Banks Lake Fish Survey, September 2000

by

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Abstract

Banks Lake (Grant County) was surveyed by the Washington Department of Fish and Wildlife (WDFW) Warmwater Fish Enhancement Program and by the Inland Fish Investigations Unit from September 25-29, 2000. Nearshore and offshore surveys were conducted concurrently and are reported here in sections 1 and 2, respectively. For the littoral zone survey, a total of 140, 400 meter sections (32% of the shoreline) were sampled using boat electrofishing, gill netting, and fyke netting. Seventeen species, plus one additional family (Cottidae), were collected within the littoral zone of the reservoir. Smallmouth bass *Micropterus dolomieu* were the most abundant fish species comprising 40% (numerically) of the sample, followed by lake whitefish *Coregonus clupeaformis* (15%) and sculpin (12%). Lake whitefish had the highest biomass at 35% (by weight), followed by carp *Cyprinus carpio* (31%) and smallmouth bass (17%). Catch-per-unit-effort (CPUE) by boat electrofishing was highest for smallmouth bass (71 fish/hour), followed by sculpin (25 fish/hour) and yellow perch *Perca flavescens* (11 fish/hour). CPUE for gill nets was highest for lake whitefish (7 fish/hour), smallmouth bass (2 fish/hour), and carp (1 fish/hour). CPUE by fyke net was highest for yellow perch (0.85 fish/hour), brown bullhead *Ameiurus nebulosus* (0.20 fish/hour), and black crappie *Pomoxis nigromaculatus* (0.15 fish/hour). Smallmouth bass, walleye *Stizostedion vitreum*, and yellow perch showed slow growth and had low condition factors, when compared to the national 75th percentile averages. Slow growth and low condition factors of smallmouth bass were most likely due to overcrowding or inter- and intra-specific competition. Growth and condition factors of largemouth bass *Micropterus salmoides*, black crappie, and pumpkinseed sunfish *Lepomis gibbosus* were above average when compared to other Washington lakes; however, CPUE for these species was low suggesting limited successful recruitment into the fishery. Small sample sizes collected for these three species made it difficult to know whether there was sampling bias related to gear type, fish distribution, or if limited suitable habitat, competition, and predation kept densities low. Yellow perch and walleye both showed good recruitment of young-of-year fish with 78% and 70% of the catch, respectively; however, low condition factor of yellow perch and walleye may have been due to interspecific competition with smallmouth bass. Limnological data in the southern section showed homogenous vertical profiles for all parameters collected, with a mean temperature of 15.8EC, and dissolved oxygen levels averaging 7.8 mg/l throughout the water column. In the northern section, thermal stratification occurred at 20-25m with epilimnetic conditions consistent with the southern site, but with cold temperatures (4.7EC) and low dissolved oxygen (1.7 mg/l) conditions in the hypolimnion. The offshore survey revealed a high abundance of lake whitefish occupying all depths of the reservoir. Lake whitefish dominated the species composition (79%), followed by walleye (11%). Kokanee salmon and rainbow trout were only a minor (1.9% each) portion of the offshore species composition. To better understand and manage the Banks Lake warmwater fishery, biologists will need to expand the survey to include angler creel interviews, limnological sampling in multiple locations, shoreline habitat analysis, population estimation through mark and recapture studies, as well as an indexing protocol for popular game fish species (i.e., walleye and bass). Currently, the Banks Lake Fishery Evaluation Project (BLFEP; WDFW), funded by Bonneville Power Administration, has begun extensive seasonal surveys of Banks Lake (Lewis et al. 2002;

Polacek et al. 2003). Sampling includes a creel survey, water quality, primary and secondary productivity, littoral and limnetic fish surveys, mark and recapture studies, habitat analysis of the shoreline, and entrainment. Additionally, the WDFW Warmwater Program began annual fall walleye index netting (FWIN) in October of 2001. These studies will provide the necessary information to understand the fishery and be able to effectively provide management recommendations for catch rates, bag and slot limits, and stocking strategies to better manage fish populations within Banks Lake. Therefore, this report will not include management recommendations; rather, it will serve as a starting point for the more extensive studies that will follow.

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Introduction

Banks Lake, an irrigation impoundment, is located in the high scrub desert of central Washington (Grant County) and occupies the Upper Grand Coulee, formerly a channel of the Columbia River. Banks Lake is located between the cities of Grand Coulee and Electric City at the north end and Coulee City at the south end. Banks Lake is contained within two earth-fill dams, North Dam and Dry Falls Dam (or South Dam). North Dam, near Electric City, is 44 meters (m) high and 442 m long. Dry Falls Dam, close to Coulee City, is 37 m high and 2987 m long and supports a two-lane highway. At full pool, Banks Lake is 43 kilometers (km) long, contains 1.6 billion m^3 of water and covers 10,881 hectares (ha) of surface area (Table 1). At an elevation of 479 m (full pool) the average depth is 14 m, with a maximum depth of 26 m throughout most of the reservoir (USBOR 1964), with the exception of an isolated embayment (*known as* Devil's Lake) that has a maximum depth of 54 m. The Banks Lake shoreline spans 218 km with a shoreline complexity, D_L, equal to 4 (D_L is the ratio of the shoreline length to the circumference of a circle of the same area to that of the lake; the D_L of a circle is 1. The greater the complexity, the greater the D_L) (Orth 1983).

Table 1. Physical parameters of Banks Lake (Grant County).

Physical Parameters	Banks Lake Parameters
Surface Area (ha)	10,881
Shoreline Length (km)	218
Maximum Depth (m)	54
Mean Depth (m)	14
Volume (m^3)	1.6×10^9
Shoreline Complexity (D_L)	4

The Bureau of Reclamation inundated Banks Lake in 1951 to create an equalizing reservoir to be used for irrigating farmlands within the Columbia Basin Reclamation Project. The main inlet for Banks Lake consists of water pumped up 85 m from a pumping plant at the left forebay of Grand Coulee Dam on the Columbia River (Lake Roosevelt) into a feeder canal 2.6 km in length (USBOR 1964). Located at the northeast end of the reservoir, Northrup Canyon Creek, an intermittent tributary to Banks Lake, and various other small creeks and springs provide a negligible amount of water into the reservoir. One main, controlled outlet at the south end takes water through Dry Falls Dam and into the Main Canal to be used for irrigation. A portion of the water at the control structure is first passed through a hydroelectric turbine. Block nets are currently in place at Dry Falls Dam to help prevent fish entrainment. Water expelled from Banks Lake into the Main Canal flows 13.5 km to Billy Clapp Lake and then another 10.6 km until it diverges into two canals, the East Low and West canals, and then on to agricultural lands. Further south, Potholes Reservoir acts as a holding reservoir for water that returns from agricultural lands, and is later used for irrigation in the southern area of the project (USBOR 1964). Water from Banks Lake irrigates approximately 271,140 ha, which is a little over onehalf of the authorized lands in the Columbia Basin Project (USFWS 2002). Approximately 3 billion m^3 of water are supplied to the Irrigation Project each year.

Prior to the inundation of Banks Lake in 1951, several small lakes, including Devil's Lake, were present in the coulee. No records exist as to the exact quantity or composition of species that inhabited these lakes, but local anglers indicated that abundant populations of largemouth bass *Micropterus salmoides* and pumpkinseed sunfish *Lepomis gibbosus* were present (Stober et al. 1975). A creel census from the 1950s showed that largemouth bass and pumpkinseed sunfish were the most prominent species with 64% and 32% of the catch, respectively. Species also identified in the creel included: yellow perch *Perca flavescens*, black crappie *Pomoxis nigromaculatus*, brook trout *Salvelinus fontinalis*, rainbow trout *Oncorhynchus mykiss*, kokanee *O. nerka*, bull trout *S. confluentis*, and burbot *Lota lota*. In the 1960s, the fishery had shifted from being dominated by largemouth bass and pumpkinseed sunfish to mainly yellow perch (59%), rainbow trout (24%), and kokanee (14%) (Spence 1965). Other fish observed in the creel included: largemouth bass, pumpkinseed sunfish, black crappie, burbot, lake whitefish *Coregonus clupeaformis*, and northern pike *Esox lucius*. In the early 1970s, yellow perch (56%) and kokanee (30%) dominated the catch. Other sport fish noted during this time were rainbow trout, black crappie, largemouth bass, pumpkinseed sunfish, lake whitefish, walleye *Stizostedion vitreum*, burbot, and a few bluegill *L. macrochirus* (Duff 1973).

Stober et al. (1975) sampled Banks Lake between 1973-1976 and discovered species that had yet to be seen in the creel, including: common carp *Cyprinus carpio*, brown bullhead *Ameiurus nebulosus*, prickly sculpin *Cottus asper*, mountain whitefish *Prosopium williamsoni*, chinook salmon *O. tshawytscha*, brown trout *Salmo trutta*, peamouth *Mylocheilus caurinus*, northern pikeminnow *Ptychocheilus oregonensis*, largescale sucker *Catostomus macrocheilus*, and longnose sucker *C. catostomus*. In 1976, Stober et al. reported that anglers were catching kokanee (43%) and yellow perch (34%) most often and discovered that the salmonid fishery had exceeded that of the spiny-ray fishery altogether. In gill net and beach seine surveys, Stober et al. (1976) discovered ninety percent of the catch was comprised of yellow perch, lake whitefish, and kokanee.

In routine creel surveys completed by the Washington Department of Fish and Wildlife (WDFW) (1974-1982 unpublished data), yellow perch and kokanee were the dominant species anglers caught from 1977-1980. Kokanee were seen in the creel in 1981-1982; however, their numbers were reduced. By the mid-1980s, the kokanee population had declined dramatically and kokanee fishing became nonexistent (USFWS 2002).

Recreational opportunities abound at Banks Lake, and include boating, camping, fishing, hunting, and numerous water sport activities. Several campgrounds along the east shore accommodate visitors year around. The land around Banks Lake is mostly uninhabited by people, with only 1% of the land containing residential homes. With only about 10% of the shoreline being accessible to anglers, nine access sites along the east side of the lake have public boat launches, as do two on the south end, and one on the northwest shore. A few private resorts also have public boat launch access.

The major statewide recreational fishing regulations affecting Banks Lake (no specific regulations existed for Banks Lake) at the time of this survey were as follows: bass, largemouth and smallmouth bass *Micropterus dolomieu* combined - no more than three fish over 15 inches; walleye - five fish daily limit with a minimum size of 18 inches and no more than one over 24 inches; additional regulations to address fishing contests allowed bass and walleye to be caught, retained, and released alive from a livewell; channel catfish - five fish daily limit with a minimum size of 12 inches; and a daily limit of 15 whitefish, five burbot, and five trout (any combination) were allowed. No limit was in place for black crappie, pumpkinseed sunfish, bluegill, yellow perch, brown bullhead, yellow bullhead *Ictalurus natalis*, largescale sucker, longnose sucker, common carp, sculpin *Cottus spp.*, or tench *Tinca tinca*. Under current statewide regulations, the following rules apply on Banks Lake: bass (both species combined) - five fish daily limit, but only bass less than 12 inches or greater than 17 inches may be kept with no more than one over 17 inches; walleye - with a five fish daily limit with a minimum size of 16 inches and no more than one over 22 inches; 15 whitefish; five burbot; and five trout (any combination). Currently, a special regulation allows a daily limit of 25 yellow perch. No limit is currently in place for black crappie, pumpkinseed sunfish, bluegill, brown bullhead, yellow bullhead, largescale sucker, longnose sucker, common carp, sculpin, or tench.

The WDFW Warmwater Fish Enhancement Program sampled Banks Lake with the goal of obtaining a nearshore fisheries evaluation, mainly of the warmwater fish community, which included species composition, abundance, growth, condition, and age of the fish populations within Banks Lake. The Lake Roosevelt Research Team conducted a hydroacoustic and gill net survey of the limnetic zone concurrent to the nearshore sample and evaluated species composition, distribution, and abundance of limnetic fishes. The goal of the limnetic survey was two-fold: first, to evaluate hatchery salmonids planted in Banks Lake that are funded by Bonneville Power Administration; and second, to supplement the littoral zone work to provide a reservoir-wide survey that will better represent the Banks Lake fish community and not overlook the potentially important limnetic zone.

1.1 Methods

Littoral Zone Data Collection

The warmwater fish community in Banks Lake was surveyed in the fall from September 25-29, 2000. Fish were sampled using boat electrofishing, gill netting, and fyke netting techniques according to Bonar et al. (2000). Seven electrofishing boats (four Smith-Root SR-16 and three Smith-Root SR18) were used to survey shoreline sections. All boats operated with 5.0 GPP pulsator units using a DC current of 120 cycles per second at 3-6 amps of power. Experimental gill nets (45.7 m long x 2.4 m deep) consisted of four sinking panels (two each at 7.6 m and 15.2 m long) with variable sized (13, 19, 25, and 51 mm, stretch) monofilament mesh. Fyke nets (6 mm nylon mesh, stretch) consisted of a series of 5, 1.2 m hoops with the traps being 4.7 m long and 1.2 m in diameter and the cod end being 2.4 m long. One lead net (30.5 m long x 1.2 m deep) and two wing nets (7.6 m long x 1.2 m deep) came off the main trap.

Sampling locations were selected by dividing the shoreline into 440, 400 m sections. Each randomly selected 400 m section was shocked for ~ 600 seconds (10 minutes) at night. Gill nets were set on the bottom, perpendicular to the shoreline, with the small mesh end attached onshore and the large mesh end anchored offshore. Fyke nets were set perpendicular to the shoreline with the lead net anchored onshore and the wing nets set at 45 degree angles to the main trap. Fyke nets were set so the top of the main trap was no deeper than one foot below the surface. Due to sloping terrain where water depth became too deep to set nets, the lead net occasionally had to be shortened (left onshore and weighted) for the desired depth of the main trap to be reached. Both gill nets and fyke nets were set in the evening and retrieved the following morning.

Sampling sections were stratified by geography and by habitat type due to the size of the reservoir (Bonar et al. 2000). The lake was divided into a northern region and a southern region with 60% of the sampling effort being focused on the northern region and 40% being focused on the southern region (Bonar et al. 2000). The northern area of the lake was thought to have greater habitat diversity and fish densities than the more homogenous southern area (G. Steinmetz; J. Korth, personal communication), which would maximize the number, size and types of fish collected. Aquatic vegetation and talus/riprap were the two principle habitat types.

To obtain an equal proportion of sampling effort, a standardized 1:1:1 ratio of electrofishing to gill netting to fyke netting (1:1:1 = 1800 seconds of boat electrofishing:2 nights of gill netting:2 nights of fyke netting) was used (Bonar et al. 2000). It was originally our goal to standardize our sampling regime to obtain an equal proportion of sampling effort using the 1:1:1 ratio with a larger amount of sites sampled. However, we did not anticipate the amount of rough weather that occurred or that the amount of equipment needed (gill nets/fyke nets) was unavailable to sample as many sites as planned. For proper lake standardization, we required a ratio of 84 electrofishing sites:56 gill net sites:56 fyke net sites. When the survey was completed, however, we had unequal proportions of electrofishing to netting, with a total of 123 electrofishing sites, 48 gill net sites, and 41 fyke net sites. Due to the irregular proportioning of sampling, the standardization ratio was altered. Using a randomly selected subset of sites, the new 1:1:1 ratio was 60 electrofishing sites:40 gill net sites:40 fyke net sites. With this amount of sampling, almost 14% of the lake would be sampled by boat electrofishing and nearly 18% by both gill netting and fyke netting combined. The total number of possible sampling sections (n = 440) containing each habitat type was determined in order to find their relative percentage to the entire reservoir.

Approximately 75% of the reservoir consisted of talus or riprap habitat, equaling 330 sections, and 25% consisted of aquatic vegetation (n = 110). Of the 140 total sections sampled, 105 sections contained talus or riprap (75%), and 35 sections contained aquatic vegetation (25%). Eighty-four of these sections (60%) were selected from the northern area of Banks Lake, while the remaining 56 sections (40%) were selected from the southern area. Of the 84 sampling sections in the northern region, 63 sections (75%; 60% of 105) contained talus or riprap and 21 sections (25%; 60% of 35) contained aquatic vegetation. In the southern region, 42 sections (75%; 40% of 105) contained talus or riprap, while 14 sections (25%; 40% of 35) contained aquatic vegetation. When analyzing data, we used the standardized 1:1:1 ratio to be able to compare Banks Lake with other Washington lakes. We later analyzed the original sampled sites for biological data and for general information, which gave us a broader scope of the fishery; however, for simplicity we are providing only the standardized analysis in this report.

All fish captured, except sculpin *Cottus spp.*, were identified to species. Each fish was measured to total length (mm TL) and weighed (g); however, if a sample contained several hundred fish of a similar size (e.g., young-of-year), a sub-sample (n = 100) was measured and weighed and the rest counted. Scale samples (up to five per 10 mm length class/species) were mounted, pressed, and aged according to Jearld (1983) and Fletcher et al. (1993). In addition to scales, both otoliths and dorsal spines were taken from each walleye. Very few largescale suckers, longnose suckers, and carp were aged. Aging structures were not taken from kokanee, burbot, bluegill, brown bullhead, yellow bullhead, tench, and sculpin.

Littoral Zone Data Analysis

Species Composition

Species composition of fish captured during the survey was expressed by biomass (weight) and by number. Species composition by weight and number were calculated from data collected using boat electrofishing, gill netting and fyke netting. Species composition by weight (kg) was determined by dividing the total weight of a fish species by the total weight of the entire sample. Similarly, species composition by number was determined by dividing the total number of a fish species by the total number in the sample. We calculated species composition for all fish, as well as for a sample consisting of all fish with the exception of young-of-year fish. For the former calculations, young-of-year were added simply to show the total catch of fish within Banks Lake and to show that recruitment may or may not be occurring for some species. Fish less than one year old were excluded from the later calculations for species composition because fry numbers could fluctuate according to location, methodology, and recruitment timing, and might misrepresent species sample sizes (Fletcher et al. 1993).

Catch-Per-Unit-Effort

Catch-per-unit-effort (CPUE) by gear type was calculated for all fish species using all fish (excluding young-of-year), as well as using only stock length fish. Stock length, which varies by species, refers to the minimum length a fish is considered to have recreational value to anglers (Weithman and Anderson 1978). Because sample locations were randomly chosen, high variability due to habitat differences can occur, in which case, 80% confidence intervals (CI) were calculated for each mean CPUE by species and gear type (Gustafson 1988). Each CI was calculated as: mean ± $t_{(\%, n-1)}$ x *SE*, where t = Student's t distribution for %confidence level with n-1 degrees of freedom (two-tailed) and *SE* = standard error of the mean. When standardized sampling is used, CPUE is a useful index of population density, which enables comparisons of relative fish abundance between Washington lakes (Bonar et al. 2000).

Length Frequency Distribution

Length-frequency histograms were calculated to evaluate the size structure of certain species in Banks Lake. Histograms were created for smallmouth bass, largemouth bass, walleye, yellow perch, carp, brown bullhead, yellow bullhead, sculpin, and lake whitefish. With the exception of brown bullhead, yellow bullhead, and sculpin, which were not aged, only fish greater than one year old were included in the length frequency histograms for reasons listed above. Histograms were not created for kokanee salmon, burbot, bluegill sunfish, tench, longnose sucker, and largescale sucker due to small sample sizes.

Stock Density Indices

Stock density indices, proportional stock density (PSD) and relative stock density (RSD), help to describe length-frequency data and provide information on population size structure. Both stock density indices were calculated for each warmwater gamefish species that have established stock lengths as well as for each gear type (Anderson and Neumann 1996) (Table 2). Proportional stock density is calculated as: the number of fish $ quality length ÷ the number of fish $ stock length x 100. Stock and quality lengths, proposed by Gabelhouse (1984), vary depending on fish species and are based on percentages of world record catch size. Stock length (20-26% of the world record) refers to the minimum size fish with recreational value, whereas quality length (36-41% of the world record) refers to the minimum size fish most anglers prefer to catch. Relative stock density is the percentage of fish in a specified length category within the sample and is calculated as: the number of fish $ specified length ÷ the number of fish $ minimum stock length x 100. In addition to proportional stock density, relative stock density includes preferred, memorable, and trophy lengths (Gabelhouse 1984). Preferred length (RSD-P [45-55% of the world record]) refers to the length of fish anglers would prefer to catch. Memorable length (RSD-M [59-64% of the world record length]) refers to the minimum length of fish most anglers remember catching, whereas trophy length (RSD-T [74-80% of the world record]) refers to the minimum length a fish is worthy of acknowledgment. Relative stock density is like PSD, providing information on population size structure, yet is more responsive to changes in year-class strength. Along with Gabelhouse's (1984) length categories, Bister et al. (2000) developed length categories for previously uncategorized, non-game fish, (i.e., brown bullhead) that were included in this sample. Eighty percent confidence intervals for PSDs and RSDs were included and were calculated using normal approximation (Gustafson 1988).

Table 2. Proportional Stock Density/Relative Stock Density length categories for fish species collected from Banks Lake (Grant County) in September 2000. Measurements are minimum total lengths (mm) for each category (Anderson and Neumann 1996; Bister et al. 2000). Numbers in parenthesis represent percentages of world record lengths (Gabelhouse 1984).

	Length Categories (mm)				
	Stock	**Quality**	**Preferred**	**Memorable**	**Trophy**
Species	**(20-26%)**	**(36-41%)**	**(45-55%)**	**(59-64%)**	**(74-80%)**
Black Crappie	130	200	250	300	380
Brown Bullhead	130	200	280	360	430
Burbot	200	380	530	670	820
Carp	280	410	530	660	840
Largemouth Bass	200	300	380	510	630
Pumpkinseed Sunfish	80	150	200	250	300
Rainbow Trout	250	400	500	650	800
Smallmouth Bass	180	280	350	430	510
Walleye	250	380	510	630	760
Yellow Bullhead	100	180	230	280	360
Yellow Perch	130	200	250	300	380

Age and Growth

Age and growth of fish sampled were evaluated according to the direct proportion method (Fletcher et al. 1993) and Lee's modification of the direct proportion method (Carlander 1982). Using the direct proportion method, total length at annulus formation was back-calculated as $L_n = (A \times TL)/S$, where *A* was the radius of the fish scale at age *n*, *TL* was the total length of the fish captured, and *S* was the total radius of the scale at capture. Using Lee's modification, L_n was back-calculated as $L_n = a + A \times (TL - a)/S$, where *a* was the species-specific standard intercept from a scale radius-fish length regression. Mean back-calculated lengths at age *n* for each species were presented in tabular form for easy comparison of growth between year classes, as well as between the reservoir average for Banks Lake and for other lakes in the state of Washington (Fletcher et al. 1993). Fletcher et al. (1993) calculated state averages from data collected for select warmwater fish populations throughout the state using the direct proportion method. These growth rates were referred to as the state average in the results section, and although they were not a true state average, they were likely representative of fish growth for lakes sampled within the state. Only smallmouth bass, largemouth bass, walleye, yellow perch, black crappie, pumpkinseed sunfish, carp, lake whitefish, and rainbow trout were aged.

Relative Weight

Fish condition was evaluated using the Relative Weight (W_r) index, which provided a relationship between the length and weight of each fish. A W_r value of 100 would indicate that a fish was in good condition when compared to the national standard (75th percentile) for that species. Relative weight was calculated as ($W_r = W/W_s$ x 100, where W was the actual weight (g) of an individual fish divided by the standard weight (W_s) for the same species at the same length, multiplied by 100 (Willis et al. 1993). The W_s was calculated from the standard $\log_{10}$weight-$\log_{10}$length relationship defined for each species. Anderson and Neumann (1996) and Bister et al. (2000) introduced W_s equations for many freshwater game and non-game species. Condition of kokanee salmon, burbot, bluegill sunfish, tench, longnose sucker, and largescale sucker was not calculated due to small sample sizes.

Limnology

Limnological data were collected on September 28, 2000 in the mid-morning from the deepest locations at the northern (Devil's Lake) and southern ends (~ 2.7 km east of Goose Island) of the reservoir. Water quality parameters were measured using a Hydrolab® probe and digital recorder at one meter intervals (south) and five meter intervals (north) throughout the water column. The parameters collected included dissolved oxygen (mg/l), temperature (°C), pH (units), turbidity (NTU), and conductivity (Fs/cm). Water clarity was determined by using a Secchi disc.

Both average annual volumetric discharge (1990-2000) and reservoir volume data were collected from the Bureau of Reclamation in Ephrata, WA and were used to calculate storage ratios. Storage ratios, calculated by dividing the volume of the reservoir at normal pool by the average annual volumetric discharge, describe the rate in which a reservoir exchanges its volume of water (0.1 = water exchanged 10 times a year; 1 = water exchanged once a year). Higher storage ratio values represent greater reservoir stability.

Habitat Suitability

Habitat suitability was determined for largemouth bass by comparing available habitat in Banks Lake to Habitat Suitability Index (HSI) models (Stuber et al. 1982). The HSI models made assumptions for attaining optimal habitat for fish under certain scenarios (i.e., food, cover, water quality, reproduction, etc.) in both riverine and lacustrine habitats. Five model parameters were used in this survey to determine where the most optimum habitat would occur for largemouth bass. They included (1) percentage of lacustrine area suitable to support submergent vegetation as well as overwintering; (2) percent of bottom cover (e.g. aquatic vegetation, logs, and debris); (3) dissolved oxygen levels; (4) pH range; and (5) water level fluctuations. The HSI for largemouth bass was compared to features in both the northern and southern sections of Banks Lake. No quantitative habitat assessments were made, rather we generalized using observations during the survey.

1.2 Results

Species Composition

Species composition varied by biomass and number; however, smallmouth bass, lake whitefish, sculpin, yellow perch, and carp were the most commonly encountered species (Table 3 and Table 4). Seventeen different species, plus the family Cottidae (sculpin) were collected within the littoral zone of Banks Lake . Smallmouth bass were the most abundant fish species, comprising 40% by number of the sample and 17.5% by weight (third most abundant by weight) with 23% of the catch (by number) being young-of-year fish. Lake whitefish were the most abundant species collected by weight (35%), but only 15% by number. The biomass for carp was high with nearly 31% of the sample by weight, but only 7.5% of the sample by number. Sculpin were the third most abundant fish collected (by number), but consisted of < 1% of the total biomass. Yellow perch, black crappie, and walleye had the highest percentages of young-of-year fish within their species' populations at 78%, 75%, and 70%, respectively.

Table 3. Species composition by number and by weight (kg) for all fish, excluding young-of-year, collected at Banks Lake (Grant County) in September 2000.

	Species Composition					
	by Number		by Weight		Size Range (mm TL)	
Species	(#)	(%n)	(kg)	(%w)	Min	Max
Smallmouth Bass	798	40.14	160.44	17.57	86	486
Lake Whitefish	302	15.19	321.80	35.24	121	558
Sculpin	254	12.78	1.93	0.21	35	187
Yellow Perch	154	7.75	5.12	0.56	86	245
Carp	150	7.55	284.01	31.10	56	730
Brown Bullhead	73	3.67	19.05	2.09	101	368
Yellow Bullhead	63	3.17	7.32	0.80	38	309
Largemouth Bass	48	2.41	15.39	1.69	100	489
Walleye	30	1.51	24.20	2.65	205	620
Longnose Sucker	23	1.16	22.69	2.49	266	512
Rainbow Trout	20	1.01	14.32	1.57	225	486
Kokanee	15	0.75	11.49	1.26	239	498
Largescale Sucker	15	0.75	16.82	1.84	135	645
Black Crappie	14	0.70	2.61	0.29	82	262
Pumpkinseed Sunfish	12	0.60	0.50	0.05	85	152
Burbot	8	0.40	4.49	0.49	330	578
Bluegill	8	0.40	0.01	0.00	25	46
Tench	1	0.05	0.90	0.10	406	406

Table 4. Species composition by number and by weight (kg) for all fish collected at Banks Lake (Grant County) in September 2000.

	Species Composition					
	by Number		by Weight		Size Range (mm TL)	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Smallmouth Bass	1041	35.95	161.40	17.56	42	486
Yellow Perch	696	24.03	7.09	0.77	45	245
Lake Whitefish	302	10.43	321.80	35.01	121	558
Sculpin	254	8.77	1.93	0.21	35	187
Carp	150	5.18	284.01	30.90	56	730
Walleye	98	3.38	27.07	2.95	68	620
Brown Bullhead	73	2.52	19.05	2.07	101	368
Yellow Bullhead	63	2.18	7.32	0.80	38	309
Largemouth Bass	60	2.07	15.42	1.68	42	489
Black Crappie	56	1.93	2.76	0.30	56	262
Longnose Sucker	23	0.79	22.69	2.47	266	512
Rainbow Trout	20	0.69	14.32	1.56	225	486
Kokanee	15	0.52	11.49	1.25	239	498
Largescale Sucker	15	0.52	16.82	1.83	135	645
Pumpkinseed Sunfish	13	0.45	0.50	0.05	42	152
Burbot	8	0.28	4.49	0.49	330	578
Bluegill	8	0.28	0.01	0.00	25	46
Tench	1	0.03	0.90	0.10	406	406

Catch-Per-Unit-Effort

Catch-per-unit-effort varied by gear type, yet smallmouth bass, sculpin, yellow perch, and lake whitefish were commonly captured at the highest catch rates (Table 5). Smallmouth bass were sampled at the highest rate by boat electrofishing (71.40 fish/hour), followed by sculpin (24.95 fish/hour), and yellow perch (10.92 fish/hour). Catch rates for gill netting were highest for lake whitefish (6.88 fish/hour), smallmouth bass (2.13 fish/hour), and carp (1.38 fish/hour). Catch rates for fyke netting were highest for yellow perch (0.85 fish/hour) and brown bullhead (0.20 fish/hour). Catch rates for stock length fish were only slightly lower than those observed for all fish, excluding young-of-year, with the exception of largemouth bass and yellow perch (Table 6). A noticeable proportion of the largemouth bass (25%) and yellow perch (42%) electrofishing catch was comprised of fish less than stock length (200 mm; 130 mm, respectively).

Table 5. Mean catch-per-unit-effort by sampling method, including 80% confidence intervals, for all fish, excluding young-of-year, collected at Banks Lake (Grant County), September 2000. To achieve the 1:1:1 ratio, 60 electrofishing sites, 40 gill netting sites (net nights), and 40 fyke netting sites (net nights) were randomly selected.

	Gear Type					
	Electrofishing		Gill Netting		Fyke Netting	
Species	**#/Hour**	**Sites**	**#/Net Night**	**Net Nights**	**#/Net Night**	**Net Nights**
Brown bullhead	5.70 ± 1.95	60	0.18 ± 0.11	40	0.20 ± 0.15	40
Black crappie	0.40 ± 0.25	60	0.10 ± 0.06	40	0.15 ± 0.11	40
Bluegill	0.69 ± 0.48	60	0	40	0.03 ± 0.03	40
Burbot	0.50 ± 0.42	60	0.08 ± 0.05	40	0	40
Sculpin	24.95 ± 6.19	60	0	40	0.03 ± 0.03	40
Carp	9.19 ± 2.06	60	1.38 ± 0.55	40	0.05 ± 0.04	40
Kokanee	0.30 ± 0.38	60	0.30 ± 0.12	40	0	40
Largemouth bass	3.87 ± 1.72	60	0.20 ± 0.11	40	0.03 ± 0.03	40
Longnose sucker	1.08 ± 0.42	60	0.20 ± 0.14	40	0.10 ± 0.10	40
Largescale sucker	0.70 ± 0.37	60	0.18 ± 0.10	40	0.03 ± 0.03	40
Lake whitefish	2.68 ± 1.49	60	6.88 ± 1.25	40	0	40
Pumpkinseed	0.90 ± 0.63	60	0.03 ± 0.03	40	0.05 ± 0.04	40
Rainbow trout	1.28 ± 0.44	60	0.13 ± 0.10	40	0.05 ± 0.04	40
Smallmouth bass	71.40 ± 17.29	60	2.13 ± 0.80	40	0.05 ± 0.04	40
Tench	0	60	0	40	0.03 ± 0.03	40
Walleye	0.79 ± 0.38	60	0.55 ± 0.21	40	0	40
Yellow bullhead	2.84 ± 0.94	60	0.83 ± 0.69	40	0.03 ± 0.03	40
Yellow perch	10.92 ± 2.84	60	0.50 ± 0.24	40	0.85 ± 0.48	40

Table 6. Mean catch-per-unit-effort by sampling method, including 80% confidence intervals, for stock length fish collected at Banks Lake (Grant County), September 2000. To achieve the 1:1:1 ratio, 60 electrofishing sites, 40 gill netting sites (net nights), and 40 fyke netting sites (net nights) were randomly selected.

	Gear Type					
	Electrofishing		Gill Netting		Fyke Netting	
Species	**#/Hour**	**Sites**	**#/Net Night**	**Net Nights**	**#/Net Night**	**Net Nights**
Brown bullhead	5.41 ± 1.96	60	0.18 ± 0.11	40	0.20 ± 0.15	40
Black crappie	0.30 ± 0.22	60	0.10 ± 0.06	40	0.15 ± 0.11	40
Burbot	0.50 ± 0.42	60	0.08 ± 0.05	40	0	40
Sculpin	24.95 ± 6.19	60	0	40	0.03 ± 0.03	40
Carp	9.00 ± 2.02	60	1.35 ± 0.55	40	0	40
Kokanee	0.30 ± 0.38	60	0.30 ± 0.12	40	0	40
Largemouth bass	2.37 ± 1.07	60	0.18 ± 0.11	40	0.03 ± 0.03	40
Longnose sucker	1.08 ± 0.42	60	0.20 ± 1.14	40	0.10 ± 0.10	40
Largescale sucker	0.70 ± 0.37	60	0.18 ± 0.10	40	0.03 ± 0.03	40
Lake whitefish	2.68 ± 1.49	60	6.88 ± 1.25	40	0	40
Pumpkinseed	0.90 ± 0.63	60	0.03 ± 0.03	40	0.05 ± 0.04	40
Rainbow trout	0.98 ± 0.36	60	0.13 ± 0.10	40	0.05 ± 0.04	40
Smallmouth bass	53.88 ± 14.85	60	2.13 ± 0.80	40	0.03 ± 0.03	40
Tench	0	60	0	40	0.03 ± 0.03	40
Walleye	0.40 ± 0.25	60	0.53 ± 0.22	40	0	40
Yellow bullhead	2.64 ± 0.89	60	0.83 ± 0.69	40	0	40
Yellow perch	4.57 ± 1.90	60	0.48 ± 0.23	40	0.23 ± 0.20	40

Stock Density Indices

Low numbers of stock-size fish (relative to the number necessary for analysis) were collected for most species (Table 7). This resulted in broad confidence levels for PSDs, which made interpretation difficult. In order to obtain fair PSD estimates, at least 55 stock length fish should be available for analysis (Bonar et al. 2000). The only species to provide reliable estimates were smallmouth bass, carp, and brown bullhead. Smallmouth bass had a high number of stock length fish collected electrofishing, yet PSD's were extremely low (i.e., 543 stock length fish with a PSD of 8 ± 2). Only 85 stock length smallmouth bass caught gill netting with PSDs of 69 ± 6. However, most of these fish were preferred length (67 ± 7). Most carp collected were of stock length with high PSDs. Carp also had high RSD-Ps (65 ± 6, electrofishing; 39 ± 9 gill netting). Several species collected were of preferred length; however, low numbers of preferred length fish were caught resulting in large confidence limits. Only brown bullhead, carp, smallmouth bass, and yellow perch had fish within memorable (RSD-M) size limits, and no trophy fish (RSD-T) were collected. All PSD and RSD values should be observed cautiously as the low number of stock length fish and low sample sizes of most species collected lowers the accuracy in which they can be interpreted (Divens et al. 1998).

Table 7. Traditional stock density indices, including 80% confidence intervals, listed by gear type for fish collected at Banks Lake (Grant County) in September 2000.

Electrofishing

Species	# Stock Length	PSD	RSD-P	RSD-M	RSD-T
Black Crappie	3	100 ± 0	0	0	0
Brown Bullhead	55	91 ± 5	36 ± 8	2 ± 2	0
Burbot	5	20 ± 23	0	0	0
Carp	91	99 ± 1	65 ± 6	4 ± 3	0
Largemouth Bass	24	42 ± 13	4 ± 5	0	0
Pumpkinseed Sunfish	9	11 ± 13	0	0	0
Rainbow Trout	10	70 ± 19	0	0	0
Smallmouth Bass	543	8 ± 2	2 ± 1	0	0
Walleye	4	75 ± 28	0	0	0
Yellow Bullhead	27	67 ± 12	37 ± 12	4 ± 5	0
Yellow Perch	46	7 ± 5	0	0	0

Gill Netting

Species	# Stock Length	PSD	RSD-P	RSD-M	RSD-T
Black Crappie	4	75 ± 28	25 ± 28	0	0
Brown Bullhead	7	86 ± 17	71 ± 22	14 ± 17	0
Burbot	3	100 ± 0	33 ± 35	0	0
Carp	54	78 ± 7	39 ± 9	4 ± 3	0
Largemouth Bass	7	43 ± 24	14 ± 17	0	0
Rainbow Trout	5	80 ± 23	0	0	0
Smallmouth Bass	85	69 ± 6	67 ± 7	11 ± 4	0
Walleye	21	81 ± 11	29 ± 13	0	0
Yellow Bullhead	33	76 ± 10	15 ± 8	0	0
Yellow Perch	19	53 ± 15	0	0	0

Fyke Netting

Species	# Stock Length	PSD	RSD-P	RSD-M	RSD-T
Black Crappie	6	83 ± 19	0	0	0
Brown Bullhead	8	100 ± 0	25 ± 20	0	0
Pumpkinseed Sunfish	2	0	0	0	0
Rainbow Trout	2	50 ± 45	0	0	0
Yellow Perch	9	44 ± 21	0	0	0

Limnology

Limnological data was collected from two sites on Banks Lake, the first located at the southern end of the lake approximately 2.7 km east of Goose Island (Figure 1; Table 8) and the second located at the northern end within Devil's Lake (Figure 1; Table 9). Water quality measurements at the southern site were homogenous throughout the water column. Temperature ranged from 15.6EC to 16EC, pH ranged between 8.1 and 8.5 (units), dissolved oxygen was between 7.5 and

9.1 (mg/l), and conductivity was 130-131 (Fs/cm). Water clarity was high according to Secchi disk readings of five meters, as well as the average turbidity readings of <1 NTU throughout the majority of the water column. All parameters were within acceptable limits for warmwater fish species (Piper et al. 1992). Water quality parameters at the northern site were similar to those at the southern site down to about 20 m. However, unlike the southern site, thermal stratification [17.2EC (0 m) to 4.7 EC (48 m)] was evident at the northern site, and water quality became less suitable for most fish in the hypolimnion. Readings for pH were within optimal range, 6.7 - 8.2 units (Piper et al. 1992). Dissolved oxygen levels varied widely from a high of 9.9 mg/l ~ 10 meters from the surface to 1.7 mg/l near the bottom. Conductivity readings at the northern site fell to 107-111 (Fs/cm), which were within optimal levels (100-400 Fs/cm) for electrofishing efficiency (Willis 1998).

Storage ratios calculated from 1990-2000 averaged 0.51 and varied little during that period. On average, Banks Lake exchanges its water volume approximately every six months, or twice a year. Approximately 3 billion m^3 of water are supplied to the Irrigation Project each year, and with the storage capacity of Banks Lake being just over 1.6 billion m^3, the reservoir water volume is completely flushed out about twice during the irrigation season for a water retention time of approximately 6 months (USFWS 2002).

Habitat Suitability

The HSI scale ranges from 0.0-1.0, with 1.0 indicating optimum habitat suitability. According to the HSI, the following assumptions exhibit preferred largemouth bass habitat: (1) largemouth bass survive best when $25% of the surface area is shallow to support submergent vegetation for food and cover, yet deep enough (3-15 m) for largemouth bass to overwinter; (2) bottom cover should incorporate 40-60% for adults and juveniles and 40-80% for fry; (3) dissolved oxygen levels should be > 8.0 mg/l (Table 8; Table 9); (4) pH should range between 6.5-8.5 units (Table 8; Table 9); (5) water levels should fluctuate minimally (!3 - +3 m) up or down for adults, juveniles, and fry, yet should not fluctuate for embryos (Stuber et al. 1982). Through observation, most parameters met the necessary criteria and indicated that largemouth bass habitat occurs primarily in the northern section of Banks Lake. Of the 140 sections sampled, largemouth bass were collected at only 17 sites (12%) with only 60 fish being caught (Figure 2). All largemouth bass collected were caught in the northern region with most fish captured in Devil's Punch Bowl (n = 32) and in Osborn Bay (n = 13) (Figure 2); both high vegetation density areas. Likewise, smallmouth bass were caught more frequently in the northern section (n = 569; 55%), yet a large proportion was caught in the southern section (n = 472; 45%), where habitat is less suited for largemouth bass.

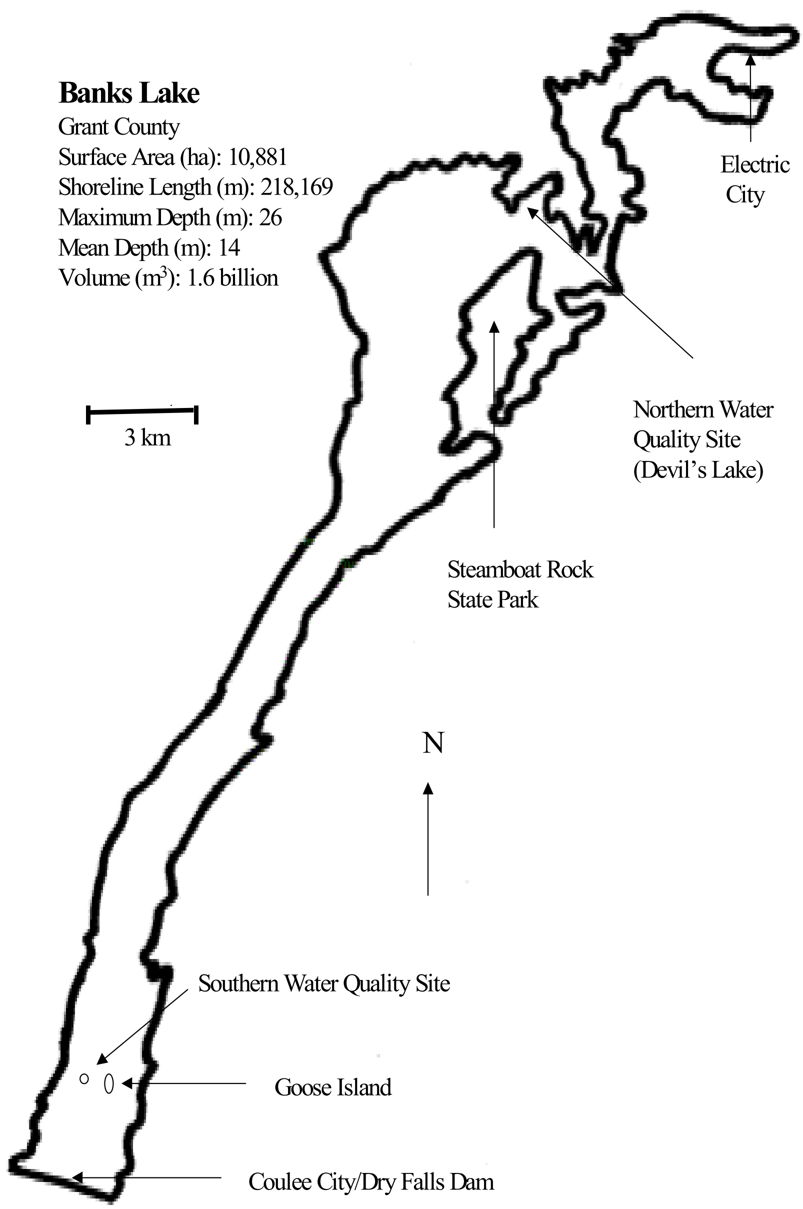

Figure 1. Banks Lake (Grant County) limnology sampling sites including landmarks.

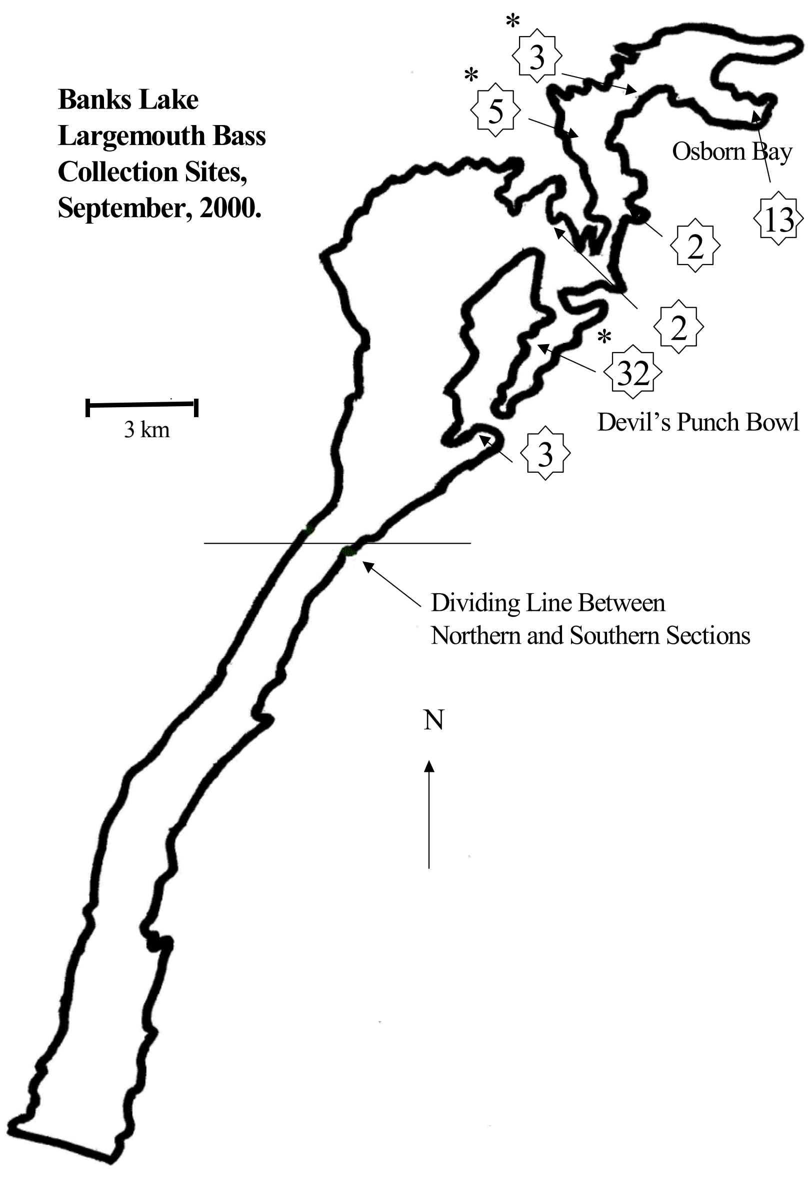

Figure 2. Sampling sites where largemouth bass were collected and the numbers of fish collected at these sites. *Multiple sites in an area were combined for simplicity.

Table 8. Water quality from southern Banks Lake (Grant County) collected east of Goose Island, mid-morning, September 28, 2000. DO = dissolved oxygen, TDS = total dissolved solids.

Secchi Depth (m)	Depth (m)	Temperature (EC)	pH (units)	DO (mg/l)	TDS (NTU)	Conductivity (FS/cm)
5	1	15.8	8.1	9.1	0.083	131
	2	16.0	8.3	8.3	0.083	131
	3	16.0	8.4	8.0	0.083	130
	4	16.0	8.4	7.8	0.084	130
	5	16.0	8.4	7.7	0.084	130
	6	16.0	8.4	7.6	0.083	130
	7	16.0	8.4	7.5	0.083	131
	8	16.0	8.4	7.5	0.083	130
	9	16.0	8.5	7.5	0.083	130
	10	16.0	8.5	7.6	0.083	131
	11	16.0	8.4	7.6	0.083	130
	12	16.0	8.4	7.6	0.084	131
	13	15.9	8.4	7.6	0.083	130
	14	15.9	8.4	7.6	0.083	131
	15	15.9	8.4	7.6	0.084	130
	16	15.9	8.4	7.7	0.084	131
	17	15.8	8.5	7.8	0.084	130
	18	15.8	8.5	7.9	0.083	130
	19	15.8	8.5	8.0	0.083	131
	20	15.7	8.5	8.0	0.084	131
	21	15.7	8.5	8.1	0.084	131
	22	15.7	8.5	8.0	0.084	131
	23	15.6	8.4	8.0	0.084	131
	24	15.6	8.4	7.8	0.084	131

Table 9. Water quality from northern Banks Lake (Grant County) collected in Devil's Lake, mid-morning, September 28, 2000. DO = dissolved oxygen; TDS = total dissolved solids; * = Secchi depth not taken at this site; **Conductivity only taken at surface and bottom depths.

Secchi Depth	Depth (m)	Temperature (EC)	pH (units)	DO (mg/l)	TDS (NTU)	Conductivity (FS/cm)
*	0	17.2	8.1	9.2	0	107
	5	17.2	8.2	9.4	0	**
	10	16.7	7.9	9.9	0	
	15	16.5	7.6	8.7	0	
	20	16.2	7.6	7.8	0	
	25	10.1	7.1	2.2	0	
	30	8.8	7.0	2.7	0	
	35	7.2	6.9	3.6	0	
	40	6.2	6.9	4.1	0	
	45	4.8	6.8	2.0	0	
	48	4.7	6.7	1.7	0	111

Smallmouth Bass

Smallmouth bass ranged from 42 to 486 mm TL (age 1-age 10; Table 10). The 1998 year-class was the most dominant followed by the 1999 year-class. When compared to Washington State averages, growth rates of smallmouth bass were generally lower for fish ages 1-3, while for older fish growth was comparable. Length frequency and age composition suggested variable year-class strength with few fish between ages 4-6 (Figure 3). Relative weights varied widely above and below the national 75th percentile, yet most fish were near or below the average with a general downward trend as fish aged (Figure 4).

Table 10. Age and growth of smallmouth bass sampled at Banks Lake (Grant County) in September 2000 compared to Washington State averages. Unshaded values are mean back-calculated lengths at annulus using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths at annulus using the Lee's modification of the direct proportion method (Carlander 1982).

		Mean Total Length (mm) at Age									
Year Class	**n**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1999	32	52									
		74									
1998	101	64	140								
		89	154								
1997	21	52	165	250							
		82	182	257							
1996	6	51	141	236	313						
		81	163	249	319						
1995	23	62	129	213	310	353					
		91	153	229	317	357					
1994	2	57	123	179	247	334	362				
		86	147	198	260	338	364				
1993	5	61	118	190	269	324	364	401			
		91	143	209	282	333	369	403			
1992	11	51	119	199	277	332	376	410	431		
		82	145	218	290	341	382	413	432		
1991	2	41	130	215	292	359	399	421	437	454	
		73	156	234	306	368	404	425	439	455	
1990	1	40	82	144	191	275	327	350	382	405	420
		72	110	167	210	287	335	357	386	407	421
Direct Proportion Overall Mean		53	128	203	271	330	365	396	416	430	420
Lee's Weighted Mean		85	156	234	303	348	377	409	430	439	421
Direct Proportion State Average		70	146	212	268	334	356	393			

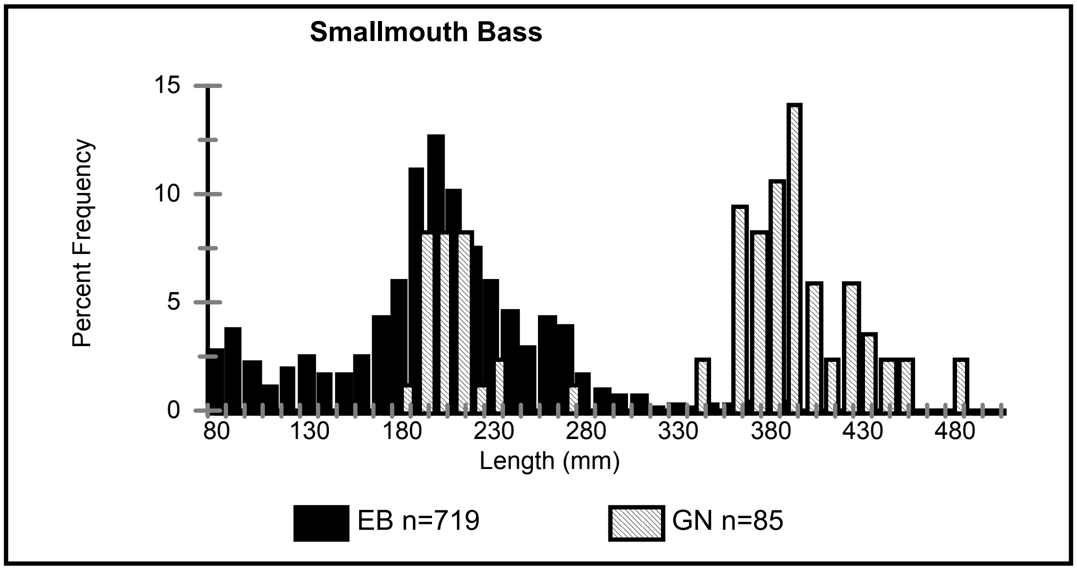

Figure 3. Length frequency of smallmouth bass, excluding young-of-year, in Banks Lake (Grant County) September 2000; captured by boat electrofishing and gill netting.

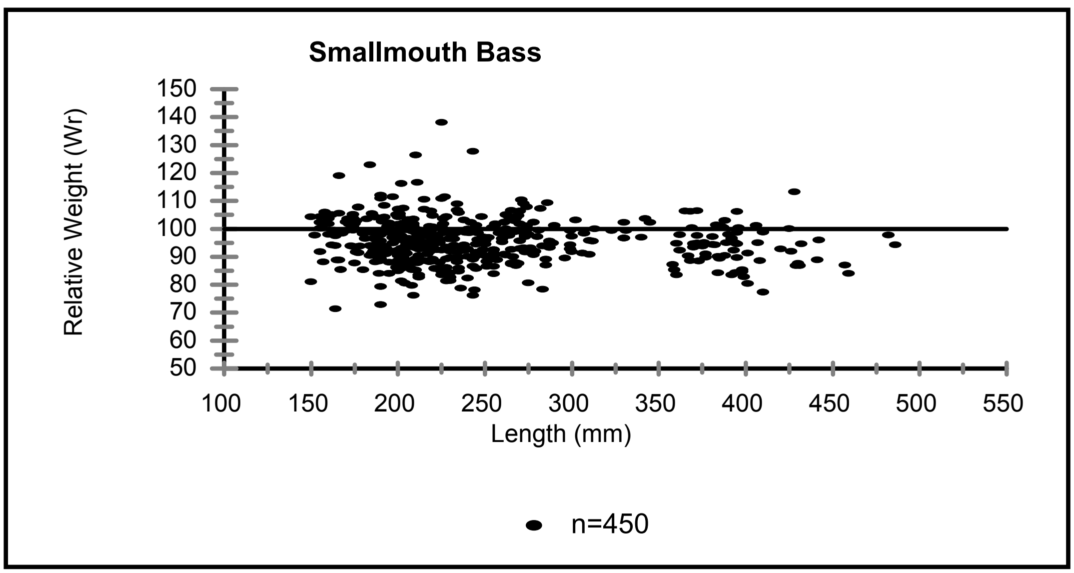

Figure 4. Relative weight (W_r) of smallmouth bass, excluding young-of-year, in Banks Lake (Grant County), September 2000, compared to the national 75th percentile. All fish were captured by boat electrofishing, gill netting, or fyke netting.

Largemouth Bass

Largemouth bass ranged from 42 to 489 mm TL (age 1-age 9; Table 11). Largemouth bass growth rates were well above the Washington State average. Despite the good growth of age 1 to age 4 largemouth bass, length frequency and age data suggested poor recruitment overall and variable year-class strength for fish over age 4 (Figure 5). Relative weights of largemouth bass were mostly at or above the national 75th percentile for fish ages 1 to 4 (Figure 6).

Table 11. Age and growth of largemouth bass sampled at Banks Lake (Grant County) in September 2000 compared to Washington State averages. Unshaded values are mean back-calculated lengths at annulus using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths at annulus using the Lee's modification of the direct proportion method (Carlander 1982).

		Mean Total Length (mm) at Age								
Year Class	**n**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1999	9	63								
		76								
1998	6	72	184							
		87	192							
1997	5	83	208	301						
		99	216	303						
1996	1	72	251	319	382					
		88	258	323	383					
1995	1	50	207	306	364	375				
		67	216	310	365	376				
1994	0									
1993	1	109	243	354	411	433	460	482		
		124	253	359	414	435	462	482		
1992	0									
1991	1	72	169	239	295	355	387	413	440	475
		89	182	249	303	361	391	416	442	475
Direct Proportion Overall Mean		74	210	304	363	388	424	447	440	475
Lee's Weighted Mean		86	209	306	366	390	426	449	442	475
Direct Proportion State Average		60	146	222	261	289	319	368	396	440

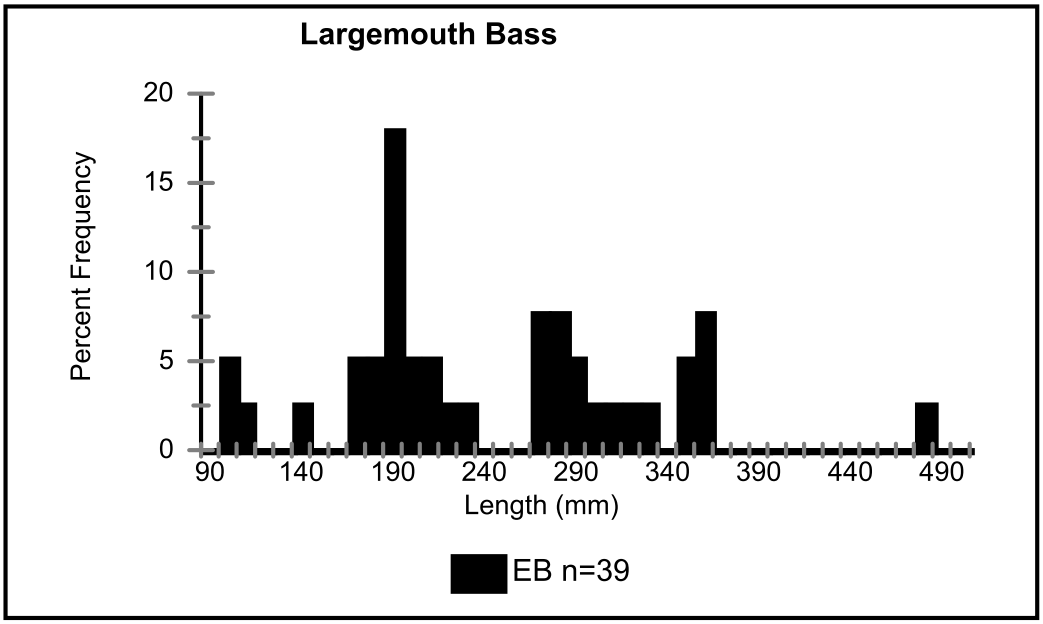

Figure 5. Length frequency of largemouth bass, excluding young-of-year, in Banks Lake (Grant County) September 2000; captured by boat electrofishing.

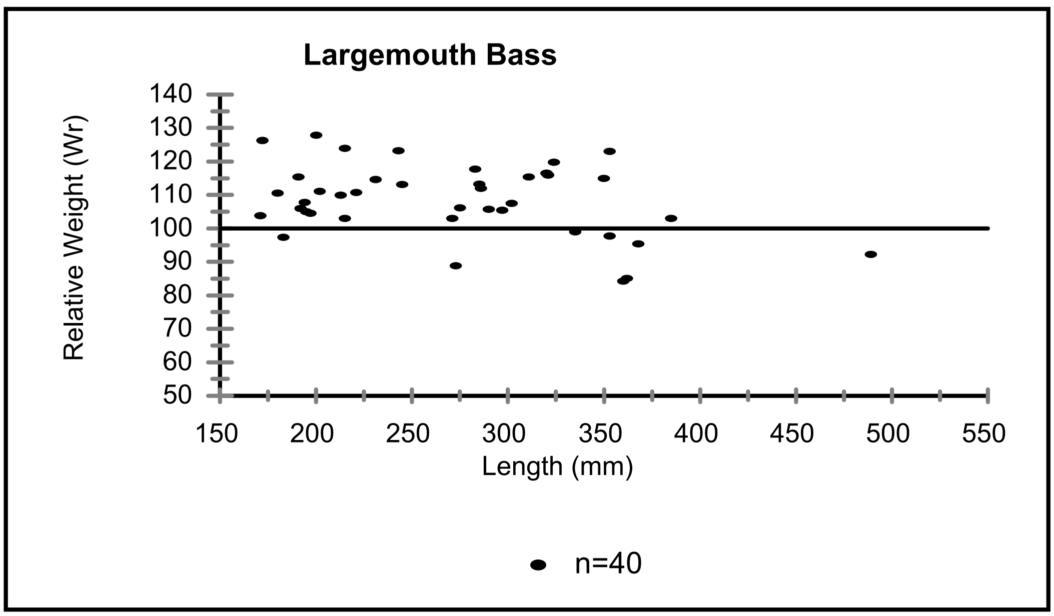

Figure 6. Relative weight (W_r) of largemouth bass, excluding young-of-year, in Banks Lake (Grant County), September 2000, compared to the national 75th percentile. All fish were captured by boat electrofishing, gill netting, or fyke netting.

Walleye

Walleye ranged from 68 to 620 mm TL; however, nearly 70% of the fish collected were less than 199 mm (age 1) (Table 3; Table 4). A state average was not available for walleye, so growth was compared to Lake Roosevelt (WA) walleye collected in 2000 (McLellan and Scholz 2001) and to walleye in 12 lakes and rivers in the United States and British Columbia, Canada, using Lee's weighted mean (Peone et al. 1990). Walleye growth in Banks Lake was found to exceed growth for all age classes when compared to several lakes in the U.S. and Canada (Table 12). Length frequency showed fairly stable year-class strength for age 1 fish and older (Figure 7); however, too few fish were aged to accurately separate fish older than age 2 or 3. Walleye W_r was generally below the national 75th percentile (Figure 8).

Table 12. Age and growth of walleye sampled at Banks Lake (Grant County) in September 2000, compared to age and growth of walleye in Lake Roosevelt, WA (Grant, Lincoln, Ferry, Stevens, and Okanogan Counties) (2000) (McLellan and Scholz 2001) and to 12 lakes and rivers in the United States and British Columbia, Canada (Peone et al.1990). Unshaded values are mean back-calculated lengths at annulus using the direct proportion method (Fletcher et al.1993). Shaded values are mean back-calculated lengths at annulus using the Lee's modification of the direct proportion method (Carlander 1982).

		Mean Total Length (mm) at Age				
Year Class	**n**	**1**	**2**	**3**	**4**	**5**
1999	5	136				
		168				
1998	14	188	328			
		219	340			
1997	5	146	363	453		
		185	379	459		
1996	0					
1995	2	137	276	375	456	509
		178	302	392	464	511
Direct Proportion Overall Mean		152	322	414	456	509
Lee's Weighted Mean		199	346	440	464	511
Lake Roosevelt Lee's Weighted Mean (2000)	138	183	273	346	406	464
U.S. and B.C. Lee's Weighted Mean (1990)		177	280	368	431	483
Direct Proportion State Average		NA				

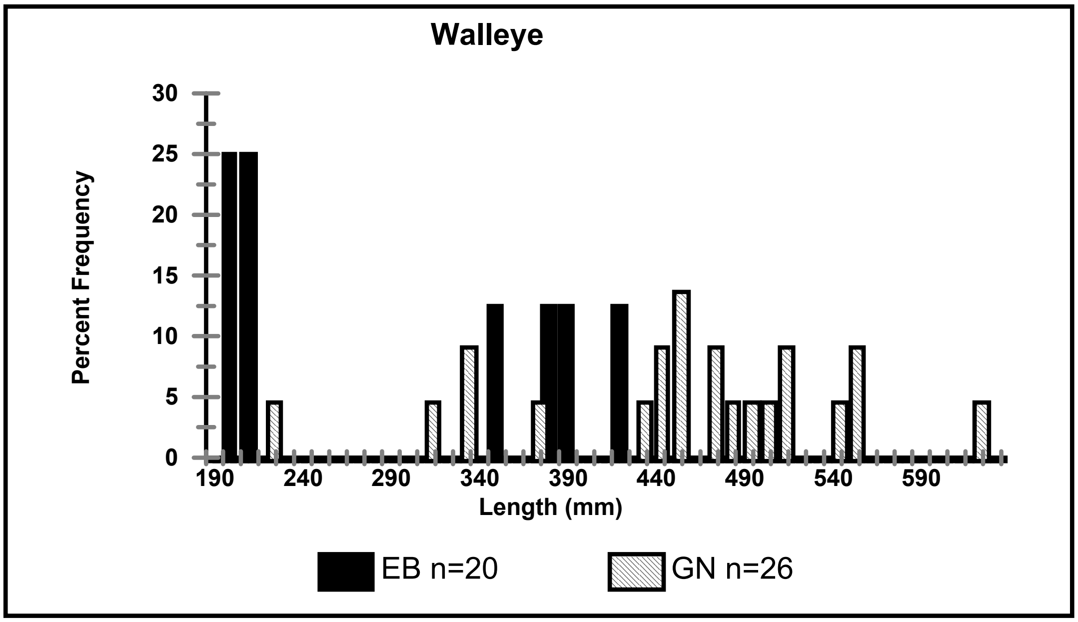

Figure 7. Length frequency of walleye, excluding young-of-year, in Banks Lake (Grant County) in September 2000; captured by boat electrofishing and gill netting.

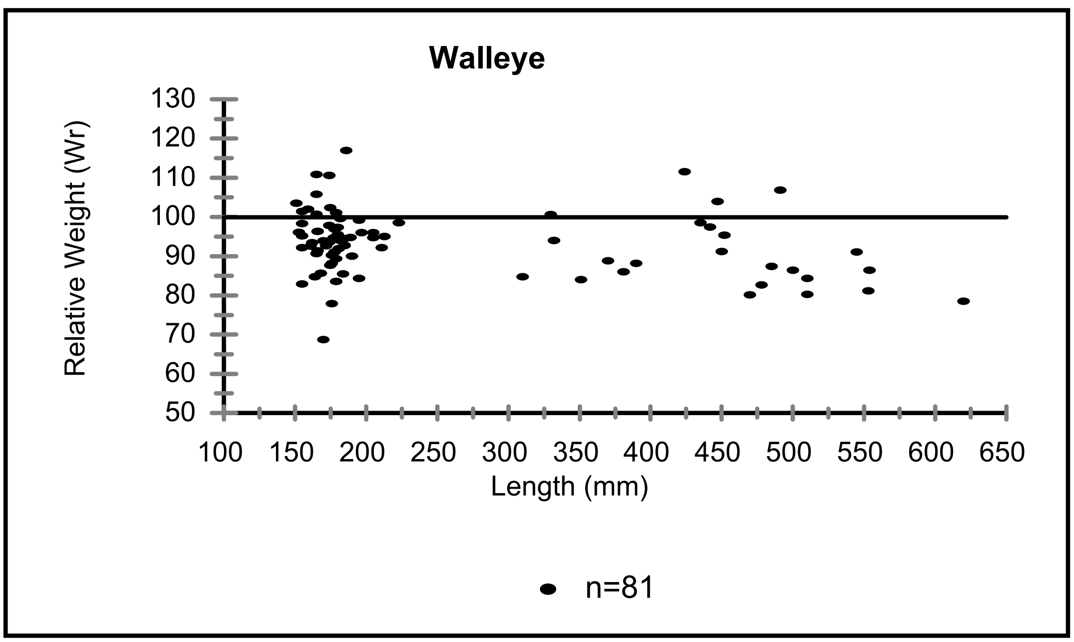

Figure 8. Relative weight (W_r) of walleye, excluding young-of-year, in Banks Lake (Grant County), September 2000, compared to the national 75th percentile. All fish were captured by boat electrofishing, gill netting, or fyke netting.

Yellow Perch

Yellow perch ranged from 45 to 245 mm TL; however, most of the fish collected (78%) were less than 85 mm (age 1) (Table 3; Table 4). No aging structures were collected for fish over age 2 (Table 13). Growth rates were generally higher for age 1 and age 2 fish when compared to Washington State averages. Length frequency data showed variable year-class strength with a gap between 160 mm and 200 mm sized fish (probably age 3+). Relative weights indicated that the condition factor was low for fish in all age classes (Figure 10).

Table 13. Age and growth of yellow perch sampled at Banks Lake (Grant County) in September 2000 compared to Washington State averages. Unshaded values are mean back-calculated lengths at annulus using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths at annulus using the Lee's modification of the direct proportion method (Carlander 1982).

		Mean Total Length (mm) at Age	
Year Class	**n**	**1**	**2**
1999	22	65	
		82	
1998	12	69	146
		90	155
Direct Proportion Overall Mean		67	146
Lee's Weighted Mean		85	155
Direct Proportion State Average		60	120

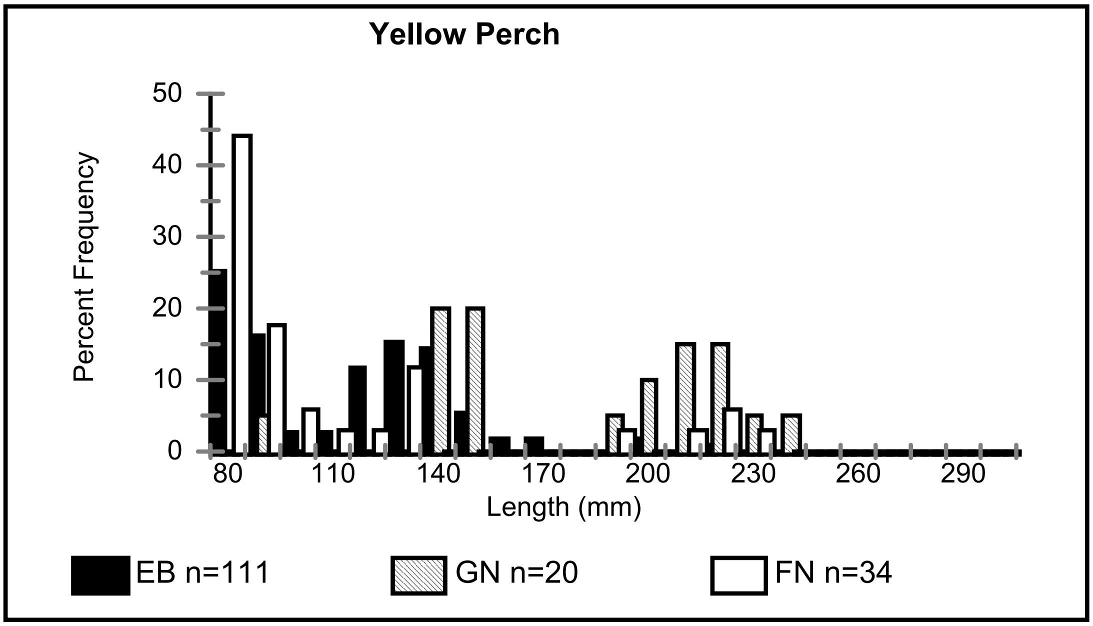

Figure 9. Length frequency of yellow perch, excluding young-of-year, in Banks Lake (Grant County) in September 2000; captured by boat electrofishing, gill netting, and fyke netting.

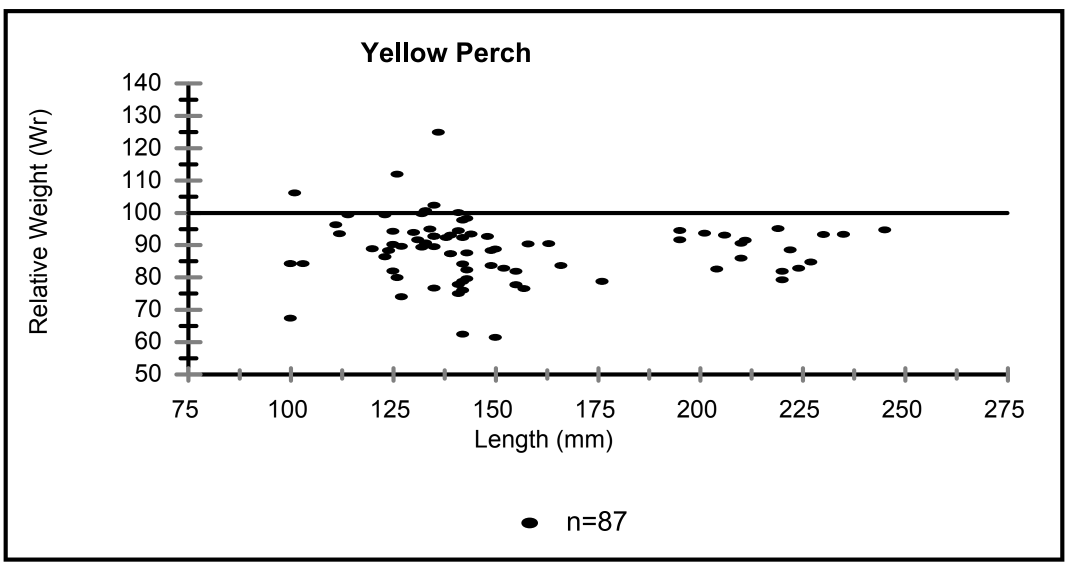

Figure 10. Relative weight (W_r) of yellow perch, excluding young-of-year, in Banks Lake (Grant County), September 2000, compared to the national 75th percentile. All fish were captured by boat electrofishing, gill netting, or fyke netting.

Black Crappie

Black crappie ranged from 56 to 262 mm TL; however nearly 75% of the fish collected were less than 79 mm (age 1) (Table 3; Table 4). The sample size was small, yet growth rates for black crappie indicated average to above average growth for all ages of fish collected (Table 14). Relative weights of black crappie were mostly above the national 75th percentile (Figure 11). Length frequency could not be calculated accurately due to the small sample of fish collected over age 1.

Table 14. Age and growth of black crappie sampled at Banks Lake (Grant County) in September 2000 compared to Washington State averages. Unshaded values are mean back-calculated lengths at annulus using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths at annulus using the Lee's modification of the direct proportion method (Carlander 1982).

		Mean Total Length (mm) at Age		
Year Class	**n**	**1**	**2**	**3**
1999	3	37		
		63		
1998	11	58	146	
		84	159	
1997	1	34	137	221
		64	154	227
Direct Proportion Overall Mean		43	142	221
Lee's Weighted Mean		79	159	227
Direct Proportion State Average		46	111	157

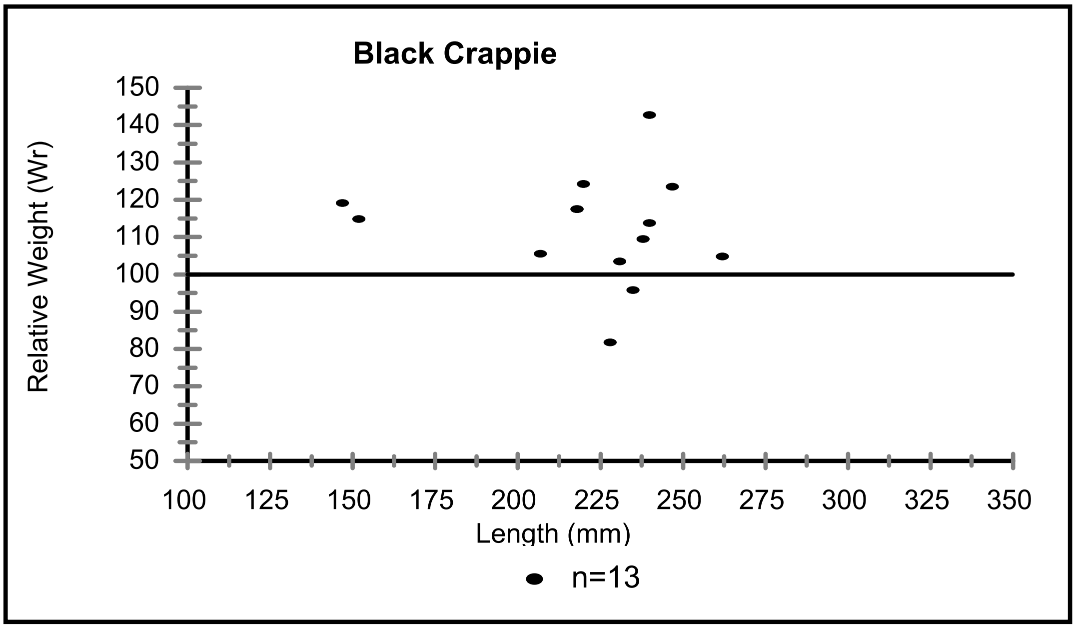

Figure 11. Relative weight (W_r) of black crappie, excluding young-of-year, in Banks Lake (Grant County), September 2000, compared to the national 75th percentile. All fish were captured by boat electrofishing, gill netting, or fyke netting.

Pumpkinseed Sunfish

Pumpkinseed sunfish ranged from 42 to 152 mm TL with most fish being larger than 50 mm (age 1) (Table 3; Table 4). Overall, the number of smaller pumpkinseed sunfish collected was low. Growth rates for pumpkinseed sunfish were well above the known Washington State average for all ages of fish (Table 15), although total sample size was low. Relative weights of pumpkinseed sunfish were at or above the national 75th percentile for all age groups (Figure 12). Length frequency could not be calculated accurately due to the small number of fish collected over age 1.

Table 15. Age and growth of pumpkinseed sunfish sampled at Banks Lake (Grant County) in September 2000 compared to Washington State averages. Unshaded values are mean back-calculated lengths at annulus using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths at annulus using the Lee's modification of the direct proportion method (Carlander 1982).

		Mean Total Length (mm) at Age		
Year Class	**n**	**1**	**2**	**3**
1999	0			
1998	3	29	83	
		48	91	
1997	1	37	112	139
		56	117	140
Direct Proportion Overall Mean		33	97	139
Lee's Weighted Mean		50	98	140
Direct Proportion State Average		24	72	102

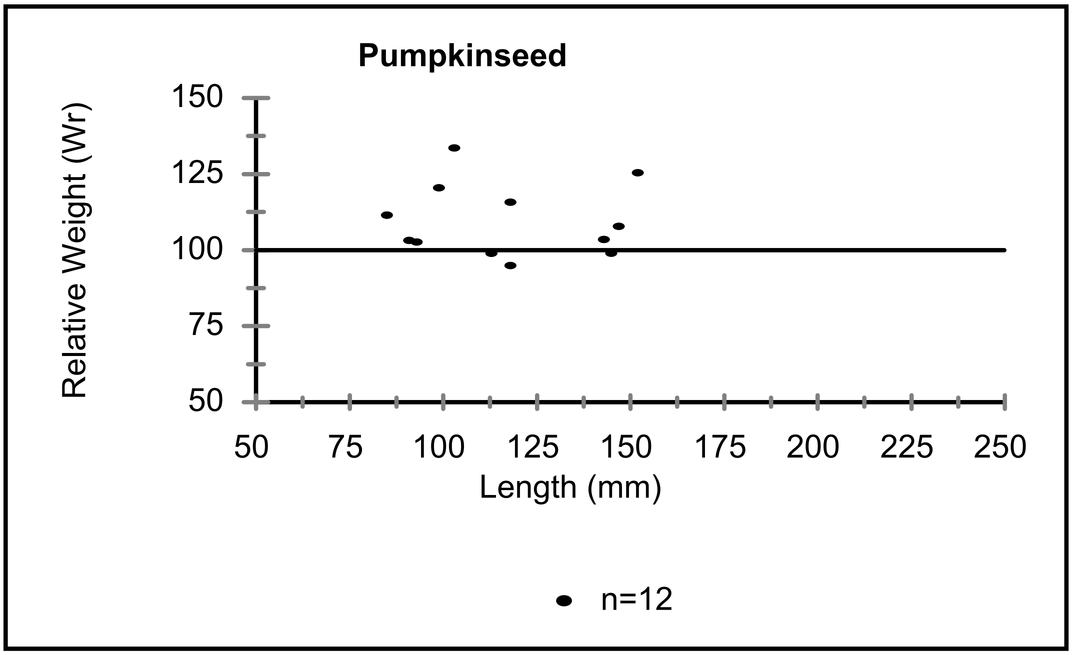

Figure 12. Relative weight (W_r) of pumpkinseed sunfish, excluding young-of-year, in Banks Lake (Grant County), September 2000, compared to the national 75th percentile. All fish were captured by boat electrofishing, gill netting, or fyke netting.

Carp

Carp ranged from 56 to 558 mm TL. As carp scales are difficult to read, aging data were sparse (Table 16); however, length frequency data suggested stable year-class strength for larger individuals with missing year-classes for smaller individuals (Figure 13). Numbers of smaller fish sampled were low. The relative weights of carp were mostly at or below the national 75th percentile with most carp having low condition factors (Figure 14). Data is currently unavailable to compare growth rates of carp in Washington State.

Table 16. Age and growth of carp sampled at Banks Lake (Grant County) in September 2000. Values are mean back-calculated lengths at annulus using the direct proportion method (Fletcher et al. 1993).

		Mean Total Length (mm) at Age				
Year Class	**n**	**1**	**2**	**3**	**4**	**5**
1999	0					
1998	0					
1997	0					
1996	1	111	266	388	441	
1995	1	60	136	209	367	445
Direct Proportion Overall Mean		86	201	298	404	445
Lee's Weighted Mean		NA				
Direct Proportion State Average		NA				

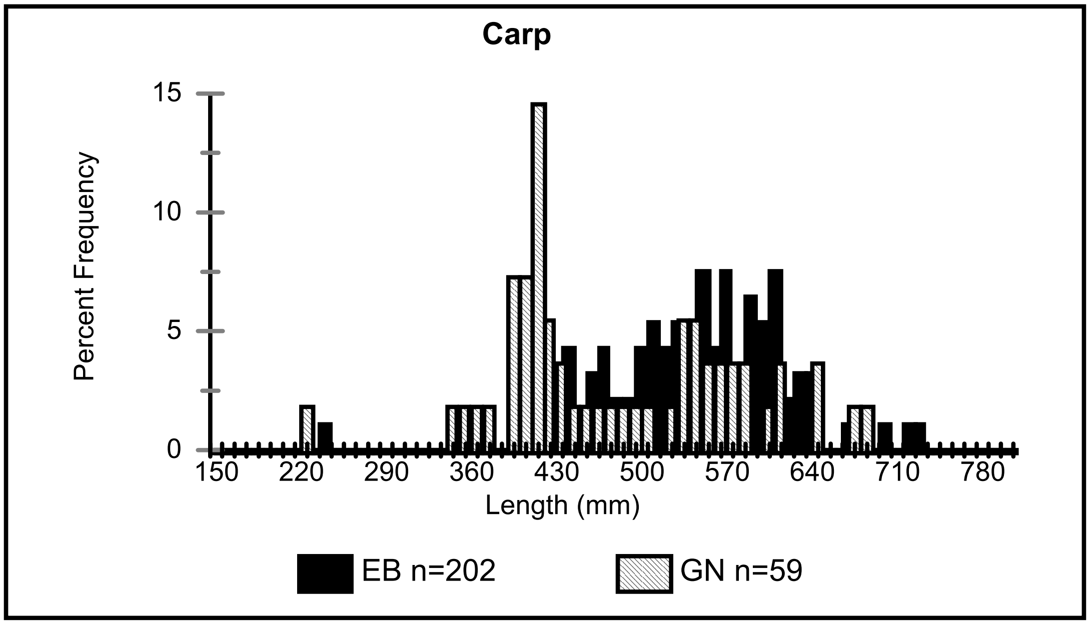

Figure 13. Length frequency of carp, excluding young-of-year, in Banks Lake (Grant County) in September 2000; captured by boat electrofishing and gill netting.

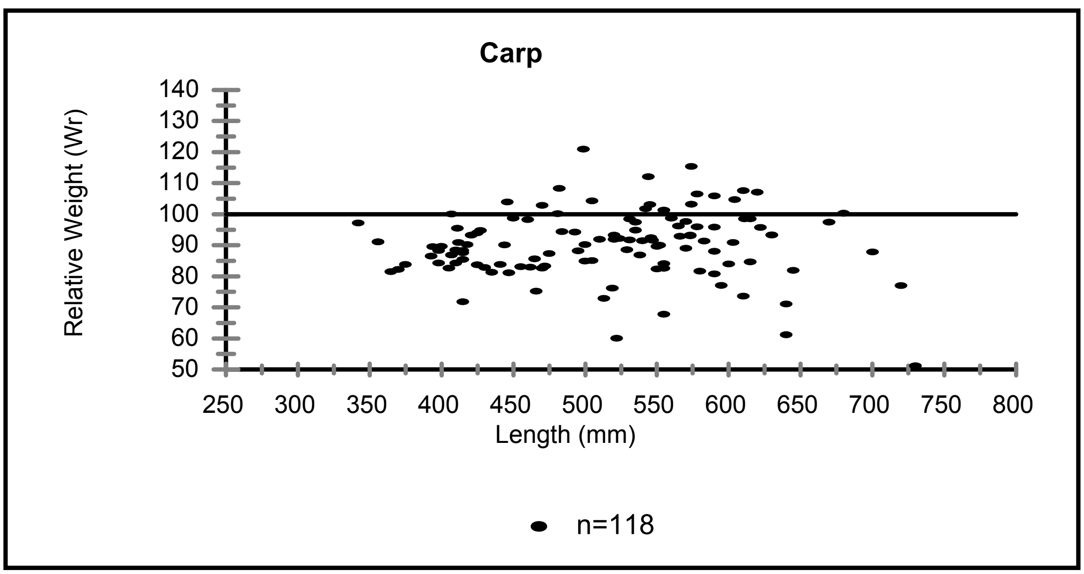

Figure 14. Relative weight (W_r) of carp, excluding young-of-year, in Banks Lake (Grant County), September 2000, compared to the national 75th percentile. All fish were captured by boat electrofishing, gill netting, or fyke netting.

Brown Bullhead

Brown bullhead ranged from 101 to 368 mm TL. Length frequency data showed average year-class strength with different size groups being represented (Figure 15). Numbers of smaller fish collected was low. Overall, condition factors of brown bullhead were low for most fish (Figure 16). Age and growth analysis was not performed for brown bullhead.

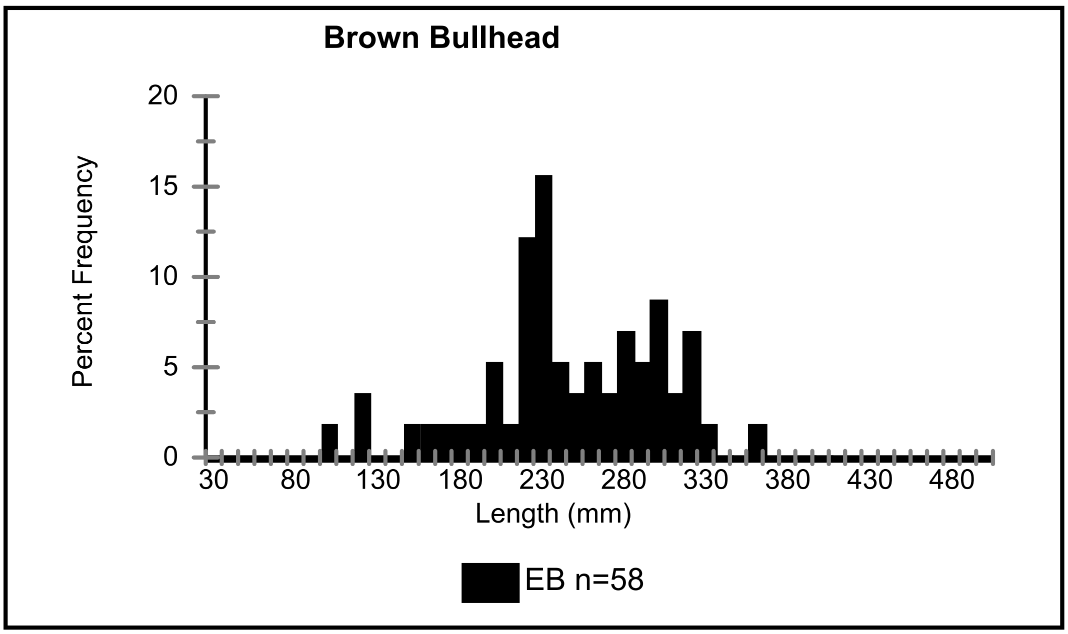

Figure 15. Length frequency of brown bullhead, excluding young-of-year, in Banks Lake (Grant County) in September 2000; captured by boat electrofishing.

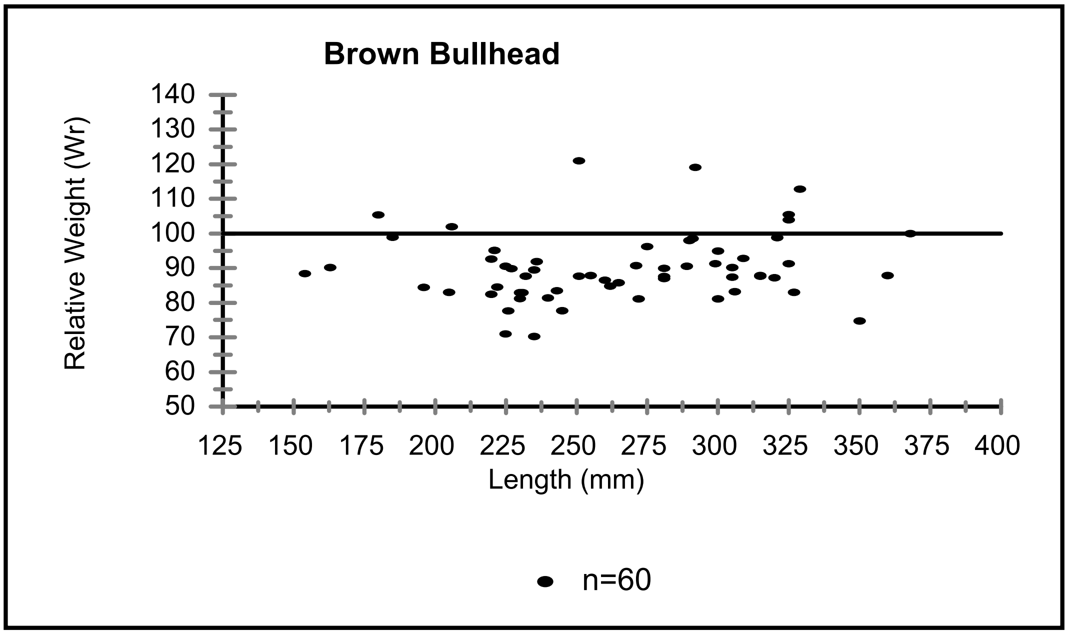

Figure 16. Relative weight (W_r) of brown bullhead, excluding young-of-year, in Banks Lake (Grant County), September 2000, compared to the national 75th percentile. All fish were captured by boat electrofishing, gill netting, or fyke netting.

Yellow Bullhead

Yellow bullhead ranged from 38 to 309 mm TL. Length frequency data showed average year-class strength with most size groups being represented (Figure 17). The number of smaller fish sampled was low. Overall, condition factors of yellow bullhead were low for most fish (Figure 18). Age and growth analysis was not performed for yellow bullhead.

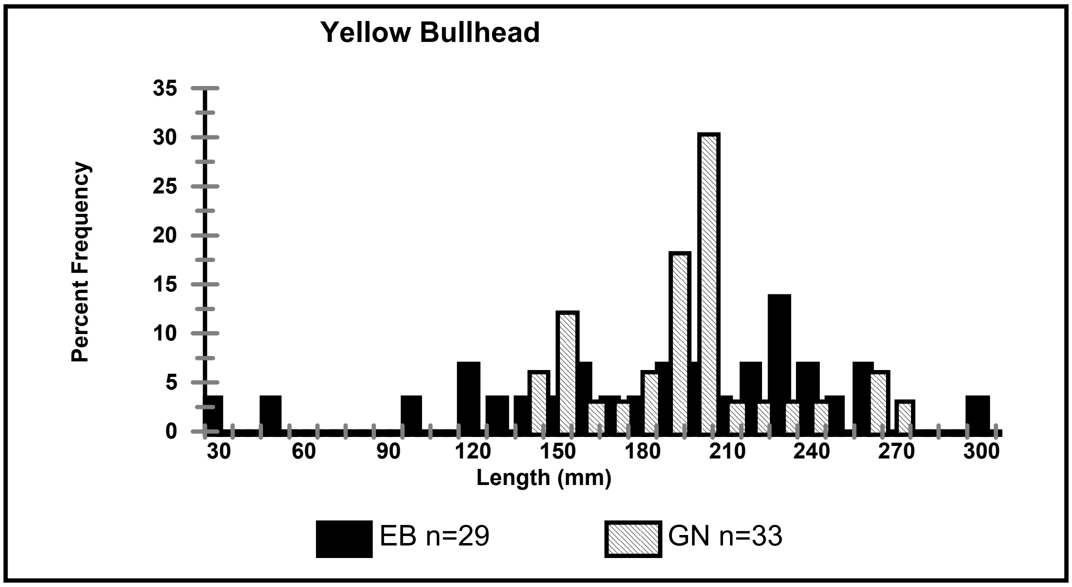

Figure 17. Length frequency of yellow bullhead, excluding young-of-year, in Banks Lake (Grant County) in September 2000; captured by boat electrofishing and gill netting.

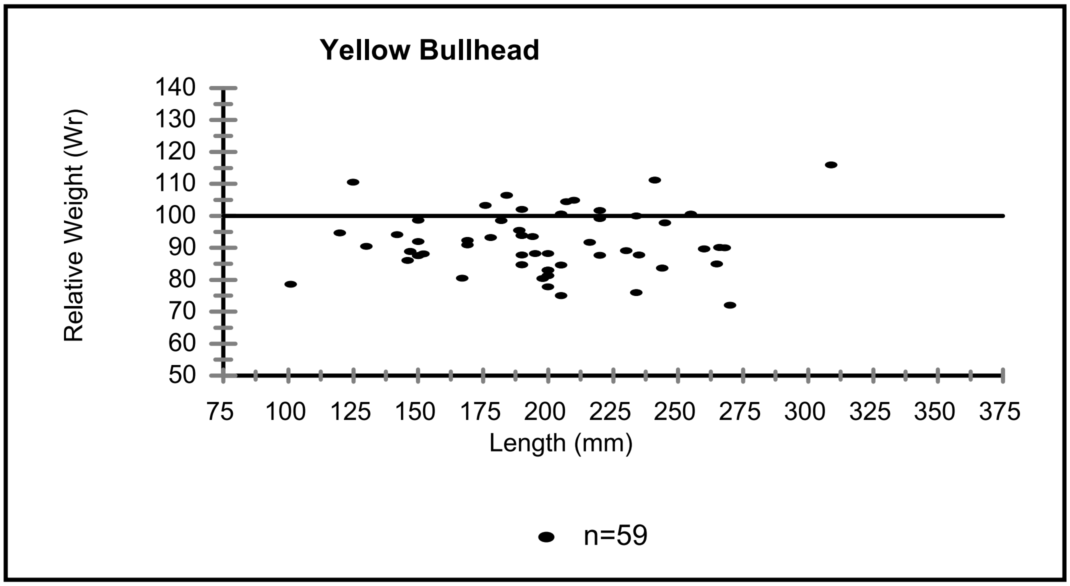

Figure 18. Relative weight (W_r) of yellow bullhead, excluding young-of-year, in Banks Lake (Grant County), September 2000, compared to the national 75th percentile. All fish were captured by boat electrofishing, gill netting, or fyke netting.

Sculpin

Sculpin ranged from 35 to 187 mm TL. Length frequency data showed variable year-class strength with more smaller fish being collected (Figure 19). An abundance of small sculpin ranging from 30-110 mm were collected. Relative weight, age, and growth analyses were not performed on sculpin.

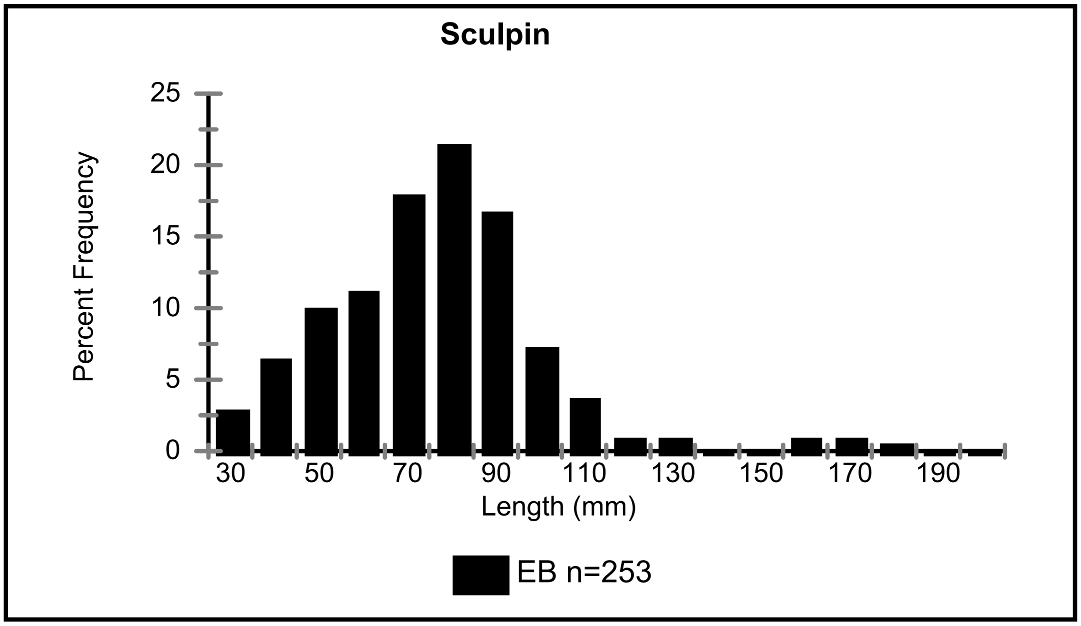

Figure 19. Length frequency of sculpin, excluding young-of-year, in Banks Lake (Grant County) in September 2000; captured by boat electrofishing.

Lake Whitefish

Lake whitefish ranged from 121 to 558 mm TL. The majority of fish captured were greater than 300 mm (Figure 20). Length frequency and age data showed year-class stability for fish ages 2 and older (Table 17). Few 0-1 year-old fish were collected. Relative weight could not be calculated for lake whitefish, as standard weights do not exist for this species.

Table 17. Age and growth of lake whitefish sampled at Banks Lake (Grant County) in September 2000. Values are mean back-calculated lengths at annulus using the direct proportion method (Fletcher et al. 1993).

		Mean Total Length (mm) at Age					
Year Class	**n**	**1**	**2**	**3**	**4**	**5**	**6**
1999	19	187					
1998	12	195	368				
1997	26	208	391	437			
1996	18	197	382	441	475		
1995	4	161	334	408	451	473	
1994	1	190	378	453	479	501	518
Direct Proportion Overall Mean		190	371	435	468	487	518
Lee's Weighted Mean		NA					
Direct Proportion State Average		NA					

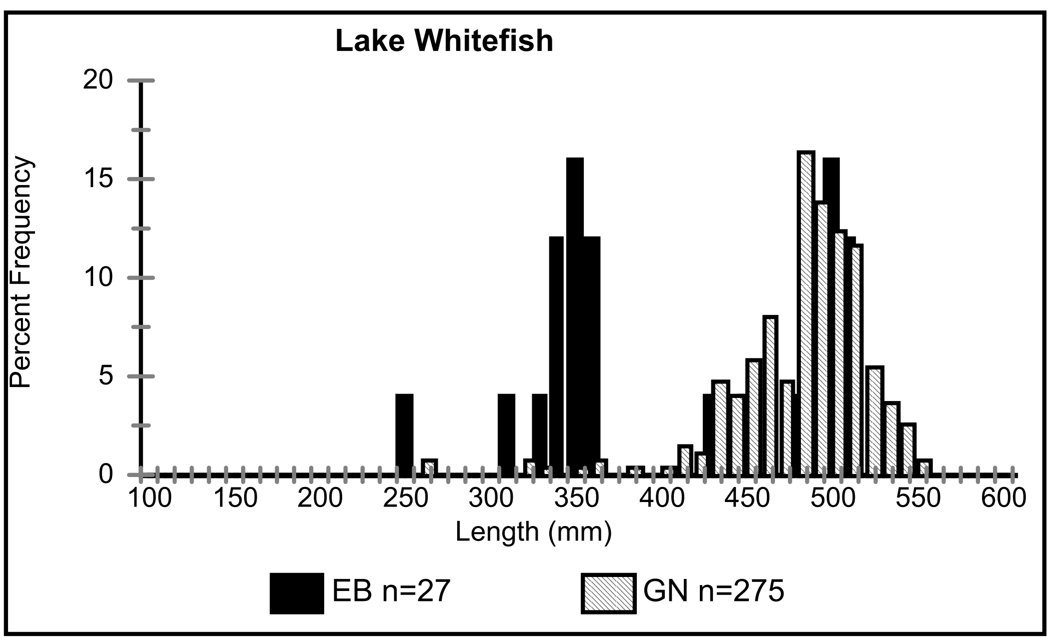

Figure 20. Length frequency of lake whitefish, excluding young-of-year, in Banks Lake (Grant County) in September 2000; captured by boat electrofishing and gill netting.

Rainbow Trout

Rainbow trout ranged from 225 to 486 mm TL. Due to the small sample size collected, age data were sparse, and comparative data are currently unavailable to compare growth rates of rainbow trout in Banks Lake to other Washington State lakes (Table 18). Relative weights showed low condition factors for most fish (Figure 21). Length frequency could not be calculated accurately due to the small number of fish collected per gear type.

Table 18. Age and growth of rainbow trout sampled at Banks Lake (Grant County) in September 2000. Values are mean back-calculated lengths at annulus using the direct proportion method (Fletcher et al. 1993). * Back-calculations may not be valid for net pen raised 1-year old fish.

		Mean Total Length (mm) at Age			
Year Class	**n**	**1**	**2**	**3**	**4**
1999	0				
1998	4	76	228		
1997	4	97	328	449	
1996	1	40	83	362	492
Direct Proportion Overall Mean		* 71	213	406	492
Lee's Weighted Mean		NA			
Direct Proportion State Average		NA			

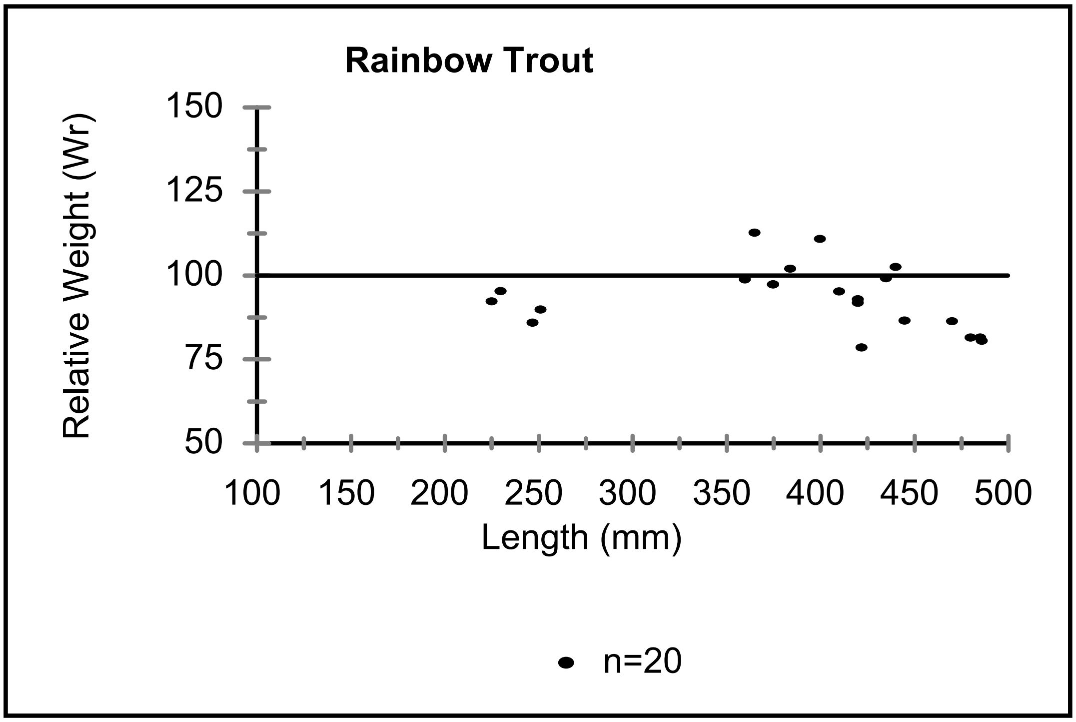

Figure 21. Relative weight (W_r) of rainbow trout, excluding young-of-year, in Banks Lake (Grant County), September 2000, compared to the national 75th percentile. All fish were captured by boat electrofishing, gill netting, or fyke netting.

1.3 Discussion

The littoral zone survey captured over 5,500 fish during September 2000, with the goal of evaluating the warmwater sportfish community. In addition to the nearshore survey, an offshore survey was conducted simultaneously, resulting in a reservoir wide survey, which better represented the entire fish community (*see* Section 2).

Boat electrofishing, gill netting, and fyke netting were conducted at 32% of the nearshore sites. This intensity of sampling was less than our goal of 45%, but still large enough to capture the various habitat types present in Banks Lake. Foul weather, high winds, and the lack of equipment kept us from sampling all the sites we originally selected. Due to funding and timing limitations, we were unable to arrange trips to the reservoir ahead of time to map out sites that would be unsuitable for particular gear types. However, the few unsuitable habitat sections sampled probably did not affect the outcome of the survey or create biases larger than the typical variation we expected from such a large and diverse system.

Stock density indices were used to measure the Banks Lake fishery as a whole, and when combined with other indices, provided a broader picture of the fish populations (Carline et al. 1984). Stock density indices can determine whether fish populations are balanced by comparing stock density indices to predetermined ranges for balanced fish populations (Willis et al. 1993). The number of predators versus prey in a system can determine whether a fish community is balanced (Anderson 1976). The low number of stock length fish collected for most species resulted in broad confidence limits for PSD values making interpretation of this data difficult. However, PSDs could show that warmwater fish populations are fairly balanced. The high electrofishing CPUE and low PSD values for smallmouth bass indicated a high-density population (Willis et al. 1993); however, smallmouth bass collected in gill nets had high PSD values, due partially to gear selectivity, but possibly to a deeper distribution of older smallmouth bass (Cole and Moring 1997). Despite low numbers, a relatively large proportion of walleye and largemouth bass had high PSDs. PSDs vary by season and may be higher or lower depending on recruitment, growth, and natural mortality (Carline et al. 1984). For Banks Lake, multiple, seasonal sampling may be most appropriate to accurately determine PSDs.

An abundance of smallmouth bass were collected; however, variation in year-class strength was observed. Relative weights were generally low for all size-classes collected suggesting the occurrence of interspecific competition for all age classes and perhaps intraspecific competition for younger age classes and was most likely contributing to the low condition factor for most other species. The bi-modal length-frequency distribution showed an obvious gap in smallmouth bass collected between 280 mm (quality length) and 350 mm (preferred length) (Figure 3); potential causes included over-harvest, failed recruitment, gear selectivity (Reynolds 1996), offshore distribution (Cole and Moring 1997), or possible cumulative effects (Jackson and Noble 2000). Over-harvest of smallmouth bass may have attributed to the low abundance of the 280-350 mm size-class being caught due to previous (prior to 2002) angling regulations. The regulation on bass fishing at the time of this survey allowed for no more than three fish over 380 mm (15 inches) and a five fish total bag limit. However, the ability of that regulation to shape the length distribution of the population depends on pressure, harvest, and catchability of the two size groups (Beamesderfer and North 1995). A formal creel survey would be necessary to determine these factors and has been implemented as part of the BPA funded project currently evaluating the Banks Lake fishery. The gap in year-classes seen in the length frequency distribution corresponded to fish age 3-6 from the 1994 to 1997 brood years. Coincidently, a 25-foot drawdown occurred from October 1994-January 1995 (Donna Kreiter, USBOR, personal communication) that may have affected the survival of the 1994-1996 year-classes. Young-of-year fish from the 1994 year-class may have been forced to occupy less preferred habitat subjecting them to increased predation, while subsequent year-classes may have had reduced survival because of less macrophyte cover or invertebrate production.

Walleye and yellow perch exhibited similar recruitment, growth, and condition patterns. Both walleye and yellow perch had an abundance of young-of-year fish, 70% and 78%, respectively. Walleye growth was high compared to Lake Roosevelt and other U.S. and Canadian waters; however, Lake Roosevelt has a slow growing population in an oligotrophic system with large water level fluctuations and few native minnows to provide a prey base (Cichoz et al. 1999). Yellow perch growth was higher than the Washington State average. Not enough aging structures were available from older yellow perch or walleye; however, length frequency distribution suggests we collected older fish. Condition factors were low for both species, with relative weights generally below the 75th percentile. Marwitz and Hubert (1997) found that the mean relative weights of walleye from two Wyoming reservoirs fell as length increased and may have occurred due to limited food resources.

Walleye were sampled at low densities, which may have been caused by limited recruitment or overexploitation (Anderson and Neumann 1996), a lack of suitable habitat, as well as by fish distribution, gear bias, and survey timing. Limited recruitment, due to poor fish condition from competition and low reservoir productivity, most likely caused fish density to be low. Overexploitation by anglers may also have caused a reduction in numbers of the walleye population (Beard et al. 1997). Exploitation may cause recruitment variability and a reduction in the age of first spawning (Spangler et al. 1977). However, exploitation can affect populations positively by reducing fish abundance, thereby reducing competition and increasing growth (Craig et al. 1995). Abiotic environmental factors, such as weather patterns causing excessive wind, no wind, or inadequate water temperatures, may have affected spawning conditions (Busch et al. 1975; Shuter and Koonce 1977). Variations in year-class strength may also have been influenced by the reproductive condition of female walleye, which may have limited the number or fecundity of spawners (Henderson and Nepszy 1994). Female reproduction may have been restricted due to limited reserves of visceral fat, which may have been induced by a lack of available prey or unfavorable water temperatures before spawning (Henderson et al. 1996). Finally, sampling bias may have contributed to under-representing the walleye population. Better results might be obtained from a survey when more fish are nearshore during spring or later in the fall, utilizing a method that targets walleye, such as fall walleye index netting (FWIN) (Morgan 2000).

Low sample sizes for largemouth bass, black crappie, and pumpkinseed sunfish made interpreting data difficult. Growth and condition of these species were above average when compared to other

Washington lakes. Relative weights of largemouth bass, black crappie, and pumpkinseed sunfish were mostly at or above the national 75th percentile averages, suggesting that these fish were able to find adequate forage and did not appear to suffer from overcrowding, yet they might not be using the resources to their fullest potential (Anderson and Neumann 1996). The CPUE for these species was low, and when combined with high condition factors may suggest high predation rates on juveniles or poor spawning conditions (Fletcher et al. 1993). These species may be subject to poor overwinter survival as well. Despite the overall good growth and condition of these species, low sample sizes made it difficult to determine whether these populations were in balance with their environment or if sampling bias related to gear type, fish being offshore and unable to catch, timing of sampling, or a lack of suitable habitat limited production and survival.

Small sample sizes of largemouth bass may have been due to a low-density population, sampling bias by gear type, deep water distribution, or survey timing. Electrofishing accounted for most (77%) of the stock length largemouth bass in our survey. Electrofishing is an effective method to evaluate largemouth bass populations, with catch rates being correlated to population density (Hall 1986; Coble 1992; McInerny and Degan 1993). Small sample size may also be due to fish being offshore at the time of sampling because of warm, inshore water temperatures (Carline et al. 1984; Hall 1986). The effect of water temperature and largemouth bass distribution, in relation to our survey methods were unknown. Seasonal patterns may also have affected our catch rates; sampling in the spring rather than in the fall might produce a better evaluation of largemouth bass (Sammons and Bettoli 1999; McInerny and Cross 2000) as they shift habitats and move inshore to spawn.

Suitable habitat may also have contributed to a low population density of largemouth bass, as good habitat for largemouth bass may be limited to certain areas within the reservoir (Figure 2). In comparison to smallmouth bass, which were caught throughout the reservoir, largemouth bass were restricted to the northern section. Comparison of largemouth bass distribution to habitat models supports the notion that much of Banks Lake does not contain suitable habitat for largemouth bass (Stuber et al. 1982). The southern section had less littoral vegetation and steeper slopes due to basin morphology (Hayes et al. 1999). When habitat is restricted to certain areas, and is combined with competition, predation, and angler harvest, it may be impossible for abundant populations of largemouth bass to exist in Banks Lake.

Low numbers of black crappie and pumpkinseed sunfish were also collected, and interestingly, 54 of the 56 black crappie and all of the pumpkinseed (n = 13) were collected in the northern section, suggesting that suitable habitat was limited to the northern section of Banks Lake for these species as well. Future studies should look more closely at habitat characteristics and fish distribution to understand interspecific competition and how it may be affected by suitable habitat.

Rainbow trout and kokanee have been stocked annually and have provided anglers the opportunity to fish when cooler water temperatures limited the catch rates of warmwater fish. Salmonids made up nearly 17% of the nearshore catch by number and 38% by weight. Lake whitefish were the third most abundant fish collected by number and had the highest biomass of all fish collected. Few 0-1 year-old lake whitefish were collected, which was probably due to sampling bias. Rainbow trout and kokanee made a minimal contribution to the sample. This was most likely due to gear type bias, as well as competition with the abundant lake whitefish population, and from predation on stocked fry and fingerling kokanee and on some net pen raised, yearling rainbow trout. Offshore gill nets also captured a high number of lake whitefish (n = 170; 79% of the catch) and determined that they were more evenly distributed throughout the water column compared to kokanee and rainbow trout, which were distributed more towards the surface (*see* Section 2).

Water quality data showed most parameters within optimal ranges for warmwater fish. Warmwater fish can exist in water with dissolved oxygen readings as low as 2.5 mg/l, yet require dissolved oxygen above 1.0 mg/l to survive (Swingle 1969). The southern end had more homogenous conditions with no stratification, providing unlimited deep water habitat. In the northern end, water quality became less suitable for most fish in the hypolimnion (DO < 4.0 mg/l) (Department of Ecology 2002), but the thermocline was at 25 m and we had no evidence of warmwater fish using these depths. Water quality profiles taken from Devil's Lake may not have represented the northern end in general, due to its greater maximum depth. In general, cool water is pumped into Banks Lake and water retention is limited in the growing season, which has lead to cooler water temperatures and lower productivity.

In the past, water levels in Banks Lake fluctuated during the spring, summer, and fall when water was released for irrigation to the Columbia Basin in spring and summer, and then again retained in the fall. Fluctuations also occurred because of flood control and waterpower regulation. In 1973 and 1974, severe water drawdowns made it difficult for littoral vegetation to grow, limiting cover and habitat availability. This negatively influenced the spawning success of the kokanee population, which at the time may have been self-sustaining (Stober et al. 1977). Water level fluctuations also altered the benthic community by changing species composition, reducing densities, and vacating them from areas of peak abundance (Stober et al. 1976). Since the drawdown in 1973-1974, two more drawdowns have occurred, one from October 1980 to February 1981, and one from October 1994 to January 1995, both reducing water levels by about 8 m from full pool (479 m). Both drawdowns probably had similar effects on the biological community in the reservoir; however, no studies were conducted. Other than the periodic maintenance drawdowns, water levels have remained fairly stable, usually fluctuating by less than 1 m. In August, the reservoir may be lowered by 1.5 m to help deliver water for lower Columbia River salmon flow augmentation. A proposal has been submitted to reduce the elevation of Banks Lake an additional 1.5 m (5 ft) annually beginning in August 2003 (USDOI 2003). In the future, habitat evaluations are needed to characterize the potential impact of the new water level regime.

This was the first extensive survey of Banks Lake in almost three decades. Currently, the Banks Lake Fishery Evaluation Project (BLFEP; WDFW), funded by Bonneville Power Administration, has begun extensive seasonal surveys of Banks Lake (Lewis et al. 2002; Polacek et al. 2003). Sampling includes a creel survey, water quality, primary and secondary productivity, littoral and limnetic fish surveys, mark and recapture studies, habitat analysis of the shoreline, and entrainment. Additionally, the WDFW Warmwater Program began annual fall walleye index netting (FWIN) in October of 2001. These studies will provide the necessary information to understand the fishery and be able to effectively provide management recommendations for catch rates, bag and slot limits, and stocking strategies to better manage fish populations within Banks Lake. Therefore, this report will not include management recommendations; rather, it will serve as a starting point for the more extensive studies that will follow.

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Section 2. Limnetic Zone Surveys

Introduction

The Washington Department of Fish and Wildlife (WDFW) 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, percids, juvenile centrarchids, and species such as burbot 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). Additionally, the Bonneville Power Administration and WDFW fund hatchery stocking of kokanee and rainbow trout with no formal evaluation of performance in Banks Lake. Therefore, a limnetic fisheries survey was conducted on Banks Lake, concurrent to the nearshore surveys, using hydroacoustics in conjunction with vertical and horizontal gill netting.

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; Mehner and Schultz 2002). Homogeny in species composition and length distribution results in increased confidence in hydroacoustic estimates.

2.1 Methods

Hydroacoustic Survey

A hydroacoustic survey was conducted on Banks Lake on September 25, 2000. Eleven transects were conducted in an elongated zigzag pattern across the offshore region between Dry Falls Dam and the North Dam. The survey began one hour after sunset and each transect covered 2 to 5 km at a speed of approximately 2.2 m/s, for a total survey distance of 44 km.

We used an HTI model 241 echosounder with a 200 kHz 15° split-beam transducer in vertical orientation. The transducer was clamped to a pole and mounted to the starboard side of 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 2 pings per second was used with a pulse width of 1.25 ms and a 10 kHz pulse width chirp. For each transect, individual tracked fish were verified as real within the post-processing software Echoscape 2.10 (HTI 2002). A series of acoustic echoes were considered a fish if tracked for at least 3 consecutive pings, within 0.3 m/ping, a maximum velocity of 5 m/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).

Fish density was calculated by range weighting acoustic fish targets to one square meter at the surface using the formula:

$$F_w = 1/[2*R*\tan(7.5)]$$

where F_w was the weighted fish value for individual targets, R was the distance to the target (depth of the fish), and 7.5 was ½ the nominal beam width of the transducer (Ransom et al. 1999; Yule 2000). Density was 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 weighted fish value for each depth bin, F_0 was the original weighted fish density per depth strata, EBW was the effective beam width for that stratum and NBW was the nominal beam width for the transducer. Data were not analyzed at an effective beam width of less than 50% of the nominal beam width (15°). The sum of all weighted fish was divided by transect length to determine the density of fish per transect. Reservoir wide density (fish/ha) was calculated by averaging the individual transects, converting m^2 to hectares, then multiplying the mean density by the surface area of Banks Lake (11,000 ha). We estimated the 95% confidence interval of the mean as two standard errors.

Limnetic Gill Net Survey

Gill net surveys were used to provide species verification, depth distributions, and length classes of acoustic targets. Net depth and placement along transect lines were indiscriminate, but generally in the middle third of the shore-to-shore axis. We set 10 vertical and 10 horizontal gill nets over a three night period beginning on 25 September. Each vertical gill net was 2.6-m wide, extended from the surface to the bottom of the reservoir (14-25 m), and consisted of one mesh size throughout (25, 51, 76, or 102-mm stretch). Horizontal nets were 2.6-m deep, 46-m long, and had 7 panels with mesh sizes from 25-102 mm in 13-mm increments. There were 10 horizontal nets; three floating nets were set at the surface, two sinking nets were set at 20-m deep, and five suspended nets were set at depths where fish were located during the hydroacoustic survey (5, 11, 12, 15, and 23 m).

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. Catch per unit effort (CPUE) was calculated for each gear type by determining the number of fish captured per net night. The water column was then divided into 8-m strata and vertical distribution was determined by correcting catch data for effort (m^2 of gill net mesh) within each stratum.

2.2 Results

Hydroacoustic Survey

The results of the acoustic survey were limited to the lower 1/3 of the water column because no data were collected on the horizontal transducer and the probability of detection of acoustic targets did not exceed 0.50 until the 14 m depth strata. Three of the transects (4, 5, and 10) were excluded from further analysis because their mean depth was not adequate (< 16 m) for our minimum probability of detection threshold.

Fish density ranged from 6 to 19 fish/ha in transects where mean bottom depth exceeded 16 m (Figure 2.1); the mean density was 10.8 fish/ha [4.3 (2SE)]. Fish were evenly distributed throughout the depth bins from 14 m to the reservoir bottom (Figure 2.2).

Limnetic Gill Net Survey

Vertical and horizontal gill nets were effective at capturing fish throughout the limnetic zone of Banks Lake. We captured 215 fish in 20 net sets for an average of 10.8 fish per net. The sinking and midwater (suspended) horizontal nets had the highest catch rates of 31.5 and 18.6 fish per night, whereas the 25, 51, and 76-mm mesh vertical gill nets only averaged 1 fish per night (Table 2.1). Lake whitefish dominated the relative abundance (79% ; n = 170), followed by walleye (11% ; n = 24), and various other species (10%; n = 21) (Table 2.2). The majority of lake whitefish were over 300 mm in length with two distinct modes in the length frequency (Figure 2.3). Length at age analysis (see section 1 of this report) indicated that the mode from 325-375 mm was age-2 whitefish and the mode from 425 to 550 included fish from age-3 and all older year classes. Therefore, the low proportion of lake whitefish in the 400 mm size range was not due to a missing age class. All walleye were over 325 mm, with a slight mode from 400-425 mm. Sample size was too small to evaluate the length frequencies of other fish species.

The vertical distribution of offshore fishes varied by species. Lake whitefish had the highest catch rate in the 16-24-m depth bin, but were fairly evenly distributed throughout the water column (Figure 2.4). Walleye were 5 fold more likely to be captured in either of the two deeper depth bins than in the 0-8-m depth bin (Figure 2.4). Conversely, rainbow trout and kokanee were only captured near the surface (Figure 2.4). One smallmouth bass and five yellow perch were captured at 11 and 12 m, respectively. One northern pikeminnow was captured at 15 m, and five smallmouth bass and one burbot were captured at 20 and 21 m, respectively.

Abundance— Due to sampling difficulties we could not estimate reservoir-wide abundance of offshore fishes. The hydroacoustic abundance estimate for fish deeper than 14 m was 119,179 (± 47,313). Assuming equal capture probabilities, our abundance estimates were 94,151 lake whitefish (79%), 13,109 walleye (11%), and 11,918 (10%) other fish.

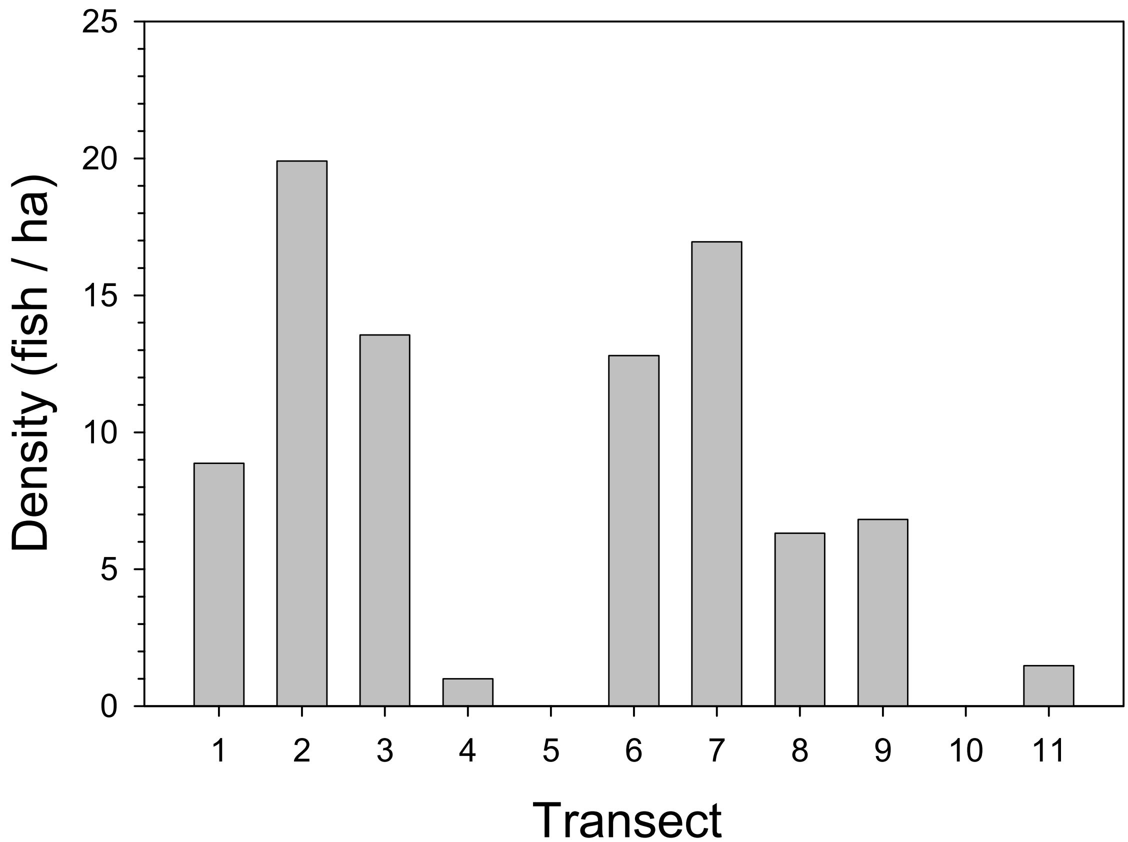

Figure 2.1. Hydroacoustic fish density estimates (fish/ha) for fish deeper than 14 m in Banks Lake, September 2000. Transects progressed from South to North with transect 1 beginning near Dry Falls Dam, transect 7 was west of Steamboat Rock State Park, and transect 11 ended at the North Dam.

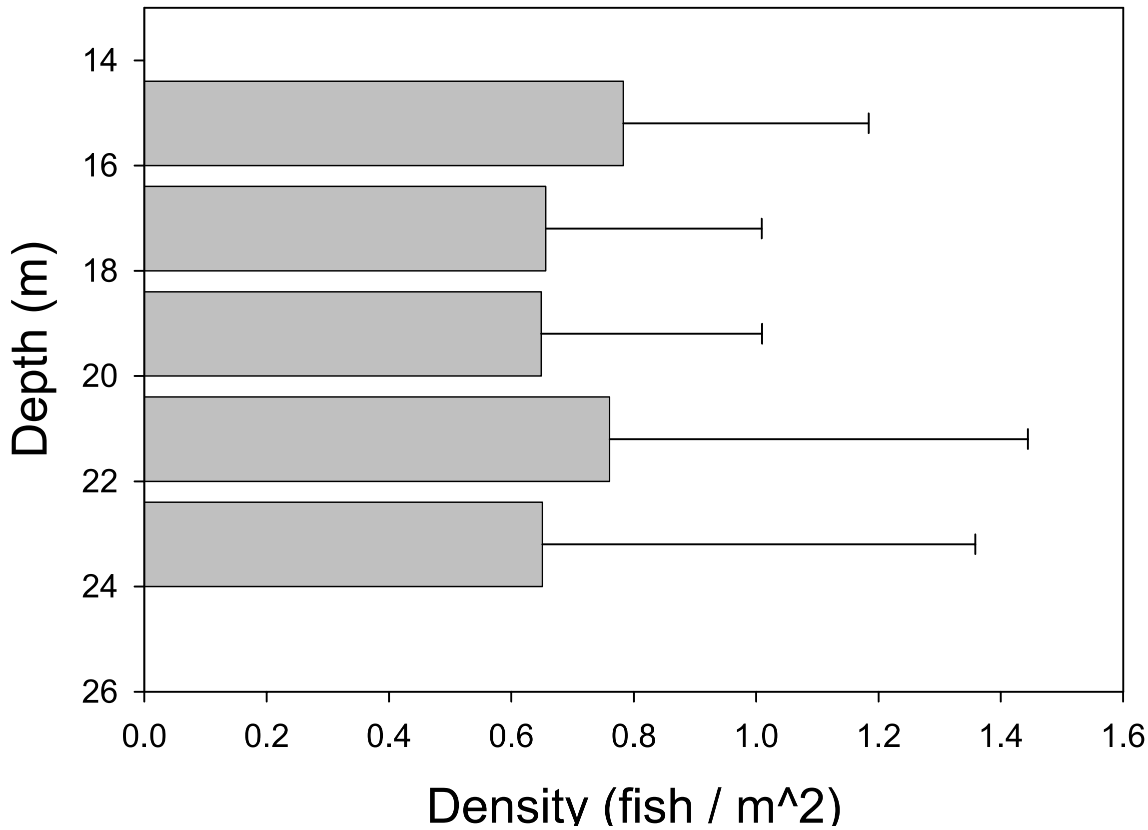

Figure 2.2. Mean density of tracked fish in 2-m depth bins from a hydroacoustic survey of Banks Lake on 25 September 2000. Error bars represent two standard errors.

Table 2.1. Catch per gill net night for each gear type from the Banks Lake offshore gill net survey, September 25, 2000. Net codes were as follows: FH = floating horizontal (n=3), MH = midwater horizontal (n=5), SH = sinking horizontal (n=2), V1 = 25-mm mesh vertical (n=2), V2 = 51-mm mesh vertical (n=3), V3 = 76 mm-mesh vertical (n=2), V4 = 102-mm mesh vertical (n=3).

	FH	MH	SH	V1	V2	V3	V4	Overall
Burbot	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.05
Kokanee	0.7	0.0	0.0	1.0	0.0	0.0	0.0	0.20
Lake whitefish	6.3	14.4	24.5	0.0	1.0	1.0	8.3	8.50
Northern pikeminnow	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.05
Rainbow trout	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.20
Smallmouth bass	0.0	0.2	2.5	0.0	0.0	0.0	0.0	0.30
Walleye	0.0	2.8	4.0	0.0	0.0	0.0	0.7	1.20
Yellow perch	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.25
Total	8.3	18.6	31.5	1.0	1.0	1.0	9.0	10.8

Table 2.2. Size range and relative abundance by number and weight for fishes captured in limnetic gill nets on Banks Lake between September 25 and 28, 2000.

					Size range (mm TL)	
Species	(n)	% (n)	(kg)	% weight	Min	Max
Burbot	1	0.5%	0.9	0.5%	538	538
Kokanee	4	1.9%	1.0	0.6%	116	449
Lake whitefish	170	79.1%	149.9	84.1%	189	544
Northern pikeminnow	1	0.5%	0.5	0.3%	376	376
Rainbow trout	4	1.9%	3.5	2.0%	405	425
Smallmouth bass	6	2.8%	1.4	0.8%	242	258
Walleye	24	11.2%	20.7	11.6%	330	550
Yellow perch	5	2.3%	0.2	0.1%	95	226

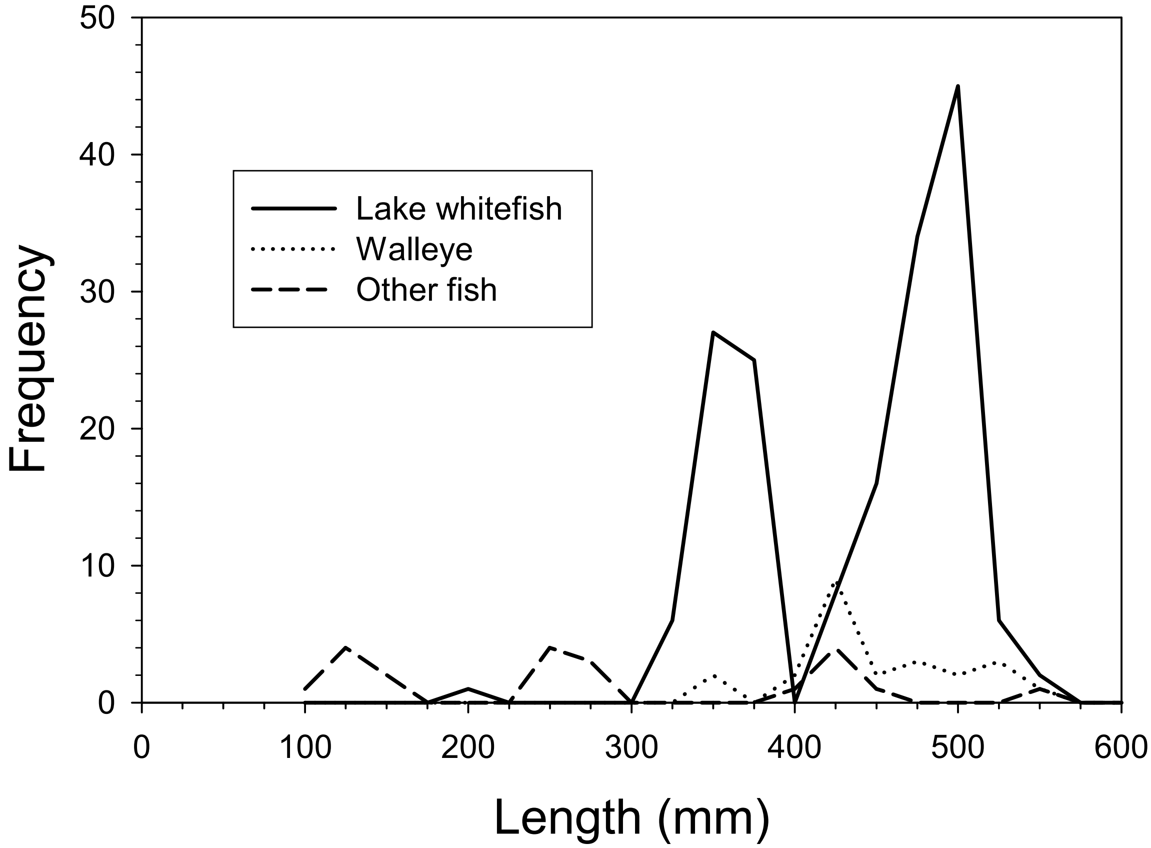

Figure 2.3. Length frequency for fishes captured in offshore gill nets in September 2000. Other fish included burbot, kokanee, northern pikeminnow, rainbow trout, smallmouth bass, and yellow perch.

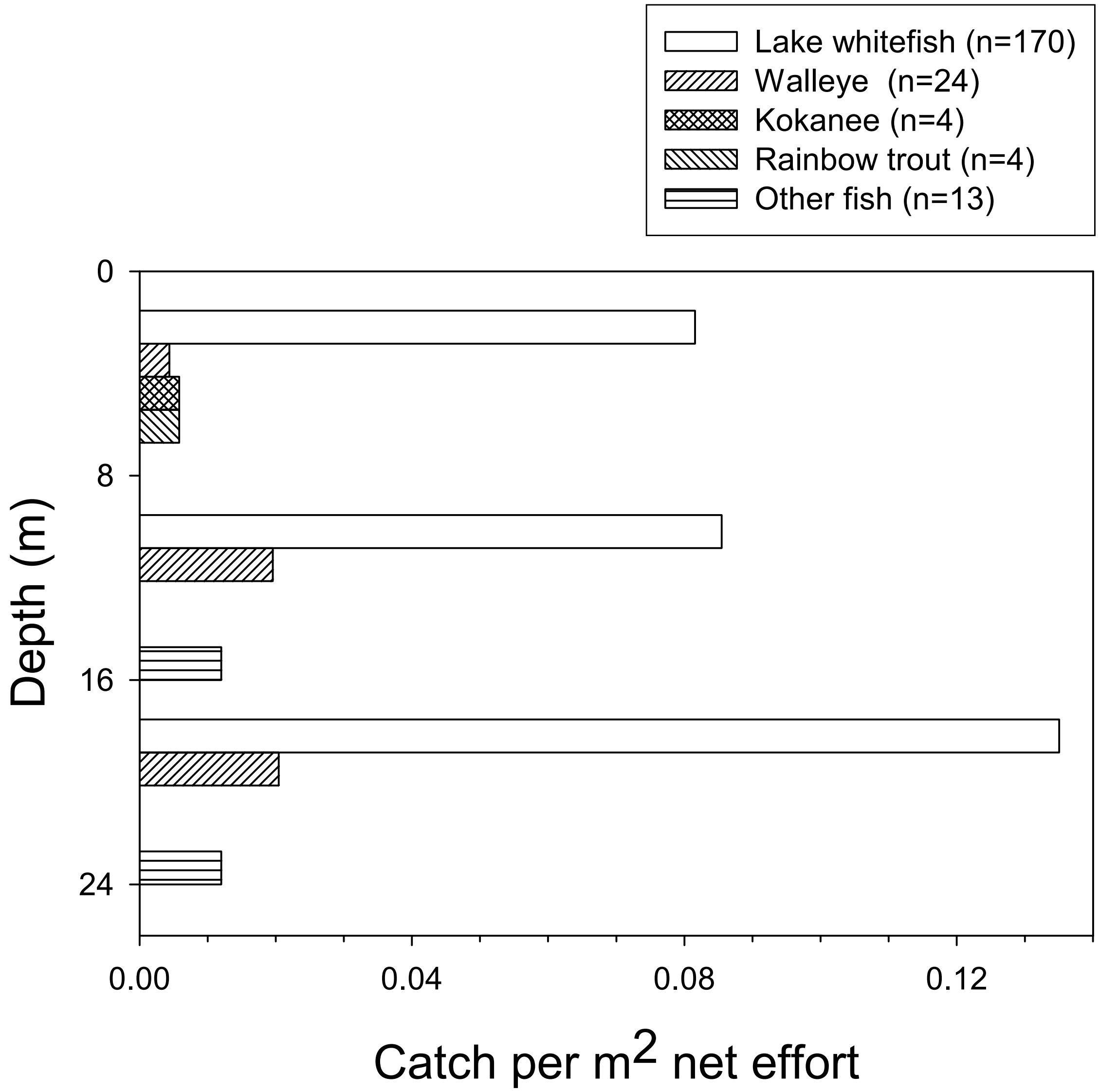

Figure 2.4. Vertical distribution, corrected for effort, for fish captured in offshore gill nets in Banks Lake, September 2000. Effort was calculated as the sum of all horizontal and gill net mesh fishing within each 8 m depth bin. The "other fish" category consisted of six smallmouth bass, five yellow perch, one northern pikeminnow, and one burbot.

2.3 Discussion

The primary limitations to our hydroacoustic survey were that the depth stratum from 0-8 m was not sampled due to the technical difficulties of the horizontal transducer and the depth strata from 8-14 m was not sampled due to an insufficiently low ping rate for the boat speed. Future studies should include a horizontal aspect transducer, due to the presence of kokanee and rainbow trout in the near surface gill nets. Catch rates and relative abundance of these species was too low in the gill nets to facilitate analysis of their abundance and distribution using hydroacoustics. Even if we had obtained acoustic data for the 0-14 m depth zone, we would not have had confidence in our reservoir-wide extrapolations. The overwhelming abundance of lake whitefish made it difficult to evaluate any other species with much confidence. Future studies should focus on other times of the year to identify depth zones or areas of the reservoir where target species, such as kokanee, can be evaluated without interference from whitefish.

The homogenous distribution of lake whitefish made them a good candidate for future abundance estimates, given similar conditions. Although whitefish are not considered a highly sought after sportfish, they need to be managed in Banks Lake for at least three reasons:

1) They are rumored to be harvested at high levels during certain times of the year for consumption
2) They have a high potential for a negative interaction with stocked salmonids and juvenile spiny rayed fishes through competition for food
3) They may provide important prey for walleye and bass in a system with very few prey fish species such as shiners, minnows, or shad.

The abundance estimates do not represent a reservoir-wide estimate of total abundance for any species. The abundance represents a partial abundance estimate for the depth zone sampled. Gill net catches for lake whitefish were fairly evenly distributed across the 3 depth bins so future studies should be able to get an accurate abundance estimate. Other species; such as walleye, burbot, and bass, tend to have a benthic distribution, thereby limiting the ability of hydroacoustics to accurately assess their abundance.

Banks Lake had substantial offshore habitat that was not covered by the WDFW warmwater survey protocol. Several species including kokanee, rainbow trout, lake whitefish, walleye, and burbot were likely to be overlooked or under-represented without offshore surveys. Despite the limitations of our hydroacoustic survey, the offshore survey was a successful complement to the WDFW littoral zone fisheries survey.

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