An Assessment of the Warmwater Fish Community in Long Lake (Thurston County) June 2000

by

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Acknowledgments

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Abstract

Long Lake was surveyed by a three-person crew from June 5-8, 2001. Multiple gear types (electrofishing, gill nets, and trap nets) were utilized to reduce any sampling bias associated with each sampling method. A total of 890 fish, representing 11 species and the family Cottidae (i.e., sculpins), were sampled from Long Lake. Of those, rock bass and rainbow trout were the most abundant, numerically, at 21.8% and 19.9%, respectively. However, in terms of biomass, common carp and largescale sucker were the most abundant at 62.3% and 42.5%, respectively. Other species sampled during the survey include: brown bullhead, bluegill, brown trout, largemouth bass, pumpkinseed, warmouth, and yellow perch. Judging from our sampling, the warmwater fish community at Long Lake is poor. Few quality (minimum size anglers like to catch) and larger size warmwater gamefish were sampled. Currently, rock bass and largemouth bass provide the best opportunity to catch quality size and larger fish. The poor condition of Long Lake's warmwater fish community may be related to the extensive aquatic plant management there. In 1991, vegetation (primarily Eurasian water milfoil) was removed from Long Lake using the aquatic herbicide SONAR. Since, vegetation (both native and non-native) has been harvested using both SCUBA divers and mechanical weed harvesters. Recommendations for Long Lake include: 1.) Study the change in vegetation coverage on a monthly basis and its affects on the warmwater fishery as a result of harvesting. and 2.) Continue to monitor the warmwater fish community in Long Lake every 2-3 years during the spring.

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Introduction

Long Lake (Thurston County) resides within an extensively developed suburban neighborhood in Lacey, WA. Approximately 255 near-shore homes reside around the lake. Additionally, 80% of the surrounding land is privately owned. Long Lake receives a high amount of recreational use by area residents, because it is one of five (Chambers, Hicks, Pattison, and St Clair lakes) Lacey area lakes where boating activities in excess of 5 mph are permitted. The aquatic environment within Long Lake has been intensively managed since the early 1980s by a local nearshore homeowners group, county, and state natural resource agencies.

Long Lake supports an array of recreational uses, including: boating, water skiing, jet skiing, swimming, and fishing. Since most of the shoreline around Long Lake is privately owned, public access is limited to two locations. These locations include a WDFW boat launch and a Thurston County public park and community swimming area. A Thurston County Public Works study on recreational use at Long Lake recorded 2,700 boats (6,000 recreationalists) accessing the lake in 1990. The majority (69.7%) of boaters were water skiers (40.3%) and recreational anglers (29.4%). The remaining users (30.3%) were recreational (i.e., jet skiers, power boaters, etc.) and unidentified boaters. Regulations at Long Lake restrict recreational use to certain times of the day and year. Boating activities in excess of 5 mph are prohibited 30 days after the trout opener (end of June) and before 11:00 am during the remainder of the year. Recreational angling is restricted to a fishing season that begins the last Saturday in April and ends October 31st. The WDFW manages Long Lake as a mixed species fishery, which provides angling opportunity for both warm and coldwater species. Coldwater species include rainbow trout *Oncorhynchus mykiss* and brown trout *Salmo trutta* that the WDFW stocks annually. Warmwater species include self-sustaining populations of bass and panfish.

Since 1983, the aquatic environment at Long Lake has been intensively managed to prevent excessive phosphorus loading **and aquatic plant growth**. A local homeowners group, called the Long Lake Management District Steering Committee (LLMD), was formed to oversee the management at Long Lake. Past management activities include chemical treatments and aquatic vegetation removal. In 1983, aluminum sulfate (Alum) was applied to Long Lake to reduce excessive phosphorus levels. From 1983 to 1990, aquatic vegetation was mechanically removed using a weed harvester. During the peak harvest years in1989 and 1990, approximately 2 million tons of aquatic vegetation was removed from the lake (Clingman and Englehardt, 1995). In 1991, infestations of Eurasian water milfoil *Myriophyllum spicatum* were treated with the aquatic herbicide SONAR (Fluridone). From 1992 to present, management at Long Lake has focused on mechanical removal of aquatic vegetation to prevent future infestations of Eurasian water milfoil and to reduce phosphorus loading. Annually, SCUBA divers survey Long Lake, hand picking any Eurasian water milfoil plants encountered. During the fall, a weed harvester is used to remove excessive mats of water lilies in boating lanes and around residential docks.

Study Area

Long Lake is located east of the town Lacey, WA off Carpenter Road. Long Lake is divided into two basins (north and south) connected by a narrow channel and covers 330 surface acres. Long Lake is moderately deep with a maximum and mean depth of 6.4 and 3.7 meters, respectively. The shoreline development value is 2.8, which describes Long Lake as oblong in shape with a moderate amount of shoreline irregularities. Long Lake, as well as all Puget Sound area lakes, was formed approximately one million years ago by advancing and retreating glaciers creating a pothole in the landscape. Long Lake is third in a chain of lakes (Hicks, Pattison, Long, and Lois) that drains into Woodland Creek, which empties into Henderson Inlet.

Long Lake supports an array of habitat types for fish. Submergent, emergent, and floating aquatic vegetation habitat types are represented in Long Lake. Aquatic vegetation species found in Long Lake include common bladder wort *Utricularia vulgaris*, water shield *Brasenia scherberi*, curly leaf pondweed *Potamogeton crispus*, common elodea *Elodea canadensis*, common water-nymph *Najas quadalupensis*, sago pondweed *Potamogeton pectinatus*, yellow water lily *Nuphar polysepalum*, water celery *Vallisneria americana*, leafy pondweed *Potamogeton foliosus*, star duckweed *Lemna trisula*, large leaf pondweed *Potamogeton amplifolius*, stonewort *Chara spp*., coontail *Ceratophyllum demersum*, fragrant water lily *Nymphaea odorata*, brittlewort *Nitella spp*., berchtolds pondweed *Potamogeton berchtoldii*, white stem pondweed *Potamogeton praelongus*, water smartweed *Polygonum coccineum*, northern water milfoil *Myriophyllum sibiricum*, and Eurasian water milfoil (TCWWMD, 2000). In addition to aquatic vegetation, both sunken timber and docks provide habitat for fish in Long Lake. Although diverse, the actual surface coverage of aquatic vegetation is low. Approximately 10-20% of the lake is covered with aquatic vegetation and most of the coverage occurring at the inlet and outlet.

Methods and Materials

Data Collection

The warmwater fish community in Long Lake was surveyed from June 5-8, 2000. Fish were sampled using electrofishing, gill and fyke netting techniques. Electrofishing utilized a Smith-Root SR-16 boat with a 5.0 GPP pulsator unit. While electrofishing, pulsed DC current at 120 cycles per second was used at 3-6 amps power. Experimental gill nets measured 45.7 and 2.4 meters in length and width, respectively, and were constructed of variable-size (13, 19, 25, and 51 mm stretch) monofilament mesh. Fyke nets consisted of a series of 5-1.2 meter hoops and a 2.4 meter cod-end covered with 6 millimeter nylon mesh. Attached to the mouth of the first hoop is a 30.5 meter lead net and two 7.6 meter wings.

Sampling gears were fished in relatively equal proportions to one another to reduce any gear induced bias in the data. An equal proportion of sampling effort of gear types for warmwater surveys entails 1800 seconds of electrofishing, 2 gill net, and fyke net nights (24 hours) (Fletcher et al., 1993). Sampling occurred during evening hours to maximize the number, size, and type of fish sampled. Sampling sections are designated by dividing the lake shoreline into 400 meter sections. Sampling sections are then chosen randomly (for each gear type) using a random numbers generator in a spreadsheet program or a calculator. Electrofishing occurred along the shallows within a sampling section for a total of 600 seconds or until the end of the section was reached, whichever came first. Gill nets were set perpendicular to the shoreline (within a sampling section) for approximately 24 hours or 1 net night. Fyke nets were set in a similar fashion, except the two wings connected to the first hoop were pulled back towards shore at a 45E angle from the lead net. Additionally, fyke nets were set so that the top of each hoop was no more than 1 meter below the water surface. At times, shortening the lead was necessary to meet the appropriate depth requirement. Total sampling effort for the Long Lake survey was 15 electrofishing sections **(9,000 seconds)**, 8 gill net sets, and 6 fyke net sets.

All fish sampled, except sculpin (family Cottidae), were identified to species. Each fish was measured to the nearest millimeter and weighed to the nearest gram. However, if a sample contained several hundred, or more, similar sized fish (i.e., young of the year or juvenile fish) a sub-sample (n = 100) was measured and weighed and rest counted. Scale samples were taken from five fish per centimeter size class (i.e., 200-290 mm, 300-390 mm, etc.) per species.

Water quality data was collected on June 6, 2000 at noon from the deepest location on the lake. Water quality parameters were measured using a Hydrolab® probe and digital recorder at 1 meter intervals throughout the water column. Water quality parameters collected include dissolved oxygen (mg/l), temperature (EC), pH, turbidity (NTU), and specific conductance (Fs/cm).

Data Analysis

Species composition of fish captured during the survey was expressed by their contribution to the sample in terms of biomass and by number. Species composition by weight (biomass) is calculated by dividing the total weight of a fish species by the total weight of the sample. Similarly, species composition by number was determined by dividing the total number of a fish species by the total number in the sample. Only fish determined to be age 1 and older were included in species composition analysis.

Catch per unit of effort (CPUE) was calculated for each species and gear type to describe their relative abundance. Electrofishing CPUE (fish per hour), for each sample section, was determined by dividing the sample size of a species (stock size and larger) by the total electrofishing time (600 seconds). Gill and fyke net CPUE was determined similarly, except the sample size of a species (stock size and larger) was divided by a net unit (~ 24 hours) and expressed as the number of fish per net night. An average CPUE, calculated from each section, was determined for all species and gear types. Average CPUE's are accompanied by 80% confidence intervals (Gustafson, 1998).

Size structure of each species was described using length frequency histograms. Length frequency histograms are constructed using individuals that are age one and older and calculated as the number of species in a given size class divided by the total of individuals of that species sampled.

Stock density indices (i.e., proportional and relative stock density) were calculated for warmwater gamefish species sampled during the survey. Proportional and relative stock density indices (PSD and RSD) were calculated for each warmwater gamefish species and gear type according to Anderson and Neuman (1996). PSD and RSD calculations are accompanied by an 80% confidence interval.

The condition or health of each species was evaluated using relative weights. Relative weights (Wr) were calculated for each species according to Anderson and Neuman (1996). Wr formulas and minimum lengths for several species are listed in Anderson and Neuman (1996).

Age and growth of warmwater fishes were evaluated according to DeVries and Frie (1996), where age is determined by counting the number of annuli on a hard part and growth is determined by back calculation. Back calculated length at age was determined by using both the direct proportion and the Fraser-Lee modification of the direct proportion methods. Back calculated length at age for each warmwater species was then compared to a state average.

Results

Water Quality

Water quality in Long Lake was found to be weakly stratified (Table 1). A single thermocline occurs at 4 meters. Water temperature and dissolved oxygen in epilimnion are within optimal limits for warmwater fish (Piper et al., 1992). However, Long Lake becomes anoxic, and unsuitable for fish, below the thermocline. Conductivity readings were withing optimal levels (100-400 Fsiemens/cm) for electrofishing efficiency according to Willis (1998). Water quality was taken from the northern basin of the lake only. No measurements were taken from the southern basin which has been found to have differing water quality than the northern half (Clingman and Englehardt, 1995).

Table 1. Water quality measurements taken from Long Lake, spring 2000. Measurements taken at midday.

Depth m	Temp CE	pH	D.O. % Sat.	Turbidity NTU	Conductance Fsiemens/cm
surface	19.9	7.4	10.0	7.1	107.6
1	19.9	7.5	8.9	7.5	107.6
2	19.9	7.5	9.6	7.7	107.5
3	18.5	7.6	9.3	8.7	106.4
4	15.7	6.8	4.1	9.2	111.3
5	13.5	6.6	0.9	11.7	122.5
6	12.2	6.9	0.4	13.9	146.6

Species Composition and Relative Abundance

A total of 890 fish, representing 11 species and the family Cottidae (i.e., sculpins), were sampled from Long Lake. Fishes sampled include brown bullhead *Ameiurus nebulosus*, bluegill *Lepomis macrochirus*, brown trout, common carp *Cyprinus carpio*, largemouth bass *Micropterus salmoides*, largescale sucker *Catostomus macrocheilus*, pumpkinseed *Lepomis gibbosus*, rainbow trout, rock bass *Ambloplites rupestris*, warmouth *Lepomis gulosus*, and yellow perch *Perca flavescens*. Of those, rock bass and rainbow trout were the most abundant, numerically, at 21.8% and 19.9%, respectively (Table 2). However, in terms of biomass, common carp and largescale sucker were the most abundant at 33.3% and 22.7%, respectively.

Electrofishing proved to be the best method for sampling fish in Long Lake. While electrofishing, rock bass and sculpins were encountered the most frequently with CPUE's of 52 (± 13) and 41 (± 12) fish per hour, respectively (Table 3). Gill nets sampled fewer fish than did electrofishing. Rock bass and rainbow trout were caught the most often in gill nets with CPUE's of 6 fish per net night each. Fyke nets were ineffective at sampling warmwater fish. Only rock bass (1 fish/net night) and largescale sucker (<1 fish/net night) were encountered in fyke nets during the survey.

Table 2. Species composition by weight and number for fish sampled (Age 1 and older) from Long Lake, spring 2000.

	Species Composition					
	by Weight		by Number		Size Range (mm TL)	
Species	(kg)	(%w)	(#)	(%n)	Min	Max
Common carp	62.3	33.3	20	2.2	160	790
Largescale sucker	42.5	22.7	46	5.2	117	605
Largemouth bass	29.6	15.8	96	10.8	78	550
Rainbow trout	19.2	10.2	177	19.9	63	460
Rock bass	15.7	8.4	194	21.8	69	269
Yellow perch	4.4	2.4	164	18.4	28	221
Brown bullhead	4.4	2.3	10	1.1	210	385
Brown trout	3.7	2.0	2	0.2	425	570
Pumpkinseed	1.9	1.0	45	5.1	90	150
Sculpin	1.9	1.0	106	11.9	15	154
Bluegill	0.8	0.4	8	0.9	115	177
Warmouth	0.7	0.4	22	2.5	85	153

Table 3. Average catch per unit effort for stock size and larger fish sampled from Long Lake, spring 2000.

	Electrofishing			Gill Netting			Fyke Netting		
Species	(#/hour)	80% CI	Sample Sites	#/net night	80% CI	# net nights	#/net night	80% CI	# net nights
Brown bullhead	3.2	1.7	15	—	—	8	—	—	8
Bluegill	3.2	1.5	15	—	—	8	—	—	8
Brown trout	<1	<1	15	<1	<1	8	—	—	8
Sculpin	41.4	11.9	15	<1	<1	8	—	—	8
Common carp	2.4	1.2	15	0.8	0.3	8	—	—	8
Largemouth bass	10.7	3.4	15	0.8	0.5	8	—	—	8
Largescale sucker	12.3	9.0	15	1.8	0.8	8	<1	<1	8
Pumpkinseed	15.8	4.9	15	0.6	0.3	8	—	—	8
Rainbow trout	4.7	1.9	15	6.0	1.6	8	—	—	8
Rock bass	52.1	13.2	15	6.1	2.1	8	1.0	0.8	8
Warmouth	3.9	2.2	15	1.5	0.7	8	—	—	8
Yellow perch	9.1	3.4	15	0.9	0.4	8	—	—	8

Summary by Species

Largemouth Bass

Largemouth bass size ranged from 78-550 mm total length, however size structure is poor (Figure 1). Recruitment beyond age 1 is limited. Largemouth bass PSD is 63 (± 12), which indicates a high density of quality and larger size ($ 300 mm) fish in the populations and that the predator population is balanced with the prey population. However, our sample of stock and larger size ($ 200 mm) fish is too low to calculate a meaningful PSD.

Largemouth bass condition is high with all individuals above the national average (Figure 2). Several age classes were either absent or weakly represented in our sample. However, growth of these largemouth bass was above the state average (Table 4).

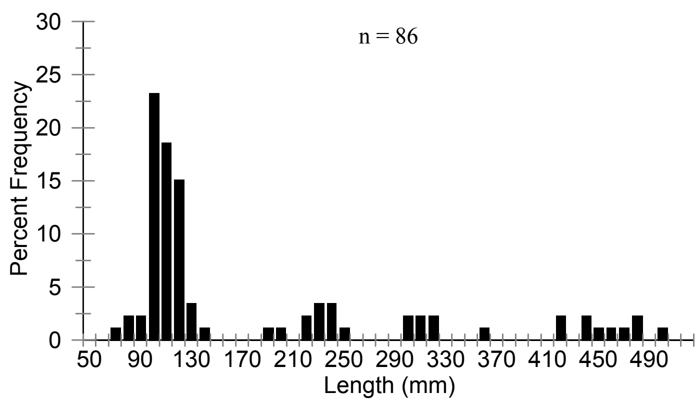

Figure 1. Length-frequency distribution of largemouth bass from the spring 2000 survey of Long Lake, Thurston County. Represents individuals one year old or older.

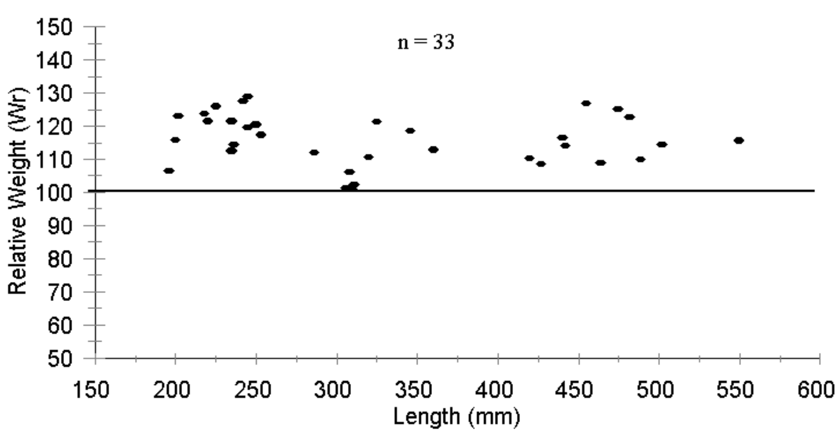

Figure 2. Relative weights of largemouth bass from the spring 2000 survey of Long Lake, Thurston County. Horizontal line at 100 represents the national 75th percentile.

Table 4. Mean back calculated length at age for largemouth bass from the spring 2000 survey of Long Lake, Thurston County.

		Mean Length at Age (mm)									
Year	**n**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
1999	26	**91**									
1998	14	71	**206**								
1997	9	73	177	**316**							
1996	0										
1995	5	99	201	348	411	**437**					
1994	2	60	231	336	408	447	**479**				
1993	0										
1992	0										
1991	1	64	124	244	378	414	439	488	511	**550**	
1990	2	91	160	259	305	343	368	425	451	478	**496**
Average		83	193	317	386	418	426	446	471	502	496
State Ave		60	146	222	261	289	319	368	396	440	485
Fraser-Lee Ave		93	200	320	389	420	429	449	473	503	496

Rock Bass

Rock bass size ranged from 69-269 mm total length. Size structure is good (Figure 3). Most individuals are stock size ($ 100 mm) and larger. Rock bass PSD is 29 (± 5) which suggests a fair number of quality size ($ 150 mm) and larger fish exist in population.

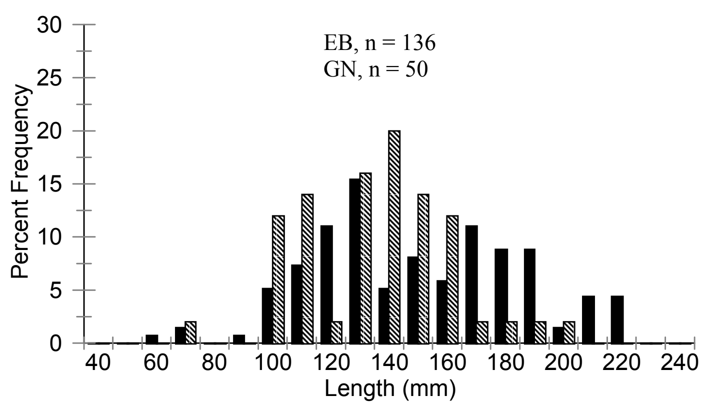

Figure 3. Length-frequency distribution of rock bass from the spring 2000 survey of Long Lake, Thurston County. Represents individuals one year old or older.

Rock bass condition is low with most individuals below the national average (Figure 4). Rock bass growth, however, is above the state average (Table 5). Similar to largemouth bass, several year classes are either absent or weakly represented in our sample.

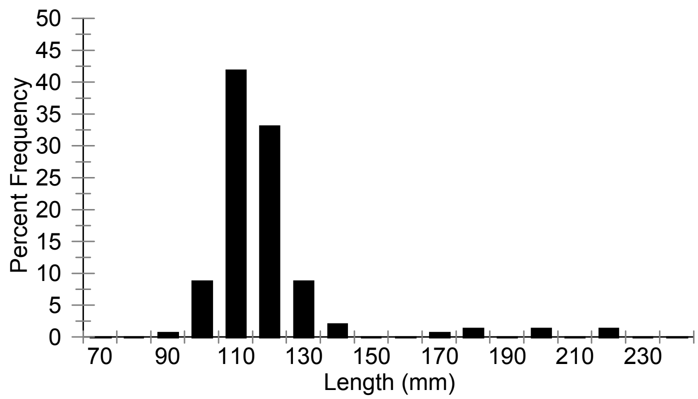

Figure 4. Length-frequency distribution of yellow perch from the spring 2000 survey of Long Lake, Thurston County. Represents individuals one year old or older.

Table 5. Mean back calculated length at age for rock bass from the spring 2000 survey of Long Lake, Thurston County.

Year class	n	I	II	III	IV	V	VI	VII	VII
		Mean Length at Age (mm)							
1999	2	**52**							
1998	24	57	**154**						
1997	21	37	101	**163**					
1996	7	30	86	153	**195**				
1995	5	34	85	141	180	**212**			
1994	1	21	88	160	189	212	**227**		
1993	0								
1992	1	42	88	155	203	240	254	262	**269**
Average		44	119	158	190	216	240	262	269
State Ave		29	70	118	152	178	193	203	n/a
Fraser-Lee Ave		62	124	162	192	217	241	263	269

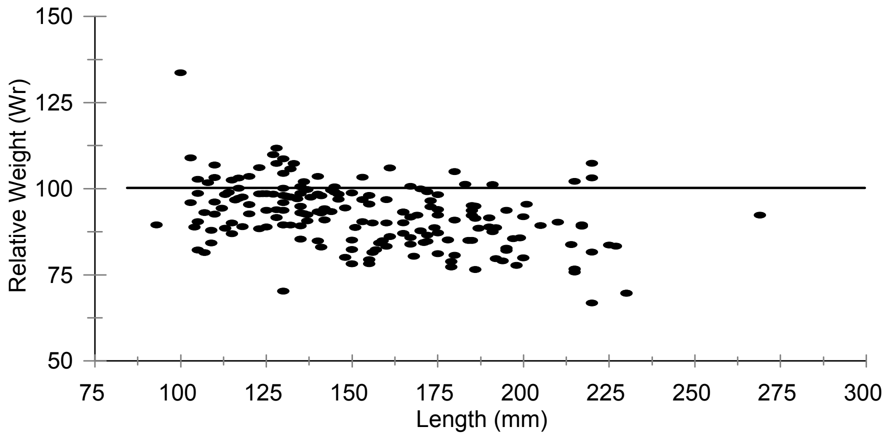

Figure 5. Relative weights of rock bass from the spring 2000 survey of Long Lake, Thurston County. Horizontal line at 100 represents the national 75th percentile.

Yellow Perch

Yellow perch size ranged from 28-221 mm total length, however, size structure is poor (Figure 5). Yellow perch PSD is 17, which indicates a low density of quality and larger ($ 200 mm) size fish exist in the population. However, our sample of stock and larger size ($ 200 mm) fish is too low to calculate a meaningful PSD.

Yellow perch condition is good with most individuals above the national average (Figure 6). Yellow perch growth is above the state average (Table 6). No age 3 and older fish were sampled during the survey.

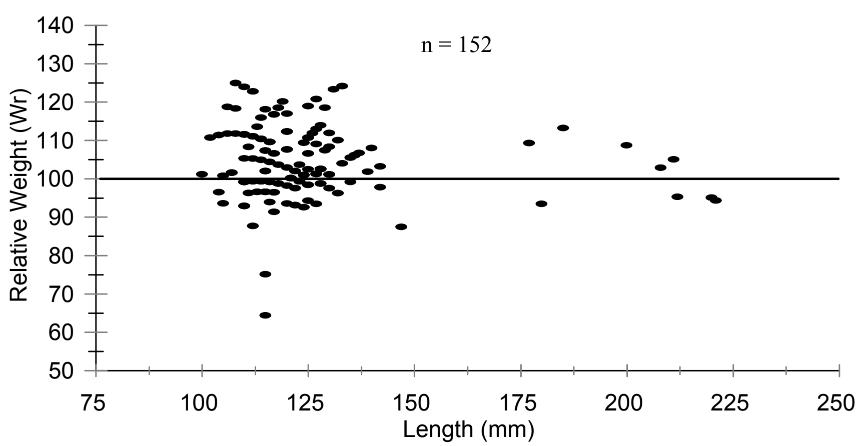

Figure 6. Relative weights of yellow perch from the spring 2000 survey of Long Lake, Thurston County. Horizontal line at 100 represents the national 75th percentile.

Table 6. Mean back calculated length at age for yellow perch from the spring 2000 survey of Long Lake, Thurston County.

		Mean Length at Age (mm)	
Year Class	**n**	**I**	**II**
1999	26	**90**	
1998	10	75	**183**
Average		86	183
State Ave		60	120
Fraser-Lee Ave		97	186

Pumpkinseed

Pumpkinseed size ranged from 90-150 mm total length. Size structure is fair with most individuals being stock size (80-150 mm) or smaller (Figure 7). Pumpkinseed PSD is 3 (± 3) which suggests a low number of quality size ($ 150 mm) and larger fish exist in Long Lake.

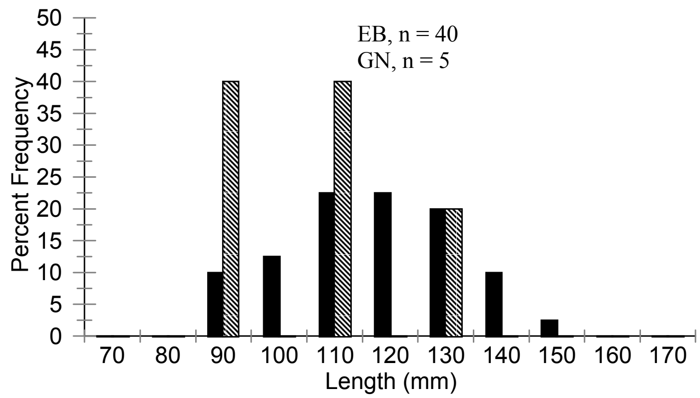

Figure 7. Length-frequency distribution of pumpkinseed from the spring 2000 survey of Long Lake, Thurston County. Represents individuals one year old or older.

Pumpkinseed condition is good with nearly all individuals above the national average (Figure 8). Pumpkinseed growth is above the state average (Table 7). No age 3 and older fish were sampled during the survey.

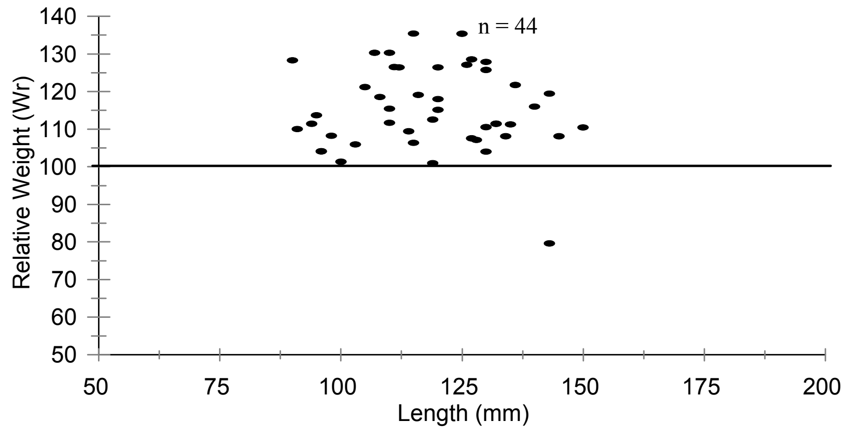

Figure 8. Relative weights of pumpkinseed from the spring 2000 survey of Long Lake, Thurston County. Horizontal line at 100 represents the national 75^{th} percentile.

Table 7. Mean back calculated length at age for pumpkinseed from the spring 2000 survey of Long Lake, Thurston County.

		Mean Length at Age (mm	
Year Class	**n**	**I**	**II**
1999	0		
1998	27	29	**105**
Average		29	105
State Ave		24	72
Fraser-Lee Ave		49	109

Warmouth

Warmouth size ranged from 85-153 mm total length. Size structure is fair with most individuals being stock size (80-150 mm) or smaller. Warmouth PSD is 10 (± 12) which suggests a low number of quality size ($ 150 mm) and larger fish exist in Long Lake.

Warmouth condition is good with nearly all individuals above the national average (Figure 9). Warmouth growth is above the state average (Table 8). No age 3 or older fish were sampled during the survey.

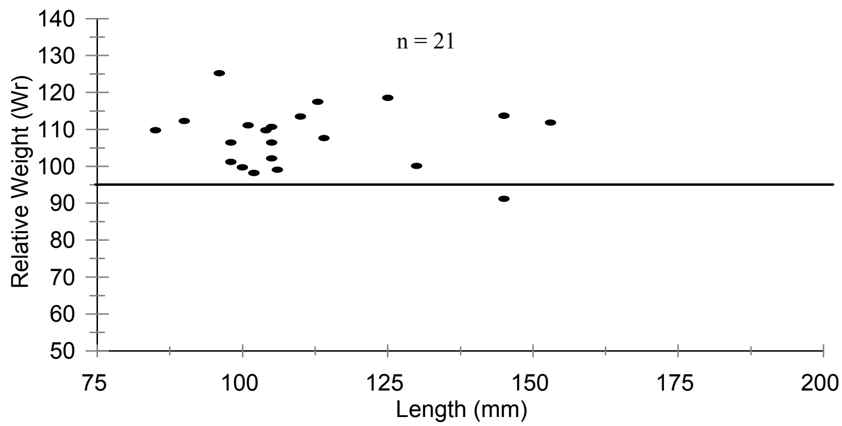

Figure 9. Relative weights of warmouth from the spring 2000 survey of Long Lake, Thurston County. Horizontal line at 100 represents the national 75th percentile.

Table 8. Mean back calculated length at age for warmouth from the spring 2000 survey of Long Lake, Thurston County.

		Mean Length at Age (mm)		
Year Class	**n**	**I**	**II**	**III**
1999	0			
1998	19	26	**82**	
1997	2	24	83	**135**
Average		26	82	135
State Ave		23	58	89
Fraser-Lee Ave		42	87	137

Bluegill

Too few bluegill (n = 8) were sampled to warrant any analysis. Of those fish captured, their lengths ranged from 115-177 mm total length. Bluegill condition is high with relative weights averaging 125.

Rainbow Trout

Rainbow trout size ranged from 63-460 mm in total length (Figure 10). All rainbow trout sampled are hatchery in origin and represent the 2000 fingerling (60-90 mm), 1999 fingerling and/or 2000 catchable (200-280 mm) plants. The larger rainbow trout (> 400 mm) are probably age 2 carryovers from a previous fingerling plant, but they may be broodstock or trophy trout plants. Condition of rainbow trout is poor with nearly all individuals below the national average (Figure 11).

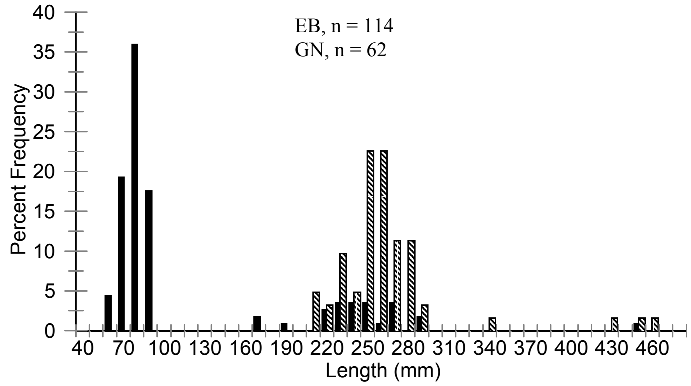

Figure 10. Length-frequency distribution of rainbow trout from the spring 2000 survey of Long Lake, Thurston County. Represents individuals one year old or older.

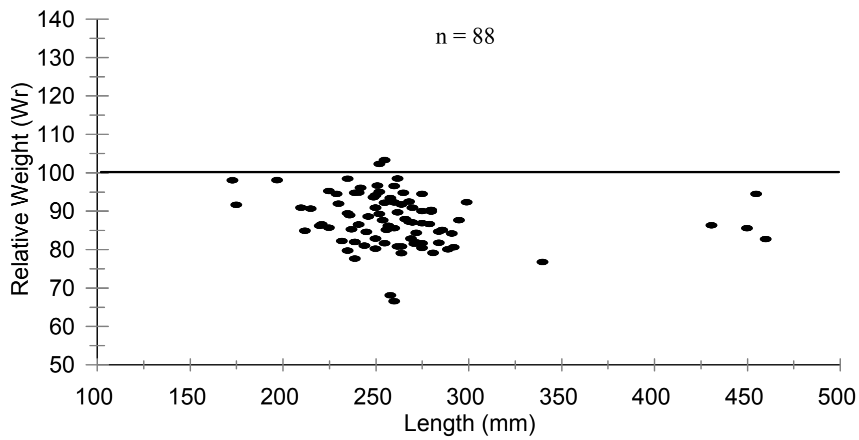

Figure 11. Relative weights of rainbow trout from the spring 2000 survey of Long Lake, Thurston County. Horizontal line at 100 represents the national 75th percentile.

Sculpins

A total of 106 sculpins were sampled from Long Lake. Sculpins size ranged from 15-154 mm total length. Condition, age, and growth analysis was not performed on sculpins.

Largescale Sucker

Largescale sucker size ranged from 117-605 mm total length. Condition, age, and growth analysis was not performed on largescale sucker.

Common Carp

Carp size ranged from 160-790 mm total length. Condition for these fish is high with relative weights averaging 108. Age and growth analysis was not performed on carp.

Brown Bullhead

Too few brown bullhead (n = 10) were sampled to warrant any analysis. Of those fish captured, their lengths ranged from 210-385 mm total length. Condition for these fish is high with relative weights averaging 109. Age and growth analysis was not performed for brown bullhead

Brown Trout

Too few brown trout (n = 2) were sampled to warrant any analysis. However, both of these fish were quite large at 425 and 570 mm total length. Brown trout condition is high with relative weights averaging 126. Age and growth analysis was not performed for brown trout.

Discussion and Conclusion

Judging from our results, the warmwater fish community at Long Lake is poor. Few quality (minimum size anglers like to catch) and larger size warmwater gamefish were sampled. Further, recruitment for most warmwater gamefish to older age classes appears limited. Currently, largemouth bass and rock bass provide the best opportunity to catch quality size and larger fish. Although the largemouth bass population is considered poor, there are angling opportunities for a few memorable size (510-629 mm) fish that exist in the lake. The rock bass population has good size structure and a high density of larger fish (quality size). Rock bass abundance and size structure has apparently increased since the SONAR treatment in Long Lake (Jackson et al., 1990). Rock bass are presently the best panfish fishery in the lake with fish up to 230 mm. In general, the other warmwater gamefish populations are low in abundance and weighted towards smaller individuals (< stock size).

The poor condition of Long Lake's warmwater fish community may be related to the extensive aquatic plant management there. In 1991, vegetation (primarily Eurasian water milfoil) was eradicated from Long Lake using the aquatic herbicide SONAR. Since, vegetation (both native and non-native) has been harvested using both SCUBA divers and mechanical weed harvesters. Aquatic vegetation densities regulate warmwater fish abundance, reproductive success, survival, growth, and predator-prey interactions (Unmuth, 1998; Heck and Crowder, 1991; Bain and Boltz, 1992; Maciena, 1999). Bettoli et al. (1993) found that 17 commonly sampled fishes in Lake Conroe, TX declined after grass carp *Ctenopharyngodon idella* eradicated aquatic vegetation, with the most notable declines seen in largemouth bass and sunfishes. Ware and Gasaway (1978) noticed a decrease in largemouth bass biomass when vegetation was completely removed in 2 Florida ponds. Further, Durocher (1984) found a positive relationship between percent vegetative cover and largemouth bass standing crop and numbers recruited to harvestable size in 30 Texas reservoirs. Optimal warmwater fish production (biomass) is considered to occur at intermediate levels of vegetation (20-60% surface coverage) (Durocher et al., 1984 and Maciena 1999). Vegetation coverage for Long Lake was estimated to be between 10-20% with most of the coverage occurring at the inlet and outlet. Reduced vegetative cover may explain why gravel and rock substrate oriented rock bass abundance has increased since 1990. However, our estimate of vegetation coverage was based on visual observation which is subjective and may not be accurate. Both the SONAR treatment and annual weed harvesting (SCUBA and mechanical) may prevent optimal warmwater fish production from occurring in Long Lake.

Aquatic vegetation removal is one method the LLMD employs to control phosphorus levels and thus algal biomass in Long Lake (Clingman and Englehardt, 1995). However, Bettoli et al. (1993) and Radomski et al. (1995) observed increased phosphorus levels (and algal biomass) and decreased water quality when aquatic vegetation was removed. Aquatic plants improve water quality by absorbing phosphorus, which would otherwise be available for algal production.

Decreased aquatic plant harvesting, except for milfoil eradication efforts, may improve water quality at Long Lake.

Presently, it appears that an increase in aquatic vegetation coverage would improve both water quality and the warmwater fish community at Long Lake. Few studies assess the impact of continued vegetation harvest following an initial eradication on fish and water quality. It would be interesting to study the change in vegetation coverage on a monthly basis during harvest (both SCUBA and mechanical) and its affects on fish and water quality over several years (3-5).

Management Recommendations

1. Vegetation Surveys: Determine the percent aquatic vegetation coverage changes in Long Lake during the year. Sampling should occur once a month for 3-5 years. However, one year of information could also be considered useful.

2. **Continue Monitoring:** Conduct surveys every 2-3 years during the spring to monitor the status of the warmwater fish population.

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