0675
		13	10.90	0.11	6.78	111.5	0.0710
		14	10.77	0.09	6.83	113.0	0.0726

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 fishermen 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 and the potential for interaction, and the adequacy of the food supplies for various foraging niches (Ricker 1975; Kohler and Kelly 1991; Olson 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 or small juveniles are often not considered because large fluctuations in their numbers may distort 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 interspecific and intraspecific competition at lower trophic levels (Olson 1995).

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 species. Stock length, which varies by species (see Table 4 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 $\pm\ t_{(\alpha,\ N\text{-}1)} \times SE$, where t = Student's t for α confidence level with N-1 degrees of freedom (two-tailed) and SE = standard error of the mean. Since it is standardized, CPUE is a useful index for comparing relative abundance of stocks between lakes and the confidence intervals express the relative uniformity of species distributions throughout the lakes. CPUE values for Lake Goodwin were then compared to western Washington State averages compiled by the WDFW Inland Fisheries Research Unit (Table 3).

Table 3. 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, gillnetting, 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	9.6	4	4.2	3	23.4	2
Yellow Perch	97.5	8	13.7	6	0.2	2
Pumpkinseed Sunfish	70.8	11	3.8	9	7.9	4
Brown Bullhead	7.8	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. Salmonid size structures were evaluated with stacked length frequency histograms as well.

The proportional stock density (PSD) of each warmwater fish species was determined following procedures outlined in Anderson and Neumann (1996). PSD, which was calculated as the number of fish $\geq$ quality length/number of fish $\geq$ stock length$\times$100, is a numerical descriptor of length frequency data that provides useful information about 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 4). 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$\times$100. For example, RSD P was the percentage of stock length fish that also were longer than preferred length, RSD M, the percentage of stock length fish that also were longer than memorable length, and so on. Eighty-percent confidence intervals for PSD and RSD were selected from tables in Gustafson (1988).

Table 4. Length categories for warmwater fish species by Gabelhouse (1984) used to calculate stock density indices (PSD, RSD) for fish captured at Lake Goodwin (Snohomish County) during late summer 1998 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
Yellow perch	130	200	250	300	380
Pumpkinseed	80	150	200	250	300
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 5).

Table 5. Stock density index ranges for largemouth bass and bluegills under three commonly implemented management options (from Willis et al. 1993). For lake Goodwin the dominant forage sunfish is pumpkinseed and PSD values for these can be compared loosely to those for bluegill.

	Largemouth Bass			Bluegill	
Option	**PSD**	**RSD-P**	**RSM-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 Goodwin with western Washington State averages compiled by the WDFW Inland Fisheries Research Unit (Table 6).

Table 6. 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	17	0	0
Black Crappie	EB	3	5	0	0	0
Yellow Perch	GN	12	53	1	0	0
Pumpkinseed	EB	12	8	0	0	0

Age and growth of warmwater fishes in Lake Goodwin 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 $L_n = a \pm A\times(TL - a)/S$, 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 Goodwin fish and the western Washington State average (listed in Fletcher et al. 1993) for the same species.

A relative weight (W_r) index was used to evaluate the condition of fish in the lake. A W_r value of 100 generally indicates that a fish has a condition value equal to the national standard (75th percentile) for that species. Furthermore, W_r is useful for comparing the condition of different size classes within a single population to determine if all sizes are finding adequate forage (ODFW 1997). Following Murphy et al. (1991), the index was calculated as $W_r = W/W_s \times 100$, where W is the weight (g) of an individual fish and W_s is the standard weight of a fish of the same total length (mm). W_s is calculated from a standard $\log_{10}$weight-$\log_{10}$length relationship defined for the species of interest. The parameters for the W_s equations of many cold- and warmwater fish species, including the minimum length recommendations for their application, are listed in Anderson and Neumann (1996). The W_r values from this study were compared to the national standard (W_r = 100) and where available, with mean W_r values from up to 25 western Washington warmwater lakes sampled during 1997 and 1998 (Steve Caromile, WDFW, unpublished data). Trends in the dispersion of points on the relative weight graph have been used to infer ecological dynamics of fish populations (Willis 1999). For example, a decrease in relative weight with increasing total length often occurs where competition is high among larger size classes. Conversely, lower relative weights occurring with smaller fish suggests competition and crowding for these fish. Testing the statistical significance of the relationship between total length and relative weight, standard transformation failed to normalize the length data. Moreover, we make no assumption that relationships would be linear. We therefore used a nonparametric correlation, Spearman's Rho (Zar 1984), to assess the significance of correlations between total length and relative weight where relationships were suggested by the graphs.

Results and Discussion

Species Composition

During late summer 1998, our sample from the fish community of Lake Goodwin was dominated by warmwater species, primarily smallmouth bass by biomass and pumpkinseed and yellow perch by number (Table 7). Together, pumpkinseed and yellow perch accounted for more than 80% of the number captured. Largemouth bass made up 12% of our sample by biomass but only 6% by number. Black crappie, cutthroat trout and brown bullhead, each, accounted for only 1% of the species composition by biomass and number. Rainbow trout made up 4% by biomass and 2% by number.

Table 7. Species composition by weight (kg) and number of fish captured at Lake Goodwin (Snohomish County) during late summer 1998.

	Species Composition				
	by weight		by number		
Species	**(kg)**	**% weight**	**(kg)**	**% weight**	**Size range (mm TL)**
Largemouth Bass (*Micropterus salmonides*)	10.587	12.2	64	6.2	79-515
Smallmouth Bass (*Micropterus dolomieu*)	37.350	43.0	81	7.8	61-520
Black Crappie (*Pomoxis nigromaculatus*)	0.777	0.9	8	0.78	151-204
Yellow Perch (*Perca flavescens*)	8.498	9.8	285	27.6	84-219
Pumpkinseed sunfish (*Lepomis gibbosus*)	23.294	26.8	558	54.1	88-172
Brown Bullhead (*Ameiurus nebulosus*)	0.567	0.7	1	0.1	327-327
Goldfish (*Carassius auratus*)	1.157	1.3	1	0.1	375-375
Cutthroat Trout (*Oncorhynchus clarki*)	0.716	0.8	1	0.1	414-414
Rainbow Trout (*Oncorhynchus mykiss*)	3.771	4.3	19	1.8	229-456
Sculpin (*Cottos spp.*)	0.219	0.3	14	1.4	41-157
Total	86.934	1,032			

CPUE

While electrofishing, catch rates were well above the western Washington State average for stock-length pumpkinseed and below the average for yellow perch (Tables 3 and 8). Catch rates for stock-length largemouth bass were highest with electrofishing but below the average. Catch rates for stock-length smallmouth bass were below average for electrofishing and above average for gill netting. Catch rates for stock-length cutthroat trout and brown bullhead were similarly low with all gear types, and cutthroat trout, black crappie, and rainbow trout were sampled only with gill nets.

Table 8. 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 Goodwin (Snohomish County) while electrofishing, gill netting, and fyke netting during late summer 1998.

	Gear Type					
Species	**Electrofishing (fish/hr)**	**n (sites)**	**Gillnetting (fish/hr)**	**n (net nights)**	**Fyke netting (fish/hr)**	**n (net nights)**
Largemouth Bass	5.32 ± 3.25	9	0.17[a]	6	0	6
Smallmouth Bass	1.32 ± 1.12	9	5 ± 2.24	6	0	6
Black Crappie	0	9	1.33 ± 1.22	6	0	6
Yellow Perch	61.03 ± 20.98	9	4 ± 1.9	6	0	6
Pumpkinseed Sunfish	353.28 ± 123.78	9	4.17[a]	6	0.17[a]	6
Brown Bullhead	0.66[a]	9	0	6	0	6
Goldfish	0.66[a]	9	0	6	0	6
Rainbow Trout	0	9	1.5 ± 0.72	6	0	6
Cutthroat Trout	0	9	0.17[a]	6	0	6
Sculpin	9.32 ± 4.26	9	0	6	0	6

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

Stock Density Indices

Proportional stock density indices (PSD) and relative stock density indices (RSD) for largemouth bass and smallmouth bass (Table 9) were above those reported in other Western Washington lakes (Mueller 1999, Downen and Mueller 1999), above state averages for largemouth bass (see Table 6), and consistent with values generally accepted for trophy waters (Willis et al. 1993). However, sample sizes were small with values for largemouth bass being based upon only eight stock length fish. We captured one trophy and two memorable smallmouth bass from Lake Goodwin, and PSD and RSD-P for smallmouth bass were both 100 (Table 9). Small sample size resulted in a low, undependable PSD for black crappie, all of which were captured at one gill net site. Pumpkinseed and yellow perch were captured in large numbers while electrofishing and gill netting with higher PSD for both species from gill netting. However, PSD values for these fish were low compared to western Washington State averages or to generally accepted ranges for either balanced communities or big waters (Willis et al. 1993).

Table 9. Traditional stock density indices, including 80% confidence intervals, for warmwater fishes collected from Lake Goodwin (Snohomish County) while electrofishing, gill netting, and fyke netting during late summer 1998. 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	8	75 ± 20	25[a]	13[a]	0
	GN	1	100	100	0	0
	FN	0	0	0	0	0
Smallmouth Bass	EB	2	0	0	0	0
	GN	30	100	100	37 ± 11	3[a]
	FN	0	0	0	0	0
Black Crappie	EB	0	0	0	0	0
	GN	8	38 ± 22	0	0	0
	FN	0	0	0	0	0
Yellow Perch	EB	92	3 ± 2	0	0	0
	GN	24	29 ± 12	0	0	0
	FN	0	0	0	0	0
Pumpkinseed	EB	532	5 ± 1	0	0	0
	GN	25	8[a]	0	0	0
	FN	1	100	0	0	0
Rainbow Trout	EB	0	0	0	0	0
	GN	9	11[a]	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

Largemouth bass ranged from 79 to 515 mm (age 0+ to 12+) (Table 10, Figure 3). Age 1+ fish were relatively abundant. Fish older than 4+ were unsampled with the exception of three older individuals. Growth of largemouth bass collected from Lake Goodwin was below the western Washington State average until age four and above the average thereafter. Relative weights were below western Washington State averages for small size classes with higher W_r values occurring with larger size classes (Figure 4). The Spearman correlation coefficient (Rho) for largemouth bass length and relative weight was 0.873 ($p < 0.01$).

Table 10. Age and growth of largemouth bass captured at Lake Goodwin (Snohomish County) during late summer 1998. 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	11	12
1997	28	71.8											
		81.0											
1996	4	86.2	140.8										
		96.7	145.1										
1995	0												
1994	5	71.8	153.1	211.7	278.3								
		87.2	163.2	218.2	280.6								
1993-1988	0												
1987	2	59.1	116.9	183.0	249.2	304.7	350.8	383.8	415.7	433.4	451.1	459.4	
		76.5	131.9	195.2	258.6	311.7	355.7	387.4	417.9	434.8	451.8	459.7	
1986	0												
1985	1	60.8	121.5	167.8	228.6	295.1	355.9	399.3	416.6	454.2	471.6	494.7	506.3
		78.4	136.8	181.3	239.7	303.7	362.1	403.8	420.4	456.6	473.3	495.5	506.7
Samples, 1984		33.0	114.0	181.1	274.1								
Samples, 1986		32.0	94.5	155.7	207.0	318.8	372.6	374.9					
Samples, 1988		58.9	128.0	187.7	236.5	325.6	373.6	415.0					
Samples, 1990		53.1	121.4	186.7	259.3	331.0	367.8	400.1	419.6				
Overall mean		69.9	133.1	187.5	252.0	299.9	353.3	391.5	416.2	443.8	461.4	477.1	506.3
Weighted mean		83.1	149.8	207.8	270.0	309.0	357.8	392.8	418.7	442.1	459.0	471.7	506.7
State average		60.4	145.5	222.2	261.1	289.3	319.0	367.8	396.0	439.9	484.6	471.7	495.6

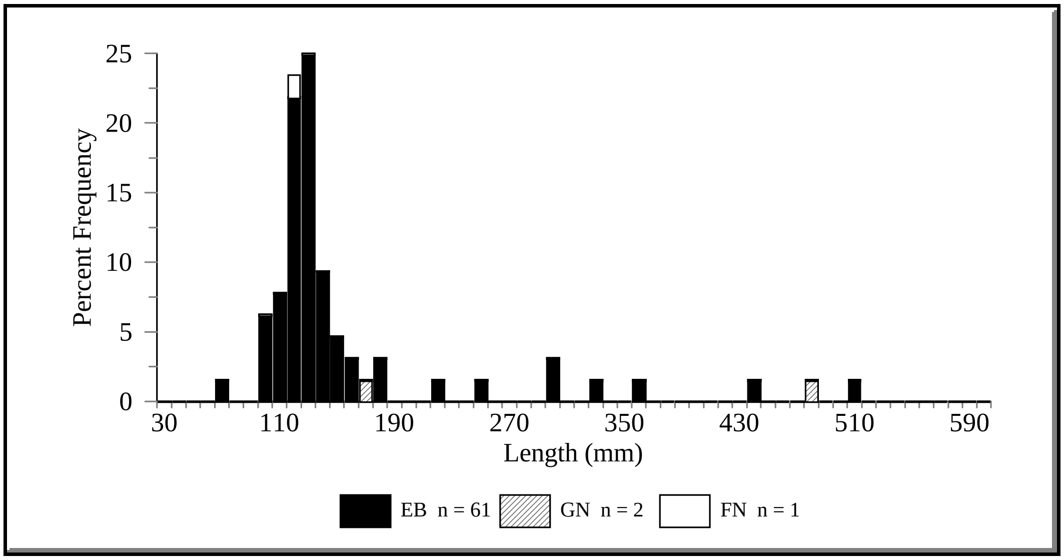

Figure 3. Length frequency histogram of largemouth bass sampled from Lake Goodwin in late summer 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

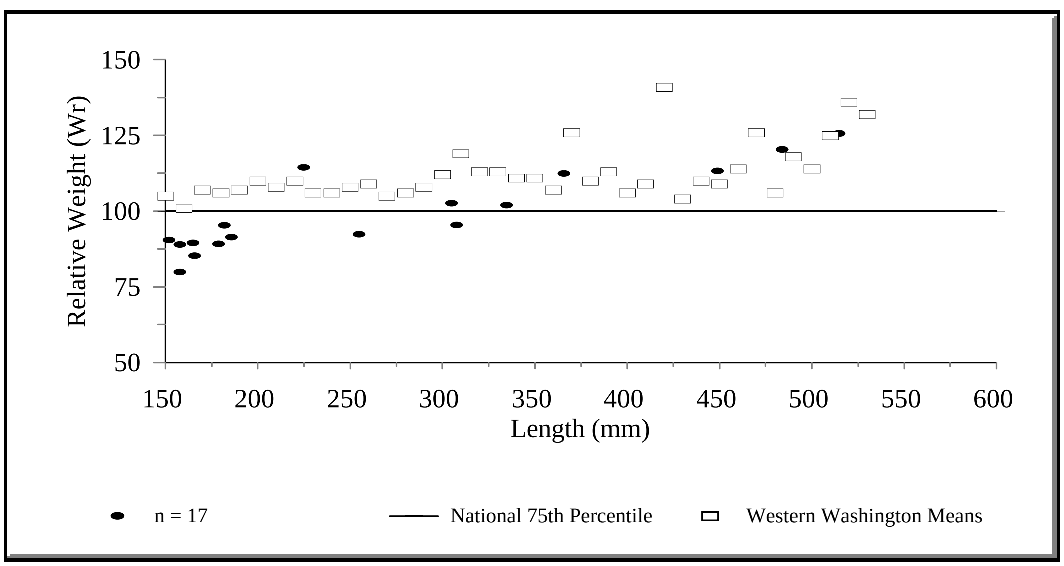

Figure 4. Relationship between total length and relative weight (W_r) of largemouth bass from Lake Goodwin, (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Smallmouth Bass

Smallmouth bass ranged from 61 to 520 mm (age 0+ to 10+) (Table 11, Figure 5). Age 1+ fish were relatively abundant. Age5+, 6+, and 7+ fish were the best represented age classes of mature fish. We did not see the same pattern of missing age classes as with largemouth bass. Growth of smallmouth bass collected from Lake Goodwin was consistent with or above the western Washington State average up to age 7+. Relative weights were generally consistent with or below western Washington State averages for most size classes. Larger W_r values occurred with larger size classes (Figure 6) with the exception of the two largest individuals. The Spearman correlation coefficient (Rho) for smallmouth bass length and relative weight was 0.222 (p = 0.15), positive but not significant.

Table 11. Age and growth of smallmouth bass captured at Lake Goodwin (Snohomish County) during late summer 1998. 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**
1997	23	72.3									
		89.7									
1996	3	87.3	136.8								
		104.8	144.3								
1995	1	86.0	137.1	209.7							
		109.0	152.9	215.3							
1994	2	107.6	208.5	311.1	368.1						
		132.9	224.8	318.1	370.0						
1993	7	84.4	159.0	241.4	327.5	373.3					
		111.9	179.9	255.1	333.6	375.3					
1992	5	65.1	129.2	180.5	252.4	307.6	361.8				
		94.1	152.3	198.9	264.3	314.4	363.6				
1991	7	76.2	143.9	194.3	255.1	326.7	375.4	404.9			
		104.9	167.0	213.2	268.9	334.5	379.1	406.2			
1990	4	92.1	157.2	220.2	275.7	344.3	387.6	424.3	444.3		
		120.2	180.4	238.6	290.0	353.4	393.4	427.4	445.8		
1989	3	74.9	136.1	196.2	237.6	303.4	353.2	404.8	435.7	453.8	
		104.3	160.9	216.6	254.9	315.8	361.8	409.6	438.2	454.9	
1988	2	105.0	157.0	201.9	266.2	329.9	372.5	415.1	441.2	469.5	485.1
		132.6	180.9	222.5	282.3	341.5	381.1	420.7	444.8	471.1	485.6
Overall mean		85.1	151.6	219.4	283.2	330.9	370.1	412.3	440.4	461.6	485.1
Weighted mean		101.7	170.3	231.4	292.3	342.3	375.9	413.9	443.1	461.4	485.6
State Average		70.4	146.3	211.8	268	334	356.1	392.7			

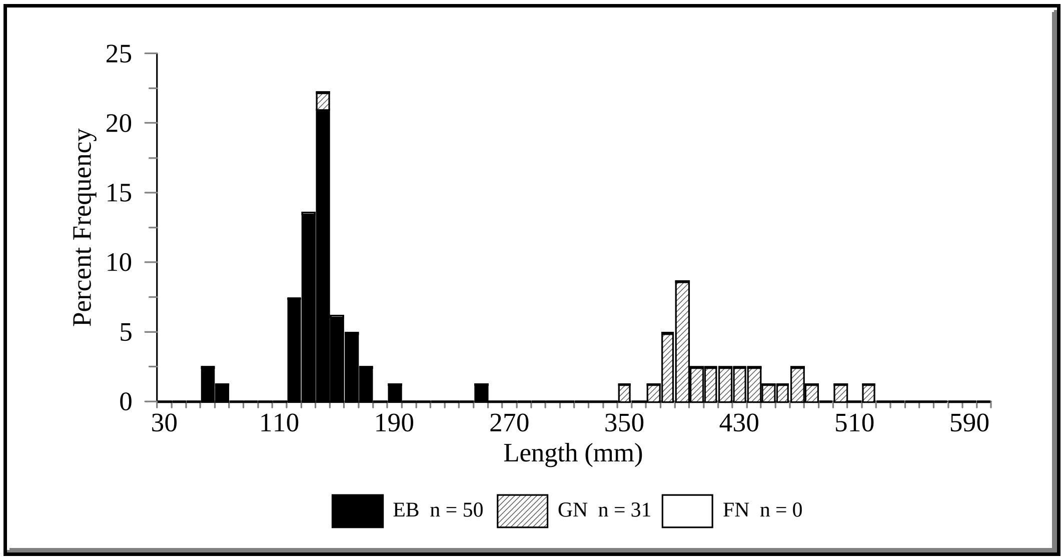

Figure 5. Length frequency histogram of smallmouth bass sampled from Lake Goodwin in late summer 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

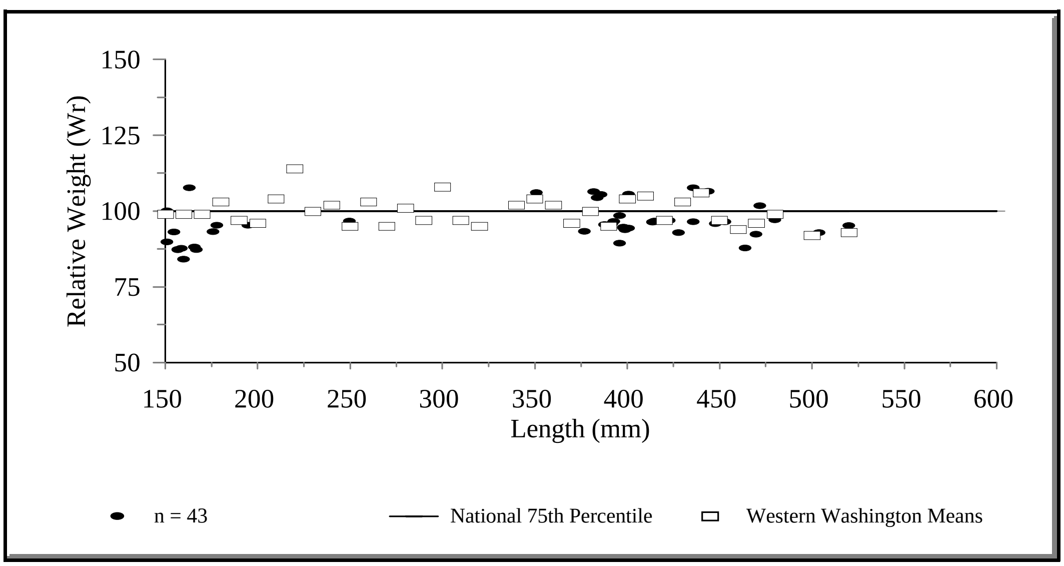

Figure 6. Relationship between total length and relative weight (W_r) of smallmouth bass from Lake Goodwin, (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75^{th} percentile.

Black Crappie

Black crappie ranged from 151 to 204 mm (TL) (age 1+ to 3+) (Table 12, Figure 7). All eight of the fish collected were captured in a single gill net. No age 0+ or age 1+ fish were collected, nor were any fish older than age 3 collected. These observations were consistent with previous data that reveals the rarity of black crappie in Lake Goodwin as well as observations that black crappie tend to school with individuals of similar age classes (Carlander 1982). Growth rates for black crappie in Lake Goodwin were generally consistent with the western Washington State average. While W_r values were consistent with the Washington State average, a downward trend appeared with increasing length (Figure 8). The Spearman correlation coefficient (Rho) for black crappie length and relative weight was –0.564 (p = 0.51), negative but not significant with low n size.

Table 12. Age and growth of black crappie captured at Lake Goodwin (Snohomish County) during late summer 1998. 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**
1997	0			
1996	3	49.7	131.2	
		73.8	137.2	
1995	5	59.4	122.8	157.8
		84.0	136.1	164.9
Overall mean		54.6	127.0	157.8
Weighted Mean		80.2	136.5	164.9
State Average		46	111.2	156.7

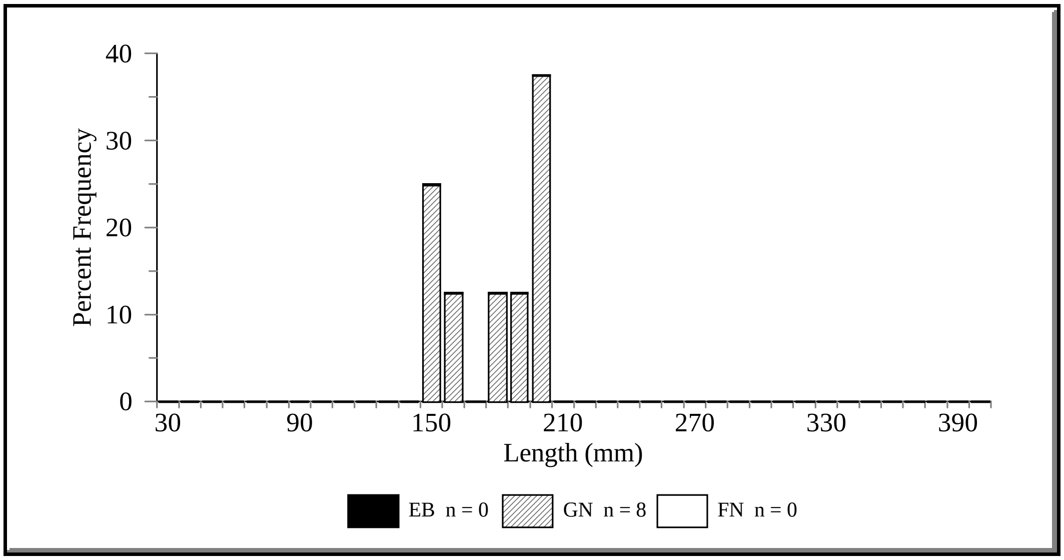

Figure 7. Length frequency histogram of black crappie sampled from Lake Goodwin in late summer 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

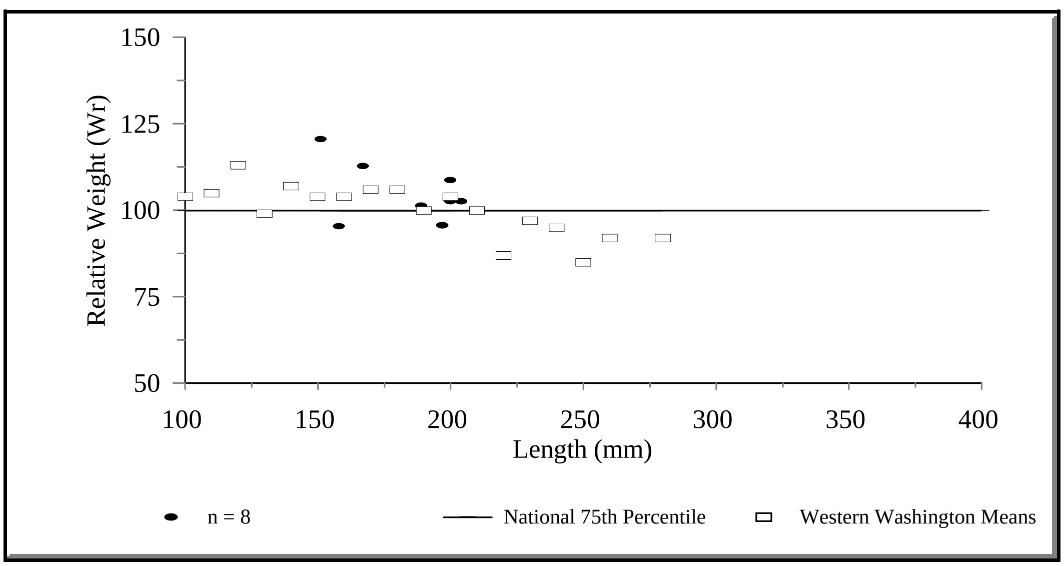

Figure 8. Relationship between total length and relative weight (W_r) of black crappie from Lake Goodwin, (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Yellow Perch

Yellow perch ranged from 84 to 219 mm (TL) (age 1+ to 6+) (Table 13, Figure 9). Growth rates for yellow perch in Lake Goodwin were below the Washington State average. Relative weight values (W_r) values were also below the Washington State average with an apparent downward trend with increasing total length (Figure 10). The Spearman correlation coefficient (Rho) for yellow perch length and relative weight was –0.552 ($p < 0.01$).

Table 13. Age and growth of yellow perch captured at Lake Goodwin (Snohomish County) during late summer 1998. 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**
1997	23	76.5					
		87.5					
1996	7	74.2	112.3				
		89.5	115.8				
1995	16	65.5	112.7	153.5			
		84.0	122.9	156.6			
1994	11	60.4	109.4	154.9	179.9		
		81.0	122.3	160.7	181.8		
1993	6	61.9	108.2	151.8	178.2	201.6	
		82.9	122.4	159.8	182.4	202.4	
1992	1	72.3	97.2	115.3	142.4	162.8	212.5
		92.3	113.8	129.3	152.7	170.3	213.1
Overall mean		68.5	108.0	143.9	166.8	182.2	212.5
Weighted mean		85.4	121.2	157.7	180.4	197.8	213.1
State Average		59.7	119.9	152.1	192.5	206	

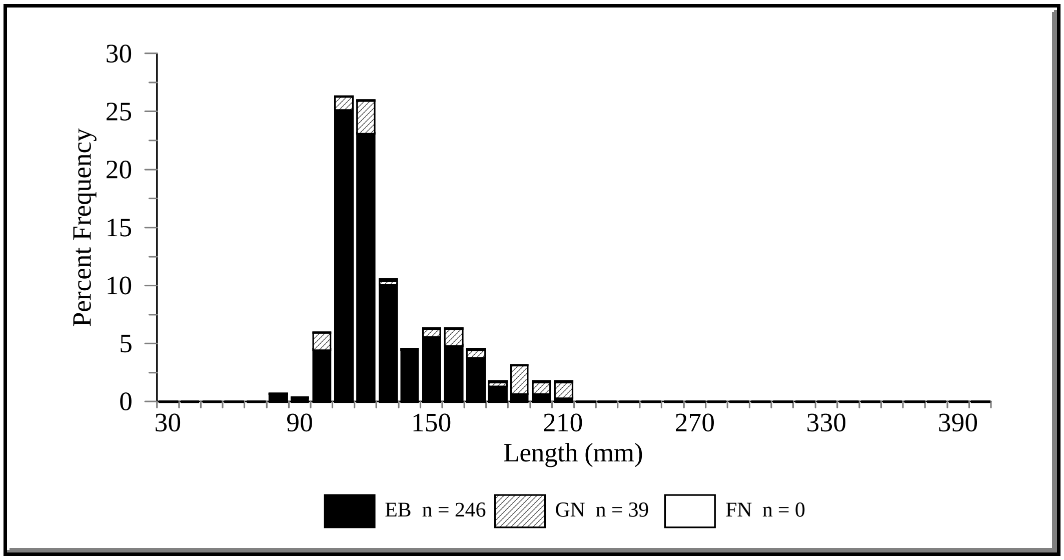

Figure 9. Length frequency histogram of yellow perch sampled from Lake Goodwin in late summer 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

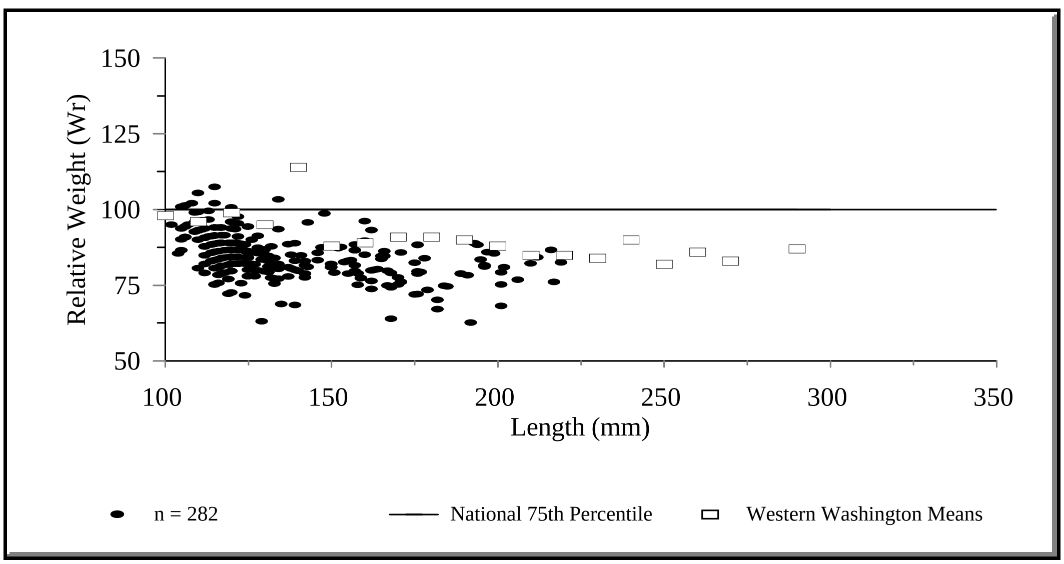

Figure 10. Relationship between total length and relative weight (W_r) of yellow perch from Lake Goodwin, (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Pumpkinseed

Pumpkinseed ranged from 88 to 172 mm (TL) (age 1+ to 7+) (Table 14, Figure 11). Despite large numbers of fish collected, age 6+ fish were absent from our sample. Growth rates for pumpkinseed in Lake Goodwin were consistent with the western Washington State average through age 5+ but relative weight values were below the Washington State average (Figure 12). The Spearman correlation coefficient (Rho) for pumpkinseed length and relative weight was –0.102 ($p = 0.016$).

Table 14. Age and growth of pumpkinseed captured at Lake Goodwin (Snohomish County) during late summer 1998. 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**
1997	4	54.5						
		64.6						
1996	7	48.8	76.7					
		61.9	82.9					
1995	11	51.5	74.0	105.2				
		66.1	84.0	108.9				
1994	20	52.8	77.5	113.9	128.2			
		68.1	88.5	118.2	130.0			
1993	5	53.2	82.2	109.3	131.9	143.8		
		69.2	93.4	116.0	134.8	144.7		
1992	0							
1991	1	41.4	67.0	92.6	114.6	136.5	148.7	160.9
		60.2	82.0	103.8	122.4	141.1	151.5	161.8
Overall mean		50.4	75.5	105.3	124.9	140.1	148.7	160.9
Weighted mean		66.4	86.9	114.8	130.6	144.1	151.5	161.8
State Average		23.6	72.1	101.6	122.7	139.4		

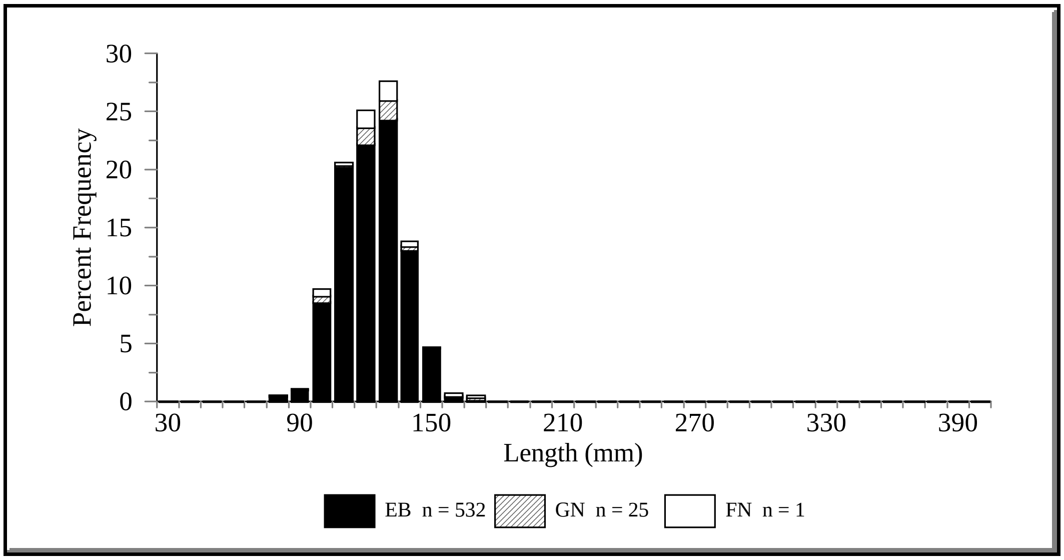

Figure 11. Length frequency histogram of pumpkinseed sampled from Lake Goodwin in late summer 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

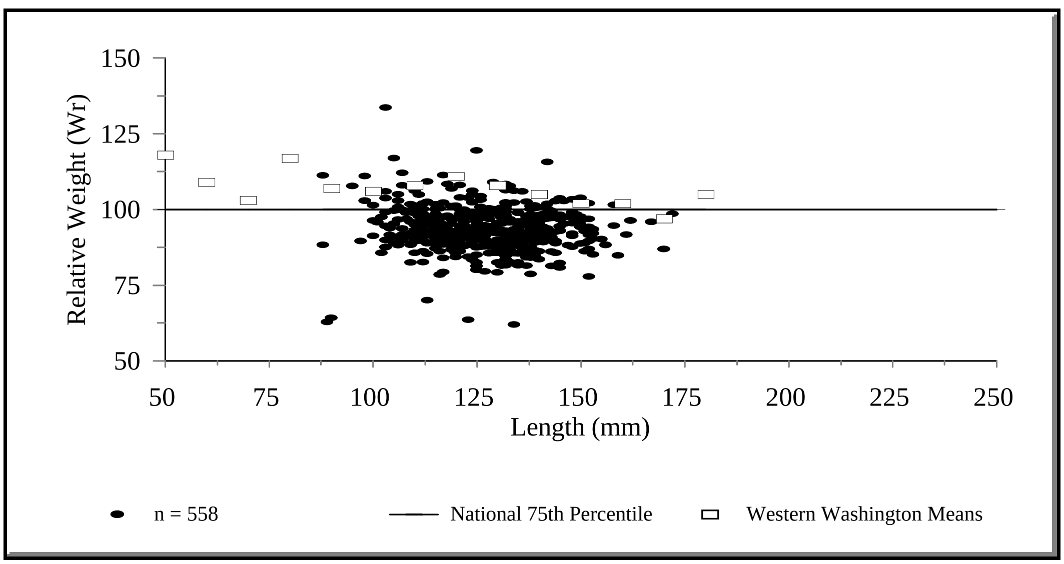

Figure 12. Relationship between total length and relative weight (W_r) of pumpkinseed from Lake Goodwin, (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Brown Bullhead

Despite historical accounts of abundance (WDFW unpublished data), only one brown bullhead with a total length of 327 mm and a relative weight of 87 was captured while electrofishing.

Members of the Family Salmonidae

One cutthroat trout with a fork length (FL) of 414 mm and a relative weight of 93 was captured while electrofishing. Eighteen rainbow trout were captured in Lake Goodwin ranging from 226 to 456 mm FL (Figure 13) and relative weights consistent with the western Washington trend of falling below the national 75th percentile (Figure 14).

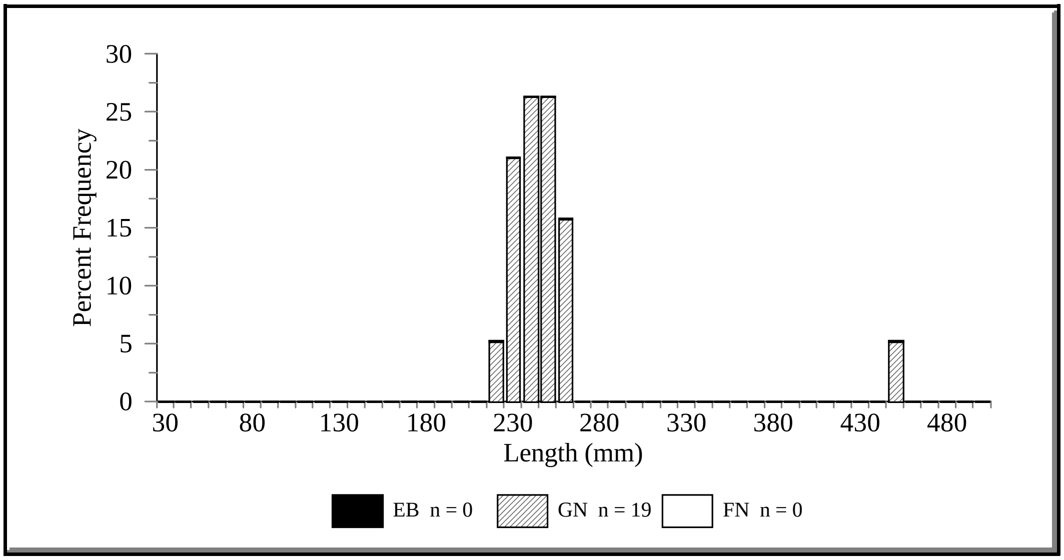

Figure 13. Length frequency histogram of rainbow trout sampled from Lake Goodwin in late summer 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

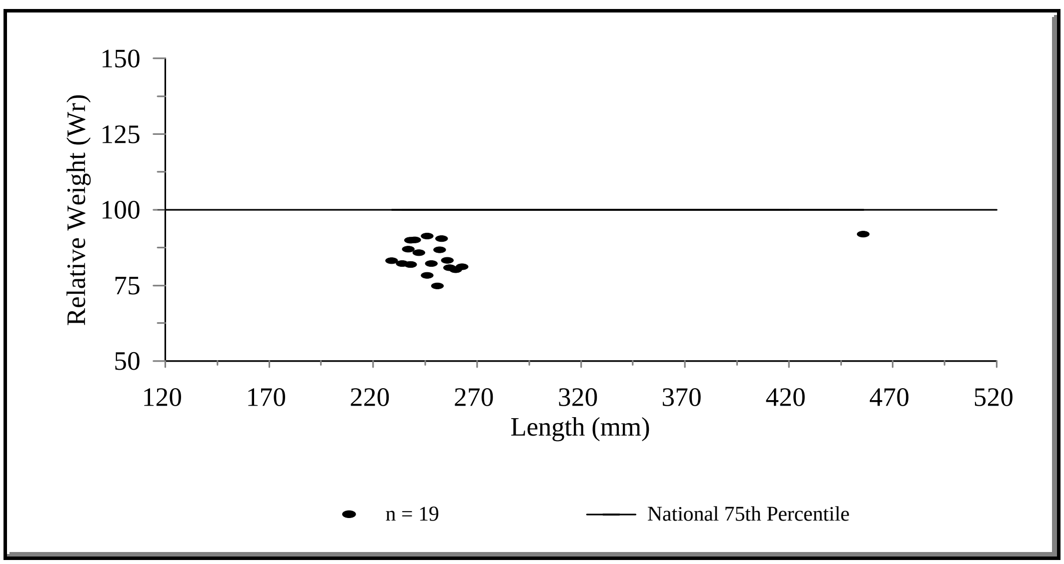

Figure 14. Relationship between total length and relative weight (Wr) of rainbow trout from Lake Goodwin, (Snohomish County) compared the national 75th percentile.

Warmwater Enhancement Options

The PSD and RSD values for largemouth bass and smallmouth bass in Lake Goodwin are consistent with values generally accepted for big bass waters (Willis et al. 1993). However, catch rates for stock length fish of both species were low. Several age classes of largemouth bass were missing from our samples. We concluded that while the size structures of these populations were good, their low abundance may be the result of angling mortality or overharvest. The possibility that Lake Goodwin could carry more large largemouth bass and smallmouth bass is supported by positive correlations between total length and relative weight. Increasing relative weight among larger fish implies reduced competition and an abundance of forage (Willis 1999). Conversely, low relative weights among smaller fish suggests crowding and reduced forage at lower trophic levels which may be directly related to low numbers of predators.

Further supporting the premise of overharvest and subsequent low abundance of larger largemouth bass and smallmouth bass, we found large numbers of forage species such as yellow perch and pumpkinseed. In addition to high abundance, these populations both demonstrated slow growth, increased longevity, and declining condition with size, suggesting crowding, reduced predation pressure, and competition for forage. Management options for improving opportunities for warmwater fishing in Lake Goodwin based upon these observations would include, but are not limited to the following:

Conduct a Standardized Creel Survey on the Lake

Historically, Lake Goodwin has been managed as a trout fishery and more recently as a mixed species fishery. The 1991 creel survey by Kraemer (1992) demonstrated a continued interest in the trout fishery of Lake Goodwin as well as increasing interest in warmwater species. However, the thorough creel survey carried out by Kraemer is nearly ten years old. More recent anecdotal information suggests interest in warmwater fishing in Lake Goodwin may be increasing dramatically. A survey following Kraemer's methods would provide valuable information about current angler interest and harvest from the lake and help answer questions about the possibility of overharvest of bass.

Monitor Aquatic Vegetation Control Efforts

Aquatic plant cover is an important habitat constituent for most warmwater fishes, which are more likely to be found around plant cover than away from it (Killgore et al. 1989). Submerged aquatic vegetation provides important foraging, refuge and spawning habitat (see review by Willis et al. 1997), improving survival and recruitment to harvestable sizes (Durocher et al. 1984). Changes in the standing crop of aquatic plants can alter fish production (Willis et al. 1993) and the structure of the fish community itself (Bettoli et al. 1993). Dense vegetation reduces foraging efficiency of many predatory warmwater fish species (Wiley et al. 1984). Fish communities seem to maximize their numbers under conditions of intermediate plant density. Balancing the contribution to habitat structure with the potential for reduced foraging efficiency should be an important aspect of aquatic plant control.

Efforts to control Eurasian watermilfoil on Lake Goodwin are currently very selective and appear to present no adverse effects on warmwater fish communities. However, we recommend continued monitoring of aquatic vegetation control plans for Lake Goodwin. A responsible aquatic plant management plan should rely on cooperative efforts of state, county, and local agencies. Clear communication should be established among interested and responsible parties, with opportunity for review and comment by those involved. The direct relationship between aquatic plant communities and fish populations requires monitoring of future vegetation control plans (Mueller and Downen 1999).

Change Existing Fishing Rules to Alter Size Structure of Largemouth Bass

Currently, a 305 – 381 mm (12 – 15 inch) slot limit makes it illegal to retain largemouth bass between 305 and 381 mm from Lake Goodwin. This limit is designed to protect smallmouth bass for two years and largemouth bass for less than two years. Of the fish retained outside the slot, no more than three of the five fish allowed per person per day can measure over 381 mm TL. Although the slot and creel limits are intended to protect fish required for a balance within the lake, the low abundance of large largemouth bass and paucity of size classes within the slot observed during late summer 1998 suggests the rule is not working as intended. Kraemer (1992) estimated a harvest rate of 5% for largemouth bass within the slot in 1991 that was substantially lower than for outside the slot. However, the length frequency distribution and age class for largemouth bass in 1998 suggest some factor has interfered with recruitment. Delayed mortality from catch and release angling may be a factor (Wilde 1998). Overharvest prior to or within the slot may be another factor.

Widening the slot limit to 254 – 457 mm TL (10 – 18 inches) while reducing the creel limit from three to one fish above the slot (while still maintaining the daily limit of five fish), might allow more largemouth bass to realize their full growth potential. This limit would protect these fish for four to five years where their growth rates rise above the western Washington State average. 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 reduction in small fish may improve growth and production of predator and prey species (McHugh 1990).

A simpler alternative would be to implement catch-and-release fishing for largemouth bass on the lake. Under this rule, all largemouth bass captured must be released back into Lake Goodwin. Since the rule is indisputable it would be simpler to enforce. Moreover, increased numbers of larger fish would act as a control on numbers of smaller fish and forage fish of all species.

The success of any rule on the lake will depend upon angler compliance with the 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). Public access to Lake Goodwin is gained through Wenberg State Park. Rules and their purpose should be posted there to inform and encourage anglers in the active management of their resource. The presence of WDFW enforcement personnel during peak harvest periods would also lessen illegal harvest.

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