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2001 Warmwater Fisheries Survey of Lake Spokane, Spokane and Stevens Counties, Washington

Warmwater Fish Enhancement

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Washington Department of
FISH AND WILDLIFE
Fish Program

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Abstract

A littoral zone survey coordinated by the Washington Department of Fish and Wildlife, of Lake Spokane (Long Lake), Spokane County, Washington, was undertaken by seven 3-person teams June 18-22, 2001, using boat electrofishers, gill nets, and fyke nets. The limnetic zone of the reservoir was surveyed by a 3-person team using hydroacoustics in conjunction with vertical and horizontal gill nets. The inshore survey was conducted to assess growth, condition, reproduction, and survival of warmwater gamefish in Lake Spokane whereas the offshore component evaluated composition, distribution, and abundance of limnetic fish species. During the inshore survey, a total of 21 fish species were observed. Largescale sucker *Catostomus macrocheilus* were most abundant (n=1,535) in the inshore samples and accounted for the majority of the biomass (49.5%). Yellow perch *Perca flavescens* were the most abundant gamefish sampled (n=1,108) inshore. Largemouth bass *Micropterus salmoides* ranged in age from 2 to 13 years but comprised only 2.3% of the inshore sample. Smallmouth bass *M. dolomieui* comprised approximately 8.5% of the inshore sample and ranged in age from 1 to 7 years. Eleven species were observed during offshore sampling, including kokanee *Oncorhynchus nerka* and chinook salmon *O. tshawytscha* not observed inshore. Northern pikeminnow *Ptychocheilus oregonensis* was the most abundant species sampled (n=139) offshore and comprised most of the biomass (49.3%). Similar to the inshore sampling, yellow perch were the most abundant gamefish sampled (n=111) during offshore sampling. Overall results of this survey were similar to studies in the late 1980s and indicate that Lake Spokane supports quality populations of largemouth bass, yellow perch, and black crappie *Pomoxis nigromaculatus*. Since their introduction in the early 1990s, smallmouth bass have established as a self-sustaining population within the reservoir. Largemouth bass recruitment in Lake Spokane appears limited, possibly due to factors including inadequate habitat, competition, predation, and reservoir operations. Although trend data is lacking, low recruitment of largemouth bass may benefit the overall quality of Lake Spokane's largemouth bass population by limiting competition. Information collected during this survey was used to identify possible management strategies that would improve the quality of fishing in Lake Spokane. Future management considerations include monitoring the response of fish populations to the recently imposed slot-limit on largemouth and smallmouth bass, continued evaluation of the seasonal catch-and-release bass regulation, conducting a creel survey to determine angler harvest, and determining what factors are limiting condition of adult black crappie in the reservoir.

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This survey consisted of both inshore and offshore sampling components. For ease of interpretation and presentation, each component is covered under its own section within this technical report. The inshore component is covered under the heading *Section 1 - Inshore Sampling* and the offshore component is covered under the heading *Section 2 - Offshore Sampling*. Each section includes an *Introduction*, a description of *Methods and Materials*, and *Results*. The *Discussion* section provides an overall summary, and discusses conclusions reached from the results of both inshore and offshore sampling.

Section 1 - Inshore Sampling

Introduction

Lake Spokane, also referred to as Long Lake, is located in Spokane and Stevens Counties, approximately 15 kilometers (km) northwest of Spokane, Washington (Figure 1). Lake Spokane was impounded in 1915 upon completion of Long Lake Dam on the Spokane River. Lake Spokane is a relatively narrow, run-of-the-river reservoir operated by Avista Corporation (formerly Washington Water Power Company). Lake Spokane is approximately 39 km in length (Table 1) and is supplied by water from the Spokane and Little Spokane rivers. The Little Spokane River enters the Spokane River approximately 2.9 km below Nine Mile Falls Dam and contributes about 10% of the inflow of the Spokane River (Pfieffer 1985). The upper 4 km of Lake Spokane is riverine and has limited shoreline development. Traveling downstream, the next 24 km of the reservoir is substantially developed, particularly the north shoreline, and is characterized by gentle slopes and shallow bays. Large macrophyte beds occur in this section and comprise most of the reservoir's littoral habitat (Pfieffer 1990). The lower 10 km has limited littoral habitat, minimal shoreline development, and is characterized by steep sandy banks and rocky shorelines. This section contains the reservoir's widest (1,100 meters (m)) and deepest (54 m) points (Pfieffer 1990). Nine Mile, Willow Bay, and Tum Tum (Forshee's) resorts are located on Lake Spokane and provide boat launch, day-use, and camping facilities for set fees. In addition, Riverside State Park and the Washington Department of Natural Resources maintain public boat launching facilities.

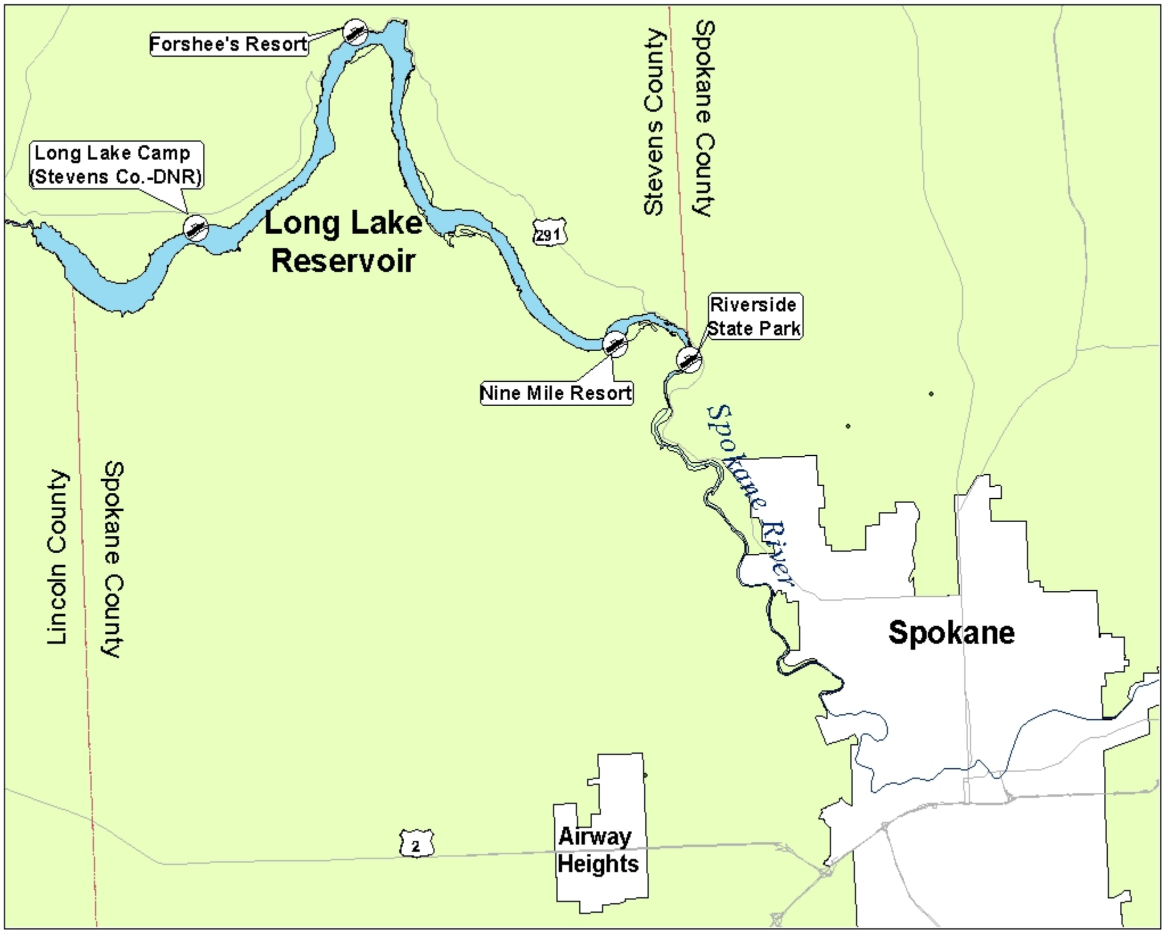

Figure 1. Map of Lake Spokane (Long Lake) in relation to the city of Spokane, Washington.

Table 1. Physical parameters of Lake Spokane (Spokane and Stevens Counties).

Physical Parameter	Measurement
Surface Area (ha)	2,048
Reservoir Length (km)	39
Maximum Depth (m)	54
Mean Depth (m)	15
Volume (acre feet)	253,519

Long Lake Dam is 213 feet high and provides a useable storage capacity of 105,000 acre-feet at a drawdown of 7.3 meters (Bennett and Hatch 1989). A drawdown (intentional dewatering) of 7.3 meters is the maximum drawdown level allowed on Lake Spokane under Avista Corporation's existing Federal Energy Regulatory Commission (FERC) license. However, during years of low water, drawdowns in excess of 4.3 m reduced the pressure in domestic wells in the area. Although fall/winter drawdowns vacillate annually (Figure 2), Avista Corporation attempts to limit reservoir level fluctuations to a maximum of 4.3 meters.

Because of water quality concerns, Lake Spokane has been investigated periodically since the late 1960s (Cunningham and Pine 1969, Soltero et al. 1975, Anderson and Soltero 1984, Jack and Roose 2002). In 1974, Lake Spokane's water quality deteriorated because of sewage effluent from the City of Spokane's wastewater treatment facility. During that time an estimated 126 metric tons of phosphate became entrapped in the reservoir (Soltero et al. 1975). Prior to the completion of the City of Spokane's Advanced Wastewater Treatment plant in 1977, raw sewage was bypassed directly into the Spokane River. That excessively high loading of phosphorus caused immense toxic blue-green algal blooms (Pfieffer 1990) which reduced the reservoir's recreational value (Patmont et al. 1987).

Historically, elevated polychlorinated biphenyls (PCBs) have been found in tissues of fish collected from the Spokane River upstream of Nine Mile Dam (Johnson 2001). At one point, contamination levels were high enough that the Spokane County Health Department issued a human health fish consumption advisory (Spokane County Health Department 2001). Elevated heavy metal concentrations in the Spokane River are caused, in part, by the leaching of these metals from the Coeur d'Alene Basin Mining Districts in Idaho (Johnson 2001) and certain industrial sites and wastewater treatment plants have been found to dispense various PCBs into the Spokane River (Golding 2001). In 2001, the Washington Department of Ecology conducted PCBs and selected metal analyses on tissue of fishes collected from Lake Spokane in cooperation with the Washington Department of Fish and Wildlife (WDFW)(Jack and Roose 2002).

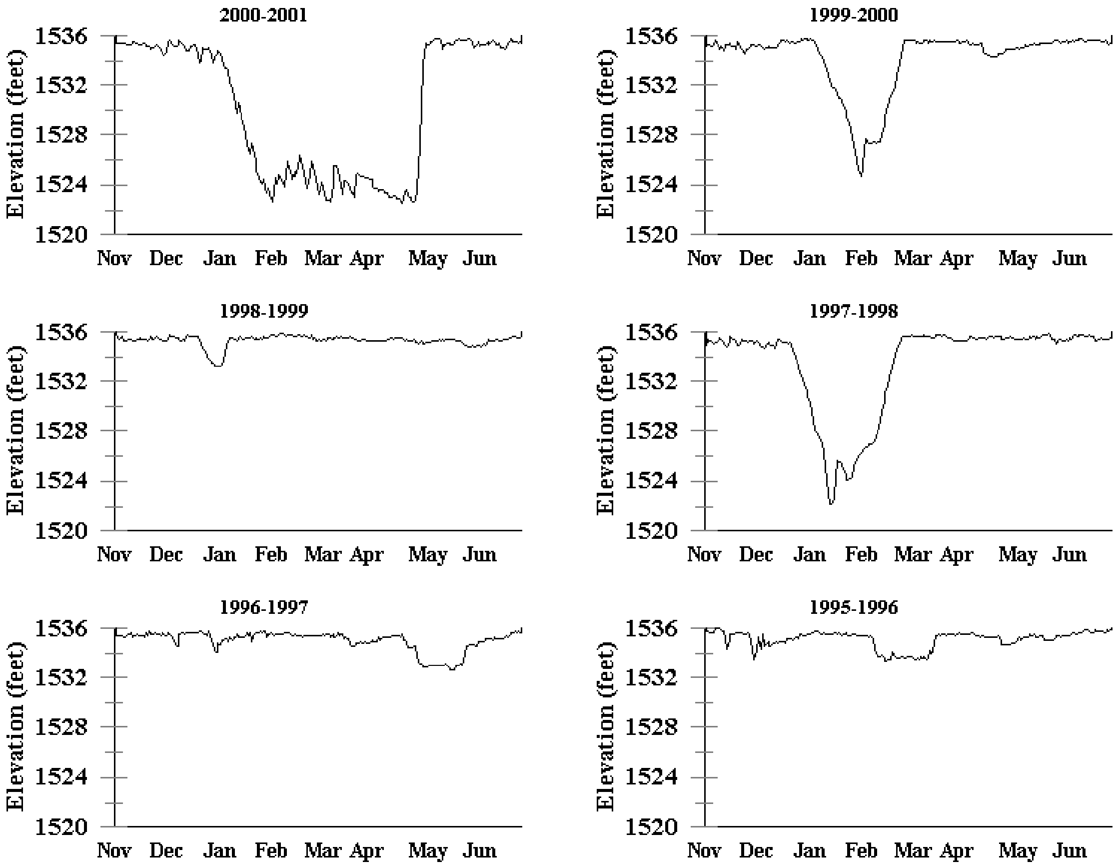

Figure 2. Lake Spokane winter reservoir level fluctuations between 1995 and 2001. Full pool occurs when the elevation of Lake Spokane reaches 1536 feet. Water level data for 2002 were not available.

Although Jack and Roose (2002) reported that metal concentrations in fish flesh were below regulatory criteria, they found certain PCB concentrations elevated and described Lake Spokane as impaired under the Department of Ecology guidelines. However, no fish consumption advisories have been issued for Lake Spokane as a result of these findings.

Lake Spokane is managed by WDFW as a mixed species fishery. In addition to the warmwater species present, WDFW has stocked the reservoir with over 1.6 million trout (rainbow trout *Oncorhynchus mykiss*, brown trout *Salmo trutta*, and eastern brook trout *Salvelinus fontinalis*) since 1974. Relatively few fisheries investigations have been conducted on Lake Spokane in the last 20 years. However, those that have sampled Lake Spokane (Anderson and Soltero 1984, Pfieffer 1985, Pfieffer 1990, Bennett and Hatch 1991) found yellow perch *Perca flavescens* to be the most abundant gamefish. Those researchers also noted that Lake Spokane contains a high abundance of non-game species such as northern pikeminnow *Ptychocheilus oregonensis*, largescale sucker *Catostomus macrocheilus*, and chiselmouth chub *Acrocheilus alutaceus*. Lake

Spokane's largemouth bass *Micropterus salmoides* population appeared stable during the 1980s and early 1990s. However, Bennett and Hatch (1991) noted that although natural reproduction was evident, Lake Spokane's largemouth bass population was below it's production capacity. Between 1990 and 2001, a total of 34 bass tournaments have been held on Lake Spokane, over half of which occurred since 1998 (Bruce Baker, WDFW, personal communication).

Tournament results indicate that although tournament catch rates of largemouth bass were slightly below the Washington State average, the mean size of individual fish were slightly larger than the State average. The WDFW first released smallmouth bass into Lake Spokane in 1992. Smallmouth bass were transferred from the Snake River near Lyons Ferry during September 1992 (n=156), and again during June 1993 (n=250)(WDFW 1995). In addition, 144 smallmouth bass were captured in Lake Roosevelt during June 1995, and transferred to Lake Spokane by the Washington Water Power Company (currently Avista Corporation). Recreational anglers have also reported catching northern pike *Esox lucius*, kokanee *O. nerka*, and chinook salmon *O. tshawytscha* , species that most likely migrated down the Spokane River from Lake Coeur d'Alene, Idaho (Anderson and Soltero 1984). Currently, anglers are allowed to fish Lake Spokane throughout the entire year but bass must be released between May 1 and June 30. Statewide fishing regulations apply to all other species.

The initial step in any fisheries management program is to establish goals and/or priorities (Baker et al. 1993). The WDFW's Warmwater Gamefish Enhancement Program's goal is to increase opportunities to fish for and catch warmwater gamefish. This survey consisted of both inshore and offshore components. The inshore survey was conducted to assess growth, condition, reproduction, and survival of warmwater gamefish in Lake Spokane whereas the offshore component evaluated composition, distribution, and abundance of limnetic fish species. Information collected during this survey was used to identify possible management strategies that would improve the quality of fishing in Lake Spokane.

Methods and Materials

Lake Spokane was surveyed by seven 3-person teams June 18-22, 2001. All fish were collected using boat electrofishers, gill nets, and fyke nets. Each electrofishing unit consisted of a Smith-Root GPP electrofishing boat, using a DC current of 120 cycles/sec at 3 to 4 amps power. Experimental gill nets (45.7 m x 2.4 m) consisted of variable size (13, 19, 25, and 51 millimeter (mm) stretched) monofilament mesh. Fyke nets were constructed of a main trap (4.7 m long and 1.2 m in diameter with five aluminum hoops), a single 30.3 m lead, and two 15.2 m wings. All netting material was constructed of 6.35 mm nylon mesh.

Lake Spokane was divided into seven primary sections (Figure 3). Sampling locations within each primary section were selected by dividing the shoreline into 400 m sections determined by GIS mapping. The number of randomly selected sampling locations within each section were as follows: electrofishing - 15; gill netting - 8; and fyke netting - 8. One reservoir section (Section

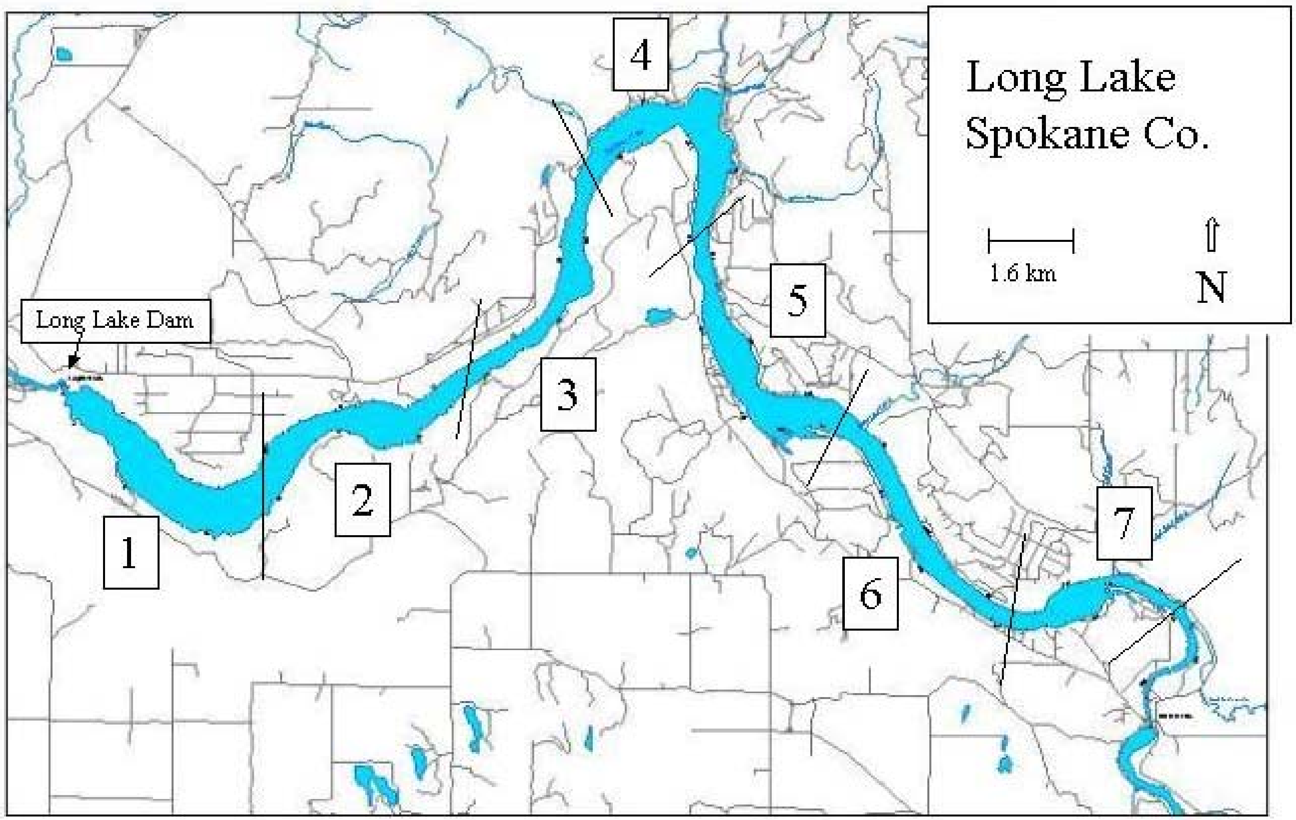

Figure 3. Map of Lake Spokane, Spokane and Stevens Counties, Washington depicting primary sampling sections.

3) lacked suitable shoreline characteristics and therefore was only sampled with fyke nets for four nights. Electrofishing occurred in shallow water (depth range: 0.2 - 1.5 m), adjacent to the shoreline at a rate of approximately 18.3 m/minute for 600 second intervals (Bonar et al. 2000). Gill nets were set perpendicular to the shoreline with the small-mesh end attached on or near the shore, and the large-mesh end anchored offshore. Fyke nets were set perpendicular to the shoreline with the wings extended at 70E angles from the lead. Gill nets and fyke nets were set overnight prior to electrofishing and were pulled the following morning (one net night each). All sampling was conducted during night-time hours when fish are most numerous along the shoreline thus maximizing the efficiency of each gear type.

All fish were identified to species, measured in millimeters to total length (TL), and weighed to the nearest gram (g). Total length data were used to construct length-frequency histograms and to evaluate the size structure of the warmwater gamefish. Scales were collected from largemouth bass, smallmouth bass *M. dolomieui*, pumpkinseed sunfish *Lepomis gibbosus*, walleye *Stizostedion vitreum*, mountain whitefish *Prosopium williamsoni*, black crappie *Pomoxis nigromaculatus*, and yellow perch to analyze age and growth. The above species were assigned to a 10 mm size group based on total length, and scale samples were collected from the first five fish in each size group (Bonar et al. 2000). Scale samples were mounted on adhesive data cards and pressed onto acetate slides using a Carver® laboratory press (Fletcher et al. 1993).

Water chemistry data were collected at 1 m increments from the area of greatest depth within the first upstream and farthest downstream reservoir sections. A Hydrolab® was used to collect information on dissolved oxygen (milligrams per liter)(mg/l), temperature (degrees Celsius)(EC), pH, conductivity (micro-siemens per centimeter)(FS/cm), and turbidity (nephelometric turbidity units)(NTU).

Species composition by weight (kg) and number was calculated for littoral area surveys using a total of 78 electrofishing sections, 52 gill netting sections, and 52 fyke netting sections. This methodology was used to maintain a standardized 3:2:2 ratio of electrofishing to gill netting to fyke netting (three 10-minute electrofishing sections:2 net-nights of gill netting:2 net-nights of fyke netting) which was consistent with statewide Warmwater Program protocol (Bonar et al. 2000). Fish less than one year old, i.e., young-of-the-year, were excluded from all analyses. Eliminating young-of-the-year fish prevents distortions in analyses that may have occurred due to sampling location, size bias of the gear, and specific timing of hatches (Fletcher et al. 1993).

Catch per unit effort (CPUE) of each sampling gear was determined for each warmwater fish species collected. The CPUE of electrofishing was determined by dividing the number of fish captured by the total amount of time that was electrofished. Similarly, CPUE of gill netting and fyke netting was determined by dividing the number of fish captured by the total time the nets were deployed. Standardized CPUE allows for comparisons of catch rates between different lakes or sampling dates on the same water.

Relative weight (W_r) was used to evaluate the condition of fish in Lake Spokane. As presented by Anderson and Neumann (1996), a W_r of 100 generally indicates that the fish is in a condition similar to the national average for that species and length. The index is defined 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 was derived from a standard weight-length ($\log_{10}$) relationship which was defined for each species of interest in Anderson and Neumann (1996). Minimum lengths were used for each species as the variability can be significant for small fish (young-of-the-year). Relative weights less than 50 were also excluded from our analyses as we suspected unreliable weight measurements.

Age and growth of warmwater gamefish in Lake Spokane were evaluated using procedures described by Fletcher et al. (1993). All samples were evaluated using both the direct proportion method (Fletcher et al.1993) and Lee's modification of the direct proportion method (Carlander 1982). Mean back-calculated lengths-at-age for all warmwater gamefish species were then compared to those of Eastern Washington and/or statewide averages (Fletcher et al.1993).

The proportional stock density (PSD) of each warmwater gamefish species was determined following procedures outlined in Anderson and Neumann (1996). PSD uses two measurements, stock length and quality length, to provide useful information about the proportion of various size fish in a population. Stock length is defined as the minimum size of a fish which provides recreational value or the approximate length when fish reach maturity (Table 2). Quality length is defined as the minimum size of a fish that most anglers like to catch or begin keeping. PSD is calculated using the number of quality size fish, divided by the number of stock size fish, multiplied by 100. Stock and quality lengths, which vary by species, are based on percentages of world-record lengths. Stock length was 20-26% of world record length, whereas quality length was 36-41% of world record length.

Relative stock density (RSD) of each warmwater gamefish species was examined using the five-cell model proposed by Gabelhouse (1984). In addition to stock and quality lengths, the Gabelhouse model adds preferred, memorable, and trophy categories (Table 2). Preferred length (RSD-P) is defined as the minimum size of fish anglers would prefer to catch. Memorable length (RSD-M) refers to the minimum size fish anglers remember catching and trophy length (RSD-T) refers to the minimum size fish worthy of acknowledgment. Preferred, memorable, and trophy length fish were also based on percentages of world record lengths. Preferred length is 45-55% of world record length, memorable length is 59-64% of world record length, and trophy length is 74-80% of world record length. RSD differs from PSD in that it is more sensitive to changes in year class strength. RSD is calculated as the number of fish within the specified length category, divided by the total number of stock length fish, multiplied by 100. Eighty percent confidence intervals for PSD and RSD were selected from tables in Gustafson (1988).

Table 2. PSD/RSD length (TL, mm) categories for fish species collected from Lake Spokane (Spokane and Stevens Counties) in June 2001. Numbers in parentheses represent percentages of world record lengths (Gabelhouse 1984).

Species	Length Category				
	Stock (20-26%)	Quality (36-41%)	Preferred (45-55%)	Memorable (59-64%)	Trophy (74-80%)
Black Crappie	130	200	250	300	380
Yellow Perch	130	200	250	300	380
Largemouth Bass	200	300	380	510	630
Smallmouth Bass	180	280	350	430	510
Walleye	250	380	510	630	760
Channel Catfish	280	410	610	710	910
Brown Bullhead	150	230	300	390	460
Yellow Bullhead	150	230	300	390	460

Results

Water Chemistry

Water chemistry data from the upper section were collected on June 21, 2002 (1012 hours), near Nine Mile Resort. In this section the reservoir was relatively homogeneous in terms of temperature, dissolved oxygen, pH, and conductivity throughout the water column (Table 3). This could be expected since this section is directly downstream from riverine conditions which experience high levels of mixing. Water conditions did not appear to be limiting warmwater species' ability to maintain good health and growth as described by Swingle (1969) and Boyd (1990). Temperature in this section varied by less than 0.5EC and dissolved oxygen varied by only 0.6 mg/l.

Water chemistry data from the lower section were collected on June 21, 2002 (1215 hours), near Long Lake Dam. In the lower section there was a thermal gradient from 21.5EC at the surface to 15EC at 12 m deep and 14EC the bottom (26 m). This likely relates to the nature of the reservoir and sampling date. Lake Spokane is operated as a run-of-the-river impoundment. A run-of-the-river system typically exhibits a low hydraulic retention time which prevents the system from fully stratifying. Moreover, these readings were collected in mid-June and the reservoir had not yet been fully influenced by the warm summer temperatures that can contribute to low dissolved oxygen concentrations and lead to thermal stratification. Like the upper section of the reservoir, temperature and dissolved oxygen were within the desirable range for warmwater fish species (Boyd 1990). In addition, pH varied only slightly in this section but were within the range (6.5-9.0) desired by warmwater fish species (Swingle 1969). Although these water chemistry investigations indicate that open water habitat is not limited at this time, more measurements

Table 3. Water chemistry data collected from Lake Spokane, Washington in June, 2001. Data were collected on June 21, 2001 near Long Lake Dam (1215 hours) and Nine Mile Resort (1012 hours).

Location	Depth (m)	Temp (C)	pH	DO (mg/l)	Conductivity (FS/cm)
Long Lake Dam	Surface	21.5	8.62	9.6	103
	1	19.6	8.73	9.8	104
	2	19.0	8.83	9.8	104
	3	18.6	8.88	9.6	104
	4	17.7	8.92	10.4	103
	5	17.2	8.97	10.6	103
	6	16.9	9.04	10.3	103
	7	16.1	8.37	9.2	110
	8	15.7	8.11	9.2	117
	9	15.6	8.04	9.1	118
	10	15.4	8.07	8.9	126
	11	15.2	7.98	8.5	127
	12	15.1	7.98	8.7	131
	13	14.9	7.94	8.4	131
	14	14.8	7.92	8.5	131
	15	14.7	7.89	8.3	130
	16	14.6	7.88	8.2	130
	17	14.6	7.86	8.2	130
	18	14.6	7.86	8.4	130
	19	14.5	7.85	8.0	130
	20	14.4	7.81	8.5	129
	21	14.3	7.77	8.3	128
	22	14.2	7.76	7.9	129
	23	14.1	7.69	7.5	127
	24	14.1	7.66	7.7	124
	25	14.1	7.65	7.3	123
	26	14.0	7.63	7.4	123
Nine Mile Resort	Surface	16.7	7.96	7.6	92
	1	16.4	7.93	7.8	91
	2	16.3	7.93	7.9	91
	3	16.3	7.93	8.0	92
	4	16.3	7.94	8.1	92
	5	16.3	7.95	8.2	92

should be made annually, and at more locations, to fully understand the water chemistry dynamics of Lake Spokane.

Species Composition

A total of 21 fish species were collected during sampling efforts on Lake Spokane (Table 4). Although not depicted in Table 4, one northern pike was collected that was 600 mm in length. One walleye was also observed that was 462 mm long, weighed 942 grams, and was 3 years of age. The catch from certain sections, including those containing the northern pike and walleye, were randomly omitted prior to species composition analysis to maintain the standard sampling ratio (see *Methods and Materials* section). Warmwater gamefish comprised approximately 44% of the total fish captured but only 16.5% of the total biomass. Largescale sucker was the most abundant (32.4%) of any species sampled and also contributed the single highest biomass (49.5%). Yellow perch was the most abundant warmwater gamefish species sampled (23.4%) and the second-most abundant species overall. However, yellow perch only made up 5.2% of the total biomass.

Over 77,000 brown trout fry and nearly 7,000 brown trout of legal size (5.7 fish/pound) were released in Lake Spokane near Riverside State Park and the mouth of the Little Spokane River in the spring of 2001. A total of 14 brown trout were observed during this survey. The techniques used during this survey probably do not effectively capture pelagic species such as trout, thus those species are likely under represented in our samples. Brown trout as large as 584 mm were observed which indicates that at least some of those fish stocked in previous years are surviving, although the rate at which they survive is unknown. Two rainbow trout were observed in our samples which were 112 and 310 mm in length. However, rainbow trout were last stocked in 1995 at a low density (n=7,005), and the fish we observed likely migrated down from the Spokane River where limited stocking below Upriver Dam has occurred. Non-game species comprised about 54% of the total fish captured but contributed almost 83% of the total biomass. These results are similar to those found during the 1980s and early 1990s with largescale sucker and northern pikeminnow dominating the catch (Anderson and Soltero 1984, Pfieffer 1985, Pfieffer 1990, Bennett and Hatch 1991).

Table 4. Species composition, by weight and number, of fish sampled inshore at Lake Spokane (Spokane and Stevens Counties) during June 2001. Analyses do not include young-of-the-year fish.

	Species Composition					
	Weight		Number		Size Range (mm TL)	
Type of Fish	**kg**	**%**	**No.**	**%**	**Min.**	**Max.**
Largescale Sucker	1,180.1	49.5	1,535	32.4	72	570
Carp	325.4	13.7	77	1.6	77	975
Northern Pikeminnow	231.1	9.7	640	13.5	54	612
Tench	221.4	9.3	189	4.0	398	518
Yellow Perch	124.5	5.2	1,108	23.4	87	335
Largemouth Bass	116.7	4.9	109	2.3	220	550
Smallmouth Bass	59.9	2.5	399	8.4	91	505
Black Crappie	38.5	1.6	249	5.3	118	325
Brown Bullhead	33.3	1.4	99	2.1	131	338
Yellow Bullhead	16.1	0.7	94	2.0	110	318
Mountain Whitefish	8.8	0.4	60	1.3	80	355
Bridgelip Sucker	6.4	0.3	31	0.7	86	502
Channel Catfish	5.6	0.2	1	0.0	725	725
Brown Trout	5.5	0.2	14	0.3	90	584
Chiselmouth	5.5	0.2	87	1.8	129	300
Longnose Sucker	2.7	0.1	24	0.5	130	278
Pumpkinseed	0.7	0.0	11	0.2	53	160
Rainbow Trout	0.3	0.0	2	0.0	112	310
Sculpin	0.0	0.0	4	0.1	78	91

Catch Per Unit Effort (CPUE)

Whether using active (e.g., electrofishing) or passive (e.g., gill netting and fyke netting) techniques to sample a lake or reservoir, CPUE can be a useful index to monitor relative abundance (Hubert 1996). Past data collection efforts on Lake Spokane (Pfieffer 1985, Bennett and Hatch 1991) followed different sampling protocols than were used in this survey. The 2001 survey information will serve as a baseline which will allow fishery managers to monitor the effectiveness of future management techniques used on Lake Spokane.

Electrofishing captured more fish (n=3,262) in Lake Spokane than gill nets (n=2,182) or fyke nets (n=347). Electrofishing catch rates were highest on largescale sucker (66.0 fish/hr), northern pikeminnow (15.9 fish/hr), and smallmouth bass (15.0 fish/hr) (Table 5). Gill netting catch rates were highest on yellow perch (17.3 fish/net-night). This was expected since yellow perch tend to inhabit limnetic water, particularly as adults, and are sampled more effectively using gill nets (Hamley 1975). Although fyke nets captured tench (3.1 fish/net-night) and largescale sucker (2.8

fish/net-night) most effectively, the broad confidence intervals limit the interpretation of CPUE data from this technique.

Table 5. Mean catch per unit effort and 80% confidence intervals, by sampling method, for fish stock length and larger collected from Lake Spokane (Spokane and Stevens Counties) during June 2001.

	Gear Type					
	Electrofishing		Gill Netting		Fyke Netting	
Species	**No./ hour**	**No. Sites**	**No./net night**	**No. Nights**	**No./net night**	**No. Nights**
Brown Bullhead	4.1 ± 1.1	104	0.2 ± 0.1	56	0.4 ± 0.2	52
Black Crappie	13.0 ± 2.7	104	0.9 ± 0.3	56	0.1 ± 0.1	52
Bridgelip Sucker	2.1 ± 1.0	104	0.1 ± 0.1	56	0.1 ± 0.1	52
Brown Trout	0.2 ± 0.1	104	0.1 ± 0.1	56	0.0	52
Channel Catfish	0.1 ± 0.1	104	0.0	56	0.0	52
Chiselmouth	2.7 ± 0.9	104	0.9 ± 0.2	56	0.0	52
Sculpin, Unknown	0.2 ± 0.2	104	0.0	56	0.0	52
Carp	4.5 ± 1.4	104	0.1 ± 0.1	56	0.1 ± 0.1	52
Largemouth Bass	7.2 ± 1.3	104	0.1 ± 0.1	56	0.0	52
Longnose Sucker	1.3 ± 0.6	104	0.2 ± 0.1	56	0.0	52
Largescale Sucker	66.0 ± 6.4	104	8.8 ± 1.0	56	2.8 ± 1.4	52
Northern Pikeminnow	15.9 ± 2.7	104	7.8 ± 0.9	56	0.2 ± 0.1	52
Northern Pike	0.0	104	0.1 ± 0.1	56	0.0	52
Peamouth Chub	0.1 ± 0.1	104	0.1 ± 0.1	56	0.0	52
Pumpkinseed	0.6 ± 0.4	104	0.1 ± 0.1	56	0.0	52
Rainbow Trout	0.1 ± 0.1	104	0.0	56	0.0	52
Smallmouth Bass	15.0 ± 1.9	104	0.4 ± 0.1	56	0.0	52
Sucker (unidentified)	2.7 ± 1.5	104	0.0	56	0.0	52
Tench	0.9 ± 0.4	104	0.3 ± 0.2	56	3.1 ± 1.8	52
Walleye	0.0	104	0.1 ± 0.1	56	0.0	52
Mountain Whitefish	1.3 ± 0.7	104	0.9 ± 0.2	56	0.0	52
Yellow Bullhead	4.1 ± 1.1	104	0.6 ± 0.2	56	0.1 ± 0.1	52
Yellow Perch	7.9 ± 1.4	104	17.3 ± 3.4	56	0.1 ± 0.1	52

Stock Density Indices

Electrofishing sample sizes of stock-length largemouth bass, smallmouth bass, black crappie, and yellow perch were high (Table 6). Gill netting sample sizes of stock length fish were high for yellow perch, but relatively low for other species. Fyke netting sample sizes for all species were inadequate to provide useful information (Bonar et al. 2000). The sample size of smallmouth bass collected by gill netting was relatively low, however, PSD and RSD values obtained from gill netted fish may provide additional insight to the size structure of the population. Higher stock density values for smallmouth bass and yellow perch from gill netting may be attributed to deep water habitat occupied by larger individuals of these species that is not readily sampled by electrofishing. Although the sample size was less than preferred, smallmouth bass PSD and RSD values from gill netted fish indicate a high quality population. High PSD values also indicate quality populations of largemouth bass, black crappie, and yellow perch. High predator PSD values are typical in a fish community exposed to annual drawdown where predator crowding occurs (Baker et al. 1993). RSD values for largemouth bass and smallmouth bass were relatively high compared to other lakes surveyed in the region.

Table 6. Traditional stock density indices, including 80% confidence intervals, of fish collected from Lake Spokane (Spokane and Stevens Counties) June 2001, by sampling method.

Species	# Stock Length	PSD	RSD-P	RSD-M	RSD-T
		Electrofishing			
Black Crappie	226	90±3	4±2	1±1	0
Largemouth Bass	125	97±2	80±5	7±3	0
Pumpkinseed	11	18±15	0	0	0
Smallmouth Bass	261	23±3	4±2	1±1	0
Yellow Perch	138	75±5	4±2	0	0
		Gill Netting			
Black Crappie	48	94±4	4±4	0	0
Smallmouth Bass	20	65±14	60±14	10±9	0
Yellow Perch	971	87±1	2±1	0	0

Largemouth Bass

Largemouth bass sampled from Lake Spokane ranged in length from 152 to 550 mm total length (Table 4; Figure 4) and ranged in age from 2 to 13 years (Table 7). Growth of Lake Spokane largemouth bass was above the statewide average at all ages observed. Missing from our samples were young-of-the-year and age 1 largemouth bass which are typically observed in higher numbers than older age fish. This may be an artifact of sample timing or may indicate unstable year-class strength. The condition of largemouth bass varied greatly (i.e., W_r 52-144) and did not appear to be related to fish size (Figure 5). Approximately equal numbers of largemouth bass exhibited condition above and below the national average.

Table 7. Back calculated mean length at age (mm) of largemouth bass collected at Lake Spokane (Spokane and Stevens Counties) during June 2001. Unshaded values represent length at age calculated using the direct proportion method (Fletcher et al. 1993). Shaded values represent length at age calculated using Lee's modification of the direct proportion method (Carlander 1982).

		Mean Total Length (mm) at Age												
Year class	**No.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
2000	0	--												
		--												
1999	1	44	209											
		60	210											
1998	12	129	232	315										
		141	237	315										
1997	4	109	248	323	374									
		123	255	326	374									
1996	13	95	225	327	377	403								
		111	234	331	378	403								
1995	22	70	199	290	356	392	409							
		87	209	296	358	393	409							
1994	15	79	213	298	348	399	420	432						
		95	223	304	352	401	421	432						
1993	7	84	252	356	403	434	456	470	481					
		100	262	361	406	436	457	470	481					
1992	6	71	179	306	370	406	432	457	474	486				
		88	192	313	375	409	435	458	474	486				
1991	3	65	219	337	399	427	456	474	488	502	510			
		83	231	344	403	430	458	475	489	502	510			
1990	1	104	212	275	308	329	359	385	400	419	429	438		
		120	222	283	314	334	363	387	402	420	430	438		
1989	2	105	258	342	375	410	440	461	480	499	516	526	534	
		121	269	349	381	414	444	464	482	501	516	526	534	
1988	1	69	202	291	380	427	452	471	488	504	516	531	541	550
		86	215	301	387	431	456	474	491	505	517	532	542	550
Overall Mean		85	221	315	369	403	428	450	469	482	493	498	538	550
Weighted Mean		103	227	316	369	404	425	450	477	488	501	506	537	550
WA State Mean		60	146	222	261	289	319	368	396	440	485	472	496	NA

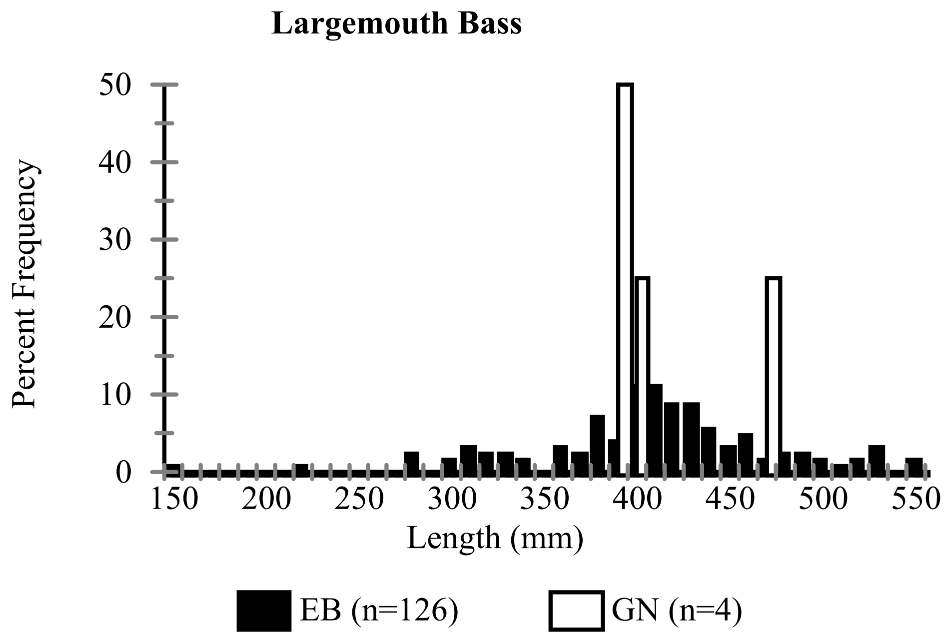

Figure 4. Length frequency distribution of largemouth bass, excluding young-of-the-year, sampled by electrofishing (EB) and gill netting (GN) at Lake Spokane (Spokane and Stevens Counties) during June 2001.

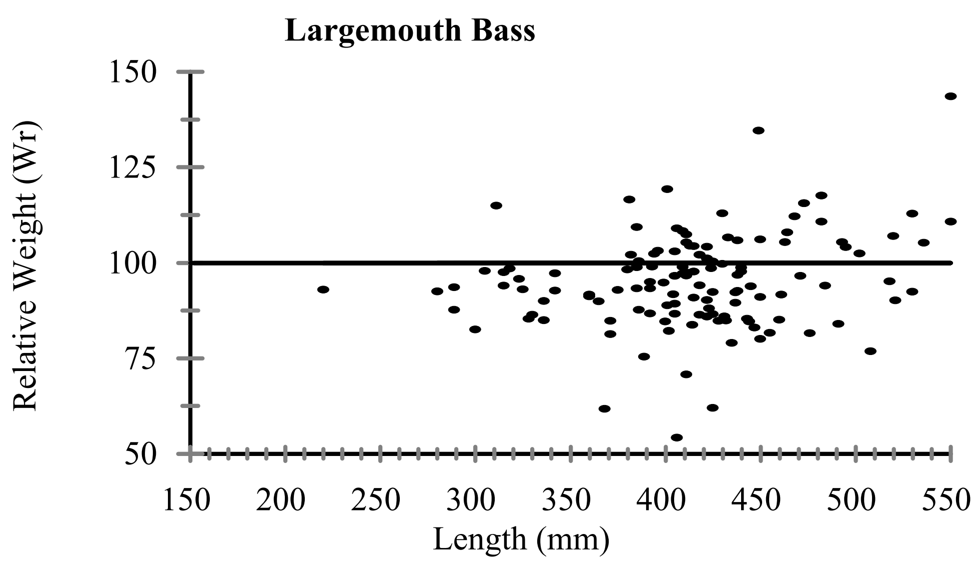

Figure 5. Relative weights of largemouth bass (n=125), excluding young-of-the-year, sampled at Lake Spokane (Spokane and Stevens Counties) during June 2001, as compared to the national average, W_r=100 (Anderson and Neumann 1996).

Smallmouth Bass

Smallmouth bass sampled from Lake Spokane ranged in length from 91 to 505 mm total length (Table 4; Figure 6). These fish ranged in age from 1 to 7 years (Table 8). Growth of smallmouth bass was above the statewide average; however, the sample size of age 6 and 7 fish was low. Smallmouth bass length frequency (Figure 6) and age data (Table 8) suggest stable year-class strength, unlike the largemouth bass population, and indicate that natural reproduction is occurring. Smallmouth bass were last stocked into Lake Spokane in June 1993. The condition of smallmouth bass less than 190 mm was at, or below, the national average (Figure 7). However, condition of smallmouth bass greater than 190 mm was relatively low and appeared to decrease as length increased, which may indicate inter- or intraspecific competition increases with size and age.

Table 8. Back calculated mean length at age (mm) of smallmouth bass collected at Lake Spokane (Spokane and Stevens Counties) during June 2001. Unshaded values represent length at age calculated using the direct proportion method (Fletcher et al. 1993). Shaded values represent length at age calculated using Lee's modification of the direct proportion method (Carlander 1982).

		Mean Total Length (mm) at Age						
Year Class	**No.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2000	25	81						
		87						
1999	25	49	152					
		73	154					
1998	50	80	168	259				
		104	181	259				
1997	11	57	191	253	311			
		86	205	260	311			
1996	11	53	154	292	353	397		
		83	175	302	357	397		
1995	2	88	247	332	382	454	481	
		117	264	343	389	456	481	
1994	3	64	198	300	347	413	438	452
		94	217	311	355	416	439	452
Overall Mean		67	185	287	348	421	460	452
Weighted Mean		91	179	269	340	408	456	452
WA State Mean		70	146	212	268	334	356	393

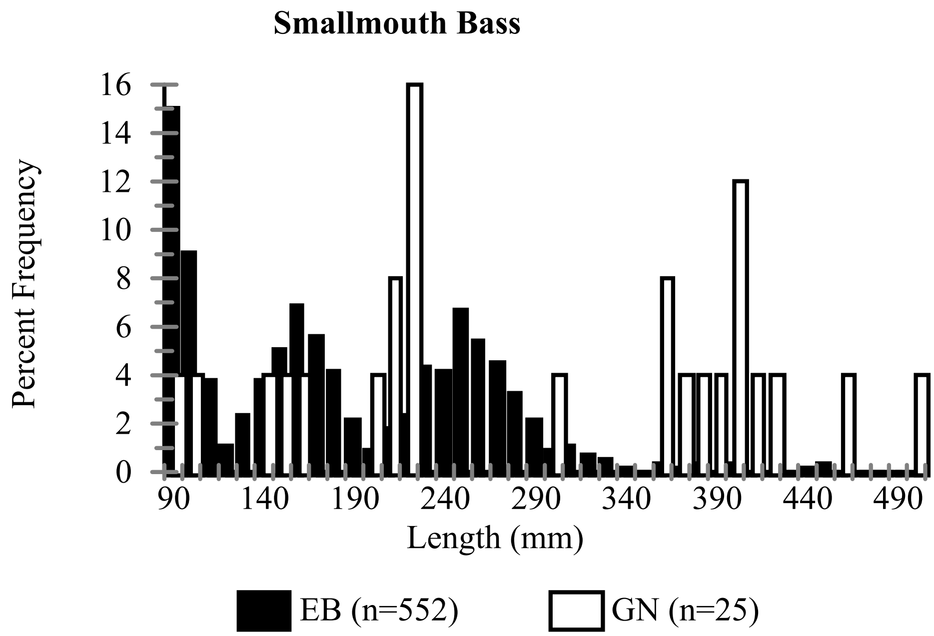

Figure 6. Length frequency distribution of smallmouth bass, excluding young-of-the-year, sampled by electrofishing (EB) and gill netting (GN) at Lake Spokane (Spokane and Stevens Counties) during June 2001.

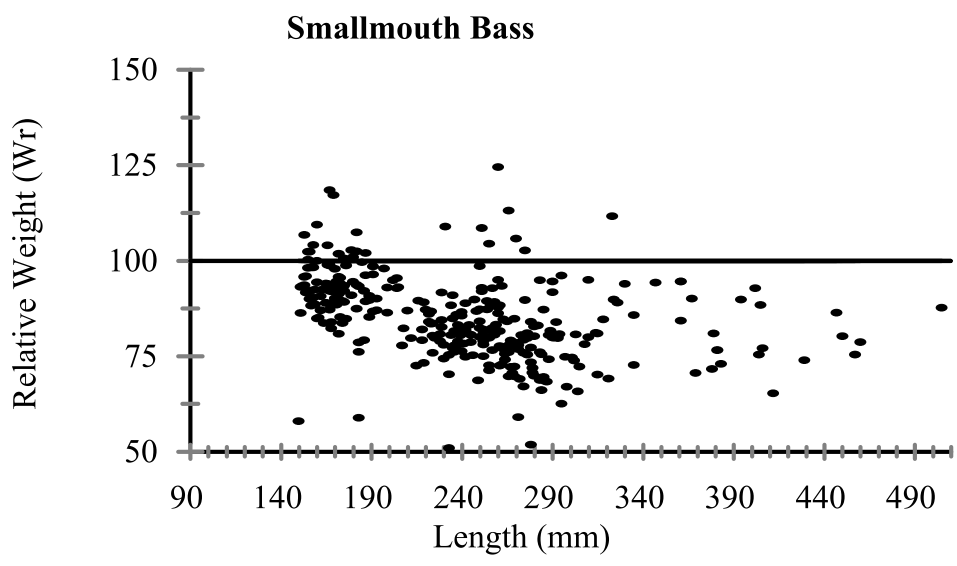

Figure 7. Relative weights of smallmouth bass (n=322), excluding young-of-the-year, sampled at Lake Spokane (Spokane and Stevens Counties) during June 2001, as compared to the national average, W_r=100 (Anderson and Neumann 1996).

Black Crappie

Total lengths of black crappie sampled at Lake Spokane ranged from 118 to 325 mm (Table 4; Figure 8). Black crappie ranged in age from 3 to 7 years (Table 9). Similar to largemouth bass, age 1 and age 2 black crappie were not observed indicating possible failures of the 2000 and 1999 year classes (Table 9; Figure 8). Growth of Lake Spokane black crappie was slightly higher than that of black crappie (n=290) collected at 16 locations throughout Washington state (Fletcher et al. 1993). The sample size of black crappie used for age analysis was small for most ages. Black crappie less than 230 mm total length were in fair condition (i.e., W_r 90-110)(Figure 9) which may indicate a moderate to low density. Condition of black crappie greater than 230 mm total length was less than the national average which may indicate high levels of inter- or intraspecific competition, or limited preyfish abundance.

Table 9. Back calculated mean length at age (mm) of black crappie collected at Lake Spokane (Spokane and Stevens Counties) during June 2001. Unshaded values represent length at age calculated using the direct proportion method (Fletcher et al. 1993). Shaded values represent length at age calculated using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age						
Year Class	**No.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2000	0	--						
		--						
1999	0	--	--					
		--	--					
1998	35	70	145	210				
		93	156	210				
1997	5	57	140	208	249			
		84	156	214	249			
1996	2	43	129	212	236	255		
		72	146	218	239	255		
1995	3	40	134	209	247	277	290	
		70	153	219	252	279	290	
1994	2	46	149	211	242	268	278	286
		75	166	221	247	270	279	286
Overall mean		51	139	210	243	267	284	286
Weighted Mean		89	156	212	248	270	286	286
WA State Mean		46	111	157	183	220	NA	NA

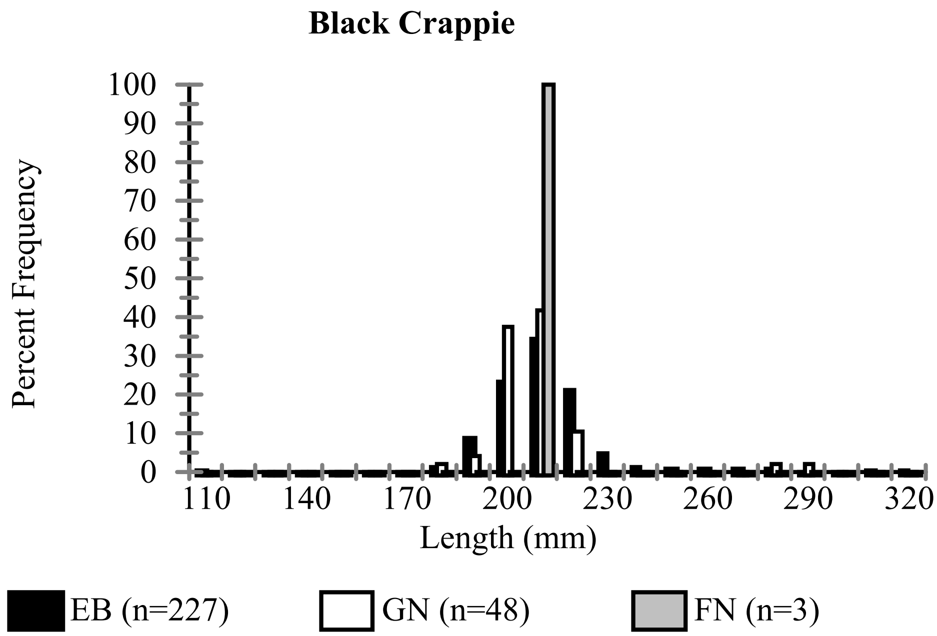

Figure 8. Length frequency distribution of black crappie, excluding young-of-the-year, sampled by electrofishing (EB), gill netting (GN), and fyke netting (FN) at Lake Spokane (Spokane and Stevens Counties) during June 2001.

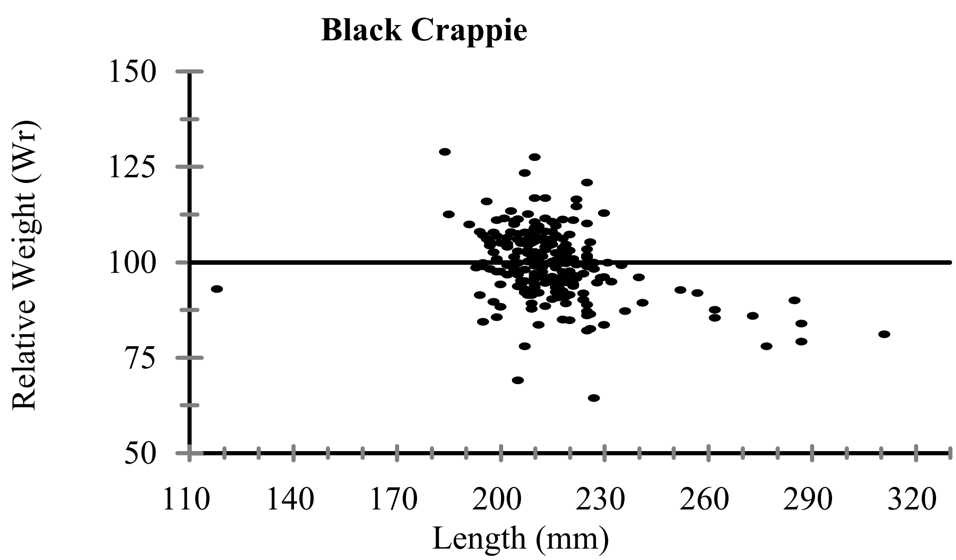

Figure 9. Relative weights of black crappie (n=224), excluding young-of-the-year, sampled at Lake Spokane (Spokane and Stevens Counties) during June 2001, as compared to the national average, W_r=100 (Anderson and Neumann 1996).

Pumpkinseed

Pumpkinseed were sampled in low numbers from Lake Spokane. Total lengths of pumpkinseed sampled from Lake Spokane ranged from 53 to 160 mm (Table 4; Figure 10) and ranged in age from 2 to 5 years (Table 10). Although growth of Lake Spokane pumpkinseed appears to be above the statewide average, the sample sizes of all ages were small which limited interpretation. With the exception of the smallest pumpkinseed sampled (53 mm), all pumpkinseed were in above average condition (Figure 11). This is indicative of a population in low density and concurs with the low number of pumpkinseed observed during this survey.

Table 10. Back calculated mean length at age (mm) of pumpkinseed collected at Lake Spokane (Spokane and Stevens counties) during June 2001. Unshaded values represent length at age calculated using the direct proportion method (Fletcher et al. 1993). Shaded values represent length at age calculated using Lee's modification of the direct proportion method (Carlander 1982).

		Mean Total Length (mm) at Age				
Year Class	**No.**	**1**	**2**	**3**	**4**	**5**
2000	0	--				
		--				
1999	1	29	90			
		47	93			
1998	5	28	79	136		
		48	90	137		
1997	0	--	--	--	--	
		--	--	--	--	
1996	1	19	102	116	143	160
		41	111	123	146	160
Overall Mean		25	90	126	143	160
Weighted Mean		47	93	135	146	160
WA State Mean		24	72	102	123	139

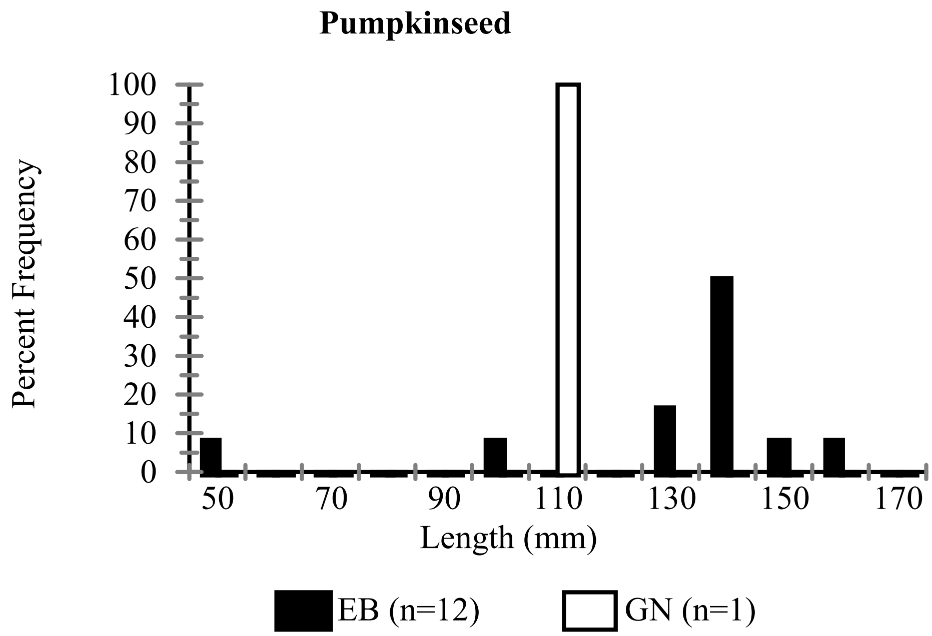

Figure 10. Length frequency distribution of pumpkinseed, excluding young-of-the-year, sampled by electrofishing (EB) and gill netting (GN) at Lake Spokane (Spokane and Stevens Counties) during June 2001.

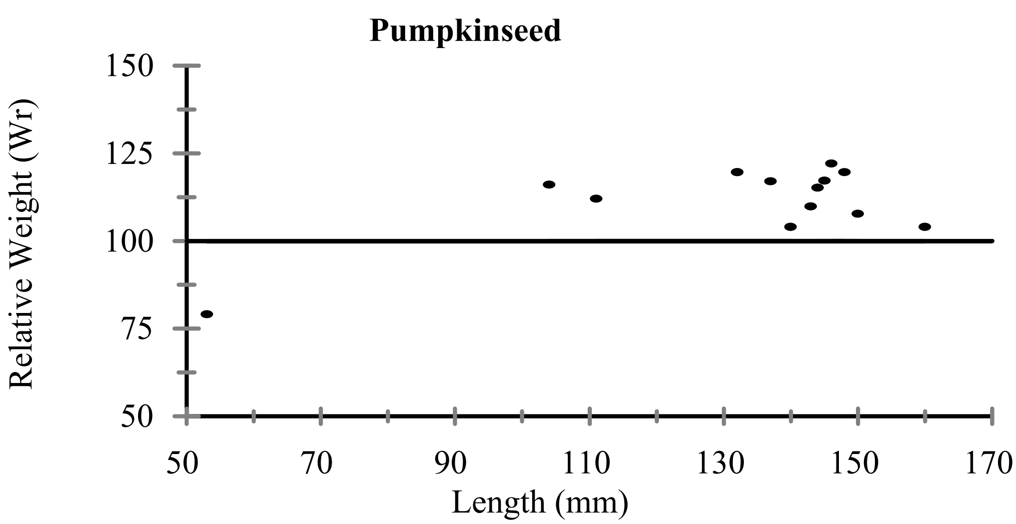

Figure 11. Relative weights of pumpkinseed (n=13), excluding young-of-the-year, sampled at Lake Spokane (Spokane and Stevens Counties) during June 2001, as compared to the national average, W_r=100 (Anderson and Neumann 1996).

Yellow Perch

Yellow perch were the most abundant gamefish sampled (n=1,108) and was second only to largescale sucker in overall abundance (Table 4). Total lengths of yellow perch sampled in Lake Spokane ranged from 87 to 335 mm (Table 4; Figure 12). Lake Spokane yellow perch ranged in age from 1 to 5 years (Table 11) and showed stable year-class strength. Growth of yellow perch was above the statewide average at all ages, although sample sizes of fish from the 1997 and 1996 year-classes were small which limited interpretation. The condition of yellow perch was below average (Figure 13). Poor condition, coupled with the high proportion of yellow perch in our samples suggest that the yellow perch population in Lake Spokane is in moderate density. Moreover, low condition can often be a result of high levels of intra- and/or interspecific competition.

Table 11. Back calculated mean length at age (mm) of yellow perch collected at Lake Spokane (Spokane and Stevens Counties) during June 2001. Unshaded values represent length at age calculated using the direct proportion method (Fletcher et al. 1993). Shaded values represent length at age calculated using Lee's modification of the direct proportion method (Carlander 1982).

		Mean Total Length (mm) at Age				
Year Class	**No.**	**1**	**2**	**3**	**4**	**5**
2000	24	74				
		80				
1999	10	52	147			
		72	149			
1998	44	77	159	218		
		96	167	218		
1997	2	55	144	201	221	
		78	155	204	221	
1996	4	51	131	215	248	266
		75	146	221	250	266
Overall Mean		62	145	211	234	266
Weighted Mean		87	162	218	240	266
WA State Mean		60	120	152	193	206

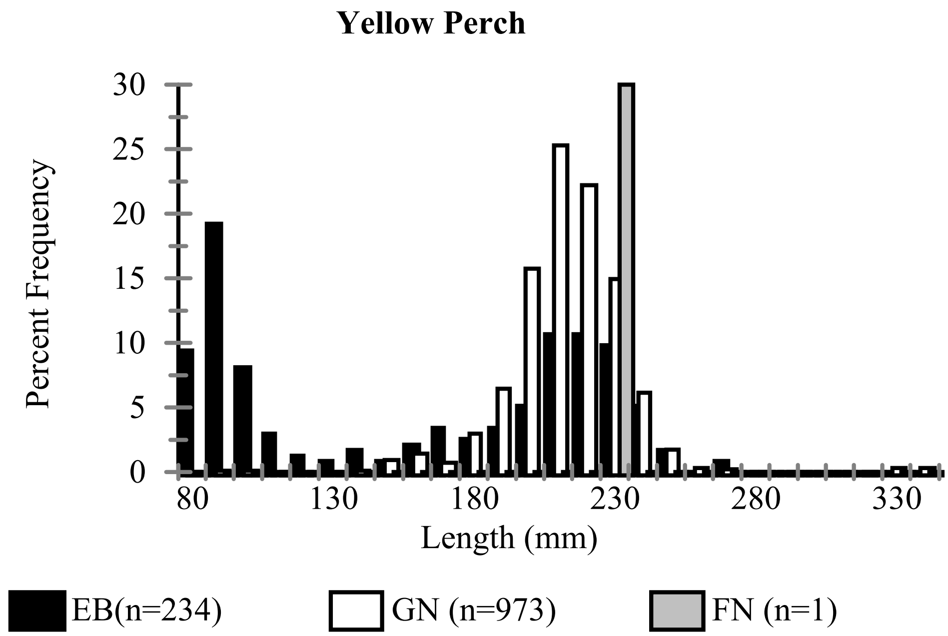

Figure 12. Length frequency distribution of yellow perch, excluding young-of-the-year, sampled by electrofishing (EB), gill netting (GN), and fyke netting (FN) at Lake Spokane (Spokane and Stevens Counties) during June 2001.

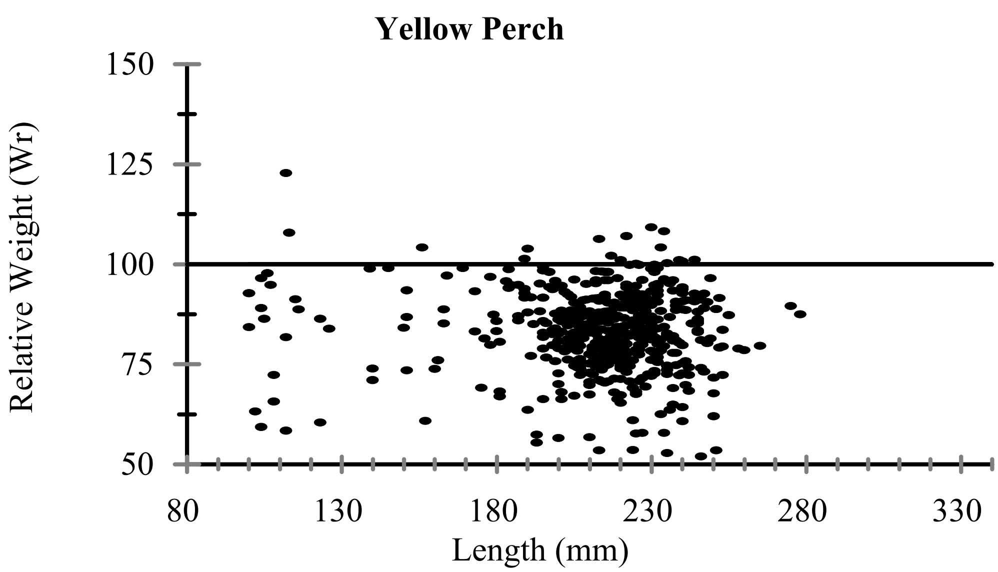

Figure 13. Relative weights of yellow perch (n=522), excluding young-of-the-year, sampled at Lake Spokane (Spokane and Stevens Counties) during June 2001, as compared to the national average, W_r=100 (Anderson and Neumann 1996).

Section 2 - Offshore Sampling

Introduction

The Washington Department of Fish and Wildlife warmwater fish surveys are designed for small lakes and ponds and focus on the littoral zone warmwater fishes (Bonar et al. 2000). Many large lakes and reservoirs in the Western United States have complex fish assemblages including cold, cool, and warmwater species that occupy a variety of habitats. Salmonids and juvenile warmwater species commonly spend certain life stages or seasons in the limnetic zone (Post et al. 1995; Beauchamp et al. 1997; Yule 2000; Baldwin et al. 2002). Therefore, a limnetic fisheries survey was conducted, concurrent to the nearshore surveys, using hydroacoustics and vertical and horizontal gill nets.

Hydroacoustics uses sound impulses transmitted through water to determine fish size, depth, and population density (Traynor and Ehrenberg 1979; Brandt 1996; Cryer 1996). Abundance and distribution are determined by expanding results from individual transects to the entire system (Thorne 1979; Levy et al. 1991; Beauchamp et al. 1997). Hydroacoustics is most effective for midwater species, such as kokanee, when surveyed with a vertically oriented transducer. However, recent advances in technology using a horizontally oriented transducer allows for fish detection within 1.5 m of the surface (Yule 2000).

Hydroacoustics cannot determine species composition, so alternative methods must complement a hydroacoustic survey. Common methods for verifying acoustic targets include trawling, purse seining, and gill netting (Parkinson et al. 1994; Bean et al. 1996; Yule 2000). Homogeny in species composition and length distribution results in increased confidence in hydroacoustic estimates.

Methods and Materials

Hydroacoustic Survey

A WDFW survey crew used an HTI model 241 echosounder with two 200 kHz transducers; a 15E split-beam transducer in vertical orientation and a 6Ex10E elliptical split-beam transducer in horizontal orientation. The transducers were clamped to a pole and mounted to the starboard side of a 6.7 m vessel, 1 m below the surface. Data were logged directly into a computer and unprocessed echoes were backed up using digital audiotapes. A pulse repetition rate of 4 pings per second was fast multiplexed between the transducers at a pulse width of 1.25 ms and a 10 kHz pulse width chirp. The horizontal transducer was offset by 7E and sampled fish targets from 1.5 to 8 m below the surface. Data within 16 m of the horizontal transducer was excluded from analysis due to the narrow beam width and potential boat avoidance by fish in the near field (Mous and Kemper 1996; Yule 2000). The vertical transducer data were analyzed from 10 m below the transducer (11 m subsurface) to within 1 m of the bottom of the reservoir. The depth stratum from 8-11 m was not sampled by hydroacoustics due to an insufficiently low ping rate for the boat speed. The density in this stratum was estimated by applying the mean density from the other vertical depth strata. Additionally, fish counts within each 2 m strata had to be corrected for the detectability of fish targets based on the diameter of the sound impulse cone and the fish velocity (boat speed).

Nine transects were conducted in an elongated zig-zag pattern across the limnetic zone of Lake Spokane (Figure 14) on June 18, 2001. The survey began one hour after sunset and each transect covered 2.5 to 3.5 km at a speed of approximately 7.2 km/hour, for a total survey distance of 25.9 km. A global positioning system (GPS) logged the latitude and longitude into the data files and transect distances were calculated using Terrain Navigator software version 4.05 (Maptech 1999).

A series of acoustic echoes were considered a fish if tracked for at least three consecutive pings, within 0.3 m/ping, a maximum velocity of 5 ms/ping, and a target strength between –55 and –28.8 dB. Target strengths were converted to fish lengths using a formula generated by Love (1971, 1977).

Density (fish/m^3) was calculated for each transect and transect densities were averaged together for a reservoir-wide estimate of fish density. Mean fish density was then multiplied by reservoir volume to estimate abundance. Two standard errors were used to estimate the 95 % confidence interval of the acoustic abundance estimate. For each transect, individual tracked fish were verified as real within the post processing software Echoscape 1.52 (Hydroacoustic Technology Incorporated 2001). Raw fish counts were then adjusted to the effective beam width within each 2 m depth strata by the equation:

$$F_1 = F_0 * [1-(EBW/NBW)]$$

where F_1 was the adjusted fish count, F_0 was the original fish count, EBW was the effective beam width for that stratum, and NBW was the nominal beam width for the transducer. Density was calculated by dividing the adjusted fish count by the total swept volume for the transect. Swept volume was calculated as the sum of the volumes for every 4 m depth strata for each transect, adjusted for bottom encroachment. The volume of each strata was calculated by the equation:

$$Vs_1 = V_1 – V_2$$

where V_1 was the volume from the transducer to the bottom of the stratum and V_2 was the volume from the transducer to the top of the stratum and:

$$V = (½ * b * h * (l*e))$$

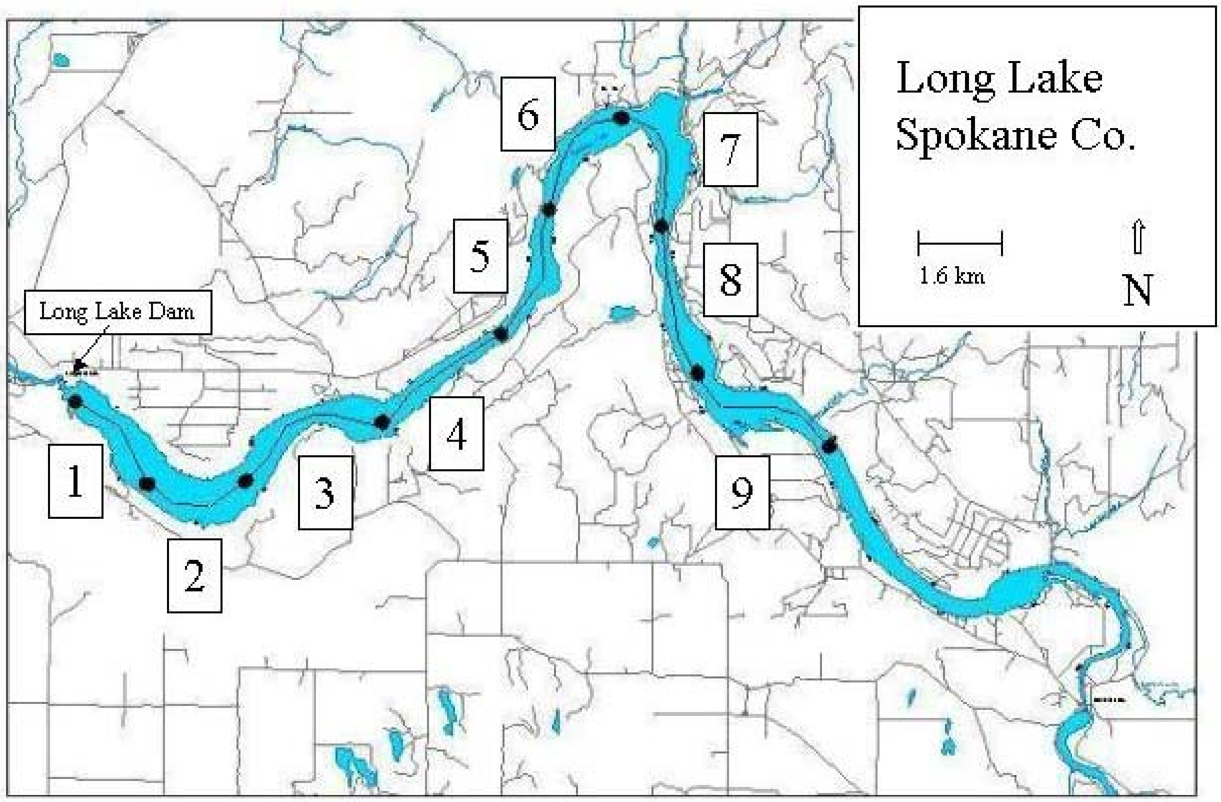

Figure 14. Map of Lake Spokane, Spokane and Stevens counties, Washington, showing hydracoustic transects collected in June of 2001. Black circles indicate the beginning of each transect and the black line represents the boat's travel path, recreated from GPS waypoints collected during the survey.

where e was the percent bottom encroachment (proportion of the transect where bottom depths were equal to or greater than the maximum depth of the stratum), l was the distance (m) of the transect, h was the distance (m) from the transducer to the end of the stratum, and b was the beam diameter calculated by:

$$b = 2\ R\ \tan(NBW/2)$$

where R was the range (m) to the end of the stratum.

Species-specific abundance estimates were calculated by multiplying the species composition of various size classes by the acoustic abundance estimates for the corresponding sizes. Length frequency from the vertical transducer were applied to the horizontal data because fish target echoes in horizontal aspect do not relate to fish length as they do in vertical aspect (Kubecka 1994; Yule 2000). The assumption that fish species composition and size distribution was the same from 1.5 to 8 m (horizontal acoustics) and from 8 to 40 m was validated with netting data.

Gill Net Survey

Gill net surveys were used to provide species verification, depth distributions, and length classes of acoustic targets. Six-seven vertical nets were set in the lower 2/3 of the reservoir on June18, 19, 2001 where bottom depths were greater than 25 m. Two floating, sinking and suspended horizontal nets were set throughout the reservoir on June 18, 19, and 20, 2001. Net depth and placement along transect lines were indiscriminate, but were generally in the middle 1/3 of the shore-to-shore axis. Depths of suspended horizontal nets were selected to cover a variety of depths to complement the vertical nets in the lower 2/3, and to cover the mid-water portion of the more shallow water column in the upper 1/3 of the reservoir. Each vertical gill net was 2.6 m wide, 46 m deep, and consisted of one mesh size throughout (25, 38, 51, 64, 76, 89, or 102 mm stretch). Horizontal nets were also 46 m long with panels 6.5 m long, 2.6 m deep, and mesh sizes from 25-102 mm in 13 mm increments.

Fish captured in the gill nets were identified to species, measured to the nearest mm, weighed to the nearest 5 g with a spring scale, and the depth of capture was recorded. The water column was divided into 5 m strata and vertical distribution was determined by correcting catch data for effort within each stratum.

Results

Hydroacoustic Survey

Fish densities were lowest near the dam (Transect 1 - 1.0 fish/10,000 m^3) and highest near the middle (Transect 4 - 4-5/10,000 m^3) and upper (Transect 9 - 9.5/10,000 m^3) portions of Lake Spokane (Figure 15). The high fish densities observed in transect 9 were due to the presence of

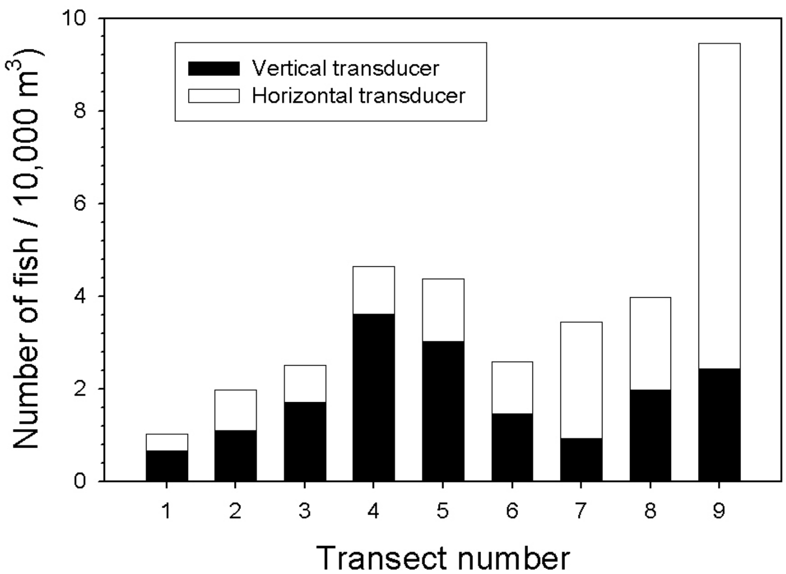

Figure 15. Density of target-tracked fish for nine transects during a mobile hydroacoustic survey of Lake Spokane, Washington on June 18, 2001. Transect 1 began near the log boom of Long Lake Dam and transect 9 ended 25.9 km upstream. The horizontal transducer observed fish from 1 to 8 m whereas the vertical transducer sampled fish from 8 m to the bottom.

many fish in the 1.5 to 8 m depth strata (Figure 15). Fish were distributed throughout the water column but modes were present in the middle depths (16 to 30 m) in the lower and middle sections and near the surface (1.5 to 8 m) in the upper transects (Figure 16).

Gill Net Survey

Thirteen vertical nets and 18 horizontal nets captured 282 fish with a numerical species composition of 49% northern pikeminnow, 39% yellow perch, and 12% other species (Table 12). There was a bi-modal length distribution with yellow perch representing 78% of the fish between 150 and 300 mm and northern pikeminnow representing 85% of the fish between 300 and 450 mm (Figure 17). Kokanee were between 224 and 339 mm and other fish were evenly distributed between 220 and 525 mm (Figure 17).

The vertical distribution of gill netted fish was bi-modal with the majority of fish near the surface (0 to 10 m) and from 15 to 20 m (Figure 18). There was little difference in vertical distribution by species, except that yellow perch had a higher mode in the 5 to 10 m depth bin, whereas pikeminnow were captured more frequently in the 0 to 5 m depth bin (Figure 18). Kokanee were captured from 5 to 27 m but too few fish were in the sample to determine a preference or pattern (Figure 18).

Limnetic Fish Abundance

The mean reservoir density (3.77/10,000 m^3) was extrapolated to total volume (12.963 x 10^7 m^3) for a total reservoir fish abundance of 48,907 (13,655-84,159; 95% CI). This represented an aerial estimate of 24 fish per hectare. The majority (64 %) of fish targets observed by hydroacoustics were juvenile fishes less than 150 mm (-41.6 dB) that were too small for target verification by gill nets. The strong bi-modal length distribution by the two predominant species (yellow perch and pikeminnow) allowed for partitioning of acoustic abundance of specific size classes and species (Figure 17). The abundance of yellow perch between 150 and 300 mm was 8,394 (± 2,344; 2 SE) and the abundance of northern pikeminnow between 300 and 450 mm was 4,138 (± 1,155)(Table 13). Kokanee abundance was evenly distributed between the two size classes with 153 (± 43) and 188 (± 53), respectively.

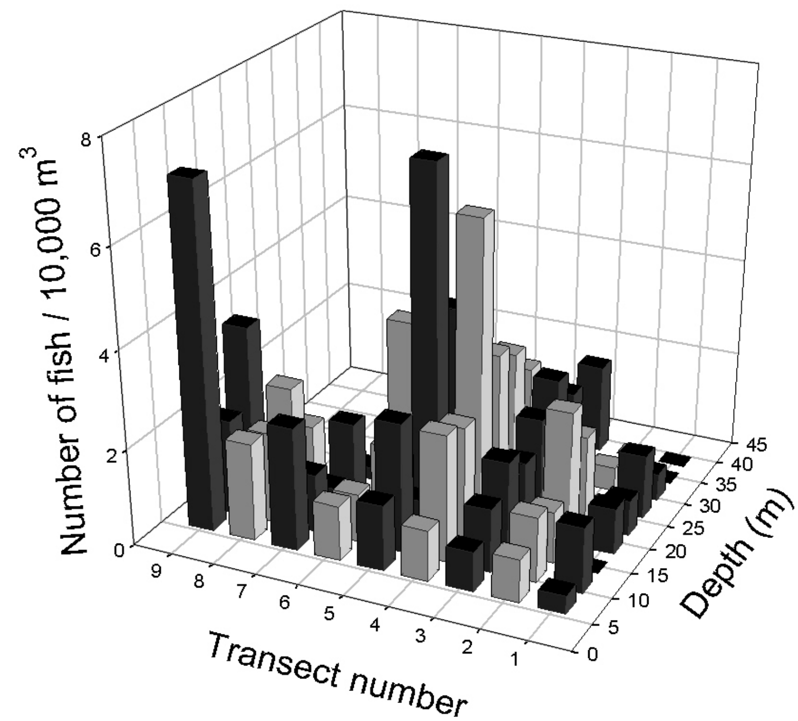

Figure 16. Density of target-tracked fish in each depth bin for nine transects during a mobile hydroacoustic survey of Lake Spokane, Washington on June 18, 2001. Transect 1 began near the log boom of Long Lake Dam and transect 9 ended 25.9 km upstream.

Table 12. Species composition by number, weight, and the minimum and maximum lengths of fish captured in offshore gill nets in Lake Spokane, Washington in June 2001.

				(kg)			Length (mm)	
Species	Number	% n		Weight	% W		Min.	Max
Northern pikeminnow	139	49.3%		43.2	63.7%		170	530
Yellow perch	111	39.4%		11.5	17.0%		102	279
Kokanee	7	2.5%		2.1	3.1%		224	339
Mountain whitefish	7	2.5%		1.7	2.5%		315	363
Largescale sucker	6	2.1%		5.5	8.1%		435	513
Brown trout	5	1.8%		1.8	2.7%		255	397
Brown Bullhead	2	0.7%		0.8	1.1%		284	316
Black Crappie	2	0.7%		0.3	0.5%		206	220
Chinook salmon	1	0.4%		0.4	0.6%		323	323
Chiselmouth	1	0.4%		0.1	0.1%		220	220
Rainbow trout	1	0.4%		0.3	0.5%		310	310
Grand Total	282	100.0%		67.8				

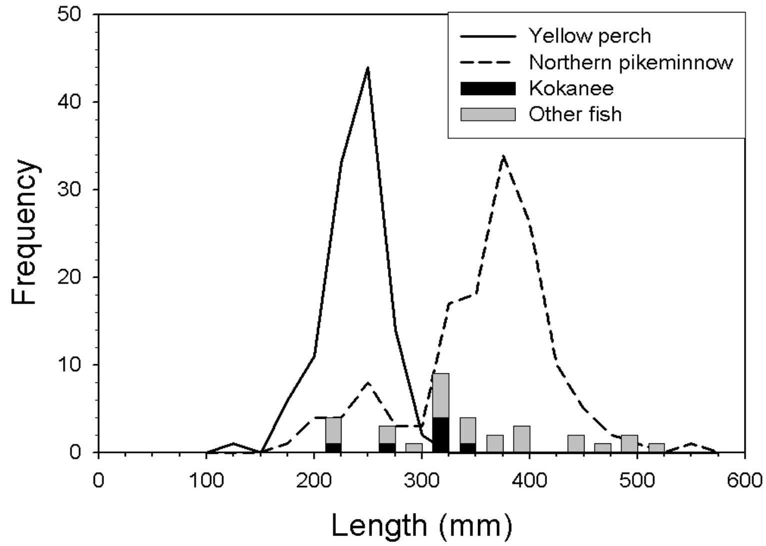

Figure 17. Frequency of each species captured in offshore vertical and horizontal gill nets in Lake Spokane, Washington during June 2001. Other fish included brown trout, black crappie, chinook salmon, chiselmouth, kokanee, largescale sucker, mountain whitefish, and rainbow trout.

Table 13. Species-specific abundance estimates for fish captured in Lake Spokane in June 2001. Abundance was based on a hydroacoustic estimate of 48,907 fish with a coefficient of variation of 0.28 based on 2 SE (~95% confidence intervals). Percent species composition (%Sp) was estimated from a vertical and horizontal gill net survey of the offshore area of Lake Spokane. Fish less than 150 mm were not effectively sampled with gill nets and therefore are labeled as unknown juveniles. Other fish included mountain whitefish, largescale sucker, brown trout, brown bullhead, black crappie, chinook salmon, chiselmouth, and rainbow trout.

Size class		Yellow Perch	Northern Pikeminnow	Kokanee	Other fish	Unknown Juveniles
	Species Comp.					100%
35-150 mm	Abundance					31,300
	2 SE					8,739
	Species Comp.	78%	16%	1%	4%	
151-300 mm	Abundance	8,394	1,755	153	458	
	2 SE	2,344	490	43	128	
	Species Comp.	0%	85%	4%	12%	
301-450 mm	Abundance	-	4,138	188	564	
	2 SE	-	1,155	53	158	
	Species Comp.	0%	50%	0%	50%	
451-600 mm	Abundance	-	978	-	978	
	2 SE	-	273	-	273	

Discussion

Results from the Lake Spokane littoral survey indicate that, similar to sampling conducted in the 1980s and 1990s (Anderson and Soltero 1984, Pfieffer 1985, Pfieffer 1990, Bennett and Hatch 1991), the relative abundance of non-game species such as northern pikeminnow, largescale sucker, and chiselmouth chub remains high. Likewise, yellow perch were the most abundant gamefish observed during the 2001 inshore survey, as they were in the offshore survey and previous studies (Anderson and Soltero 1984, Pfieffer 1985, Pfieffer 1990, Bennett and Hatch 1991). Although low in relative abundance, kokanee and chinook salmon were the only two species observed during offshore sampling but not during inshore sampling. These species are not stocked, but likely entered Lake Spokane from Lake Coeur d'Alene via the Spokane River. Inshore and offshore sampling captured yellow perch within the same size range. Inshore sampling captured a larger size range of northern pikeminnow than was observed during the offshore survey.

Lake Spokane's yellow perch and black crappie populations are above average in terms of their quality and the angling opportunity they provide. Both populations exhibit faster than average growth and relatively high stock density index values. Pumpkinseed sunfish in Lake Spokane appear in good condition, exhibit good growth, and remain at the low density observed during the late 1980s (Bennett and Hatch 1991). The results of this survey suggest that these panfish populations are not experiencing the common problem of overcrowding often observed in Washington's lowland lakes. Overall, Lake Spokane has a limited amount of littoral vegetation and an abundance of, both warmwater (e.g., largemouth bass and smallmouth bass) and non-game (e.g., northern pikeminnow), predators. These characteristics likely keep yellow perch and black crappie from overpopulating, ultimately resulting in higher quality fisheries.

Yellow perch and black crappie populations exhibit some characteristics of quality populations, however, both populations exhibited lower than average condition when compared to the national average. Although the relative weights of only a few yellow perch exceeded that of the national average (W_r=100), Lake Spokane yellow perch may be in respectable condition for a system operated as run-of-the-river and containing a complex species composition. Lower than average relative weights are common for yellow perch populations in Washington and have been observed in numerous other lakes in the central and eastern areas of the state (Divens and Phillips 1999, Divens and Phillips 2000, Osborne and Petersen 2001, Petersen et al. 2001, Phillips and Divens 2001, Osborne and Petersen in prep., Osborne et al. in prep.). The factor(s) limiting the condition and overall quality potential of the Lake Spokane black crappie population is unknown. Most piscivores tend to exhibit higher condition values when they are able to shift their diet from invertebrates to fish (Olson 1996). The low condition of larger and older black crappie observed in Lake Spokane may be an indication of limited prey-fish availability and/or intensive interspecific competition with other deeper water piscivores such as smallmouth bass, yellow perch, and northern pikeminnow.

Lake Spokane is inhabited by both smallmouth and largemouth bass, and although the bass fishery is not considered a "trophy" fishery, the reservoir does provide quality bass fishing for both tournament anglers and the general public. The largemouth bass population in Lake Spokane appears to be dominated by fish 5 years of age and older. Although young-of-the-year largemouth bass may not have been large enough to effectively sample with the gear we used, no age 1 largemouth bass were observed, indicating low recruitment. Many factors may contribute to low recruitment, however, in drawdown reservoirs such as Lake Spokane, predation and/or lack of winter cover are likely causes. Reservoir drawdowns increase water velocity, entrain zooplankton, and concentrate predators (Bennett and Hatch 1991, Ploskey et al. 1993). High predation during annual drawdowns is likely responsible for the high PSD's of the predatory fish in Lake Spokane. Goldman and Horne (1983) stated that water level control in reservoirs can increase the size of individuals. Somewhat related to predation, lack of suitable overwinter cover is also likely responsible for the low recruitment of largemouth bass in Lake Spokane. Bennett and Hatch (1991) suggested Lake Spokane was lacking low water cover which provides juvenile largemouth bass shelter from current and predators. Ploskey (1986) reported that survival of juvenile largemouth bass increases in systems where abundant cover is present and that lack of habitat exposes juvenile bass to increased predation. Miranda and Hubbard (1994) indicated that winter-induced stressors like changes in habitat composition caused by water fluctuations can cause mortality of young-of-the-year largemouth bass. Shuter and Post (1990) stated that energy stores exhaustion is size dependent and affects smaller fish more negatively than larger ones. With little or no cover during periods of low water, juvenile largemouth bass use critical energy stores to avoid predation. Since trend data is lacking, it is unknown whether the largemouth bass population in Lake Spokane is in decline or has stabilized in its current state. Recruitment of juvenile largemouth bass appears low, however, the size structure of the population is similar to what was observed in the late 1980s by Bennett and Hatch (1991). Although the abundance of young bass may not be high, lower recruitment may help to increase the overall quality of Lake Spokane's largemouth bass population.

Compared to largemouth bass, the smallmouth bass population is relatively young. Most smallmouth bass were observed in the deeper areas of the reservoir where overall fish density was relatively low. Few smallmouth bass larger than quality size were observed, however, this may have been a result of sample timing. Age and growth data indicate that the smallmouth bass population in Lake Spokane is dominated by fish less than three years of age. Relative weights of Lake Spokane smallmouth were lower than the national average. Between 1992-1995, 550 juvenile smallmouth bass were released into Lake Spokane in an attempt to increase standing stock of bass, utilize the unoccupied rocky habitat in the lower portion of the reservoir, and to provide additional fishing opportunity to the public (Bob Peck, WDFW-retired, personal communication). Although trend data for smallmouth bass in this reservoir are lacking, smallmouth bass were observed in low numbers by Avista Corporation personnel in 1996 (unpublished data) and the results of this survey suggest that a population has become well established. Considering the angling opportunity they now provide, smallmouth bass should be considered a successful introduction.

Currently, two regulations are in place to regulate harvest of Lake Spokane bass. Both bass species are protected by the statewide bass slot limit regulation which allows anglers to harvest five bass less than 305 mm (12 inches) or greater than 432 mm (17 inches), with no more than one over 432 mm. This conservative regulation went into effect in 2000 on select waters, including Lake Spokane, and expanded into a statewide regulation in 2002. The previous less conservative statewide regulation allowed anglers to retain five bass, but only three could exceed 381 mm (15 inches). The current, more restrictive, regulation may have an effect on the bass population over time. However, this survey was conducted only two years following the regulation change and the size structure of the largemouth and smallmouth bass populations observed during this survey is likely more representative of the populations under the previous regulation. In addition to the slot limit regulation, Lake Spokane anglers are also required to release all bass caught between May 1-June 30. This regulation was enacted in April 1992 in an attempt to increase largemouth bass production by limiting their harvest during spawning season when they are most vulnerable. Although recruitment of juvenile largemouth bass appears low, this catch-and-release regulation still seems appropriate and may be allowing recruitment to occur at levels sufficient to sustain a quality largemouth bass size structure.

The limnetic hydroacoustic and gill net survey provided a successful complement to the littoral warmwater fish survey. The limnetic gill net catch was dominated by yellow perch and northern pikeminnow. Few salmonids were encountered in the gill nets, which limited the ability to assess salmonids in Lake Spokane using hydroacoustics. Acoustic data were analyzed for kokanee, the most abundant salmonid in our netting, though sample size was small (n =7) and confidence in the estimates was low.

Assuming each species shared equal probability of gill net capture, abundance of species more vulnerable to gill nets may have been overestimated. For example, if perch were more active than northern pikeminnow, but just as likely to be retained by the net once it was encountered, then perch abundance was overestimated while pikeminnow abundance was underestimated. This potential bias was minimized by determining abundance within particular size classes. Results of the limnetic survey suggest salmonids were not under represented in the gill net catch due to their high relative catch rates in other lakes and reservoirs. The error bounds for the abundance estimates do not include variance in species composition. Assuming species composition in the gill nets was an accurate representation of the limnetic fishery could effect species-specific estimates, but would not influence the total acoustic abundance estimate.

The volume of water in the limnetic zone could not be determined independently from the littoral zone. Mean density was extrapolated to reservoir wide volume; therefore, it was assumed that fish density in the littoral zone was equal to the limnetic zone for the species composition observed in limnetic gill nets. Yellow perch and northern pikeminnow were commonly captured in littoral samples, but the similarity in density between habitat types could not be confirmed. The relatively small volume of water in the littoral zone minimized the potential bias from this assumption. If nearshore densities were higher than offshore densities then reservoir-wide abundance was underestimated .

The horizontal transducer could not differentiate target strength, so density of specific size classes for near-surface targets could not be determined. Similar mean lengths for each species and depth interval from the gill nets verified the assumption that the size distribution of fish was the same from 1.5-8 m and from 11 m to the bottom.

Considering the potential fishing opportunities Lake Spokane warm water fish populations provide, future management strategies should be developed with the WDFW Warmwater Gamefish Enhancement Program's goal in mind. Although Lake Spokane presently provides the public with quality populations of largemouth bass, smallmouth bass, yellow perch, and black crappie, the following are management aspects that should be considered when attempting to enhance fishing opportunity in Lake Spokane.

Management Considerations

One management option would be to allow the fish populations in Lake Spokane to regulate themselves. As with any management strategy, periodical monitoring should be conducted to determine if future management adjustments were drastically needed. Currently, Lake Spokane is managed as a mixed-species fishery. Although it is argued whether or not mixed-species fisheries management provides for maximum opportunity in smaller lowland lakes, the variety of habitat throughout a reservoir like Lake Spokane may provide for spacial separation where a variety of fish species may increase angling opportunity. The upper reaches of the reservoir, characterized by shallow littoral areas, may provide habitat for species such as largemouth bass and black crappie whereas the lower reaches, characterized by steep rocky shoreline and an extensive limnetic zone, may be better suited for species such as smallmouth bass, yellow perch, or kokanee. Under the current water regime, species occupying the lower, deeper reaches of the reservoir may have an advantage over their littoral counterparts in terms of habitat. Suitable habitat, such as boulders, rock outcroppings, and rock slides for smallmouth bass (Bennett and Hatch 1991), and deeper limnetic areas for yellow perch, are available even during low water conditions whereas most habitat associated with littoral species, such as weed beds, is greatly reduced under those conditions. In addition, smallmouth bass may outperform largemouth bass in terms of feeding during low water conditions. Smallmouth bass are a coolwater species and will forage more actively than largemouth bass at low temperatures such as those experienced during winter drawdown. Regardless, Lake Spokane's gamefish populations appear to be doing well under current conditions and management strategies, and changes in the management of one species, such as largemouth bass, may do little to improve the quality of the population and could have negative effects on the overall condition of the other gamefish populations

Water Level Management

The low recruitment of largemouth bass in Lake Spokane could be due to lack of cover during drawdown, or other drawdown-related conditions such as zooplankton entrainment, stress, low condition of young-of-the-year bass as they enter winter, or habitat loss due to sedimentation. If a management goal is to increase juvenile largemouth bass survival, managers may consider managing water levels to keep water levels higher for a longer period in the winter and raising the level earlier in the spring. Ploskey and Aggus (1984) stated that above average fall surface area increases survival of fish hatched the previous spring. Similarly, Aggus and Elliot (1975) suggested that the duration of high water highly influenced the survival and recruitment of juvenile largemouth bass in drawdown reservoirs. A shorter drawdown period during winter would likely reduce the chance of energy store exhaustion by juvenile largemouth bass and may decrease effects of predation. The annual drawdown has undoubtedly molded the composition and interactions of fish species in Lake Spokane, and any changes in water level management should be closely monitored to record the affect to fish populations.

Artificial Structures

If water level management in Lake Spokane continues unchanged, the addition of low water structure may increase juvenile largemouth bass survival. The addition of structure to a system has been found to provide refuge to juvenile bass and protects them from current and predators (Crowder and Cooper 1979). Ample cover during drawdown conditions may help preserve energy stores of juvenile bass in Lake Spokane and increase their overwinter survival (Shuter and Post 1990). Bennett and Hatch (1991) suggested that, since largemouth bass recruitment was limited, a habitat improvement program may benefit juvenile largemouth bass if structures were added to areas of the reservoir that experience low draft-level velocity. During the late 1980s and early 1990s, Washington Water Power Company and WDFW personnel added a small number of applewood branch clusters to provide low water fish refuge, but the overall effect on the fish community was not evaluated. Considering the large size of Lake Spokane, the amount of structure needed to achieve a measurable change in the largemouth bass population may be so great as to make a habitat improvement project unfeasible. Miranda and Pugh (1997) examined over-winter survival and recruitment of largemouth bass in coves with plant coverage of 0-65% and found the highest values were associated with plant coverage of 10-25%. Considering the affect structure has on predator-prey interactions, optimal levels of structure have been theorized to be from 20-50% coverage (Miranda and Pugh 1997). In their literature review of the use of artificial structure, Bolding et al. (2001) reported that the addition of enough cover to increase juvenile fish survival would probably be practical only in small ponds and lakes. Moreover, the addition of artificial structures most often facilitates an increase in catch rates and harvest by attracting fish and making them more vulnerable to anglers.

Largemouth Bass Supplementation

It has been suggested that stocking young-of-the-year largemouth bass may be effective to increase their abundance in Lake Spokane. Bennett and Hatch (1991) suggested that, because of low recruitment, supplementing Lake Spokane with juvenile largemouth bass would likely enhance their population. The results of the 2001 survey also indicated that largemouth recruitment was low, although the size structure of largemouth bass during both sampling periods were similar indicating that the population may be in a stable, high quality state. The research by Bennett and Hatch (1991), however, was conducted prior to the introduction of smallmouth bass.

The results of this survey suggest that a smallmouth bass population has become established in the lower reaches of the reservoir, an area previously occupied by few sportfish. With the recent introduction of smallmouth bass, supplementation of the largemouth bass population could be detrimental to both bass species. If future investigations warranted largemouth bass supplementation, several options are available to managers. Bennett and Hatch (1991) recommended the construction of a largemouth bass brood pond adjacent to the reservoir which would alleviate mortality caused by transport and could increase numbers of young-of-the-year bass. If considered a priority, juvenile largemouth bass could also be cultured by the WDFW Warmwater Program.

Future Monitoring and Research Needs

Slot-limit Regulation Monitoring

The 12- to 17-inch slot-limit on largemouth bass in Lake Spokane was implemented in 2000 and the indices of population structure from this spring 2001 survey are likely representative of the population under the previous regulation. Therefore, this survey may serve as a baseline for documenting changes in the Lake Spokane fish community under the new, more restrictive regulation. Considering this, management biologists should consider developing a long-term monitoring plan to document any changes in the fish community over time. Objectives of such a program should focus on monitoring the reservoir every three to five years and documenting changes in population density and size structure of largemouth bass and smallmouth bass, and changes in panfish population structures possibly due to increased predation by largemouth bass and smallmouth bass. Additionally, creel survey data should be collected regularly to evaluate angler compliance.

Creel Survey

Warmwater fisheries surveys can provide management biologists useful information on the state of a fish community; however, they provide only circumstantial evidence as to the effects of angler harvest. Detailed and well planned creel surveys can provide more conclusive information. Creel surveys can provide information on fishing effort, angler catch per unit effort (e.g., number fish/hour fishing), and numbers of fish caught or harvested. Creel surveys can also be used to determine angler preferences with regard to management actions, regulations, as well as species and sizes of fish desired (Hahn et al. 1993). Additionally, creel survey data can also provide insights into the economic value provided by a fishery.

Biological information collected from the anglers creel can provide information not typically colleted during standard surveys. The preference of WDFW biologists is to return sampled fish back to the lake alive when conducting surveys. However, information collected from fish retained by anglers can be collected without additional harm to fish populations. For example, otoliths collected from dead fish are very accurate when determining fish age.

Creel survey objectives for Lake Spokane should include documenting fishery utilization throughout the year, angler catch per unit effort, and angler preferences. Otoliths should be collected from dead fish retained by anglers for more definitive aging of warmwater populations in the reservoir. Over time, creel information should aid management biologists in evaluating current regulations and their effect on fisheries management objectives.

Black Crappie Condition

Although growth of Lake Spokane black crappie is above the statewide average, the condition of black crappie greater than 230 mm is relatively poor. Further research is required to determine the factor(s) that is(are) limiting the condition of the larger black crappie in Lake Spokane. In systems with suitable forage, condition of black crappie usually increases after they shift to piscivory. Forage fish abundance should be assessed to determine whether or not suitable forage is lacking. In addition, analyzing the diet of other Lake Spokane piscivores could help determine whether interspecific competition is contributing to the poor condition of adult black crappie.

Zooplankton and Benthic Invertebrate Monitoring

Food limitation and competition can limit fish populations in lakes and reservoirs (Schneidervin and Hubert 1987; Tabor et al. 1996; Stein et al. 1996). Most fishes forage on zooplankton and benthic invertebrates during certain stages of ontogeny, but reservoir drawn down causes zooplankton and other limnetic invertebrates to be entrained (Goldman and Horne 1983). A high abundance of suitable forage is critical for adequate pre-winter growth of young-of-year warmwater fishes (Aggus and Elliot 1975). Inadequate growth will lead to higher rates of mortality during winter due to starvation or predation (Shuter and Post 1990; Miranda and Hubbard 1994). In some reservoirs, however, fluctuating environmental conditions, such as water level variations, can limit nutrients, habitat and ultimately influence abundance of forage (Aggus and Elliot 1975). Small invertebrate prey size has been used to indicate food limitation for fish predators because of size selection removing the preferred, large bodied invertebrates (Brooks and Dodson 1965; Galbraith 1967; Mills and Forney 1983; Crowder et al. 1987). If invertebrate productivity is limiting the growth and survival of fishes in Lake Spokane, then increased entrainment due to draw downs might be a critical limiting factor for juvenile fishes. Future studies should examine the impact of reservoir operations on the abundance and composition of the zooplankton and benthic invertebrate communities in Lake Spokane.

Literature Cited

Aggus, L.R. and G.V. Elliot. 1975. Effects of cover and food on year-class strength of largemouth bass. Pages 317-322 *in* H. Clepper, editor, Black Bass Biology and Management.

Anderson, E. and R.A. Soltero. 1984. An evaluation of the information available for the Long Lake and lower Spokane River fisheries, and a preliminary assessment of un-ionized ammonia and chlorine toxicity potential. Completion Report - City of Spokane Contract No. 414-430-000-501.34-3105. Eastern Washington University, Cheney, Washington. 39 pp.

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

Baker, J.P., H. Olem, C.S. Creager, M.D. Marcus, and B.R. Parkhurst. 1993. Fish and fisheries management in lakes and reservoirs. EPA 841-R-93-002. Terrene Institute and United States Environmental Protection Agency, Washington, DC.

Baldwin, C. M., D.A. Beauchamp, and C. P. Gubala. 2002. Seasonal and diel distribution and movement of cutthroat trout from ultrasonic telemetry. Transactions of the American Fisheries Society 131:143-158.

Bean, C. W., I. J. Winfield, and J. M. Fletcher. 1996. Stock assessment of the artic charr (*Salvelinus alpinus*) population in Loch Ness, UK. Pages 206-223 *in* I. G. Cowx, editor. Stock Assessment in Inland Fisheries. Fishing News Books, London, England.

Beauchamp, D. A. and seven co-authors. 1997. Hydroacoustic assessment of abundance and diel distribution of sockeye salmon and kokanee in the Sawtooth Valley Lake, Idaho. North American Journal of Fisheries Management 17:253-267.

Bennett, D.H. and D.R. Hatch. 1989. Factors limiting the fish community in Long Lake, Spokane County, Washington. Annual Progress Report FY 1988. University of Idaho, Moscow, Idaho. 28 pp.

Bennett, D.H. and D. R. Hatch. 1991. Factors limiting the fish community with emphasis on largemouth bass in Long Lake, Spokane County, Washington. Doc. No. 1991-0361. Washington Water Power Company, Spokane, Washington. 76 pp.

Bolding, B., S. Bonar, and M. Divens. 2001. Use of artificial structure to enhance freshwater sportfish communities in lakes, ponds and reservoirs: a literature review. Technical Report No. FPT01-06. Washington Department of Fish and Wildlife, Olympia, Washington. 35 pp.

Bonar, S. A., B. D. Bolding, and M. Divens. 2000. Standard fish sampling guidelines for Washington State pond and lake surveys. Report No. FPT 00-28, Washington Department of Fish and Wildlife, Olympia, Washington. 24pp.

Boyd, E.C. 1990. Water quality in ponds for aquiculture. Birmingham Publishing Company, Birmingham, Alabama.

Brandt, S. B. 1996. Acoustic assessment of fish abundance and distribution. Pages 385-432 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Brooks, J. L. and S. I. Dodson. 1965. Predation, body size, and composition of plankton. Science 150:28-35.

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

Crowder, L.B. and W.E. Cooper. 1979. Structural complexity and fish-prey interactions in ponds: a point of view. Pages 2-10 *in* D.L. Johnson and R.A. Stein, editors. Response of Fish to Habitat Structure in Standing Water. North Central Division American Fisheries Society, Special Publication 6.

Crowder, L.B., M.E. McDonald, and J.A. Rice. 1987. Understanding recruitment of Lake Michigan fishes: the importance of size-based interactions between fish and zooplankton. Canadian Journal of Fisheries and Aquatic Sciences. 44:141-147.

Cryer, M. 1996. A hydroacoustic assessment of rainbow trout (*Oncorhynchus mykiss*) Population in a deep oligotrophic lake. Pages 196-205 *in* I. G. Cowx, editor. Stock Assessment in Inland Fisheries. Fishing News Books, London, England.

Cunningham, R.K. and R.E. Pine. 1969. Preliminary investigation of the low dissolved oxygen concentrations that exist in Long Lake located near Spokane, Washington. Technical Report No. 69-1. Washington State Water Pollution Control Commission.

Divens, M. and L. Phillips. 1999. 1998 warmwater fisheries survey of Jumpoff Joe Lake. Technical Report # FPT 99-13. Washington Department of Fish and Wildlife, Spokane, Washington. 19 pp.

Divens, M. and L. Phillips. 2000. 1998 warmwater fisheries survey of Powerline Lake (Franklin County). Technical Report # FPT 00-30. Washington Department of Fish and Wildlife, Spokane, Washington. 17 pp.

Fletcher, D., S. A. Bonar, B. D. Bolding, A. Bradbury, and S. Zeylmaker. 1993. Analyzing warmwater fish populations in Washington State. Warmwater fish survey manual. Washington Department of Fish and Wildlife, Olympia, Washington. 164pp.

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

Galbraith, M.G. 1967. Size-selective predation on *Daphnia* by rainbow trout and yellow perch. Transactions of the American Fisheries Society 96:1-10.

Garvey, J.E., R.A. Wright, and R.A. Stein. 1998. Overwinter growth and survival of age-0 largemouth bass (Micropterus salmoides): revisiting the role of body size. Canadian Journal of Fisheries and Aquatic Sciences 55:2414-2424.

Golding, S. 2001. Spokane River PCB and source survey August 2000. Publication No. 01-03-016. Washington Department of Ecology, Olympia, Washington. 27 pp.

Goldman, C. R. and A. J. Horne. 1983. Limnology. McGraw-Hill, Inc. New York, New York. 464 pp.

Gustafson, K.A. 1988. Approximating confidence intervals for indices of fish population size structure. North American Journal of Fisheries Management 8:139-141.

Hahn, P., S. Zeylmaker, and S. Bonar. 1993. WDW methods manual: creel information from sport fisheries. Washington Department of Wildlife, Fisheries Management Division Report #93-18.

Hamley, J.M. 1975. Review of gillnet selectivity. Journal of the Fisheries Research Board of Candada 32:1943-1969.

Hubert, W. A. 1996. Passive capture techniques. Pages 157-192 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Hydroacoustic Technology Incorporated. 2001. Echoscape Version 2.10, Seattle, Washington.

Jack, R. and M. Roose. 2002. Analysis of fish tissures from Long Lake (Spokane River) for PCBs and selected metals. Publication No. 02-03-049. Washington Department of Ecology, Olympia, Washington.

Johnson, A. 2001. An ecological hazard assessment for PCBs in the Spokane River. Publication No. 01-03-015. Washington Department of Ecology, Olympia, Washington. 64 pp.

Kubecka, J. 1994. Simple model on the relationship between fish acoustic target strengths and aspect for high-frequency sonar in shallow waters. Journal of Applied Ichthyology 10:75-81.

Levy, D. A., B. Ransom, and J. Burczynski. 1991. Hydroacoustic estimation of sockeye salmon abundance and distribution in the Strait of Georgia, 1986. Pacific Salmon Commission Technical Report Number 2, Vancouver, British Columbia.

Love, R. H. 1971. Dorsal-aspect target strength of an individual fish. Journal of the Acoustical Society of America 49:816-823.

Love, R. H. 1977. Target strength of an individual fish at any aspect. Journal of the Acoustical Society of America 62:1397-1403.

Maptech. 1999. Terrain Navigator, Version 4.05. Andover, Maryland.

Mills, E.D.,and J.F. Forney. 1983. Impact on *Daphnia pulex* of predation by young yellow perch in Oneida Lake, New York. Transactions of the American Fisheries Society 112:154-161.

Miranda, L.E. and W.D. Hubbard. 1994. Winter survival of age-0 largemouth bass relative to size, predators, and shelter. North American Journal of Fisheries Management 14:790-796.

Miranda, L.E. and L.L. Pugh. 1997. Relationship between vegetation coverage and abundance, size, and diet of juvenile largemouth bass during winter. North American Journal of Fisheries Management 17(3):601-610.

Mous, P. J. and J. Kemper. 1996. Application of hydroacoustic sampling technique in a large wind-exposed shallow lake. Pages 179-195 *in* I. G. Cowx, editor. Stock Assessment in Inland Fisheries. Fishing News Books, London, England.

Olson, M.H. 1996. Ontogenetic niche shifts in largemouth bass: variability and consequences for first-year growth. Ecology 77:179-190.

Osborne, R.S. and M.R. Petersen. In Preparation. 2000 warmwater fisheries survey of Rock Island Ponds, Douglas County, Washington. Washington Department of Fish and Wildlife, Ephrata, Washington.

Osborne, R.S., M.R. Petersen, and C.S. Jackson. In Preparation. 1999 warmwater fisheries survey of Red Rock Lake, Grant County, Washington. Washington Department of Fish and Wildlife, Ephrata, Washington.

Osborne, R. S. and M. R. Petersen. 2001. 2000 warmwater fisheries survey of Whitestone Lake, Okanogan County, Washington. Technical Report #FPT 01-16. Washington Department of Fish and Wildlife, Ephrata, Washington.

Parkinson, E. A., B. E. Ransom, and L. G. Rudstam. 1994. Comparison of acoustic and trawl methods for estimating density and age composition of kokanee. Transactions of the American Fisheries Society 123:841-854.

Patmont, C.R., G.J. Pelletier, L.R. Singleton, R.A. Soltero, W.T. Trial, and E.B. Welch. 1987. The Spokane River basin: allowable phosphorus loading. Contract No. C0087074. Washington Department of Ecology, Olympia, Washington.

Petersen, M.R., R.S. Osborne, and C.S. Jackson. 2001. 1999 Lower Goose Lake warmwater survey, Grant County, Washington. Technical Report # FPT 01-15. Washington Department of Fish and Wildlife, Ephrata, Washington. 28 pp.

Pfieffer, D.E. 1985. A general assessment of aquatic resources on the lower Spokane River reservoirs. Doc. No. 1985-0284. Washington Water Power Company, Spokane, Washington. 33 pp.

Pfieffer, D.E. 1990. Long Lake Reservoir angler and boater user survey: May 1988-April 1989. Doc. No. 1990-0037. Washington Water Power Company, Spokane, Washington. 53 pp.

Phillips, L. and M. Divens. 2001. Warmwater fish survey of Bennington Lake, Walla Walla County. Technical Report # FPT 01-04. Washington Department of Fish and Wildlife, Spokane, Washington. 23 pp.

Pine, W.E., III, S.A. Ludsin, and D.R. DeVries. 2000. First-summer survival of largemouth bass cohorts: is early spawning really best. Transactions of the American Fisheries Society 129:504-513.

Ploskey, G.R. 1986. Effects of water-level changes on reservoir ecosystems, with implications for fisheries management. Pages 86-97 *in* G.E. Hall and M.J. Van Den Avyle, editors, Reservoir Fisheries Management: Strategies for the 80's. Southern Division American Fisheries Society, Bethesda, Maryland.

Ploskey, G.R. and L.R. Aggus. 1984. Effects of water levels and hydrology on fisheries in hydropower storage, hydropower mainstream, and flood control reserviors. Technical Report E-84-8. United States Army Corps of Engineers, Vicksburg, Mississippi.

Ploskey, G.R., M.C. Harberg, G.J. Power, C.C. Stone, and B. Weidenheft. 1993. Assessing impacts of operations on fish reproduction in Missouri River reservoirs. Technical Report EL-93-21. United States Army Corps of Engineers, Vicksburg, Mississippi.

Post, J. R., L. G. Rudstam, and D. M. Schael. 1995. Temporal and spatial distribution of pelagic age-0 fish in Lake Mendota, Wisconsin. Transactions of the American Fisheries Society 124:84-93.

Schneidervin, R.W., and W.A. Hubert. 1987. Diet overlap among zooplanktophagus fishes in Flaming Gorge Reservoir, Wyoming-Utah. North American Journal of Fisheries Management 7:379-385.

Shuter, B.J. and J.R. Post. 1990. Climate, population viability, and the zoogeography of temperate fishes. Transactions of the American Fisheries Society 119:314-336.

Soltero, R.A., A.F. Gasperino, P.H. Williams, and S.R. Thomas. 1975. Response of the Spokane River periphyton community to primary sewage effluent and continued investigation of Long Lake. Project Completion Report - D.O.E. Project No. 74-144. Eastern Washington State College, Cheney, Washington.

Spokane County Health Department. 2001. Health advisory for Spokane River fish consumption. Spokane County Health Department website: http://www.spokanecounty.org/health/EHS/Advisories/SR_Fish_PCBi.pdf.

Stein, R.A., M.T. Bremigan, and J.M. Dettmers. 1996. Understanding reservoir systems with experimental tests of ecological theory: a prescription for management. Pages 12-22 *in* L. E. Miranda and D. R. Devries, editors. Multidimensional Approaches to Reservoir Fisheries Management. American Fisheries Society Symposium 16.

Swingle, H.S. 1969. Methods for the analysis of waters, organic matter, and pond bottom soils used in fisheries research. Auburn University, Auburn, Alabama.

Tabor, R., C. Luecke, and W. Wurtsbaugh. 1996. Effects of *Daphnia* availability on growth and food consumption of rainbow trout in two Utah reservoirs. North American Journal of Fisheries Management 16:591-599.

Traynor, J. J., and J. E. Ehrenberg. 1979. Evaluation of the dual beam acoustic fish target strength measurement method. Journal of Fisheries Research Board of Canada 36:1065-1071.

Thorne, R. E. 1979. Hydroacoustic assessments of adult sockeye salmon (*Oncorhynchus nerka*) in Lake Washington 1972-1975. Journal of the Fisheries Research Board of Canada 36:1145-1149.

WDFW. 1995. Inland fish investigations in Washington: July 1, 1994 - June 30, 1995. 1994 Annual Progress Report submitted to the U.S. Fish and Wildlife Service, Project No. F-114-R-1.

Yule, D. L. 2000. Comparison of horizontal acoustic and purse-seine estimates of salmonid densities and sizes in eleven Wyoming waters. North American Journal of Fisheries Management 20:759-775.

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