1998 Warmwater Fish Survey of Lake Limerick (Mason County): A Small Lake Intensively Managed to Control Aquatic Plants

by

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Abstract

The warmwater fish population was sampled at Limerick Lake during the fall of 1998, subsequent to the start of a five-year, intensive aquatic plant management program designed to control the invasive macrophyte, Eurasian water-milfoil *Myriophyllum spicatum*. The fish community was found to be dominated by largemouth bass *Micropterus salmoides* and yellow perch *Perca flavescens*. The reduction in fish habitat, brought on by the aquatic herbicide treatments, has caused an imbalance in the fish community, which will likely continue until a level of stability is reached in aquatic macrophyte production. Due to the presence of coho salmon *Oncorhynchus kisutch* and the possible importance of this watershed for their rearing, warmwater fish enhancement activities must be consistent with coho management objectives in Limerick Lake.

Acknowledgments

I would like to thank Steve Anderson, Chris Sergeant, John Pahutski and Dan Collins for their efforts in the field. Scales analysis was completed by Doug Fletcher. This project was funded by the Warmwater Enhancement Program, through a license surcharge, which is providing greater opportunity to fish for and catch warmwater fish in Washington.

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Introduction and Background

Limerick Lake (Figure 1) is a 132 acre, man made lake located in the town of Shelton, Mason County. The lake was impounded by the construction of a 4.6 m high earthen dam in 1966, which includes a masonry spillway and a pool and weir type fishway. The dam creates a total lake volume of 52,272,000 m^3, a maximum depth of 7.3 m and a mean depth of 2.7m. Limerick Lake is predominantly fed by Cranberry Creek, which flows from Cranberry Lake about 1 km upstream, and by several perennial tributaries on the northern and western shores. One of these tributaries flows directly out of the adjacent shallow bog lake, Lake Leprechaun. Another perennial tributary is Beaver Creek and additionally there are two large culverts draining adjacent wetlands. Surface water exits the lake over the concrete spillway, and/or through the fish passage structure into lower Cranberry Creek. Cranberry Creek empties into upper Oakland Bay in southern Puget Sound and supports steelhead, chum and coho salmon runs; lower Cranberry Creek is important spawning habitat for early chum, while the upper reaches are more important for coho.

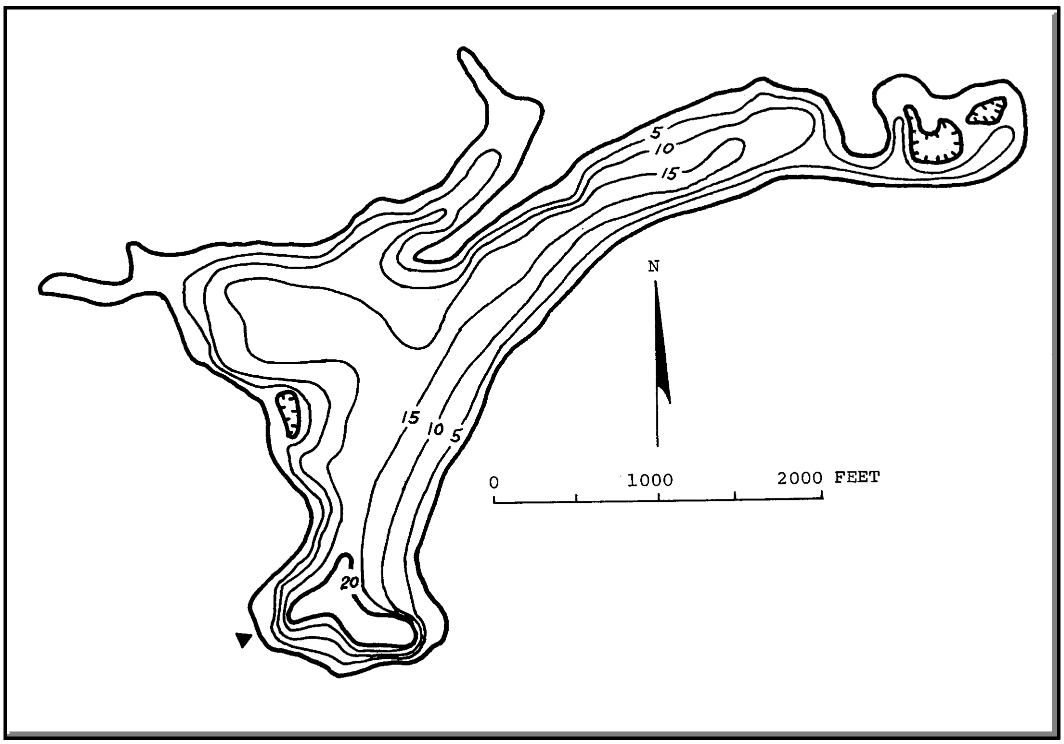

Figure 1. Bathymetric map of Limerick Lake, Mason County. The solid triangle on the bottom left indicates the location of the public boat launch. This map is taken from Bortelson et al. (1976).

Limerick Lake's large, shallow coves and wide litoral zones are ideal growing conditions for aquatic plants, and the lake supports a large and diverse aquatic plant community. The lake is considered mesoeutrophic or moderately enriched with nutrients. Although there is limited data on aquatic plant cover prior to 1991, Bortleson (1976) reported the vegetation coverage (surface area) in the lake to be less than 1% in 1974. It appears that sometime after that point, but prior to more recent surveys, the aquatic plant community became dominated by submersed vegetation, including; the nonnative invasive Brazilian elodea (*Egeria densa*, dominant prior to1996), and big floating bladderwort (*Utricularia inflata*), and the native species: Canadian waterweed (*Elodea canadensis*, dominant in one NW bay), and pondweeds (*Potamogeton spp*.). Emergent vegetation includes rushes (family Juncaceae), sedges (family Cyperaceae) and cattails (*Typha spp.*) (WATER, 1991). Submersed plant coverage of the lake was more than 50% in 1991 and dominated by Brazilian elodea. Since its introduction, Brazilian elodea had spread quickly and overpopulated the shallow portions of the lake due to the productive nature of the system and the weed's ability to easily colonize new areas when fragmented by boat propellers or other disturbance.

Limerick Lake has an extensive history of aquatic plant management and prior to 1994 the community relied upon spot treatment and mechanical removal of aquatic weeds. These treatments included copper compounds, Rodeo® (Glyphosate), Aquathol K® (Endothall) and Sonar® (Fluridone). Since 1994, the residents around the lake have worked to co-develop a comprehensive five year aquatic plant management plan through the Department of Ecology, Aquatic Weed Management Fund (D.O.E., 1994). In 1996 this effort centered around a lake-wide treatment using the chemical herbicide Sonar® to remove the large mats of vegetation. Initially the treatment was successful, however as of this writing surveys of the aquatic plant community suggest both the native plants and Brazilian elodea are making a slow comeback (Mary Beth Gibbons, WATER Environmental Services, Inc., personal communication).

Lake Limerick has a highly developed residential shoreline, with a community golf course, and park. Public access is through a state owned boat launch at the southern end of the lake, and a community maintained private boat launch. USFWS maintains a bird sanctuary on the small islands at the far northeastern end of the lake.

Materials and Methods

Data Collection

Limerick Lake was surveyed by a three-person team during August 26 - September 3, 1998. Fish were captured using three sampling techniques: electrofishing, gill netting, and fyke netting. The electrofishing unit consisted of a Smith-Root SR-16s electrofishing boat, with a 5.0GPP pulsator unit. The boat was fished using a pulsed DC current of 60 or 120 cycles/sec at 3 - 4 amps power. Experimental gill nets (45.7 m long x 2.4 m deep) were constructed of four sinking panels (two each at 7.6 m and 15.2 m long) of variable-size (1.3, 1.9, 2.5, and 5.1 cm stretch) monofilament mesh. Fyke (modified hoop) nets were constructed of 5 - 4 ft diameter hoops with two throats, and an 8 ft cod-end (1/4 in nylon delta mesh). Attached to the mouth of the net were two 25 ft wings, and a 100 ft lead.

In order to reduce the gear induced bias in the data, the sampling time for each gear was standardized so that the ratio of electrofishing to gill netting to fyke netting was 1:1:1. The standardized sample is 1800 sec of electrofishing (3 sections), 2 gill net nights, and 2 fyke net nights. Sampling occurred during the evening hours to maximize the type and number of fish captured. Sampling locations were selected from a map by dividing the entire shoreline into 400 m sections, and numbering them consecutively. Nightly sampling locations were randomly chosen (without replication) utilizing a random numbers table (Zar 1984). While electrofishing, the boat was maneuvered through the shallows at a slow rate of speed (~18 m/min, linear distance covered over time) for a total of 600 sec of “pedal-down” time or until the end of the section was reached, whichever came first. Nighttime electrofishing occurred along 70-80% of the available shoreline, for a total of 8,286 seconds. Gill nets were fished perpendicular to the shoreline; the small-mesh end was tied off to shore, and the large- mesh end was anchored off shore. Fyke nets were fished perpendicular to the shoreline as well. The lead was tied off to shore, and the cod-end was anchored off shore, with the wings anchored at approximately a 45° angle from the net lead. We set fyke nets so that the hoops were 1 - 2 ft below the water surface, this sometimes would require shortening the lead. A gill net was set overnight at one location on the lake, whereas fyke nets were set overnight at two locations.

With the exception of sculpin (Cottidae), all fish captured were identified to the species level. Each fish was measured to the nearest millimeter (mm) and assigned to a 10 mm size class based on total length (TL). For example, a fish measuring 156 mm TL was assigned to the 150 mm size class for that species, and a fish measuring 113 mm TL was assigned to the 110 mm size class, and so on. However, if a sample included several hundred young-of-year (YOY) or small juveniles (<100 mm TL) of a given species, then a sub-sample (N ~100 fish) were measured, and the remainder were just counted. The frequency distribution of the sub-sample was then applied to the total number collected. At least 10 fish from each size class were weighed to the nearest gram (g); in some instances, multiple small fish were weighed together to get an average weight.

Scales were taken from five individuals per size class, mounted, pressed, and aged using the Fraser-Lee method. However, members of the bullhead family (Ictaluridae), and non-game fish like carp (Cyprinidae), were not usually aged.

Water Quality

Water quality data (see Table 1) was collected during midday from two locations on August 25, 1998. Using a Hydrolab® probe and digital recorder, dissolved oxygen, redox, temperature, pH, and conductivity data was gathered in the littoral zone and in the deepest section of the lake at 1 m intervals through the water column. Secchi disk readings, used to measure transparency, were taken by the methods outlined by Wetzel (1983).

Table 1. Water quality from two locations at Limerick Lake, Mason County. Samples were collected mid-day on August 25, 1998.

Location	Depth (m)	Temp (°C)	pH	DO (mg/l)	Total Dissolved Solids	Conductivity (Micromhos/cm)
Location 1	0	23.0	8.7	8.6		54.4
	1	21.0	8.1	8.5		54.3
	2	21.0	7.8	7.9		54.3
Location 2	0	21.6	8.0	8.3	0.035	54.8
	1	21.3	7.9	8.0	0.035	54.4
	2	20.9	7.9	8.7	0.035	54.5
	3	20.7	7.7	7.5	0.035	54.4
	4	20.6	7.5	6.5	0.035	55.1

Data Analysis

Species Composition

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

Table 2. Species composition (excluding young of year) by weight (kg), and number of fish captured at Limerick Lake (Mason County) during the fall 1998 warmwater fish survey.

	Species Composition					
	by Weight		by Number		Size Range (mm TL)	
Species	**(kg)**	**(%w)**	**(#)**	**(%n)**	**Min**	**Max**
Yellow perch	43.2	54.2	891	57.3	64	242
Largemouth bass	28.1	35.3	561	36.1	41	452
Brown bullhead	5.0	6.3	31	2.0	144	325
Rainbow trout	1.7	2.1	4	0.3	290	432
Sculpin	1.2	1.4	49	3.1	50	169
Coho	0.4	0.5	14	0.9	106	173
Pumpkinseed	0.1	0.2	4	0.3	115	119
Bluegill	> 0.1	> 0.1	2	0.1	43	48
Total	79.7		1556			

Catch Per Unit of Effort

The catch per unit of effort (CPUE) of electrofishing for each species was determined by dividing the total number in all size classes equal or greater than stock size, by the total electrofishing time (sec). The CPUE for gill nets and fyke nets was determined similarly, except the number equal or greater than stock size was divided by the number of net-nights for each net (usually one). An average CPUE (across sample sections) with 80% confidence interval was calculated for each species and gear type, and is shown in Table 3.

Table 3. Average catch per unit effort (number of fish caught / hour electrofishing and # fish caught / night gillnetting or fyke netting) for stock-sized and larger fish (except for sculpin and coho) sampled in Limerick Lake during the fall 1998 survey.

	Electrofishing			Gill Netting			Fyke Netting		
Species	**(#/hour)**	**80% CI**	**Shock Sites**	**No. per GN night**	**80% CI**	**# Nights**	**No. per FN night**	**80% CI**	**# Nights**
Yellow perch	81.7	38.6	13	6.6	3.8	7	0.14	0.18	7
Sculpin, Unknown	20.9	7.8	13	0.0	-	7	0.14	0.18	7
Coho	4.2	5.3	13	0.6	0.4	7	0.00	-	7
Brown bullhead	6.1	4.0	13	0.6	0.7	7	1.60	1.00	7
Largemouth bass	4.7	1.7	13	1.4	1.1	7	0.00	-	7
Pumpkinseed	0.5	0.6	13	0.4	0.4	7	0.00	-	7
Rainbow trout	0.0	-	13	0.6	0.4	7	0.00	-	7

For fishes in which there is no published stock size (i.e., sculpins, suckers, etc.), CPUE is calculated using all individuals captured. Furthermore, since it is standardized, the CPUE is useful for comparing stocks between lakes.

Table 4. Stock density indices by gear type and length categories for the fall 1998 Limerick Lake Survey.

		Quality		Preferred		Memorable		Trophy	
	# Stock Length	PSD	80% (CI)	RSD	80% (CI)	RSD	80% (CI)	RSD	80% (CI)
Electrofishing									
Brown bullhead	14	29	16	0	-	0	-	0	-
Largemouth bass	10	40	20	10	12	0	-	0	-
Yellow perch	183	90	3	0	-	0	-	0	-
Gill Netting									
Brown bullhead	4	25	28	25	28	0	-	0	-
Largemouth bass	10	90	12	20	16	0	-	0	-
Pumpkinseed	3	0	-	0	-	0	-	0	-
Rainbow trout	4	25	28	0	-	0	-	0	-
Yellow perch	46	83	7	0	-	0	-	0	-
Fyke Netting									
Brown bullhead	10	50	20	10	12	0	-	0	-

Table 5. Western Washington Average Catch Per Unit Effort (number of fish caught / hour) of stock sized fish from various gear types for warmwater species. Number of lakes averaged denoted in a parenthesis.

	LMB	SMB	PS	BG	BC	YP	BBH
Electrofishing	41.6	5.8 (3)	70.8	169.1 (7)	9.63 (4)	97.5 (8)	7.8 (10)
Gillnetting	1.9 (8)	3.2 (3)	3.8 (9)	1.6 (4)	4.2 (3)	13.7 (6)	14.4 (7)
Fyke netting	0.3 (1)	-	7.9 (4)	20.7 (5)	23.4 (2)	0.2 (2)	12.7 (6)

Length Frequency

A length-frequency histogram was calculated for each species and gear type in the sample (see Figures 3, 4, 7, 8). Length-frequency histograms are constructed using individuals that are age one and older (determined by the aging process), and calculated as the number of individuals of a species in a given size class, divided by the total individuals of that species sampled. Plotting the histogram this way tends to flatten out large peaks created by an abundant size class, and makes the graph a little easier to read. These length-frequency histograms are helpful when trying to evaluate the size and age structure of the fish community, and their relative abundance in the lake.

Stock Density Indices

Stock density indices are used to assess the size structure of fish populations. Proportional stock density (PSD and relative stock density RSD) are calculated as proportions of various size-classes of fish in a sample. The size classes are referred to as minimum stock (S), quality (Q), preferred (P), memorable (M), and trophy (T). Lengths have been published to represent these size classes for each species, and were developed to represent a percentage of world-record lengths as listed by the International Game Fish Association (Gablehouse 1984).

The indices calculated here are described by Gablehouse (1984) as the traditional approach. The indices are accompanied by a 80% confidence interval (Gustafson 1988) to provide an estimate of statistical precision.

Relative Weight

A relative weight index (W_r) was used to evaluate the condition (plumpness or robustness) of fish in the lake. A W_r value of 100 generally indicates a fish in good condition when compared to the national average for that species and size. Furthermore, relative weights are useful for comparing the condition of different size groups within a single population to determine if all sizes are finding adequate forage or food (ODFW 1997). Following Murphy and Willis (1991), the index was calculated as $W_r = W/W_s$ x 100, where W is the weight (g) for an individual fish from the sample and W_s is the standard weight of a fish of the same total length (mm). W_s is calculated from a standard log weight - log length relationship defined for the species of interest. The parameters for the W_s equations of many fish species, including the minimum length recommendations for their application, are listed in Anderson and Neumann (1996). For the species where data is available, the W_r values from this study are compared to an average W_r value calculated from lakes that have been surveyed across the state by the warmwater enhancement teams (Stephen Caromile, WDFW, unpublished data), and the national standard (W_r=100).

Age and Growth

Age and growth of warmwater fishes were evaluated according to Fletcher et al. (1993). Total length at annulus formation, L_n, was back-calculated using the Fraser-Lee method. Intercepts for the y axis for each species were taken from Carlander (1982). Mean back-calculated lengths at each age for each species were presented in tabular form for easy comparison between year classes. Mean back-calculated lengths at each age for each species were compared to averages calculated from scale samples gathered at lakes sampled by the warmwater enhancement teams.

Results and Discussion

Water Quality and Habitat

Water quality data (Table 1) was gathered at two locations around the lake on August 25, 1998. Temperatures and dissolved oxygen levels were pretty consistent throughout the water column, and are within the limits required by most fish. Trout require dissolved oxygen levels of at least 5 mg/l, while many warmwater fish can tolerate levels far below that.

Species Composition and Relative Abundance

A total of eight species of fish were sampled from Limerick Lake during our August, 1998 survey: yellow perch *Perca flavescens*, largemouth bass *Micropterus salmoides*, brown bullhead *Ameiurus nebulosus*, rainbow trout *Oncorhynchus mykiss*, sculpin Cottidae, coho *Oncorhynchus kisutch*, pumpkinseed *Lepomis gibbosus*, and bluegill *L. macrochirus*. Currently the lake is dominated by yellow perch and largemouth bass in terms of both weight and number of fish caught. These two species represent nearly 90% of the biomass captured and over 93% captured by number. Not surprisingly, warmwater fish account for 96% of the biomass captured at Limerick Lake.

Yellow perch and brown bullhead catch rates were the highest amongst the warmwater species and came close to state averages (Table 3), however largemouth bass, bluegill and pumpkinseed catch rates were well below state averages. Nearly all warmwater species were below state average catch rates for gillnetting and fyke netting, with the exception of largemouth bass caught in gillnets, which were below the state average.

Summary by Species

Largemouth Bass (*Micropterus salmoides)*

Largemouth bass length at age (Table 6) in Limerick Lake is above state average. Relative weight (Figure 2) indicates good condition for fish at the time of the survey. However, a review of the length frequency data (Figure 3), species composition data (see Table 2) and CPUE information in Table 3 all indicate a conspicuous lack of larger bass, with only two fish over 400mm. The two missing year classes from 1992-93 may be due to a sampling bias or possibly from the fact that this is probably just a really low density bass population.

Table 6. Age and growth of Largemouth bass captured at Limerick Lake during the fall 1998 survey. Table data represents mean back-calculated lengths at annulus formation.

		Mean Length at Age (mm)						
Year	**n**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
1997	55	78						
1996	6	106	228					
1995	2	76	177	273				
1994	3	56	121	198	288			
1993	-	-	-	-	-	-		
1992	-	-	-	-	-	-	-	
1991	2	59	114	176	268	307	364	413
Fraser-Lee		79	178	213	280	307	364	413
Direct Proportion		67	169	205	274	301	360	412
State Average (DP)		60	146	222	261	289	319	368

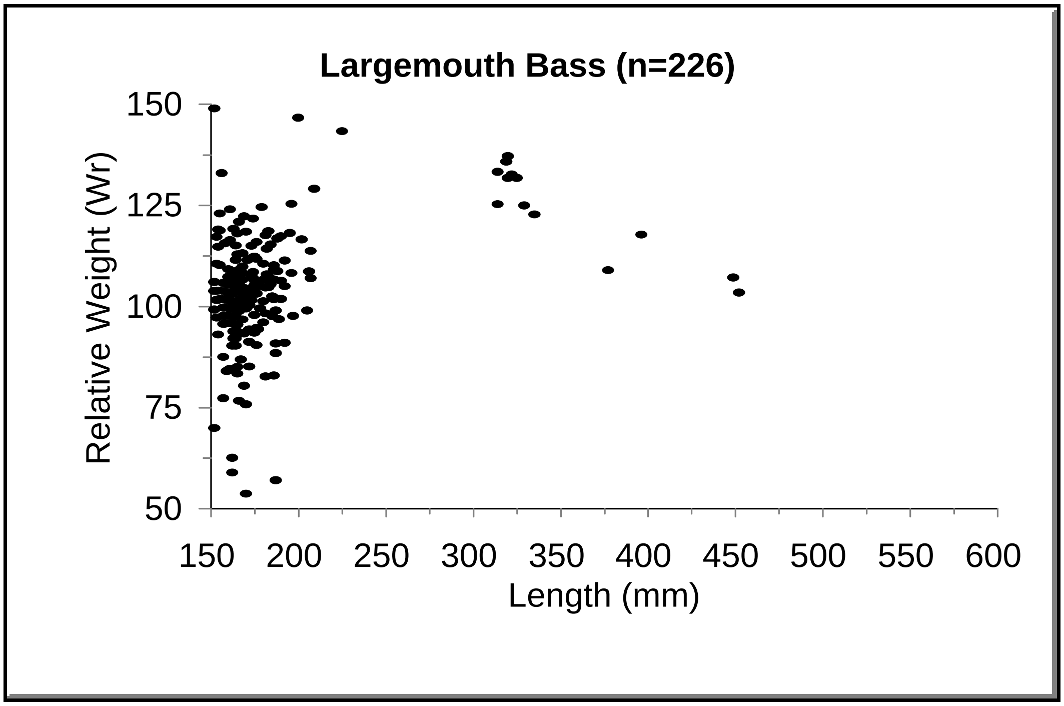

Figure 2. The relationship between total length and relative weight (W_r) of largemouth bass from Limerick Lake, as compared to the national standard (horizontal line at 100).

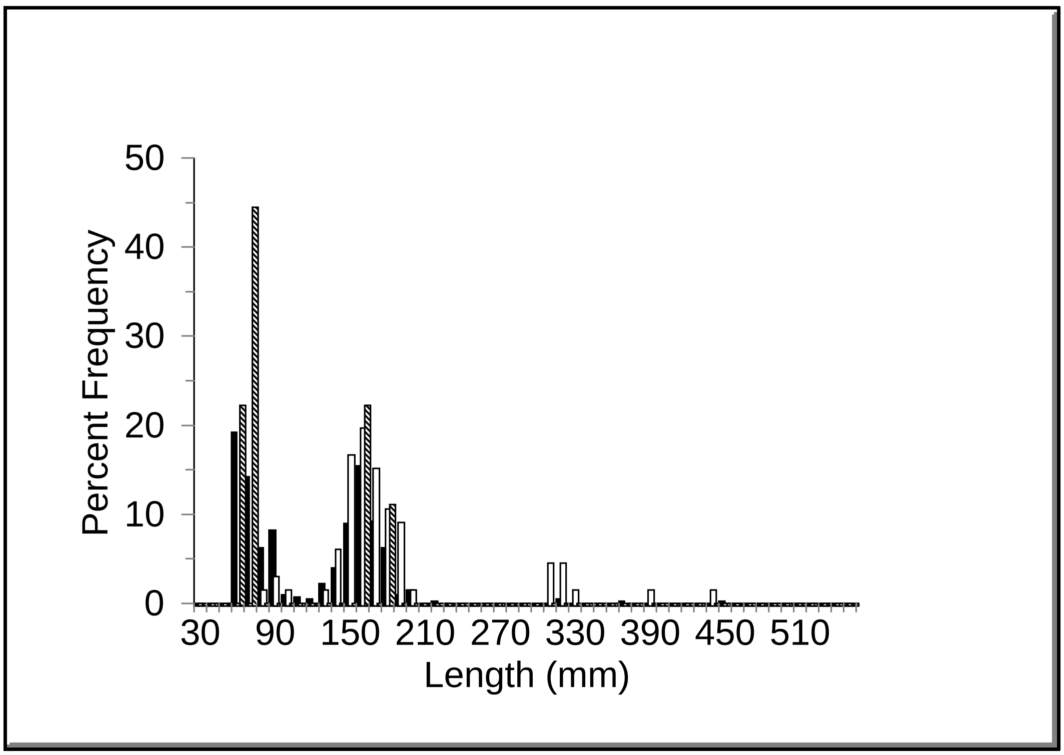

Figure 3. Length frequency distribution of largemouth bass from electrofishing (black bars, n=401), gillnetting (white bars, n=64), and fyke netting (hatched bars, n=9) from the fall 1998 survey of Limerick Lake.

Yellow Perch (*Perca flavescens*)

The yellow perch population appears to be well balanced and in good condition, with younger perch being in average condition and older age classes being slightly above national average. The species composition data (see Table 2), CPUE data (see Table 3) and relative weight data (Figure 5) all indicate a robust population of yellow perch for the year classes present; however, there appears to be missing year classes. Although yellow perch relative weights are usually lower than the national average here in western Washington, Figure 5 seems to suggest that the yellow perch population in Limerick Lake has plenty of available prey, at least during the time of our survey.

Both of the Figures (4 and 5) show that there are size classes missing in our sampling. The cause of this can either be inadequate sampling, or it may have been caused directly or indirectly from the vegetation control program.

Table 7. Age and growth of Yellow Perch captured at Limerick Lake during the fall 1998 survey. Table data represents mean back-calculated lengths at annulus formation using the Fraser-Lee method.

		Mean Length at Age (mm)		
Year Class	n	I	II	III
1997	15	89		
1996	30	132	194	
1995	9	116	165	207
Fraser-Lee	55	117	187	207
Direct Proportion		104	183	205
State Average (d.p.)		60	120	152

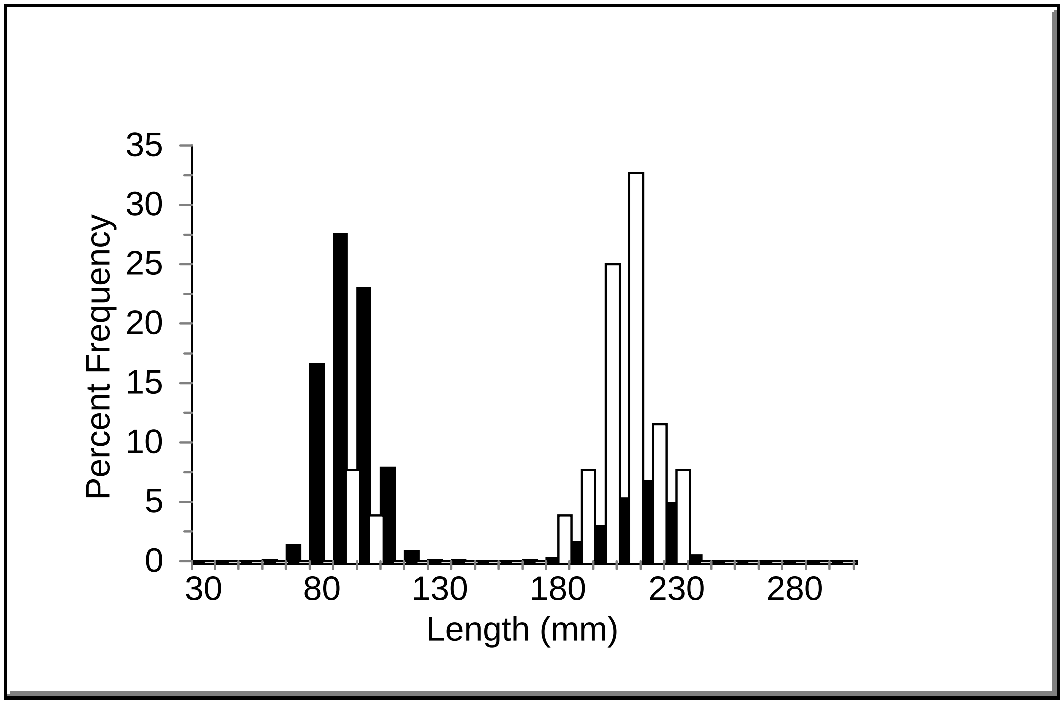

Figure 4. Length frequency distribution of yellow perch from electrofishing (black bars, n=813), and gillnetting (white bars, n=53) from the fall 1998 survey of Limerick Lake.

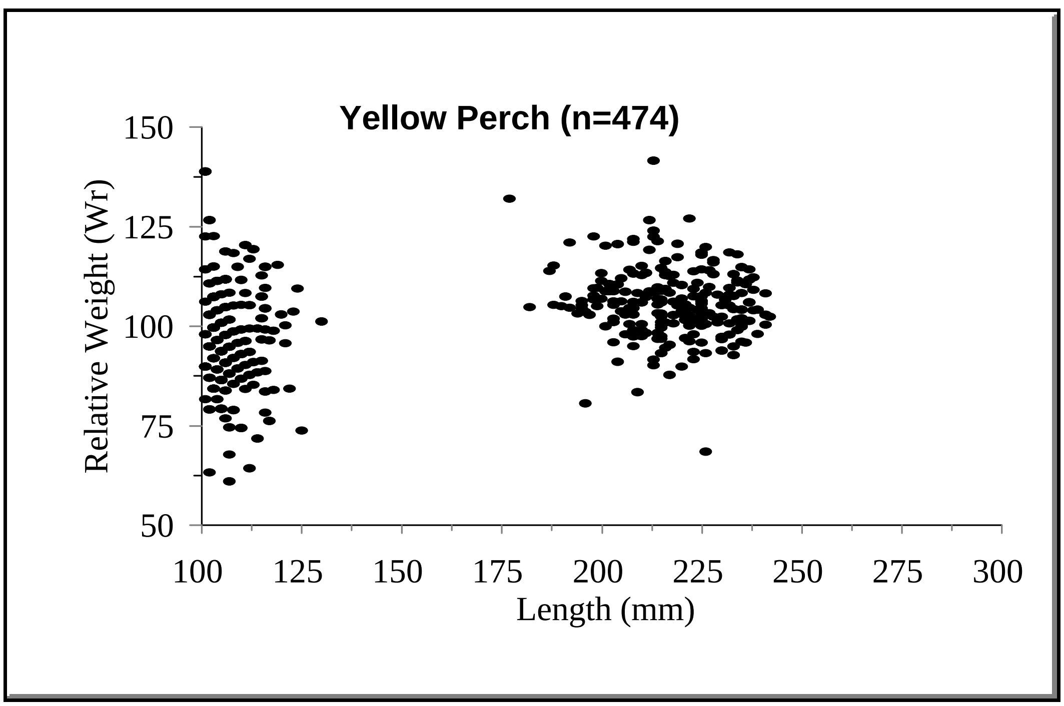

Figure 5. The relationship between total length and relative weight (Wr) of yellow perch from Limerick Lake, as compared to the national standard (horizontal line at 100).

Pumpkinseed (*Lepomis gibbosus*)

There was a surprising lack of pumpkinseed, as well as other sunfish, in our Limerick Lake sample. Usually, a lake that has a dense aquatic macrophyte community has a high probability of having a dense, stunted sunfish population as well. It seems that pumpkinseed are especially vulnerable to this overpopulation. Table 8 shows the back calculation of our few pumpkinseed samples, and that they do not appear to be stunted; their growth is actually higher than the state average. It is possible that the vegetation removal resulted in higher predation on the sunfishes, and hence a less dense population with increased growth.

Table 8. Age and growth of pumpkinseed captured at Limerick Lake during the fall 1998 survey. Table data represents mean back-calculated lengths at annulus formation using the Fraser-Lee method.

Year Class	N	I	II
1997	1	57	
1996	2	50	99
Fraser-Lee		53	99
Direct Proportion		35	95
State Average (DP)		24	72

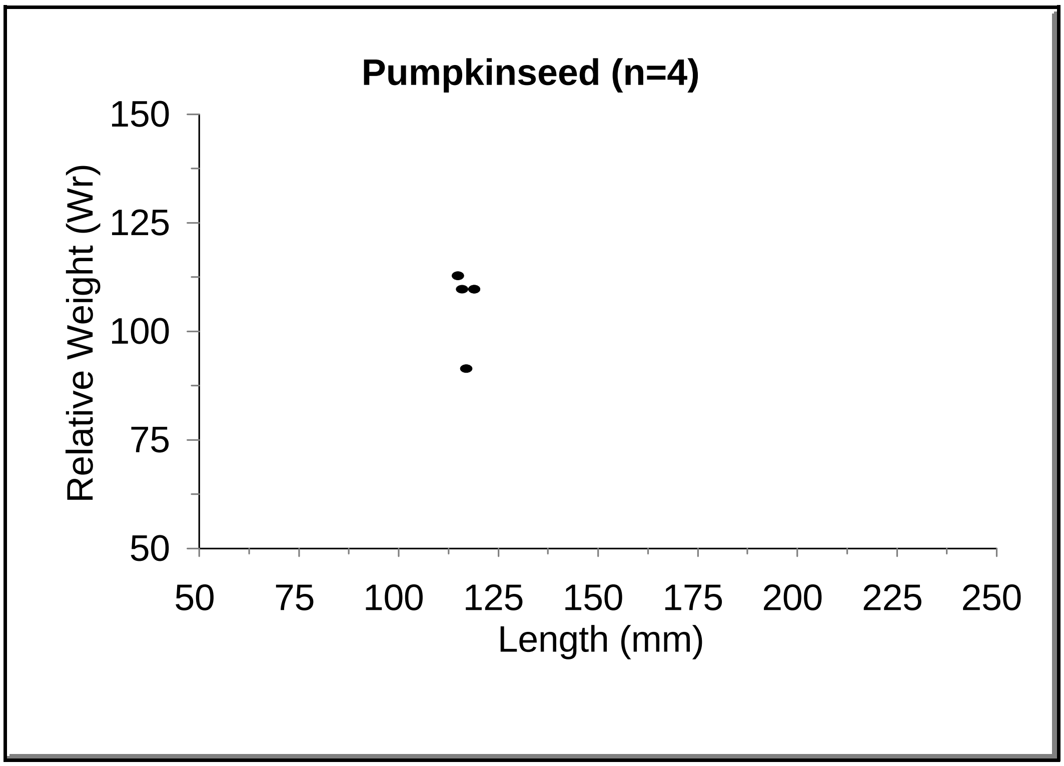

Figure 6. The relationship between total length and relative weight (Wr) of pumpkinseed sunfish from Limerick Lake, as compared to the national standard (horizontal line at 100).

Brown bullhead, (*Ameiurus nebulosus*)

Brown bullhead are, in general, not a very important sport fish in western Washington. Their importance usually lies in the fact that they are used by many as a abundant food fish. Not many bullhead were collected during our sampling efforts, but the length-frequency histogram (Figure 7) shows that the population is comprised of a wide range of size classes, and probably four of five age classes. No spines were collected for aging purposes, and there is no data that would suggest an average length at age for western Washington bullheads.

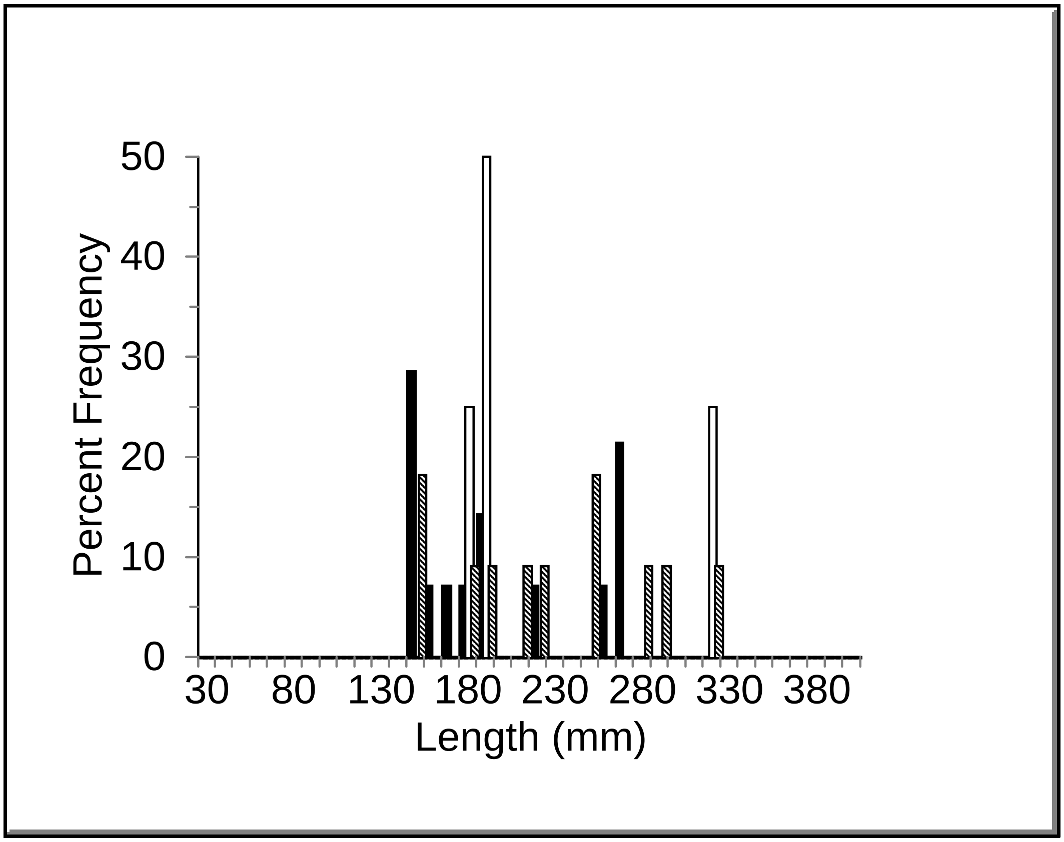

Figure 7. Length frequency distribution of brown bullheads from electrofishing (black bars, n=14), gillnetting (white bars, n=4), and fyke netting (hatched bars, n=11) during the fall 1998 survey of Limerick Lake.

Other Fish

Sculpin (*Cottidae*)

There were enough sculpin in our sample to calculate a decent length frequency histogram (Figure 8). The two peaks in the histogram probably correspond to the two and three year old fish; age one fish were probably missed by our sampling due to their size and the fact that negatively buoyant species are easily missed in the vegetation. Sculpin are not an important sport or food fish, but may be an important prey species for many fish species. This section is merely to recognize their existence in the fish community at Limerick Lake.

Due to their morphological variation, we identify these fish only to the family level, Cottidae. But, the most commonly found sculpin species in western Washington lakes will be the prickly sculpin, *Cottus asper* Richardson, 1836 (Paul Mongillo, WDFW, personal communication). Other possibilities will include the reticulate sculpin, *C. perplexus* Gilbert & Everman, 1894, and the torrent sculpin, *C. rhotheus* (Smith, 1882).

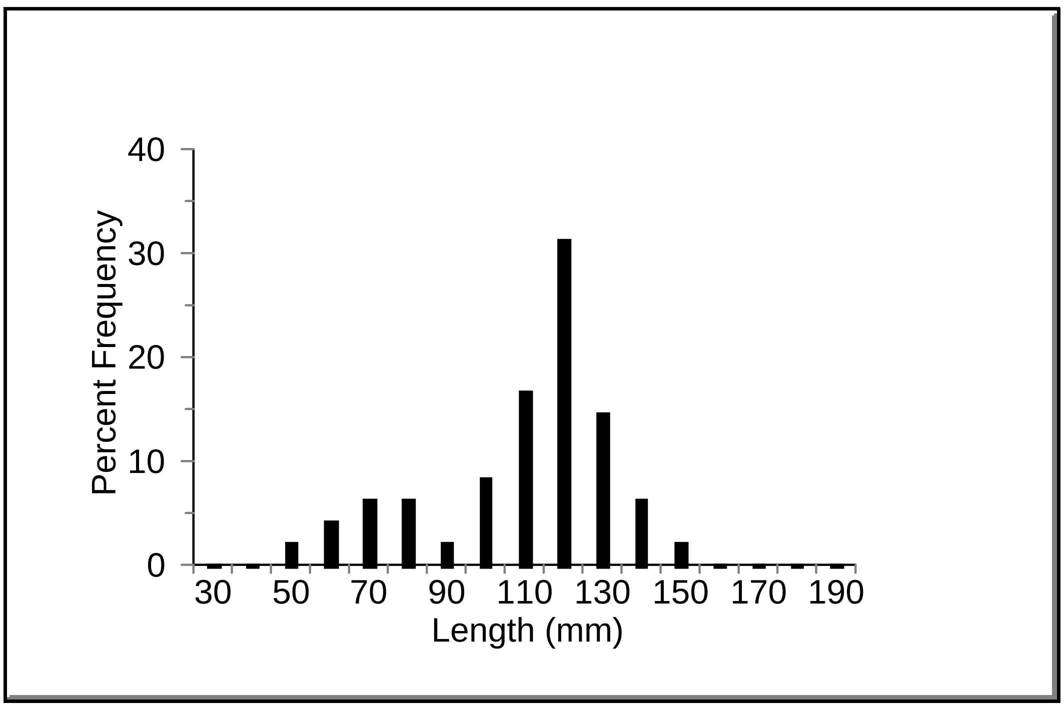

Figure 8. Length frequency distribution of sculpin from electrofishing (black bars, n=48), from the fall 1998 survey of Limerick Lake.

Coho (*Oncorhynchus kisutch*)

A few coho smolts were captured while electrofishing in some of the coves by the inlets to Limerick Lake. During the late 1950's and early 1960's Cranberry Lake, which feeds Limerick Lake through Cranberry Creek, was used as a natural rearing site for coho.

Beginning around April 22, 1999, coho smolts were being trapped and enumerated at the Limerick Lake outlet to estimate the coho production within the lake and its tributaries. An initial estimate of 2,756 coho smolts had been trapped at the lake outlet as of May 18, 1999 when the run was starting to peak (Chuck Baranski, WDFW, personal communication). A finalized number was not available at the time of this report, but it is possible that it will be significantly higher then the initial estimate.

Rainbow trout *(Oncorhynchus mykiss*)

A few rainbow trout were sampled by our gillnets in Limerick Lake. The lake is managed as a mixed species lake, with more emphasis on hatchery trout plants to supply a put-and-take fishery.

Management Options

Fish Community

Limerick Lake has been intensively and successfully managed to control excessive aquatic plant growth for several years and the resultant habitat shift appears to have had a direct impact on the warmwater fish community of the lake. Although there are both bluegill and pumpkinseed present, their numbers are practically nonexistent when compared to the overwhelming dominance of yellow perch and largemouth bass. The biomass or numbers of perch and bass combined, represent more than 90 percent of the fish community.

The vegetation control program at Limerick Lake has been an intensive-sustained effort and as such may have reached a point of momentary equilibrium sufficient enough to maintain a balanced largemouth bass-perch dominated community. However, in speaking with Mary Beth Gibbons of WATER Environmental Services, Inc., her most recent plant surveys (WATER, 1999) indicate that although the percentage of submersed plant coverage hasn't changed much since pre-treatment, an extensive transition of the plant community has taken place from one dominated by macrophytes to one dominated by the much lower growing macroalgae species *Nitella spp.* and *Chara spp.* and big floating bladderwort *Utricularia inflata*. These macroalgae species provide less structural complexity and thus protection from predation is reduced. This transition of the plant community has most likely had a significant impact on adult spawning success and cover for young of the year, thereby effecting production and predation rates of young fish. Furthermore, the aquatic plant community is making a slow comeback, which may trigger a subsequent change in the fish community unless further successful treatments occur.

Aquatic vegetation plays a key role in fish communities by providing habitat for many species of fish, refuge from predators, foraging grounds, and as a spawning substrate. Bluegill and pumpkinseed numbers may be severely depressed due to a combination of factors centering around the removal of vegetation. Pumpkinseed prefer more dense aquatic vegetation, while bluegill favor less dense rooted vegetation. On the other hand, yellow perch and largemouth bass numbers and reproduction at Limerick Lake seem to be less affected by the removal of the large matts of aquatic vegetation. Although perch often lay eggs on vegetation, they will also deposit eggs on sand, gravel or other structure such as submerged brush. So, it is probable that the removal of vegetation coupled with higher predation rates of young fish has altered the size structure and yellow perch-largemouth bass population dynamics of the lake.

Typically, relationships between largemouth bass-bluegill communities in smaller lakes tend to balance in one of two states: a high population of bass comprised mostly of smaller individuals, with a resulting balanced population of bluegill or the inverse relationship of a balanced population of bass and a stunted population of bluegill (Anderson 1978; Gablehouse 1984; Guy and Willis 1990). Although research of largemouth bass-perch communities is less extensive, Guy and Willis (1991) have shown that largemouth bass-perch communities can behave in a similar way in small lakes or impoundments. Limerick lake, at 132 acres, is on the boundary between a small lake and a large lake, therefore predator-prey interactions are less likely to drive population dynamics as they would in a small system. However, the removal of vegetation seems to have dramatically altered the rates of predation, and the fish community as a whole. Interestingly, the fish community at Limerick Lake shows both bass and perch populations somewhat balanced and in above average condition. These observations tend to further support the idea that vegetation removal is the primary force at work, although likely aided by some effects of predation. For instance, the young of the year bass and perch are highly vulnerable to predation once significant quantities of vegetation are removed. Other evidence supporting this idea comes from the lower observed bass recruitment rates one would expect to keep the perch population from stunting, if bass were the sole driving force. Therefore it is likely that a combination of vegetation removal and some predation is currently driving the system.

Several grass carp were sighted in Limerick Lake both by the survey team, it is assumed that these had escaped from Lake Leprechaun since none were ever stocked into Limerick Lake. Although they will most likely have little effect on the plant community due to the assumed low numbers and open passage to lower Cranberry Creek.

It is highly likely that Limerick Lake is providing an important rearing area for coho salmon. It is known that young coho are quite territorial when in streams, and will displace excess juveniles downstream; once the carrying capacity of the stream is reached, excess coho will rear in the lake. If one is to estimate that the total smolt migration reached 4,000 fish, assuming each female produces approximately 50 smolts, there would have been approximately 80 adult females spawning in the tributaries to Limerick Lake. That is a pretty significant figure for a small tributary in southern Puget Sound.

It is unclear wether or not the warmwater fish population was taken into consideration when the vegetation control program was being implemented, or if people knew how the population would react to removal of the vegetative cover. It is clear that the plant community is still fluctuating, and this probably means more fluctuations for the fish community as well. Until there is more stability within the lake community as a whole, it is our recommendation to manage the lake as status quo. Additionally, with the uncertain status of coho within the Limerick Lake drainage area, it is best to be conservative when deciding how to manage the warmwater fishery; enhancement would probably be inappropriate at this time. There is abundant angler opportunity angling for yellow perch and for hatchery trout.

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Appendix A

Appendix Table 1. Length categories that have been proposed for various fish species. Measurements are for total lengths (updated from Neumann and Anderson 1996).

	Category									
	Stock		Quality		Preferred		Memorable		Trophy	
Species	**(in)**	**(cm)**	**(in)**	**(cm)**	**(in)**	**(cm)**	**(in)**	**(cm)**	**(in)**	**(cm)**
Black bullhead [a]	6	15	9	23	12	30	15	38	18	46
Black crappie	5	13	8	20	10	25	12	30	15	38
Bluegill [a]	3	8	6	15	8	20	10	25	12	30
Brook trout	5	13	8	20						
Brown bullhead [a]	5	13	8	20	11	28	14	36	17	43
Brown trout	6	15	9	23	12	30	15	38	18	46
Burbot	8	20	15	38	21	53	26	67	32	82
Channel catfish	11	28	16	41	24	61	28	71	36	91
Common carp	11	28	16	41	21	53	26	66	33	84
Cutthroat trout	8	20	14	35	18	45	24	60	30	75
Flathead catfish	11	28	16	41	24	61	28	71	36	91
Green sunfish	3	8	6	15	8	20	10	25	12	30
Largemouth bass	8	20	12	30	15	38	20	51	25	63
Pumpkinseed	3	8	6	15	8	20	10	25	12	30
Rainbow trout	10	25	16	40	20	50	26	65	31	80
Rock bass	4	10	7	18	9	23	11	28	13	33
Smallmouth bass	7	18	11	28	14	35	17	43	20	51
Walleye	10	25	15	38	20	51	25	63	30	76
Warmouth	3	8	6	15	8	20	10	25	12	30
White catfish [a]	8	20	13	33	17	43	21	53	26	66
White crappie	5	13	8	20	10	25	12	30	15	38
Yellow bullhead	4	10	7	18	9	23	11	28	14	36
Yellow perch	5	13	8	20	10	25	12	30	15	38

[a] As of this writing, these new, or updated length classifications have yet to go through the peer review process, but a proposal for their use will soon be in press (Timothy J. Bister, South Dakota State University, personal communication).