1997 South Lewis County Regional Park Pond Survey: The Warmwater Fish Community Before Implementing Biological Control of Nuisance Aquatic Vegetation and Overproduction of Forage and Non-game Fish

by

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

February 2000

Acknowledgments

We thank John Pahutski and Steve Anderson of the Washington Department of Fish and Wildlife (WDFW) for their unfailing, invaluable assistance in the field and lab. Bill Zook provided technical assistance, encouragement and support, whereas Scott Bonar, Bruce Bolding, and Marc Divens (WDFW) provided helpful advice. Jack Tipping (WDFW) provided the data from 1996. We also thank Bill Wamsley of Lewis County Noxious Weed Control Board and Carol Hamilton of the Lewis County Department of Community Services for providing useful background information. Steve Jackson, Jack Tipping, and John Weinheimer (WDFW) provided thoughtful criticism of the original draft of the manuscript, whereas Darrell Pruett and Peggy Ushakoff (WDFW) designed the cover. Lauren Munday, Walt Cooper, Everett Latch, and Ted Morton (WDFW) proved indispensable when preparing and printing the final report. This project was funded by the Warmwater Enhancement Program, which is providing greater opportunities to fish for and catch warmwater fish in Washington.

Table of Contents

List of Tables ii

List of Figures iii

Introduction and Background 1

Materials and Methods 3
Data Analysis 3

Results and Discussion 8
Species Composition 8
CPUE 10
Stock Density Indices 10
Black Crappie 11
Bluegill 13
Brown Bullhead 16
Largemouth Bass 19
Pumpkinseed 22
Yellow Perch 25
Members of the Family Salmonidae, Tiger Muskellunge, Grass Carp, and Other Non-game Fish 26

Warmwater Enhancement Options 29
Change Existing Fishing Rules to Alter Size Structure of Largemouth Bass 30
Make Provisions to Prevent Escape of Grass Carp and Tiger Muskellunge 31
Conduct Follow-up Fisheries Surveys 31

Literature Cited 32

List of Tables

Table 1. Length categories for cold- and warmwater fish species used to calculate stock density indices (PSD and RSD; Gabelhouse 1984) of fish captured at South Lewis County Regional Park Pond (Lewis County) during 1996 and 1997 4

Table 2. Mean catch per unit effort (# fish/hour) for stock-size warmwater fishes sampled from western Washington lakes while electrofishing during 1997 and 1998 (Scott Bonar, WDFW, unpublished data) 5

Table 3. Stock density index ranges for largemouth bass and bluegill under three commonly implemented management strategies (from Willis et al. 1993) 6

Table 4. Mean stock density indices for warmwater fishes sampled from western Washington lakes during 1997 and 1998 (Scott Bonar, WDFW, unpublished data) 6

Table 5. Species composition by weight (kg) and number of fish captured at South Lewis County Regional Park Pond (Lewis County) during a spring 1996 survey of warmwater fish 8

Table 6. Species composition by weight (kg) and number of fish captured at South Lewis County Regional Park Pond (Lewis County) during a fall 1996 survey of warmwater fish 9

Table 7. Species composition by weight (kg) and number of fish captured at South Lewis County Regional Park Pond (Lewis County) during a fall 1997 survey of warmwater fish 9

Table 8. Catch per unit effort (number of fish/hour electrofishing) for stock-size warmwater fish, salmonids and non-game fish collected from South Lewis County Regional Park Pond (Lewis County) while electrofishing during 1996 and 1997 10

Table 9. Traditional stock density indices for warmwater fishes collected from South Lewis County Regional Park Pond (Lewis County) while electrofishing during 1996 and 1997 11

List of Figures

Figure 1. Map of South Lewis County Regional Park Pond (Lewis County) 1

Figure 2. Length frequency histogram of black crappie (n = 4) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996 11

Figure 3. Length frequency histogram of black crappie (n = 14) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997 11

Figure 4. Relationship between total length and relative weight (Wr) of black crappie sampled from South Lewis County Regional Park Pond during fall 1997 compared with means from up to 25 western Washington lakes and the national 75^{th} percentile 13

Figure 5. Length frequency histogram of bluegill (n = 16) sampled from South Lewis County Regional Park Pond while electrofishing during spring 1996 14

Figure 6. Relationship between total length and relative weight (Wr) of bluegill sampled from South Lewis County Regional Park Pond during spring 1996 compared with means from up to 25 western Washington lakes and the national 75^{th} percentile . . 14

Figure 7. Length frequency histogram of bluegill (n = 53) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996 15

Figure 8. Length frequency histogram of bluegill (n = 284) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997 15

Figure 9. Relationship between total length and relative weight (Wr) of bluegill sampled from South Lewis County Regional Park Pond during fall 1997 compared with means from up to 25 western Washington lakes and the national 75^{th} percentile . . 16

Figure 10. Length frequency histogram of brown bullhead (n = 3) sampled from South Lewis County Regional Park Pond while electrofishing during spring 1996. 16

Figure 11. Relationship between total length and relative weight (Wr) of brown bullhead sampled from South Lewis County Regional Park Pond during spring 1996 compared with means from up to 25 western Washington lakes and the national 75^{th} percentile 17

Figure 12. Length frequency histogram of brown bullhead (n = 9) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996. 17

Figure 13. Length frequency histogram of brown bullhead (n = 4) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997 18

Figure 14. Relationship between total length and relative weight (Wr) of brown bullhead sampled from South Lewis County Regional Park Pond during fall 1997 compared with means from up to 25 western Washington lakes and the national 75th percentile 18

Figure 15. Length frequency histogram of largemouth bass (n = 40) sampled from South Lewis County Regional Park Pond while electrofishing during spring 1996 19

Figure 16. Relationship between total length and relative weight (Wr) of largemouth bass sampled from South Lewis County Regional Park Pond during spring 1996 compared with means from up to 25 western Washington lakes and the national 75th percentile 20

Figure 17. Length frequency histogram of largemouth bass (n = 76) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996. 20

Figure 18. Length frequency histogram of largemouth bass (n = 688) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997. 21

Figure 19. Relationship between total length and relative weight (Wr) of largemouth bass sampled from South Lewis County Regional Park Pond during fall 1997 compared with means from up to 25 western Washington lakes and the national 75th percentile 21

Figure 20. Length frequency histogram of pumpkinseed (n = 17) sampled from South Lewis County Regional Park Pond while electrofishing during spring 1996 22

Figure 21. Relationship between total length and relative weight (Wr) of pumpkinseed sampled from South Lewis County Regional Park Pond during spring 1996 compared with means from up to 25 western Washington lakes and the national 75th percentile 23

Figure 22. Length frequency histogram of pumpkinseed (n = 12) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996 23

Figure 23. Length frequency histogram of pumpkinseed (n = 8) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997. 24

Figure 24. Relationship between total length and relative weight (Wr) of pumpkinseed sampled from South Lewis County Regional Park Pond during fall 1997 compared with means from up to 25 western Washington lakes and the national 75th percentile . . 24

Figure 25. Length frequency histogram of yellow perch (n = 9) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996. 25

Figure 26. Length frequency histogram of yellow perch (n = 120) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997. 26

Figure 27. Length frequency histogram of rainbow trout (n = 6) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997 27

Figure 28. Length frequency histogram of brown trout (n = 13) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997 27

Figure 29. Length frequency histogram of grass carp (n = 22) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996 28

Introduction and Background

South Lewis County Regional Park Pond (Figure 1) is a small body of water [surface area = 7.1 hectare (ha) or 17 acres] that lies within a severely sensitive aquifer recharge area of the Cowlitz River drainage basin. The pond is located just off the Cowlitz River, approximately 0.8 km south of the City of Toledo, Washington. Springs and subterranean flow from the river feed the pond, which is subject to periodic flooding. There are no outlets. Average annual rainfall in the area is 102 to 127 cm (40 – 50”). The shoreline environment is primarily urban. Historically, the pond was used as a gravel borrow pit by a local contractor. In 1987, Lewis County leased and purchased land around the pond [17.9 ha (43 acres) including the pond] in order to develop South Lewis County Regional Park. The park is open from March 1 through October 31; activities include fishing [the pond is stocked regularly with rainbow trout (*Oncorhynchus mykiss*) and brout trout (*Salmo trutta*)], swimming, and picnicking. The county maintains a public boat launch, fishing piers, a walking path, and various play areas.

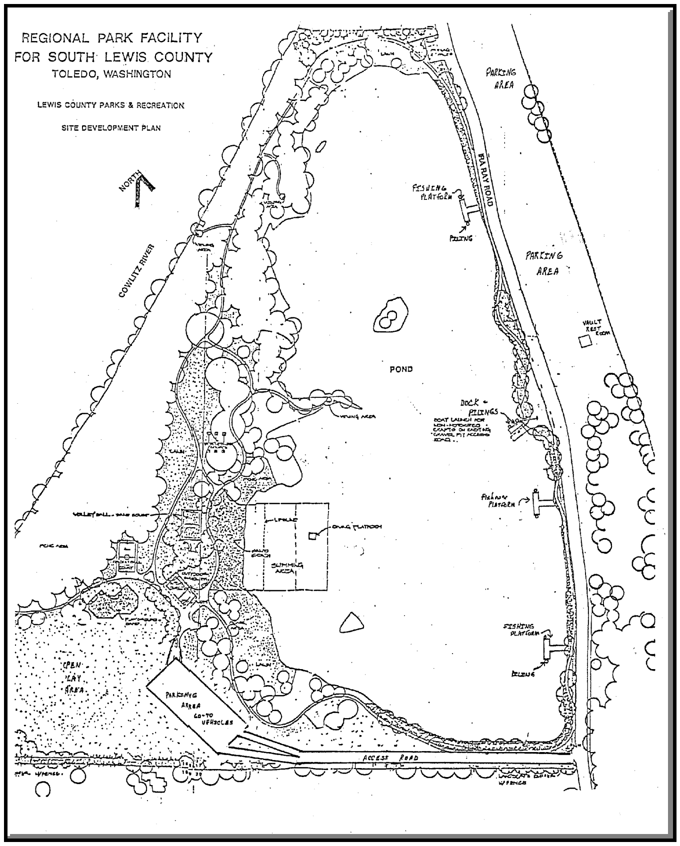

Figure 1. Map of South Lewis County Regional Park Pond (Lewis County).

During the 1990’s, the aquatic plant community of South Lewis County Regional Park Pond became dominated by invasive Eurasian watermilfoil (*Myriophyllum spicatum*). Other aquatic plants include native pondweeds (*Potamogeton* sp.) [Bill Wamsley, Lewis County Noxious Weed Control Board (NWCB), personal communication]. Concerns about the invasion of Eurasian watermilfoil led NWCB to explore management options available to control the errant vegetation. On August 7, 1995, the county settled on the use of sterile, triploid grass carp (*Ctenopharyngodon idella*) as a way of reducing the standing crop of Eurasian watermilfoil. Since the mid-1980’s, grass carp have been shown to be a cost-effective aquatic plant management tool in the Pacific Northwest (Pauley et al. 1994). In Washington, public satisfaction concerning the use of grass carp has been moderate to high (Bonar et al. 1996). Subsequently, on February 1, 1996, the Washington Department of Fish and Wildlife (WDFW) issued a permit to NWCB to stock up to 170 sterile, triploid grass carp into South Lewis County Regional Park Pond. On June 7, 1996, 100 grass carp ranging from 254 to 305 mm (10 – 12”) total length (TL) were released into the pond. Four months later, an additional 70 grass carp were released for a total stocking density of 24 fish/ha (10 fish/acre).

Beside aquatic vegetation problems, South Lewis County Regional Park Pond harbors populations of undesirable, non-game fish such as northern pikeminnow (*Ptychocheilus oregonensis*) and largescale sucker (*Catostomus macrocheilus*). Furthermore, warmwater species such as largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*) tend to overpopulate the pond resulting in crowded, stunted fish populations. It is unknown whether this is because of natural or anthropogenic factors. However, it is clear that adequate predation is lacking in order to control overproduction of the non-game and forage fish populations. Consequently, in 1996, biologists from WDFW recommended stocking a hybrid, apex predator - sterile, yearling tiger muskellunge (*Esox masquinongy* × *E. lucius*) - as a way of decreasing the number of non-game species and superabundant, small warmwater fishes (Jack Tipping, WDFW, personal communication). In May 1997 and each spring thereafter, 20 tiger muskellunge were released into the pond by WDFW hatchery personnel for a stocking density of 2.8 fish/ha (1.2 fish/acre). Each fish measured approximately 305 mm (12”) TL and weighed 114 g (1/4 lb).

If the introductions of grass carp and tiger muskellunge into South Lewis County Regional Park Pond are successful, the subsequent changes in the aquatic plant community and species composition of fishes will undoubtedly affect the sport fish community. Whether this impacts the fisheries of South Lewis County Regional Park Pond positively or negatively remains to be seen. Changes in the standing crop of aquatic plants can alter fish production (Wiley et al. 1984) as well as the structure of the fish community itself (Bettoli et al. 1993). Stocking predators can alter the size structure of stunted, prey fish populations (Boxrucker 1992), while a decrease in non-game fish numbers can restore a desirable sport fish community (Wingate 1986; Tipping 1996, 1999). For these reasons, it is important to gather baseline information and carefully review all proposals to limit or control aquatic vegetation and nuisance fish species for a given lake, especially when the lake supports popular fisheries. In an effort to assess its warmwater fish community, WDFW personnel conducted fisheries surveys at South Lewis County Regional Park Pond during spring and fall 1996, and again during fall 1997. Since it was gathered shortly after the introductions of grass carp and tiger muskellunge, the baseline information presented here will be useful when monitoring the long-term effects of these species at the pond.

Materials and Methods

South Lewis County Regional Park Pond was surveyed by a four-person team during the evenings of May 11 and October 8, 1996, and then again on the night of October 1, 1997. Fish were captured using a 5.5 m Smith-Root 5.0 GPP electrofishing boat set to pulsed DC at 120 Hz and 3 to 4 amps power. Sampling occurred during evening hours to maximize the type and number of fish captured. Nighttime electrofishing occurred along the entire shoreline of the pond. In 1996, the survey teams made two trips around the pond each night, whereas in 1997, the team circled the pond only once. While electrofishing, the boat was maneuvered through the shallows (depth range: 0.2 - 1.5 m), adjacent to the shoreline, at a rate of 18.3 m/minute. On May 11, 1996, the team electrofished for 3,783 seconds (actual “pedal-down” time), on October 8, 1996, 4,000 seconds, and on October 1, 1997, 2,275 seconds.

All fish captured were identified to the species level. Except for common carp (*Cyprinus carpio*), largescale sucker, red-side shiner (*Richardsonius balteatus*), and chinook salmon (*Oncorhynchus tshawytscha*), each fish was measured to the nearest 1 mm and assigned to a 10-mm size class based on total length (TL). For example, a fish measuring 156 mm TL was assigned to the 150-mm size class for that species, a fish measuring 113 mm TL was assigned to the 110-mm size class, and so on. When possible, up to 10 fish from each size class were weighed to the nearest 1 g. However, if a sample included several hundred individuals of a given species, then a sub-sample ($n \geq 100$ fish) was measured and weighed while the remainder was counted overboard. The length frequency distribution of the sub-sample was then applied to the total number collected. Weights of individuals counted overboard were estimated using a simple linear regression of $\log_{10}$-length on $\log_{10}$-weight of fish from the sub-sample.

Data Analysis

Balancing predator and prey fish populations is the hallmark of warmwater fisheries management. According to Bennett (1962), the term ‘balance’ is used loosely to describe a system in which omnivorous forage fish or prey maximize food resources to produce harvestable-size stocks for fishermen 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 food supplies for various foraging niches (Ricker 1975; Kohler and Kelly 1991; Olson 1995). The balance and productivity of a fish community can also be addressed using such evaluations (Swingle 1950; Bennett 1962).

Species composition by weight (kg) was calculated as the weight of fish captured of a given species divided by the total weight of all fish captured × 100. The species composition by number was calculated as the number of fish captured of a given species divided by the total number of all fish captured × 100. Young-of-year or small juveniles are often not considered when analyzing species composition, as was the case in 1996, because large fluctuations in their numbers may distort results (Fletcher et al. 1993). For example, 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. However, many young-of-year and small juveniles would be subject to high mortality during their first winter (Chew 1974), resulting in a different size distribution the following year. Still, the presence of these fish in the system relates directly to fecundity and inter- and intraspecific competition at lower trophic levels (Olson et al. 1995). For these reasons, and since their relative contribution to the total biomass captured was small, we chose to include young-of-year and small juveniles when analyzing the 1997 species composition data.

The size structure of each species captured was evaluated by constructing a length frequency histogram (percent frequency of fish in a given size class). However, age and growth of warmwater fishes in South Lewis County Regional Park Pond were not evaluated.

Catch per unit effort (CPUE) by gear type was determined for all species (number of fish/hour electrofishing). Only stock size fish and larger were used to determine CPUE for warmwater species and rainbow trout, whereas CPUE for other salmonids and non-game fish were calculated for all sizes. Stock length, which varies by species (see Table 1 and discussion below), refers to the minimum size of fish having recreational value. Since it is standardized, CPUE is a useful index for comparing relative abundance of stocks between lakes. The CPUE values from this study were compared to the mean values from up to 12 western Washington warmwater lakes (Table 2) sampled during 1997 and 1998 (Scott Bonar, WDFW, unpublished data).

Table 1. Length categories for cold- and warmwater fish species used to calculate stock density indices (PSD and RSD; Gabelhouse 1984) of fish captured at South Lewis County Regional Park Pond (Lewis County) during 1996 and 1997. Measurements are minimum total lengths (mm) for each category (Anderson and Neumann 1996).

	Size				
Type of fish	**Stock**	**Quality**	**Preferred**	**Memorable**	**Trophy**
Black crappie	130	200	250	300	380
Bluegill	80	150	200	250	300
Brown bullhead [a]	130	200	280	360	430
Common carp [a]	280	410	530	660	840
Largemouth bass	200	300	380	510	630
Pumpkinseed	80	150	200	250	300
Rainbow trout	250	400	500	650	800
Yellow perch	130	200	250	300	380

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

Table 2. Mean catch per unit effort (# fish/hour) for stock-size warmwater fishes sampled from western Washington lakes while electrofishing during 1997 and 1998 (Scott Bonar, WDFW, unpublished data). Values in parentheses are number of lakes averaged. BBH = brown bullhead, BC = black crappie, BG = bluegill, LMB = largemouth bass, PS = pumpkinseed, and YP = yellow perch.

BBH	BC	BG	LMB	PS	YP
7.8 (10)	9.6 (4)	169.1 (7)	41.6 (12)	70.8 (11)	97.5 (8)

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

The relative stock density (RSD) of each warmwater fish species was examined using the five-cell model proposed by Gabelhouse (1984). In addition to stock and quality length, Gabelhouse (1984) introduced preferred, memorable, and trophy length categories (Table 1). Preferred length (45-55% of world-record length) refers to the minimum size fish anglers would prefer to catch when given a choice. Memorable length (59-64% of world-record length) refers to the minimum size fish most anglers remember catching, whereas trophy length (74-80% of world-record length) refers to the minimum size fish considered worthy of acknowledgment. Like PSD, RSD provides useful information regarding population dynamics, but is more sensitive to changes in year-class strength. RSD was calculated as the number of fish≥specified length/number of fish≥stock length × 100. For example, RSD P was the percentage of stock length fish that also were longer than preferred length, RSD M, the percentage of stock length fish that also were longer than memorable length, and so on.

Stock density indices have become important tools for assessing size structures of warmwater fish populations and developing management strategies for warmwater fisheries (Willis et al. 1993). Strategies commonly used in warmwater fisheries management include panfish, balanced predator-prey, and big bass options. The stock density index ranges for these options are listed in Table 3. The PSD and RSD values for species other than largemouth bass and bluegill can be compared loosely to the values below. The PSD and RSD values from this study were evaluated with the common management options in mind and compared to the mean values from up to 12 western Washington warmwater lakes sampled during 1997 and 1998 (Table 4) (Scott Bonar, WDFW, unpublished data).

Table 3. Stock density index ranges for largemouth bass and bluegill under three commonly implemented management strategies (from Willis et al. 1993). PSD = proportional stock density, whereas RSD = relative stock density of preferred length fish (RSD-P), and memorable length fish (RSD-M).

	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

Table 4. Mean stock density indices for warmwater fishes sampled from western Washington lakes during 1997 and 1998 (Scott Bonar, WDFW, 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 boat.

Species	Gear type	No. lakes	PSD	RSD-P	RSD-M	RSD-T
Black crappie	EB	3	5	0	0	0
Bluegill	EB	9	16	0	0	0
Brown bullhead	EB	3	11	2	0	0
Largemouth bass	EB	12	29	13	0	0
Pumpkinseed	EB	12	8	0	0	0
Yellow perch	EB	12	20	2	0	0

A relative weight (W_r) index was used to evaluate the condition of all species except non-game fish and chinook salmon. A W_r value of 100 generally indicates that a fish is in good condition when compared to the national standard (75th percentile) for that species. Furthermore, W_r is useful for comparing the condition of different size groups within a single population to determine if all sizes are finding adequate forage or food (ODFW 1997). Following Murphy and Willis (1991), the index was calculated as $W_r = W/W_s \times 100$, where W is the weight (g) of an individual fish and W_s is the standard weight of a fish of the same total length (mm). W_s is calculated from a standard $\log_{10}$weight-$\log_{10}$length relationship defined for the species of interest. The parameters for the W_s equations of many cold- and warmwater fish species, including the minimum length recommendations for their application, are listed in Anderson and Neumann (1996). With the exception of non-game fish and chinook salmon, 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).

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. Standard transformation failed to normalize the length data when testing the statistical significance of the relationship between total length and relative weight. Moreover, no assumptions were made that relationships would be linear. We therefore used a nonparametric 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

Largemouth bass and sunfish (*Lepomis* sp.) comprised over 75% of the biomass and number of fish captured at South Lewis County Regional Park Pond during all sample periods. Brown bullhead (*Ameiurus nebulosus*) accounted for less than 11% of the biomass and number captured, whereas black crappie (*Pomoxis nigromaculatus*) comprised less than 4%. Apparently, the yellow perch (*Perca flavescens*) population expanded during the study period (Tables 5, 6, and 7). Species other than the warmwater variety comprised less than 13% of the number captured. Of these, common carp and largescale sucker were dominant in spring 1996 (Table 5), grass carp were dominant in fall 1996 (Table 6), while trout and largescale sucker were dominant in fall 1997 (Table 7). Differences between sample periods can probably be attributed to seasonal influences and dip netting or gear-related biases between survey crews (Pope and Willis 1996). For example, severe winter flooding of the Cowlitz River resulted in the presence of chinook salmon in the system during spring 1996, while survey personnel noted the presence of, but did not capture or count, several common carp and largescale sucker during the same period (Table 5) (Jack Tipping, WDFW, personal communication).

Table 5. Species composition by weight (kg) and number of fish captured at South Lewis County Regional Park Pond (Lewis County) during a spring 1996 survey of warmwater fish.

	Species composition				
	by weight		by number		
Type of fish	(kg)	(%)	(#)	(%)	Size range (mm TL)
Black crappie (*Pomoxis nigromaculatus*)	0.082	1.30	1	1.20	185
Bluegill (*Lepomis macrochirus*)	0.468	7.44	16	19.28	82 – 148
Brown bullhead (*Ameiurus nebulosus*)	0.542	8.62	3	3.61	228 - 258
Chinook salmon (*Oncorhynchus tshawytscha*)	---	---	2	2.41	Not recorded
Common carp (*Cyprinus carpio*) [a]	---	---	---	---	---
Largemouth bass (*Micropterus salmoides*)	4.754	75.59	40	48.19	130 - 445
Largescale sucker (*Catostomus macrocheilus*) [a]	---	---	---	---	---
Northern pikeminnow (*Ptychocheilus oregonensis*)	---	---	2	2.41	Not recorded
Pumpkinseed (*Lepomis gibbosus*)	0.443	7.04	17	20.48	82 - 135
Red-side shiner (*Richardsonius balteatus*)	---	---	2	2.41	Not recorded
Total	6.289		83		

[a] Rolled several while electrofishing, but none captured, weighed or measured.

Table 6. Species composition by weight (kg) and number of fish captured at South Lewis County Regional Park Pond (Lewis County) during a fall 1996 survey of warmwater fish.

Type of fish	Species composition by weight (kg)	(%)	by number (#)	(%)	Size range (mm TL)
Black crappie (*Pomoxis nigromaculatus*)	0.469	3.64	4	2.14	147 - 234
Bluegill (*Lepomis macrochirus*)	0.959	7.44	53	28.34	60 - 122
Brown bullhead (*Ameiurus nebulosus*)	1.307	10.14	9	4.81	184 - 242
Grass carp (*Ctenopharyngodon idella*)	---	---	22	11.76	260 - 392
Largemouth bass (*Micropterus salmoides*)	9.337	72.45	76	40.64	80 - 463
Northern pikeminnow (*Ptychocheilus oregonensis*)	---	---	2	1.07	170 - 248
Pumpkinseed (*Lepomis gibbosus*)	0.388	3.01	12	6.42	72 - 182
Yellow perch (*Perca flavescens*)	0.423	3.32	9	4.81	73 - 186
Total	12.888		187		

Table 7. Species composition by weight (kg) and number of fish captured at South Lewis County Regional Park Pond (Lewis County) during a fall 1997 survey of warmwater fish.

Type of fish	Species composition by weight (kg)	(%)	by number (#)	(%)	Size range (mm TL)
Black crappie (*Pomoxis nigromaculatus*)	0.186	1.29	14	1.21	90 – 118
Bluegill (*Lepomis macrochirus*)	5.922	41.16	284	24.52	38 – 164
Brown bullhead (*Ameiurus nebulosus*)	0.569	3.95	4	0.34	216 – 235
Brown trout (*Salmo trutta*)	---	---	13	1.12	207 – 245
Common carp (*Cyprinus carpio*)	---	---	6	0.52	Not recorded
Largemouth bass (*Micropterus salmoides*)	5.167	35.91	688	59.41	50 – 252
Largescale sucker (*Catostomus macrocheilus*)	---	---	12	1.04	Not recorded
Pumpkinseed (*Lepomis gibbosus*)	0.226	1.57	8	0.69	77 - 128
Rainbow trout (*Oncorhynchus mykiss*)	0.806	5.60	6	0.52	214 - 247
Tiger muskellunge (*Esox masquinongy* × *E. lucius*)	0.786	5.46	3	0.26	~ 380
Yellow perch (*Perca flavescens*)	0.726	5.05	120	10.36	64 - 120
Total	14.388		1,158		

CPUE

During spring 1996, catch rates were highest for stock-size pumpkinseed (*Lepomis gibbosus*), bluegill, and to a lesser degree, largemouth bass. Yet the CPUE values (# fish/hour) for these species (16.2, 15.2, and 5.7, respectively; Table 8) were far below the western Washington averages for stock-size pumpkinseed (70.8), bluegill (169.1), and largemouth bass (41.6) (Table 2). The catch rates for stock-size brown bullhead (2.8) and black crappie (1.0) (Table 8) were below average (7.8 and 9.6, respectively; Table 2) as well. During fall 1996, catch rates were highest for stock-size bluegill (38.7), and to a lesser degree, grass carp (19.8) and stock-size largemouth bass (18.0). Still, the CPUE values for warmwater species, including stock-size yellow perch (Table 8), were below average (Table 2). During fall 1997, the catch rate for stock-size bluegill increased greatly to 314.9 fish/hour (Table 8). This value far exceeded the western Washington average for the species (Table 2). Besides bluegill, catch rates were fairly high for brown trout and largescale sucker; however, the CPUE value for stock-size yellow perch decreased to 0 (Table 8).

Table 8. Catch per unit effort (number of fish/hour electrofishing) for stock-size warmwater fish, salmonids and non-game fish collected from South Lewis County Regional Park Pond (Lewis County) while electrofishing during 1996 and 1997.

	Sample period		
	Spring 1996	Fall 1996	Fall 1997
Type of fish	# fish/hour electrofishing	# fish/hour electrofishing	# fish/hour electrofishing
Black crappie	1.0	3.6	0
Bluegill	15.2	38.7	314.9
Brown bullhead	2.8	8.1	6.3
Brown trout	None observed	None observed	20.6
Chinook salmon	1.9	None observed	None observed
Common carp	Several rolled	None observed	9.5
Grass carp	Not yet stocked	19.8	None observed
Largemouth bass	5.7	18.0	3.2
Largescale sucker	Several rolled	None observed	19.0
Northern pikeminnow	1.9	1.8	None observed
Pumpkinseed	16.2	9.9	11.1
Rainbow trout	None observed	None observed	0
Red-side shiner	1.9	None observed	None observed
Tiger muskellunge	Not yet stocked	Not yet stocked	4.7
Yellow perch	None observed	6.3	0

Stock Density Indices

Very few quality-size warmwater fish were captured during spring and fall 1996 (Table 9). Although PSD values for largemouth bass were low, the fish captured were of preferred length. PSD values for black crappie (25) and brown bullhead (44 - 67) were high when compared to the western Washington averages for the species (5 and 11, respectively; Table 4). However, these 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). Except for bluegill and brown bullhead, no quality-size fish were captured during fall 1997 (Table 9).

Table 9. Traditional stock density indices for warmwater fishes collected from South Lewis County Regional Park Pond (Lewis County) while electrofishing during 1996 and 1997. PSD = proportional stock density, whereas RSD = relative stock density of preferred length fish (RSD-P), memorable length fish (RSD-M), and trophy length fish (RSD-T).

Type of fish	Sample period	# Stock length fish	PSD	RSD-P	RSD-M	RSD-T
Black crappie	Spring 1996	1	0	0	0	0
	Fall 1996	4	25	0	0	0
	Fall 1997	0	0	0	0	0
Bluegill	Spring 1996	16	0	0	0	0
	Fall 1996	43	0	0	0	0
	Fall 1997	199	7	0	0	0
Brown bullhead	Spring 1996	3	67	0	0	0
	Fall 1996	9	44	0	0	0
	Fall 1997	4	50	0	0	0
Largemouth bass	Spring 1996	6	17	17	0	0
	Fall 1996	20	15	15	0	0
	Fall 1997	2	0	0	0	0
Pumpkinseed	Spring 1996	17	0	0	0	0
	Fall 1996	11	9	0	0	0
	Fall 1997	7	0	0	0	0
Yellow perch	Spring 1996	0	0	0	0	0
	Fall 1996	7	0	0	0	0
	Fall 1997	0	0	0	0	0

Black Crappie

Only one black crappie was captured during spring 1996. The fish measured 185 mm TL and weighed 82 g (Table 5). Its relative weight was 89, which was below the national standard (100) and western Washington average (106) for the species. During fall 1996, four black crappie were captured measuring 147 to 234 mm TL each (Table 6, Figure 2); however, the fish were not weighed. Fourteen black crappie were captured during fall 1997. The fish ranged from 90 to 118 mm TL (Table 7, Figure 3); their relative weights were consistent with or above the national standard and western Washington averages for the species (Figure 4).

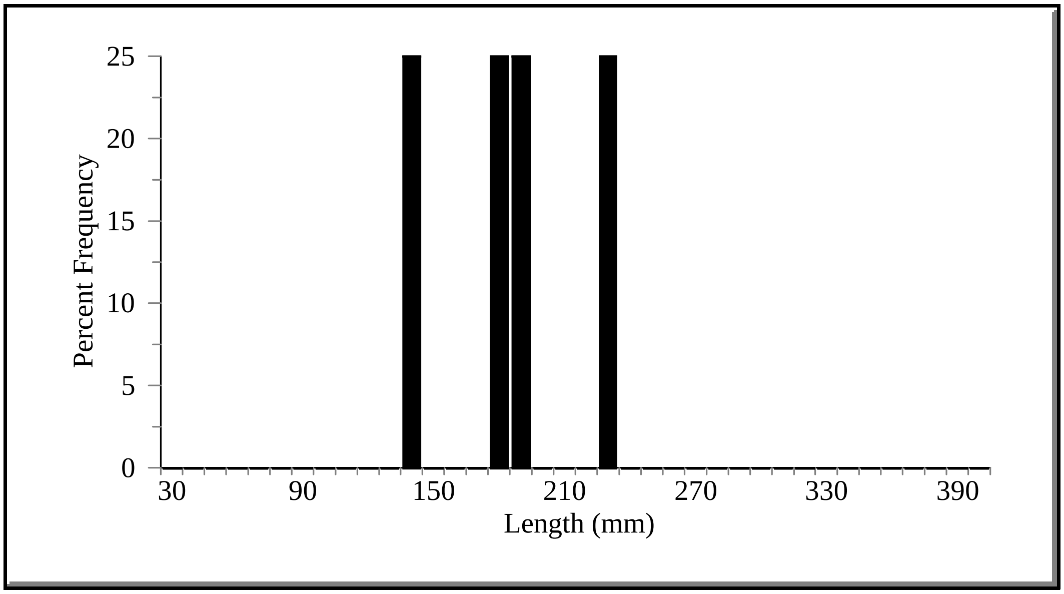

Figure 2. Length frequency histogram of black crappie (n = 4) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996.

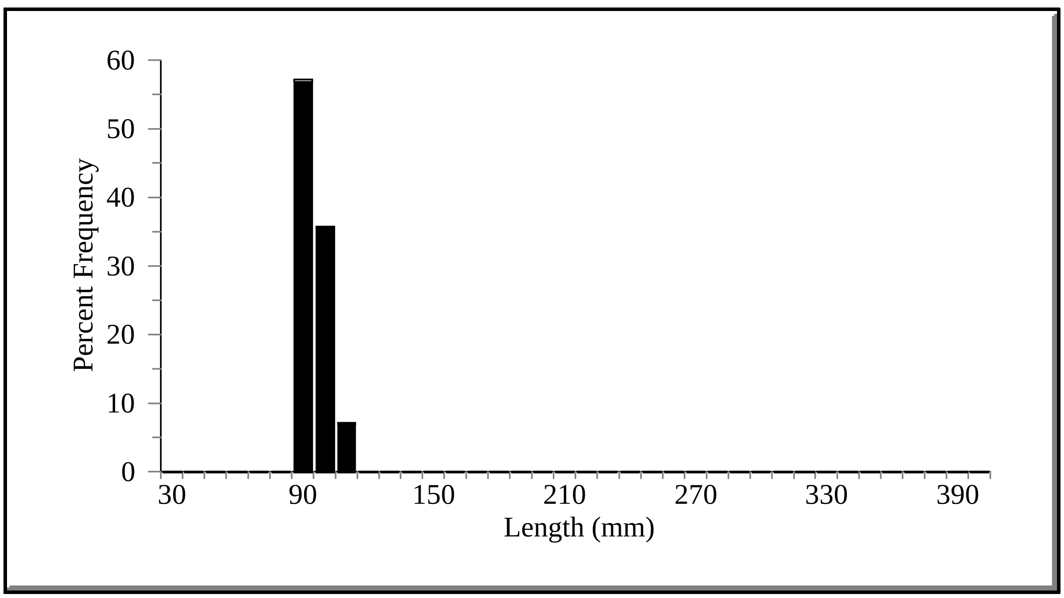

Figure 3. Length frequency histogram of black crappie (n = 14) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997.

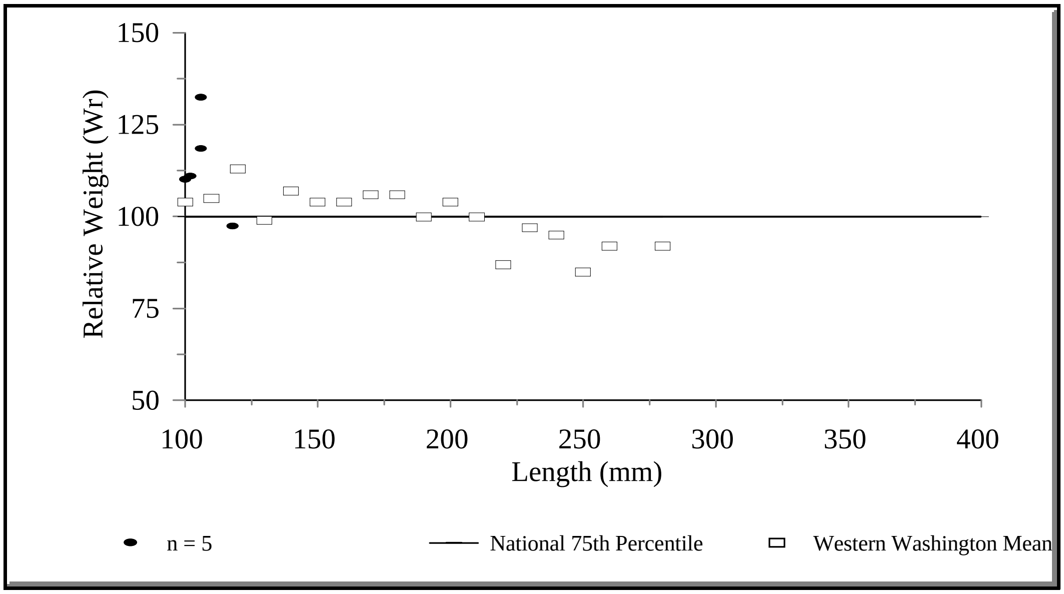

Figure 4. Relationship between total length and relative weight (Wr) of black crappie sampled from South Lewis County Regional Park Pond during fall 1997 compared with means from up to 25 western Washington lakes and the national 75th percentile.

Bluegill

During spring 1996, South Lewis County Regional Park Pond bluegill ranged from 82 to 148 mm TL (Table 5, Figure 5). The relative weights of these fish (Figure 6) were consistent with or above the national standard and western Washington averages for the species and decreased with size [Spearman correlation coefficient (Rho) for total length and relative weight = −0.451, p = 0.079]. By fall 1996, their length frequency distribution had shifted somewhat toward smaller fish measuring 60 to 122 mm TL (Table 6, Figure 7). During fall 1997, a much greater number and wider size range (38 to 164 mm TL) of fish were captured (Table 7, Figure 8). Their relative weights decreased with size [Spearman correlation coefficient (Rho) for total length and relative weight = −0.205, p = 0.011], and were generally well below the national standard and western Washington averages for the species (Figure 9).

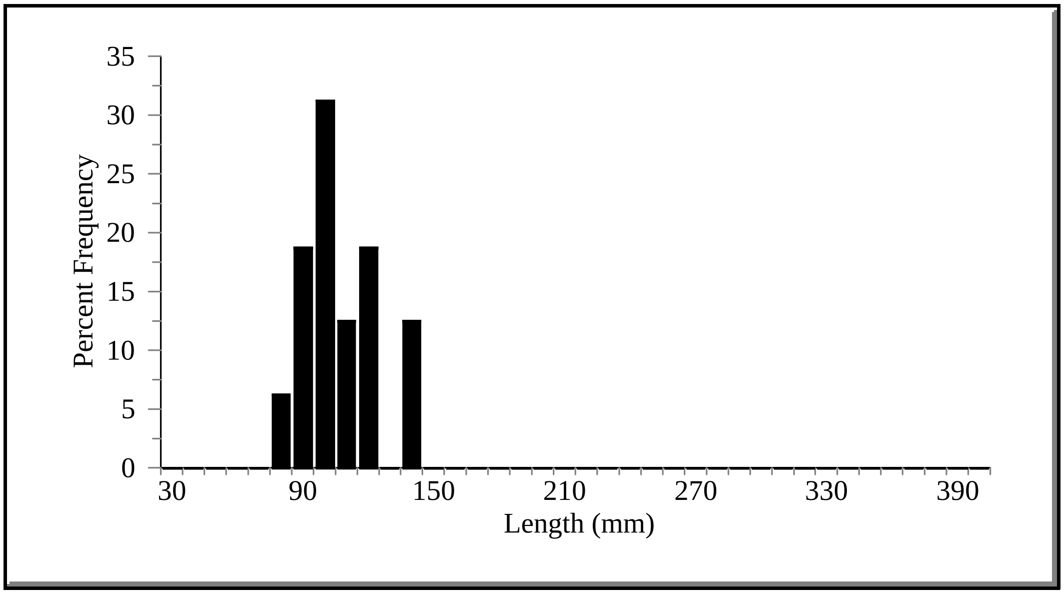

Figure 5. Length frequency histogram of bluegill (n = 16) sampled from South Lewis County Regional Park Pond while electrofishing during spring 1996.

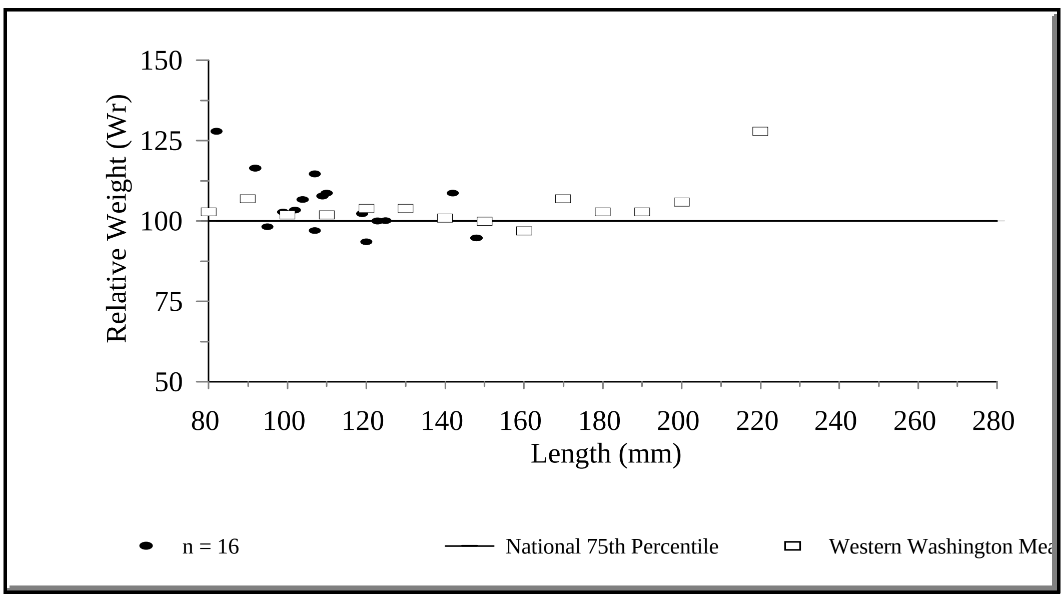

Figure 6. Relationship between total length and relative weight (Wr) of bluegill sampled from South Lewis County Regional Park Pond during spring 1996 compared with means from up to 25 western Washington lakes and the national 75th percentile.

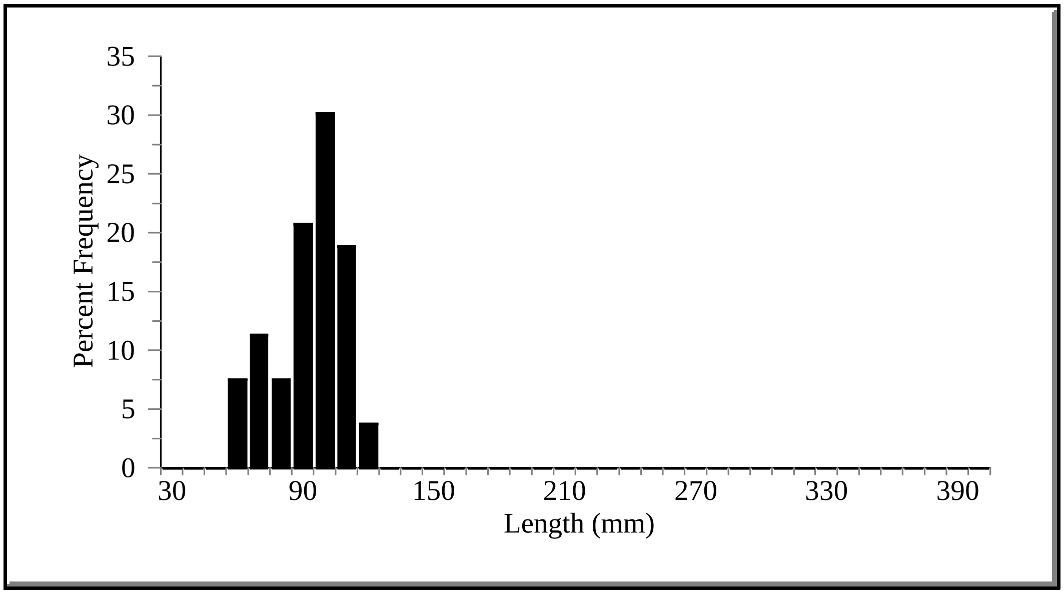

Figure 7. Length frequency histogram of bluegill (n = 53) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996.

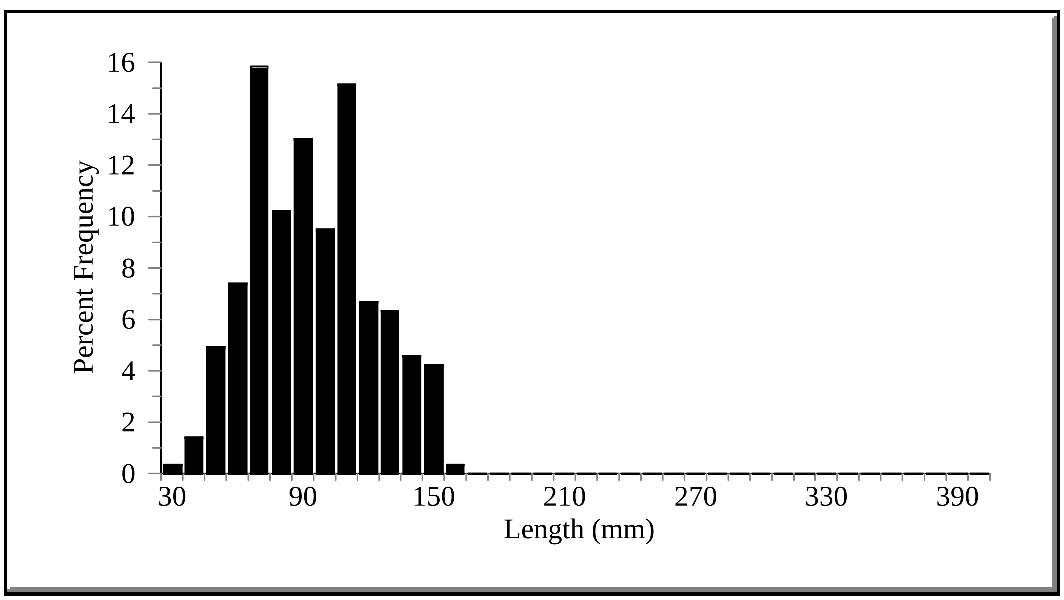

Figure 8. Length frequency histogram of bluegill (n = 284) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997.

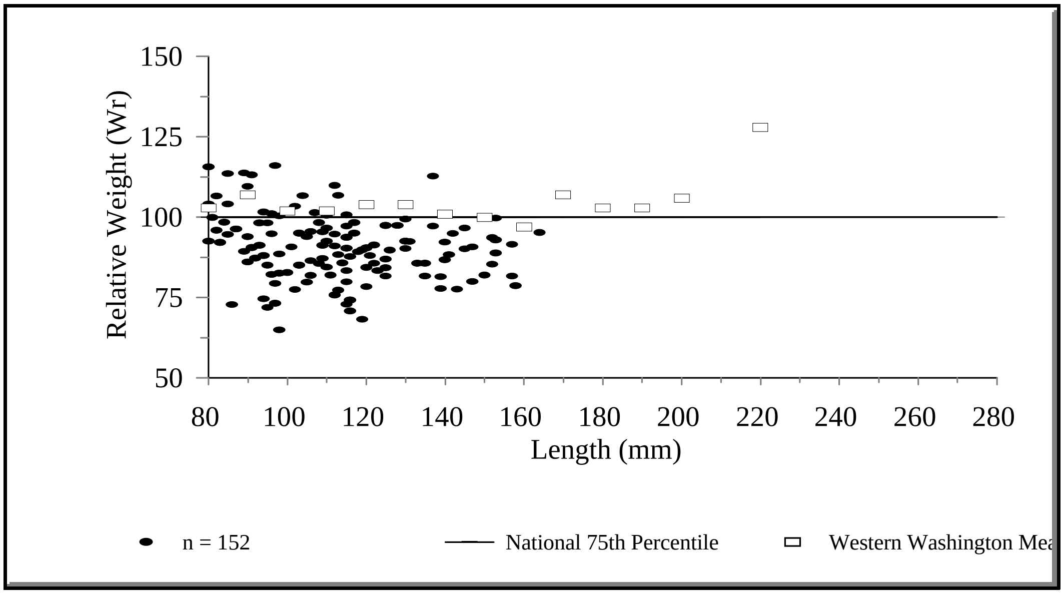

Figure 9. Relationship between total length and relative weight (Wr) of bluegill sampled from South Lewis County Regional Park Pond during fall 1997 compared with means from up to 25 western Washington lakes and the national 75th percentile.

Brown Bullhead

Most of the brown bullhead from South Lewis County Regional Park Pond were of quality-size and measured between 210 and 240 mm TL. Their size structures varied little between sampling periods (Figures 10, 12, and 13). However, the relative weights of fish from spring 1996 and fall 1997 were below the national standard for the species (Figures 11 and 13).

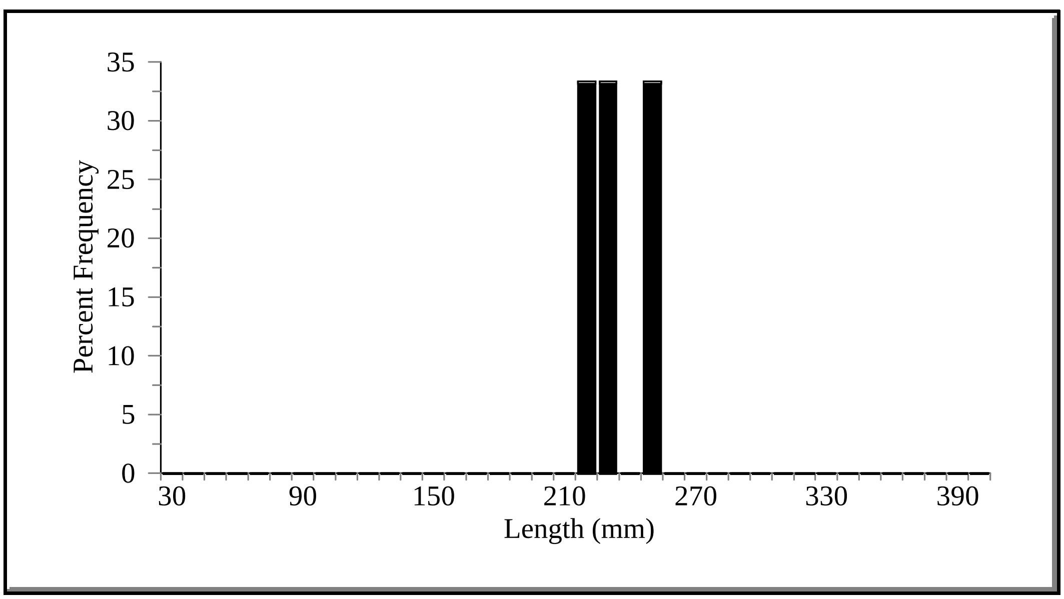

Figure 10. Length frequency histogram of brown bullhead (n = 3) sampled from South Lewis County Regional Park Pond while electrofishing during spring 1996.

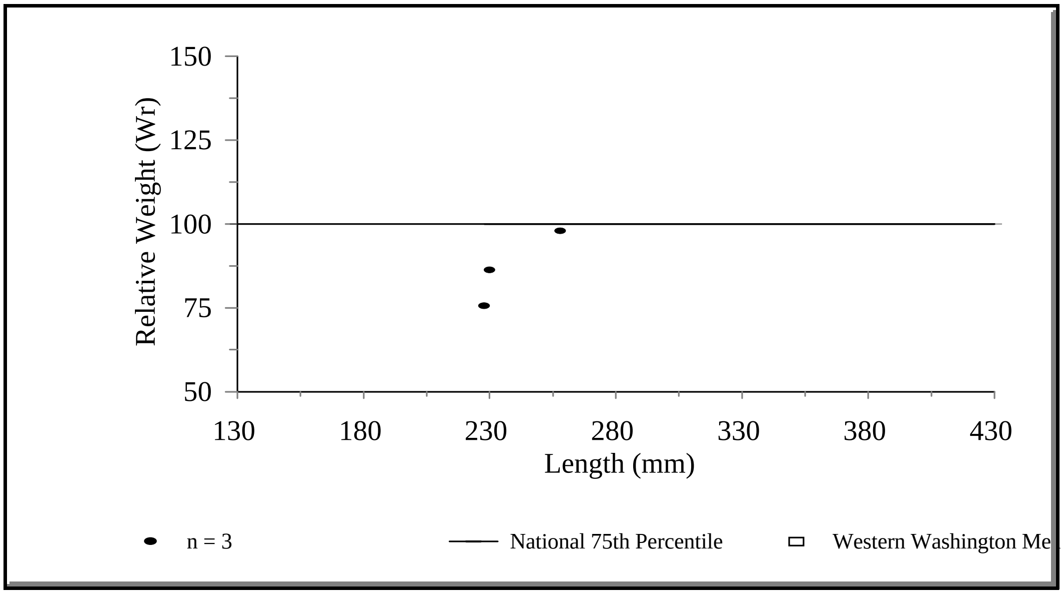

Figure 11. Relationship between total length and relative weight (Wr) of brown bullhead sampled from South Lewis County Regional Park Pond during spring 1996 compared with means from up to 25 western Washington lakes and the national 75th percentile.

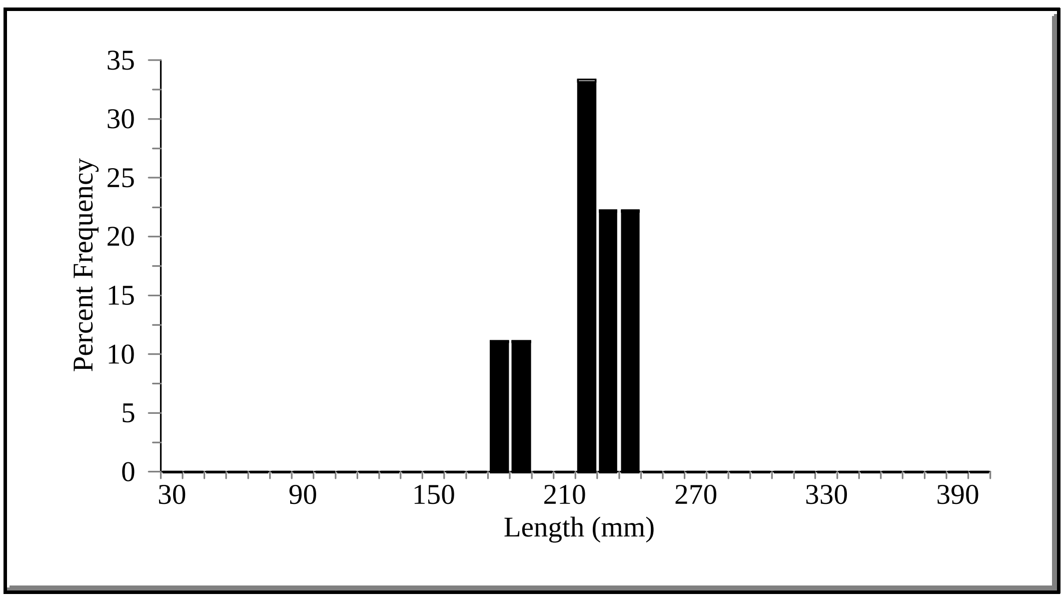

Figure 12. Length frequency histogram of brown bullhead (n = 9) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996.

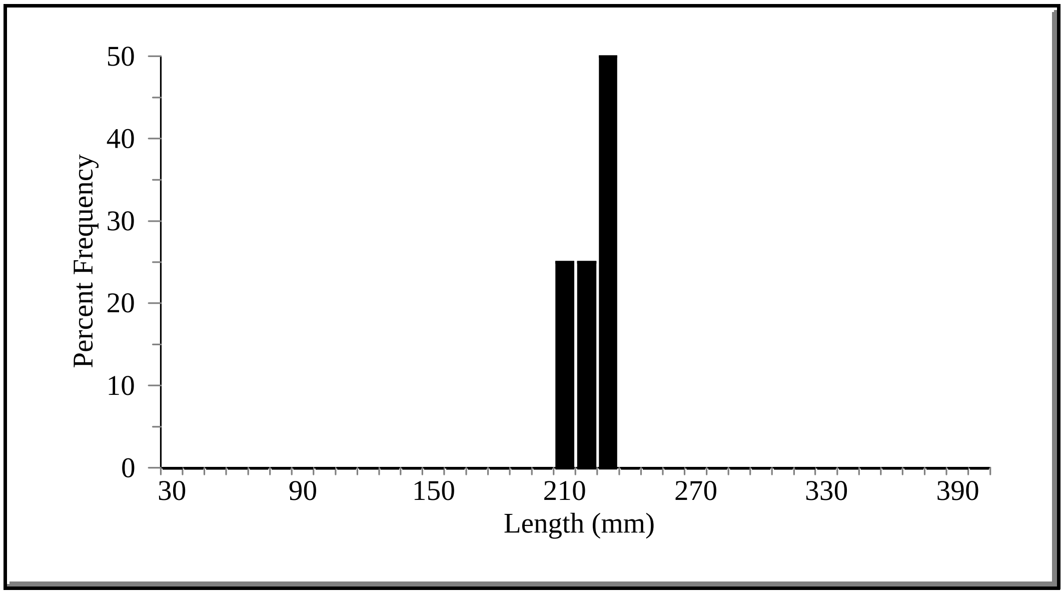

Figure 13. Length frequency histogram of brown bullhead (n = 4) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997.

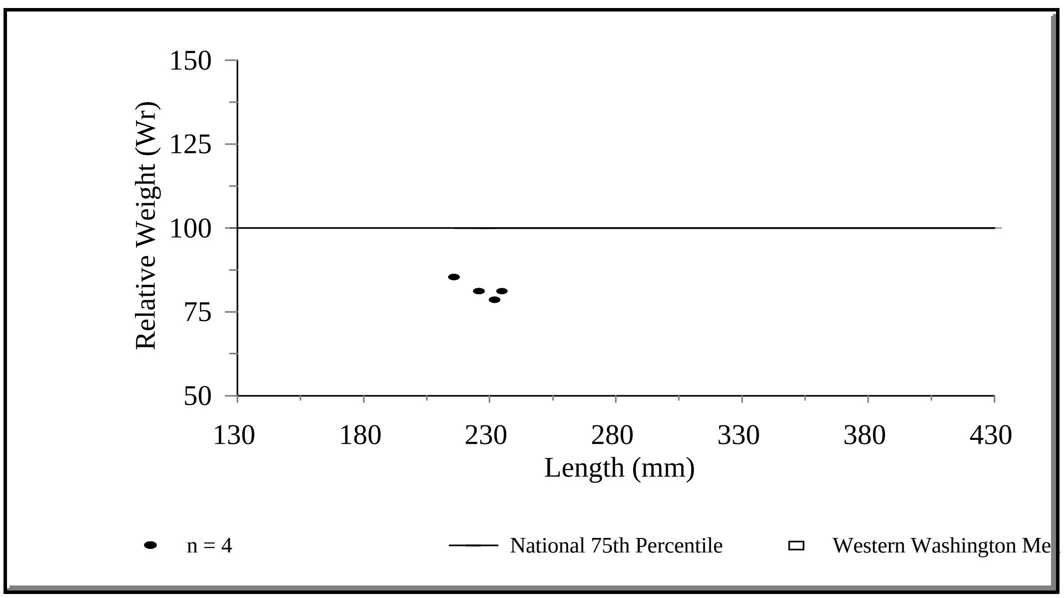

Figure 14. Relationship between total length and relative weight (Wr) of brown bullhead sampled from South Lewis County Regional Park Pond during fall 1997 compared with means from up to 25 western Washington lakes and the national 75th percentile.

Largemouth Bass

During spring 1996, largemouth bass ranged from 130 to 445 mm TL (Table 5), but their lengths were skewed toward smaller size classes (Figure 15). The relative weights of largemouth bass increased with size [Spearman correlation coefficient (Rho) for total length and relative weight = 0.529, p = 0.003] and were consistent with the national standard and western Washington averages for the species (Figure 16). By fall 1996, the size structure of largemouth bass was more evenly distributed (Figure 17) with lengths ranging from 80 to 463 mm TL (Table 6). However, during fall 1997, a much greater number but narrower size range (50 to 252 mm TL) of fish were captured consisting mostly of small juveniles (Table 7, Figure 18). Moreover, the relative weights of the two stock-size largemouth bass captured were below the national standard and western Washington averages for the species (Figure 19).

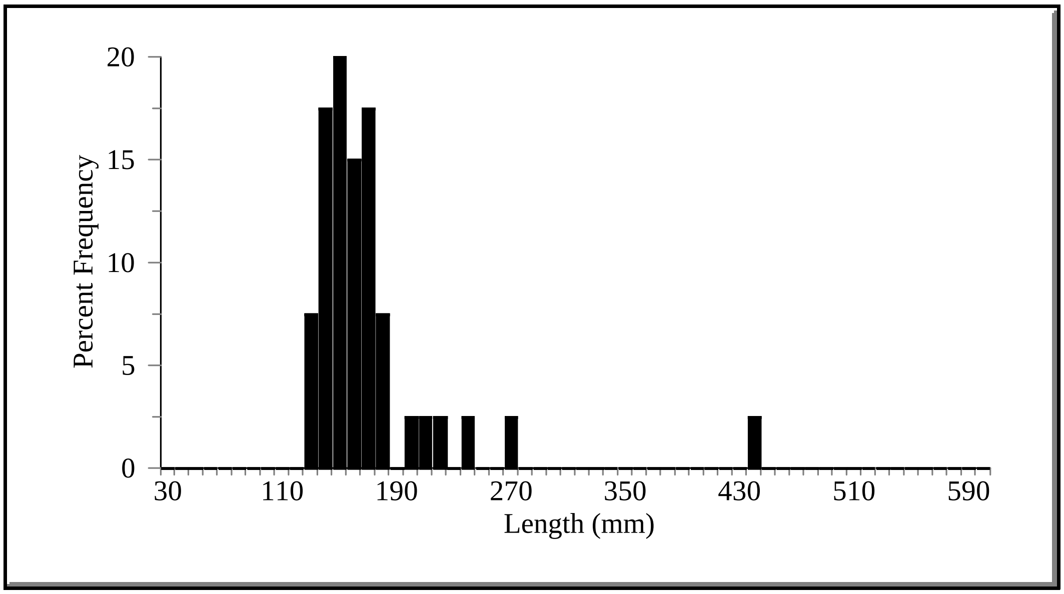

Figure 15. Length frequency histogram of largemouth bass (n = 40) sampled from South Lewis County Regional Park Pond while electrofishing during spring 1996.

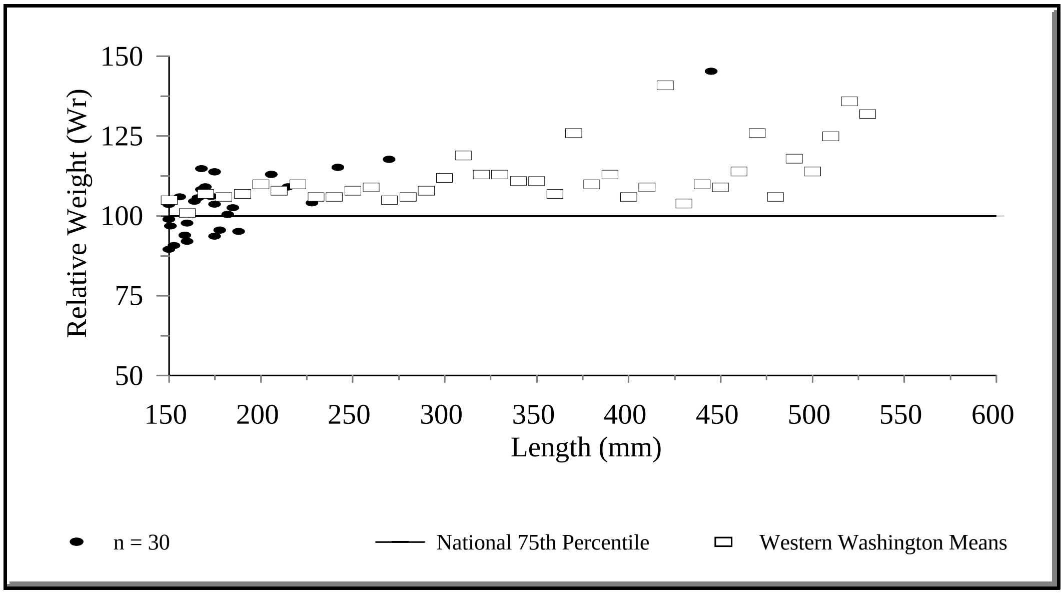

Figure 16. Relationship between total length and relative weight (Wr) of largemouth bass sampled from South Lewis County Regional Park Pond during spring 1996 compared with means from up to 25 western Washington lakes and the national 75th percentile.

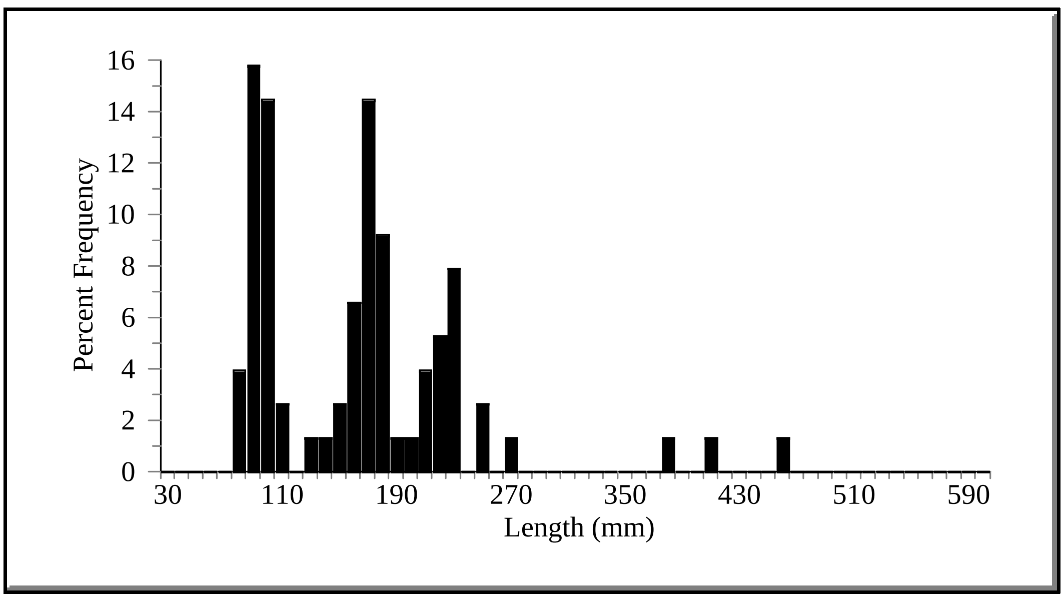

Figure 17. Length frequency histogram of largemouth bass (n = 76) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996.

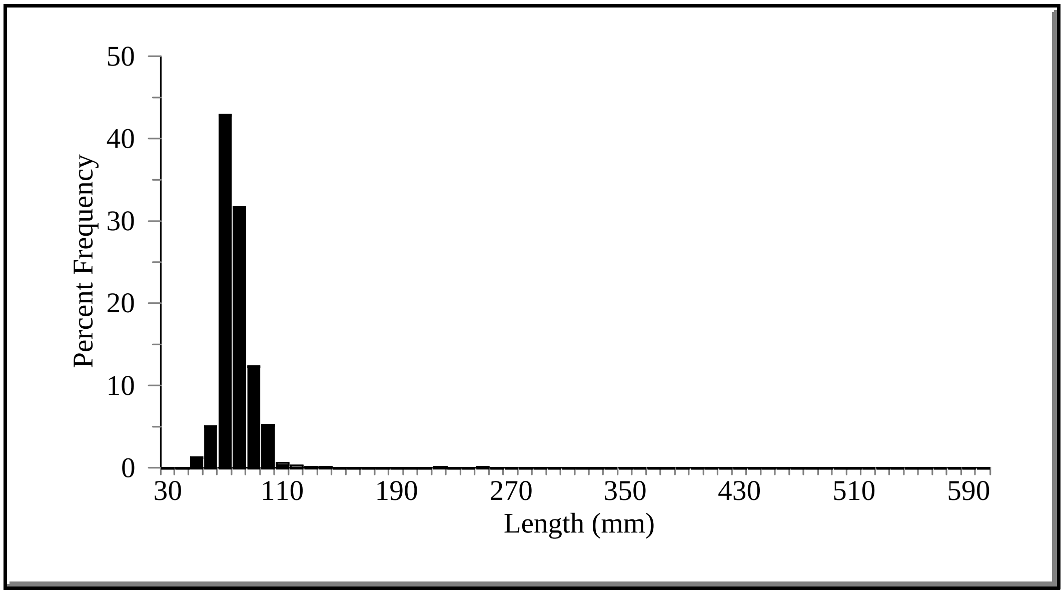

Figure 18. Length frequency histogram of largemouth bass (n = 688) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997.

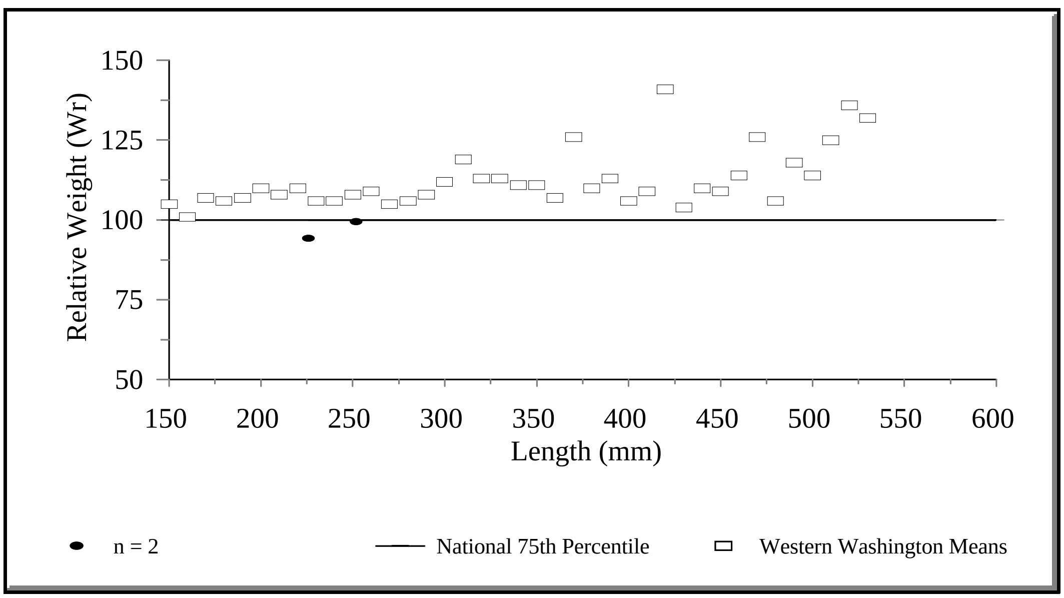

Figure 19. Relationship between total length and relative weight (Wr) of largemouth bass sampled from South Lewis County Regional Park Pond during fall 1997 compared with means from up to 25 western Washington lakes and the national 75th percentile.

Pumpkinseed

During spring 1996, the pumpkinseed of South Lewis County Regional Park Pond ranged from 82 to 135 mm TL, most of which were in the 90-mm size class (Table 5, Figure 20). Their relative weights were generally below the western Washington averages for the species, yet above the national standard (Figure 21). The Spearman correlation coefficient (Rho) for total length and relative weight was 0.175 with p = 0.501. During fall 1996, the length frequency distribution of pumpkinseed favored the 100-mm size class, with fish measuring 72 to 182 mm TL (Table 6, Figure 22). By fall 1997, the size structure shifted again toward larger fish (~ 120 mm TL). However, their relative weights decreased with size [Spearman correlation coefficient (Rho) for total length and relative weight = −0.245, p = 0.558] and were below the western Washington averages and national standard for the species (Figures 23 and 24).

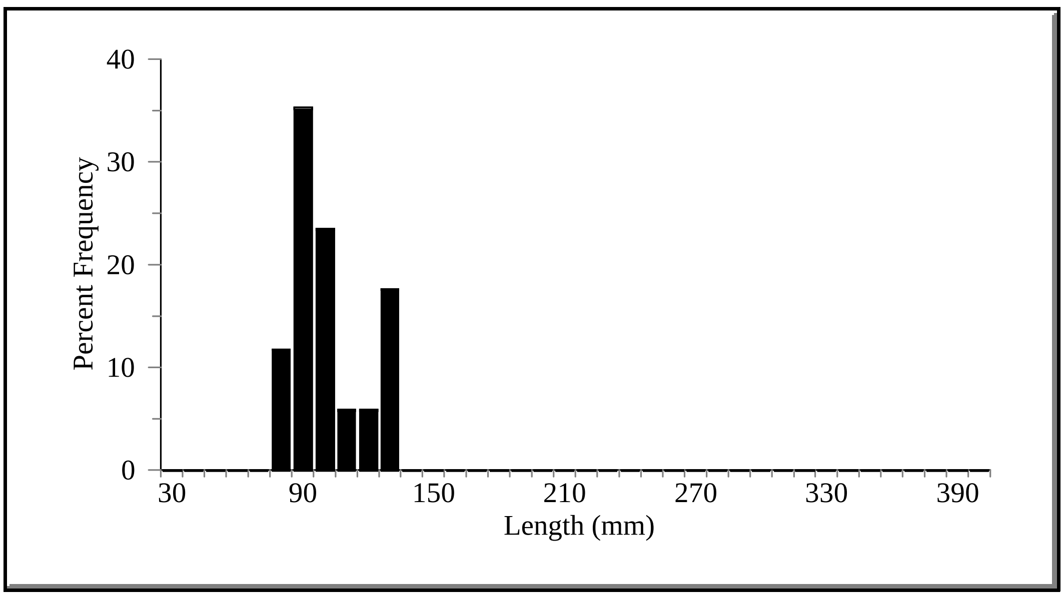

Figure 20. Length frequency histogram of pumpkinseed (n = 17) sampled from South Lewis County Regional Park Pond while electrofishing during spring 1996.

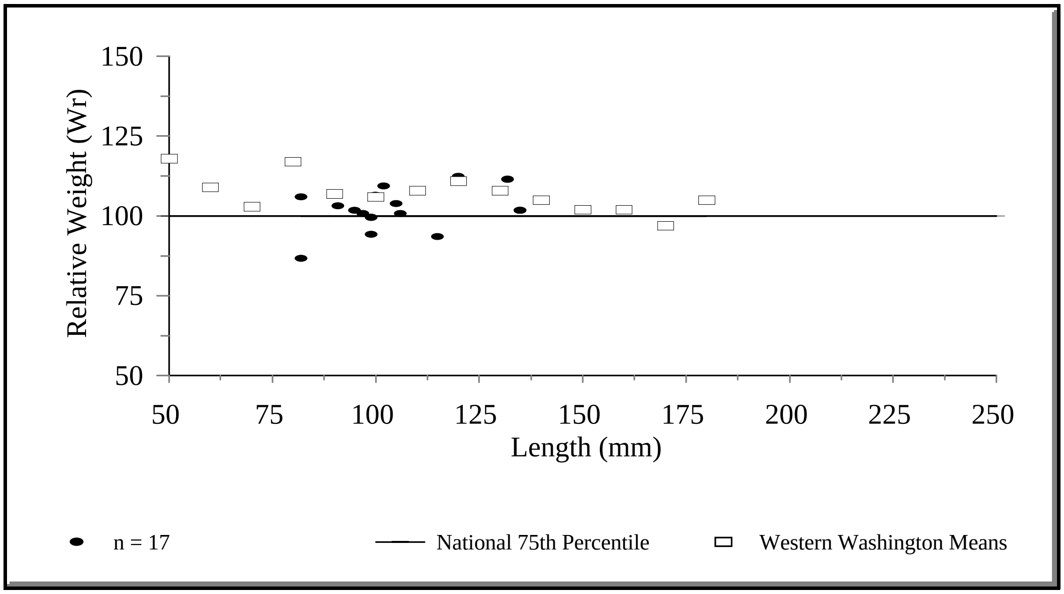

Figure 21. Relationship between total length and relative weight (Wr) of pumpkinseed sampled from South Lewis County Regional Park Pond during spring 1996 compared with means from up to 25 western Washington lakes and the national 75th percentile.

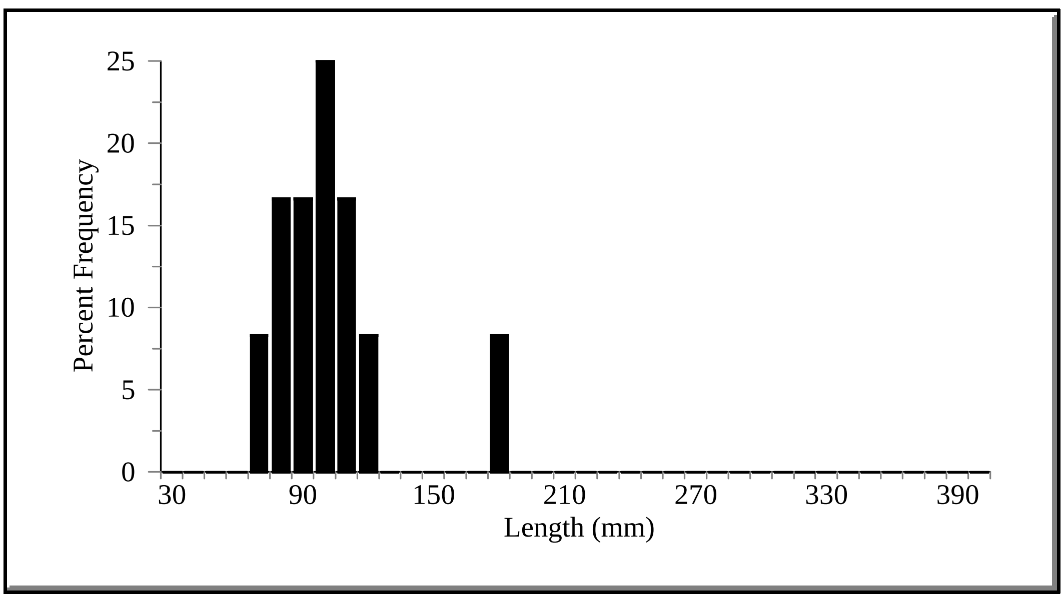

Figure 22. Length frequency histogram of pumpkinseed (n = 12) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996.

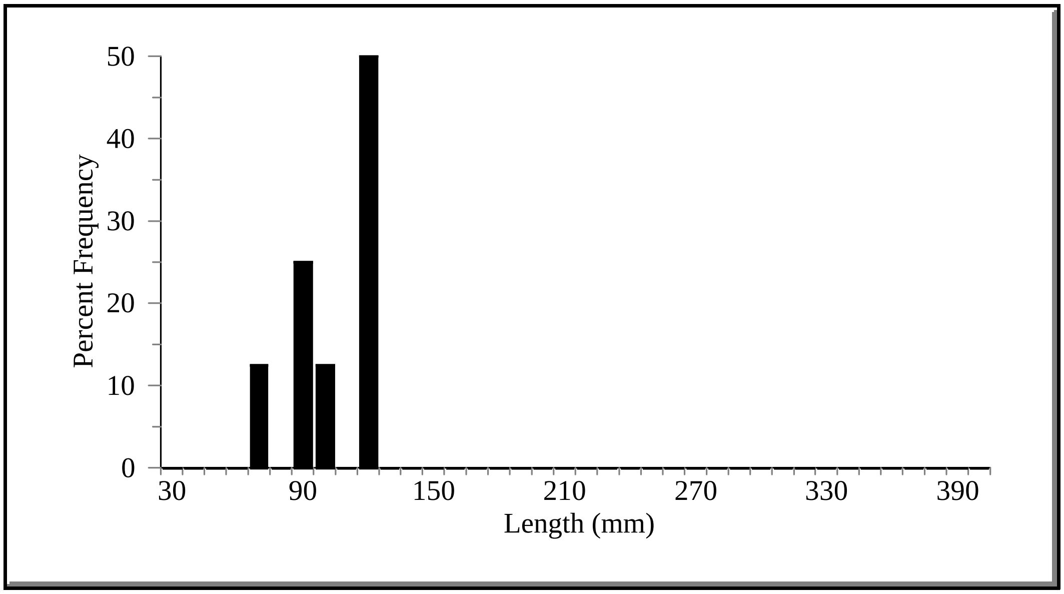

Figure 23. Length frequency histogram of pumpkinseed (n = 8) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997.

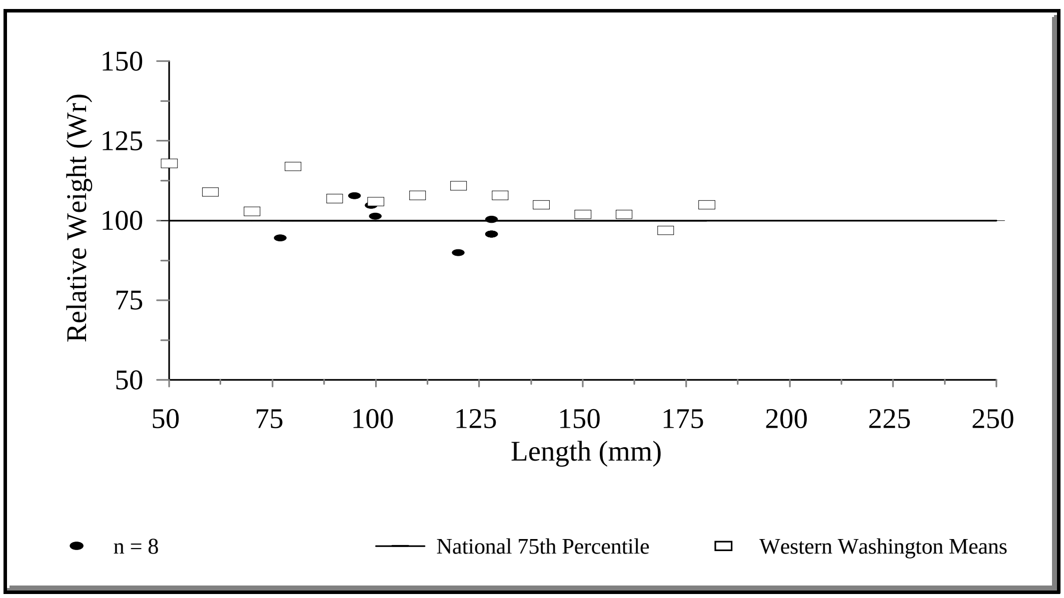

Figure 24. Relationship between total length and relative weight (Wr) of pumpkinseed sampled from South Lewis County Regional Park Pond during fall 1997 compared with means from up to 25 western Washington lakes and the national 75th percentile.

Yellow Perch

Yellow perch were not observed during spring 1996. During fall 1996, nine fish were captured measuring 73 to 186 mm TL, yet no weights were recorded. Seven of these fish were stock-size (≥ 130 mm TL). At least two age classes were evident from the length frequency histogram (Figure 25). Several dozen yellow perch were captured during fall 1997 that measured only 64 to 120 mm TL (Figure 26). These fish comprised 10% of the catch by number but only 5% by weight (Table 7).

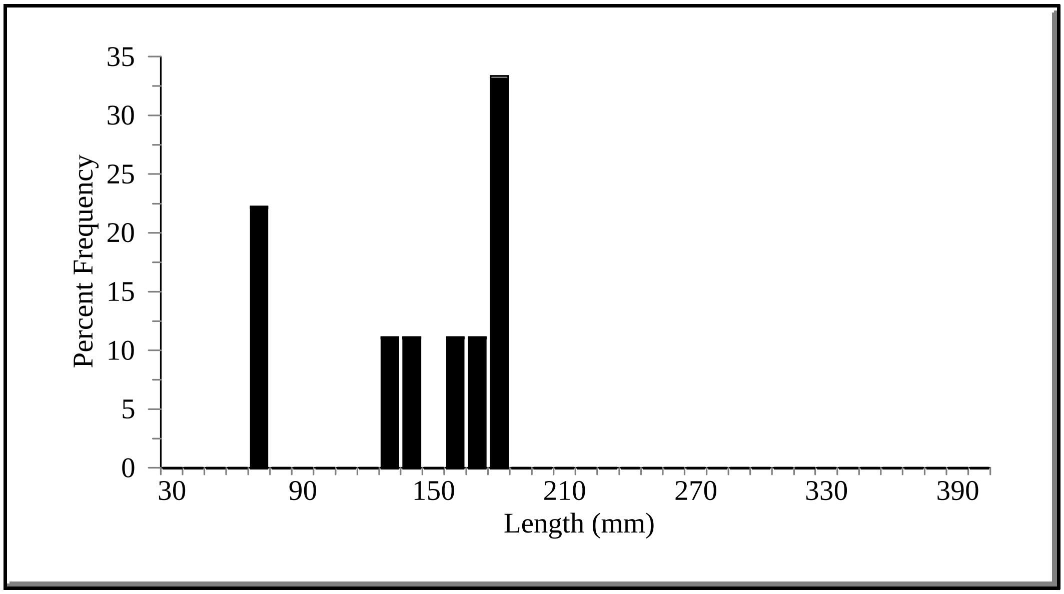

Figure 25. Length frequency histogram of yellow perch (n = 9) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996.

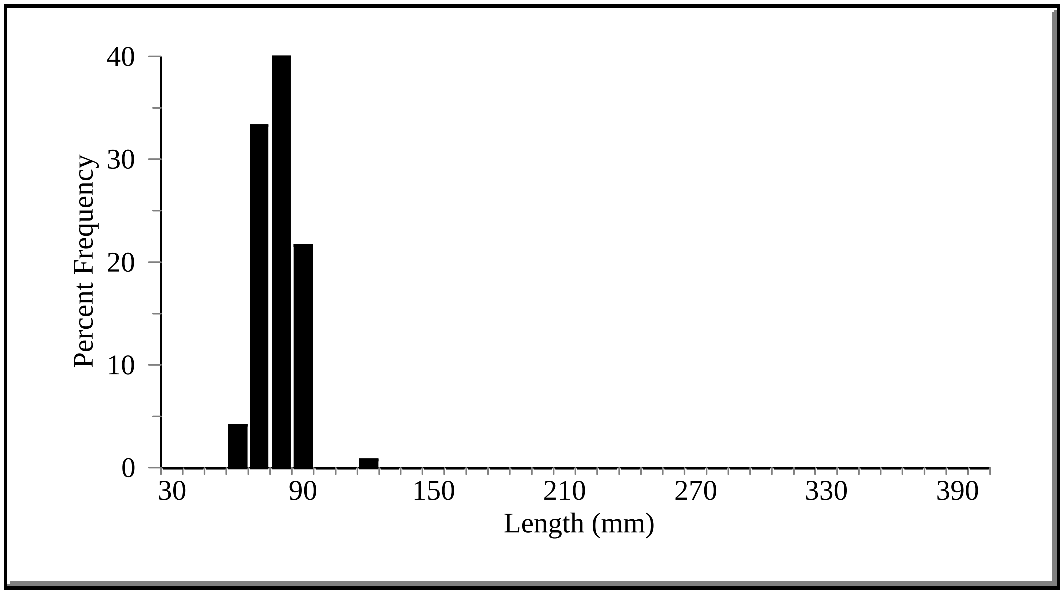

Figure 26. Length frequency histogram of yellow perch (n = 120) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997.

Members of the Family Salmonidae, Tiger Muskellunge, Grass Carp, and Other Non-game Fish

WDFW releases several thousand hatchery-stock trout into South Lewis County Regional Park Pond for its annual put-and-take fishery. During 1996, no trout were observed or recorded; however, two chinook salmon were captured during spring 1996, their presence the result of severe winter flooding of the Cowlitz River. During fall 1997, both rainbow and brown trout were sampled (Table 7). The rainbow trout measured 214 to 247 mm TL (Figure 27), whereas the brown trout measured 207 to 245 mm TL (Figure 28). Their size at release is typically 178 to 305 mm TL.

Three tiger muskellunge were captured during fall 1997, but only one was successfully landed, measured (380 mm TL), and weighed (262 g). All three fish were roughly the same size. The captured fish had a relative weight of 86, which was below the national 75th percentile for the species. Still, given the mean length (~ 305 mm) and weight (~ 114 g) at stocking, the tiger muskellunge apparently doubled its weight and increased its length by 25% over the summer.

Shortly after their release into the pond during fall 1996, 22 grass carp were captured that measured 260 to 392 mm TL (Figure 29). The sample was a mix of both summer and fall releases. Given the original stocking size of 254 to 305 mm TL, the two largest fish (370 and 392 mm TL) apparently increased their lengths by at least 25% between releases. No biological information was gathered on the other non-game species.

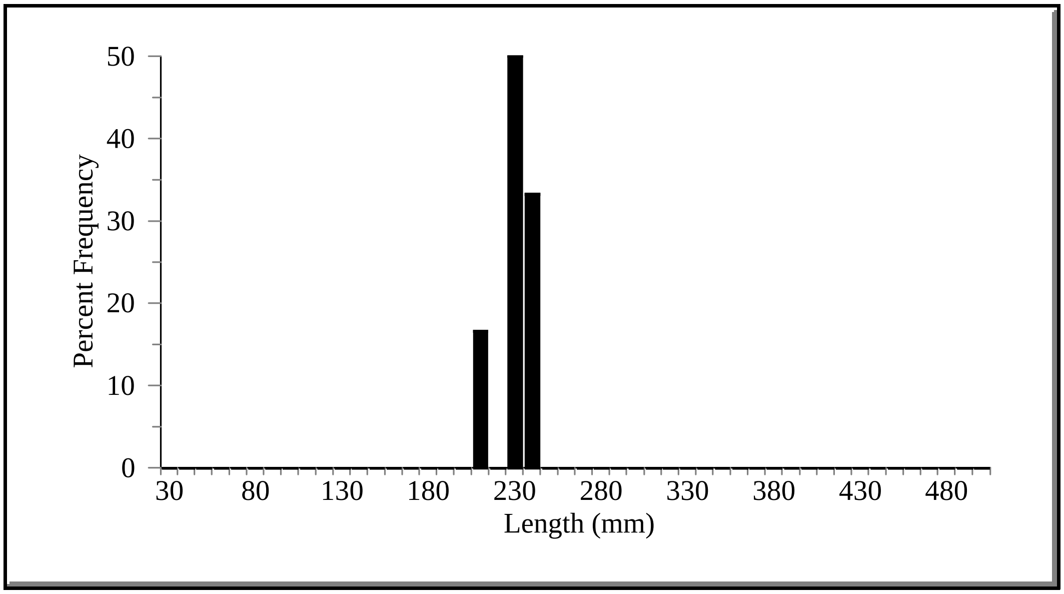

Figure 27. Length frequency histogram of rainbow trout (n = 6) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997.

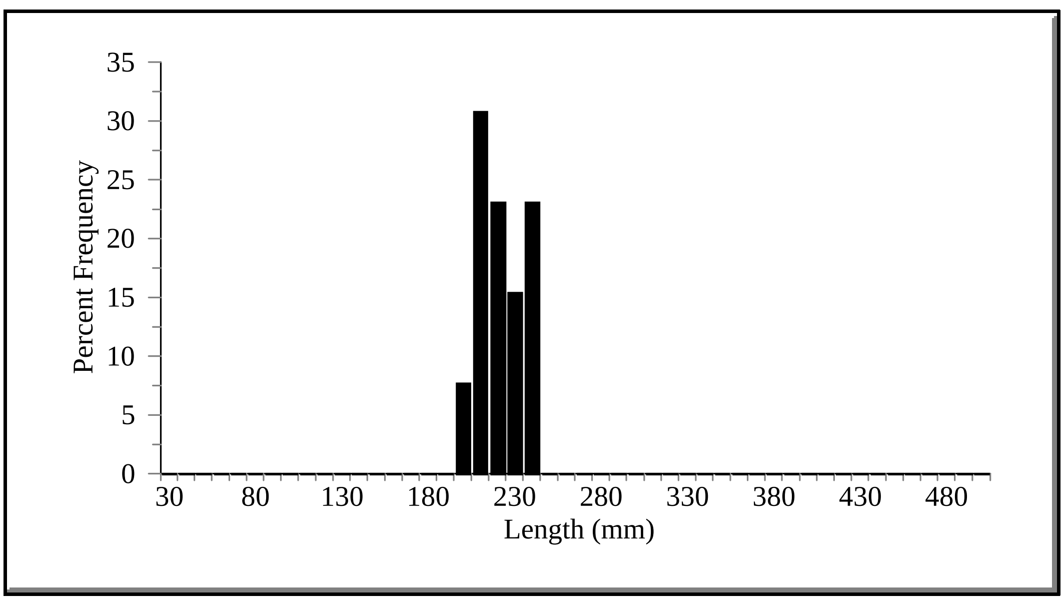

Figure 28. Length frequency histogram of brown trout (n = 13) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1997.

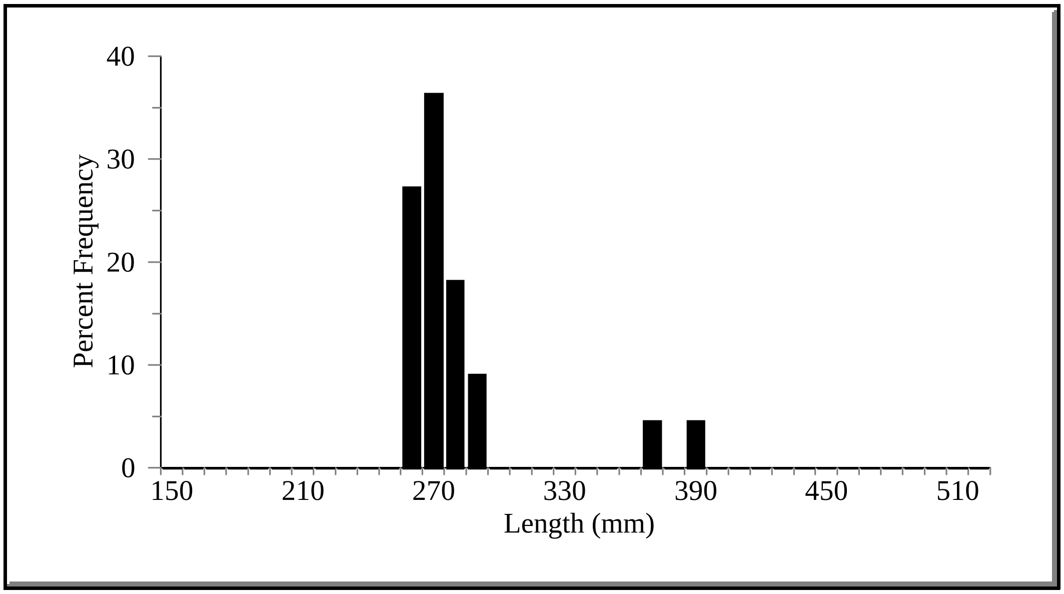

Figure 29. Length frequency histogram of grass carp (n = 22) sampled from South Lewis County Regional Park Pond while electrofishing during fall 1996.

Warmwater Enhancement Options

A diverse, thriving aquatic plant community is essential for the well-being of many warmwater fish species, which are more likely to be found in areas with aquatic plants than in areas without them (Killgore et al. 1989). Submersed aquatic vegetation provides important foraging, refuge, and spawning habitat (see review by Willis et al. 1997), improving survival and recruitment to harvestable sizes (Durocher et al. 1984). Changes in the standing crop of aquatic plants can alter fish production (Wiley et al. 1984) as well as the structure of the fish community itself (Bettoli et al. 1993). Most researchers agree that a low or moderate level of aquatic vegetation is better than no vegetation or too much (Savino and Stein 1982; Durocher et al. 1984; Wiley et al. 1984; Killgore et al. 1989; Davies and Rwangano 1991). For example, Wiley et al. (1984) showed a positive correlation between the concentration of aquatic plants and the production of both epiphytic invertebrates and forage fish such as bluegill, whereas largemouth bass production was reduced at both high and low concentrations of aquatic plants.

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

The size structures observed at South Lewis County Regional Park Pond suggest that the warmwater fishes were not able to forage effectively, possibly due to dense vegetation, overcrowding, or competition with the dominant bluegill and juvenile largemouth bass. Indeed, Hoyer and Canfield (1996) showed an inverse relationship between macrophyte abundance and growth of one- and two-year old largemouth bass. As macrophyte density increases, predator foraging efficiency decreases because of increased refuge available to prey. The increased survival of prey leads to greater population density (crowding) and more competition among these fish (Olson et al. 1998 and references therein). Thus, crowding leads to slow growth and stunted fish populations (Swingle 1956). This was evident in the largemouth bass and bluegill populations at South Lewis County Regional Park Pond.

Beside stocking grass carp to increase foraging efficiency of warmwater fishes at South Lewis County Regional Park Pond, stocking tiger muskellunge should provide some control of undesirable, non-game fish (Wingate 1986; Tipping 1996, 1999) that compete directly or indirectly with sport fish for resources within the pond. Furthermore, increased predation of forage fish and juvenile largemouth bass should allow the remaining fish to realize their full growth potential. This technique has been used with varied degrees of success for years (Bennett 1962; Noble 1981; Newman and Storck 1986; Wahl and Stein 1988; Boxrucker 1992; Bolding et al. 1997). Although tiger muskellunge prefer fusiform, soft-rayed prey, such as cyprinids or catostomids, over deep-bodied, spiny-rayed prey, such as centrarchids, they generally fare well irrespective of the forage base (Tomcko et al. 1984; Newman and Storck 1986; Wahl and Stein 1988; Kohler and Kelly 1991; Tipping 1996, 1999). Moreover, tiger muskellunge grow rapidly in Washington (Hillson and Tipping 1999). Therefore, in addition to improving balance, stocking tiger muskellunge may also provide a trophy fishing opportunity at South Lewis County Regional Park Pond (Adair 1986; Storck and Newman 1992; Tipping 1996). Other management strategies that might improve the warmwater fishery at the pond include, but are not limited to, the following:

Change Existing Fishing Rules to Alter Size Structure of Largemouth Bass

Currently, South Lewis County Regional Park Pond anglers are allowed to harvest five largemouth bass daily, including no more than three over 381 mm (15") TL. The PSD and RSD-P values of largemouth bass (Table 9) suggest that an unbalanced condition exists in the pond (Table 3; Willis et al. 1993). Changes in the size structure of largemouth bass, possibly due to the dense stands of Eurasian watermilfoil, may require implementing corrective length and bag limits on largemouth bass (*sensu* Willis 1989) to restore balance in the pond.

Implementing a 305 – 432 mm (12 – 17") slot limit for largemouth bass might succeed where the current rule failed. The main objective of a slot limit is to improve the size structure of largemouth bass. Under this rule, only fish less than 305 or greater than 432 mm TL may be kept. Decreasing the creel limit from three fish over 381 mm TL to one fish over 432 mm TL would stimulate harvest of small fish while still protecting large fish. A reduction of small fish may improve growth and production of predator and prey species alike (McHugh 1990).

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

Make Provisions to Prevent Escape of Grass Carp and Tiger Muskellunge

One of the prerequisites of stocking grass carp in Washington is the construction of barriers that prevent the migration of fish out of the lake or pond in which they were originally released (Loch and Bonar 1997). Similar requirements exist for stocking tiger muskellunge. However, the hydrography of South Lewis County Regional Park Pond precludes the need for such conditions: there are no inlets or outlets at the pond. Still, some provisions must be made in order to prevent the escape of grass carp and tiger muskellunge from the pond, especially given the periodic flooding that occurs in the area. For example, the pond lies within a severe aquifer discharge area; its elevation changes with the elevation of the Cowlitz River. In February 1996, raging floodwaters broke through the dike between the Cowlitz River and South Lewis County Regional Park causing severe damage to park facilities while inundating the pond (Mackey 1996). Furthermore, in January 1997, heavy rainfall led nearby Salmon Creek to swell, which swamped South Lewis County Regional Park and caused the pond to overflow (Bill Wamsley, NWCB, personal communication). The likelihood of fish escaping during one of these episodes is high, a risk that must be weighed by Lewis County officials if the grass carp and tiger muskellunge stocking programs are to continue. The existing barrier should be inspected and, if necessary, modified to prevent migration of fish during high water periods.

Conduct Follow-up Fisheries Surveys

If the introductions of grass carp and tiger muskellunge into South Lewis County Regional Park Pond are successful, the subsequent changes in the aquatic plant community and species composition of fishes will undoubtedly affect the sport fish community. Whether this impacts the fisheries of South Lewis County Regional Park Pond positively or negatively remains to be seen. Our results provide some baseline information necessary to monitor the long-term effects of grass carp herbivory and tiger muskellunge predation at South Lewis County Regional Park Pond. However, without follow-up study, any impacts from the introductions of these species will remain enigmatic.

Literature Cited

Adair, B.C. 1986. Tiger muskellunge as a trophy species in Iowa lakes. Page 343 *in* Hall, G.E. (ed.), Managing Muskies. American Fisheries Society, Special Publication 15, Bethesda, MD.

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

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

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

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.

Bolding, B., S.A. Bonar, M. Divens, D. Fletcher, and E. Anderson. 1997. Stocking walleye to improve growth and reduce abundance of overcrowded panfish in a small impoundment. Washington Department of Fish and Wildlife, Research Report No. RAD97-05, 27 p.

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

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

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

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

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

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

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

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

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

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

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.

Hillson, T.D., and J.M. Tipping. 1999. Lewis River Hatchery complex fish biologist annual report for 1998. Washington Department of Fish and Wildlife, Technical Report No. 99-7, 30 p.

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

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

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

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

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

Mackey, B. 1996. 4,000 rainbow trout stocked in 17-acre south county pond. June 19, 1996 edition of Lewis County News.

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

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

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

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

Newman, D.L., and T.W. Storck. 1986. Angler catch, growth, and hooking mortality of tiger muskellunge in small centrarchid-dominated impoundments. Pages 346-351 *in* Hall, G.E. (ed.), Managing Muskies. American Fisheries Society, Special Publication 15, Bethesda, MD.

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

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

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

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

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

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

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Board of Canada No. 191, 382 pp.

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

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

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

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

Tipping, J.M. 1996. Mayfield Lake tiger muskie progress report for 1995. Washington Department of Fish and Wildlife, Technical Report No. H96-01, 21 p.

Tipping, J.M. 1999. Mayfield Lake tiger muskie progress report for 1998. Washington Department of Fish and Wildlife, Technical Report No. IN99-01, 20 p.

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

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

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

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

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

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

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

Wingate, P.J. 1986. Philosophy of muskellunge management. Pages 199-202 *in* Hall, G.E. (ed.), Managing Muskies. American Fisheries Society, Special Publication 15, Bethesda, MD.

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