2000 Warmwater Fisheries Survey of Whitestone Lake, Okanogan County, Washington

by

Randall S. Osborne and Marc R. Petersen
Warmwater Fish Enhancement Program
Washington Department of Fish and Wildlife
1550 Alder Street NW
Ephrata, Washington 98823

September 2001

Acknowledgments

We would like to thank Bryan Jacobs for his assistance with data collection. We would also like to thank Heather Bartlett, Joe Foster and Jeff Korth (WDFW) for reviewing drafts of this manuscript and Chris Donley (WDFW) who provided us with technical support. Appreciation is extended to John Sneva and Lucinda Morrow for aging scales collected during this survey. A sincere thanks also goes out to Dale Swedberg for allowing us to use the facilities at the Sinlahekin Wildlife Management Area. This survey was funded by the WDFW Warmwater Fish Enhancement Program.

Abstract

Whitestone Lake, Okanogan County, Washington was surveyed June 26-29, 2000 using a boat electrofisher, gill nets, and fyke nets. A total of eight fish species were observed during 2000: largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieu*), bluegill (*Lepomis macrochirus*), pumpkinseed (*L. gibbosus*), yellow perch (*Perca flavescens*), brown bullhead (*Ictalurus nebulosus*), channel catfish (*I. punctatus*), and common carp (*Cyprinus carpio*). Warmwater gamefish comprised over 99% of the total fish captured. Bluegill were the most abundant (87%) species sampled and accounted for the majority (48%) of the biomass. Largemouth bass comprised 4% of the sample and ranged in age from 1 to 12 years. Of the stock length largemouth bass that were sampled by electrofishing (n = 86), 76% were of quality size and 31% were of preferred size. Largemouth bass ranged in total length from 69 to 562 mm. Largemouth bass greater than 300 mm were in good condition whereas those less than 300 mm were in less than average condition. Bluegill comprised 87% of the sample and ranged in age from 1 to 10 years. Total lengths of bluegill ranged from 40 to 224 mm and were shorter than the Washington State average at all ages. Of the stock length bluegill sampled (n = 3,953 by all gear types), no more than 6% were of quality size and no preferred size bluegill were observed. Yellow perch ranged in age from 2 to 5 years and were longer than the Washington State average at all ages. Total lengths of yellow perch ranged from 145 to 251 mm. Although yellow perch exhibited good growth, they were in poor condition. All yellow perch sampled had relative weights less than 100. It appears that bluegill density has increased to alarming levels since 1998 and measures should be taken to reduce bluegill density and minimize future impacts on the other fish populations in the lake. Measures may include, but are not limited to, regulation changes, partial-lake rehabilitations, physical bluegill removal, and predator stocking. In addition, future monitoring would likely forecast whether additional predators were needed, additional bluegill should be removed, and/or adjustments in regulations should be made.

Table of Contents

List of Tables

List of Figures

Introduction and Background

Whitestone Lake is located in the Okanogan River drainage approximately 5.7 miles northwest of Tonasket, Washington in Okanogan County (Figure 1). The lake, which is used primarily for irrigation, has a surface area of 70 hectares (ha)(173 acres) and a maximum depth of approximately 7.6 meters (m)(25 feet). The basin (Whitestone Flats) lies about 4 kilometers (km) (2.5 miles) southeast and approximately 34 m (113 feet) below (elevation) Spectacle Lake, which supports Whitestone Lake through underground seepage (Heather Bartlett, Washington Department of Fish and Wildlife (WDFW), personal communication). Whitestone Lake originates from springs located in a 32 ha (80 acre) cattail *Typha spp.* marsh at the northwest end which contributes an estimated 1.5 cubic feet per second (cfs) of accumulated inflow.

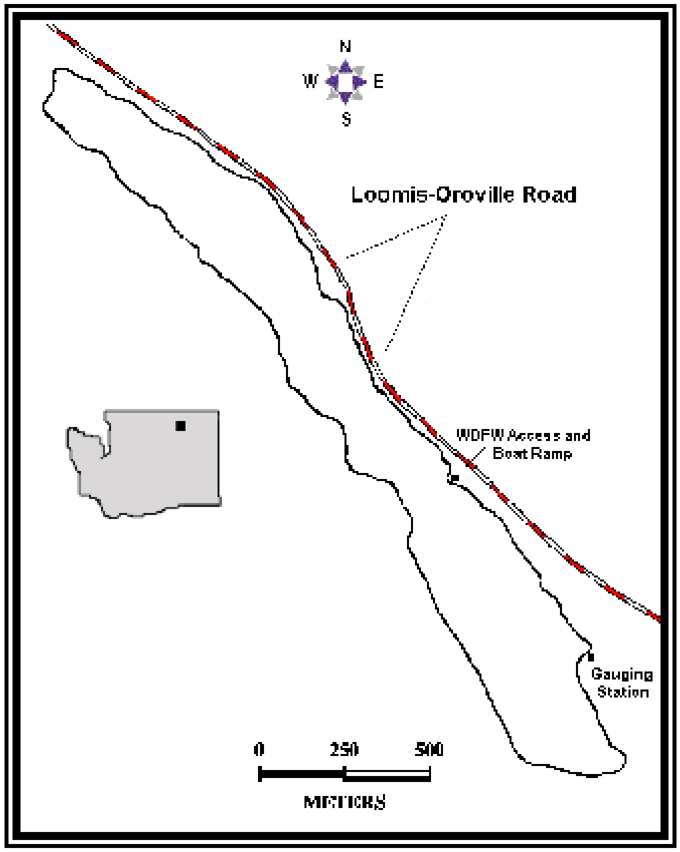

Figure 1. Map of Whitestone Lake, Okanogan County, Washington.

Whitestone Lake is a natural lake, although a small outlet dam was constructed in the 1920's by the Whitestone Reclamation District (WRD) as part of the Whitestone Project (Jerry Barnes, WRD, personal communication) which increased the lake's volume by approximately 20%. Although the current volume of water (2,144 acre-feet) is the maximum amount that can be impounded by the dam, the WRD possesses a storage right of 3,144 acre-feet. To utilize its full storage right, WRD would have to construct a new outlet dam and dikes and address problems associated with inundating a county road (Loomis-Oroville Road), portions of orchards, and a few residences (Heather Bartlett, WDFW, personal communication). In 1986, WRD installed a spillway on the outlet dam to prevent hydraulic erosion. In addition, a concrete drop structure was installed about 1 km downstream from the dam to prevent upstream migration of non-game fish species.

Until the mid-1960's, Whitestone Lake was managed as a rainbow trout (*Oncorhynchus mykiss*) fishery. Due to the lake's shallow depth, summer fish kills were common and most trout were harvested during the winter. WDFW rehabilitated Whitestone Lake in 1954, 1959, and 1965 to eliminate warmwater fish populations. Although most of the rehabilitation efforts were successful, repeated unauthorized introductions of warmwater fish species influenced the decision to manage the lake as a warmwater fishery (Williams 1979). WDFW introduced smallmouth bass (*Micropterus dolomieu*) to the lake in 1972 and largemouth bass (*M. salmoides*) in 1973 (Table 1) in an attempt to selectively control the black crappie (*Pomoxis nigromaculatus*) population. The smallmouth bass were collected from the Columbia River near Hanford and the largemouth bass were collected from Big Goose Lake on the Colville Indian Reservation (Heather Bartlett, WDFW, personal communication). Although their origin is unknown, black crappie and brown bullhead (*Ictalurus nebulosus*) existed many years prior to the bass introductions. In 1978, angler creel surveys indicated the black crappie size was increasing but a substantial bass fishery had yet to materialize, although bass ranging from 7 to 9 inches were abundant. In 1979, increased size of black crappie was apparent and larger size bass began to enter the fishery (Williams 1979). Bluegill (*Lepomis macrochirus*) were introduced to the lake in 1988 (Table 1).

Table 1. Fish stocked in Whitestone Lake, Okanogan County, Washington since 1972.

Year	Species	Size	No. Stocked
2000	black crappie	adults	1,000
	black crappie	fry	733
	channel catfish	adults	120
	channel catfish	sub-adults	3,000
1999	black crappie	fry	10,132
	channel catfish	fingerlings	2,500
1997	channel catfish	fingerlings	2,500
1988	bluegill	adults	900
1974	rainbow trout	fingerlings	19,600
1973	rainbow trout	fingerlings	40,600
	largemouth bass	adults	40
1972	smallmouth bass	adults	20

Currently, anglers are allowed to fish the lake year round. All bass species in Whitestone Lake are protected by a slot-length limit regulation which allows anglers to harvest five bass per day less than 12 inches or greater than 17 inches to include no more than one bass over 17 inches in length. Anglers are also allowed to harvest 5 channel catfish (*I. punctatus*) over 12 inches in length per day, with only 1 exceeding 24 inches in length. With the exception of those species mentioned previously, there is currently no minimum size or daily bag limit on the remaining fish species (yellow perch *Perca flavescens*, pumpkinseed *L. gibbosus*, black crappie, and brown bullhead) present in Whitestone Lake.

Most of the land surrounding Whitestone Lake is owned by Ellis-Barnes Livestock Company, Jim Atwood, and Whitestone Mountain Orchards and consists of fruit orchards and cattle range land. Residential development is limited to a few houses and cabins associated with the orchard farms (Heather Bartlett, WDFW, personal communication). WDFW operates a well developed access area on the lake which provides parking, boat launch, and toilet facilities.

The floor of Whitestone Lake supports voluminous mats of Chara (macro-algae) and watermilfoil (*Myriophyllum spp.*) Various sub-aquatic (cattail *Typha latifolia*, bulrush *Scirpus spp.*) and terrestrial (Russian olive *Elaeagnus angustifolia*, sagebrush *Artemisia tridentata*, willow *Salix spp.*) vegetation are also common in the area. The riparian area of the lake hosts various mammals including coyote (*Canis latrans*) and muskrat (*Ondatra zibethicus*). In addition, numerous species of waterfowl, including mallard ducks (*Anas platyrhynchos*) and Canada geese (*Branta canadensis*), utilize the lake during the spring and fall.

This survey was conducted to measure the warmwater gamefish stocking success and effectiveness, and to monitor growth, condition, reproduction, and survival of warmwater gamefish in the lake. Information collected during this survey was used to identify possible management strategies that would improve the quality of fishing in Whitestone Lake.

Methods and Materials

Whitestone Lake was surveyed by a three-person team June 26-29, 2000. All fish were collected using a boat electrofisher, gill nets, and fyke nets. The electrofishing unit consisted of a 5.5 meter (m) (18 ft.) Smith-Root GPP electrofishing boat, using a DC current of 120 cycles/sec at 3 to 4 amps power. Experimental gill nets (45.7 m x 2.4 m) consisted of variable size (13, 19, 25, and 51 millimeter (mm) stretched) monofilament mesh. Fyke nets were constructed of a main trap (four 1.2 m aluminum rings), a single 30.3 m lead, and two 15.2 m wings. All netting material was constructed of 13 mm nylon mesh.

Sampling locations were selected by dividing the shoreline into 400 m sections determined from a map. The number of randomly selected sections surveyed were as follows: electrofishing - 12, gill netting - 8, and fyke netting - 8. Electrofishing occurred in shallow water (depth range: 0.2 - 1.5 m), adjacent to the shoreline at a rate of approximately 18.3 m/minute for 600 second intervals (Bonar et al. 2000). Gill nets were set perpendicular to the shoreline with the small-mesh end attached on or near the shore, and the large-mesh end anchored offshore. Fyke nets were set perpendicular to the shoreline with the wings extended at 70E angles from the lead. Gill nets and fyke nets were set overnight prior to electrofishing and were pulled the following morning (1 net night each). All sampling was conducted during night-time hours when fish are most numerous along the shoreline thus maximizing the efficiency of each gear type.

All fish were identified to species, measured in millimeters (mm) to total length (TL) from the anterior-most part of the head to the tip of the compressed caudal fin, and weighed to the nearest gram (g). Total length data was used to construct length-frequency histograms and to evaluate the size structure of the warmwater gamefish in the lake. Warmwater gamefish were assigned to a 10 mm size group based on total length, and scale samples were collected from the first five fish in each size group (Bonar et al. 2000). Scale samples were mounted on adhesive data cards and pressed onto acetate slides using a Carver® laboratory press (Fletcher et al. 1993).

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

Species composition, by weight in kilograms (kg) and number, was determined from fish captured. Fish less than one year old, i.e., young-of-the-year (YOY), were excluded from all analyses. Eliminating YOY fish prevented distortions in analyses that may have occurred due to sampling location, method, and specific timing of hatches (Fletcher et al. 1993).

Catch per unit effort (CPUE) of each sampling gear was determined for each warmwater fish species collected. The CPUE of electrofishing was determined by dividing the number of fish captured by the total amount of time that was electrofished. Similarly, CPUE of gill netting and fyke netting was determined by dividing the number of fish captured by the total time the nets were deployed. Since CPUE is standardized, it can be useful in comparing catch rates between lakes or between sampling dates on the same water.

A relative weight (W_r) index was used to evaluate the condition of fish in Whitestone Lake. As presented by Anderson and Neumann (1996), a W_r of 100 generally indicates that the fish is in a condition similar to the national average for that species and length. The index is defined as $W_r = W/W_s \times 100$, where W is the weight (g) of an individual fish and W_s is the standard weight of a fish of the same total length (mm). W_s was derived from a standard weight-length ($\log_{10}$) relationship which was defined for each species of interest in Anderson and Neumann (1996). Minimum lengths were used for each species because the variability can be significant for small fish (YOY). Relative weights less than 50 were also excluded due to suspected invalid weight measurements.

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

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

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

Table 2. Minimum total length (mm) categories of warmwater fish used to calculate PSD and RSD values (Willis et al. 1993).

	Length Category				
Species	**Stock**	**Quality**	**Preferred**	**Memorable**	**Trophy**
black crappie	130	200	250	300	380
white crappie	130	200	250	300	380
bluegill	80	150	200	250	300
yellow perch	130	200	250	300	380
largemouth bass	200	300	380	510	630
smallmouth bass	180	280	350	430	510
walleye	250	380	510	630	760
channel catfish	280	410	610	710	910
brown bullhead	150	230	300	390	460
yellow bullhead	150	230	300	390	460

Certain analyses were compared to information collected from Whitestone Lake in 1979 (Williams 1979), 1986 (Walton and Wirt 1989), and 1998 (Jackson 1998 - unpublished). Although similar, the sampling protocols used by these researchers were not the same as those used in 2000. Regardless, the information collected in 1979, 1986, and 1998 may be used to identify trends in certain dynamics of the warmwater gamefish populations in Whitestone Lake.

Results and Discussion

Species Composition

A total of 8 fish species were observed in June 2000 (Table 3). Warmwater gamefish comprised 99.9% of the total fish captured. Bluegill were the most abundant species (87.3%) encountered in the samples and contributed the highest proportion (48.1%) of the total biomass. Although largemouth bass represented only 4.0% of the total number of fish sampled, they contributed 34.3% of the total biomass.

Table 3. Species composition, by weight and number of fish sampled at Whitestone Lake, Washington during June 2000. Analyses does not included YOY.

	Species Composition					
	Weight		Number		Total Length (mm)	
Species	**kg**	**%**	**No.**	**%**	**Min.**	**Max.**
brown bullhead	0.7	0.3	2	0.1	249	292
bluegill	109.2	48.1	4,447	87.3	40	224
channel catfish	4.8	2.1	11	0.2	211	454
carp	15.8	7.0	7	0.1	517	620
largemouth bass	77.8	34.3	206	4.0	69	562
pumpkinseed	11.2	5.0	326	6.4	70	167
smallmouth bass	0.9	0.4	1	0.1	401	401
yellow perch	6.4	2.8	96	1.9	145	251

Bluegill were sampled in proportions greater than what was expected. In 1998, Jackson (1998 - unpublished) found that bluegill (n = 179) comprised approximately 44% of the total catch (Table 4) whereas bluegill (n = 4,447) comprised over 87% of the catch in 2000 (Table 3). A total of 10,132 black crappie were stocked in Whitestone Lake in 1999 and were expected to be observed in the 2000 samples. Black crappie comprised 7% and 53% of the samples collected in 1979 and 1986, respectively, but were not observed in 1998 or 2000. Coincidently, bluegill and yellow perch were not observed until 1998 and pumpkinseed have increased in abundance since 1986. Due to their increased abundance, bluegill, yellow perch, and pumpkinseed may have out-competed and led to the demise of the black crappie in the lake. Smallmouth bass were observed in low numbers in 1979 (n = 2) and 2000 (n = 1). These low numbers were expected since smallmouth bass typically inhabit and spawn in rocky substrate which is found in only minimal quantities in the lake. A total of 11 channel catfish were observed in 2000 which was expected since 2,500 sub-adults were stocked in the lake in both 1997 and 1999 (Table 1). The number of largemouth bass observed in 2000 (n = 206) was similar to what was observed in 1979 (n = 258).

However, due to the high abundance of bluegill sampled, the proportion of largemouth bass observed in 2000 (4.0%) remained similar to what was observed in 1986 (4.7%).

Table 4. Species composition, by number of fish sampled at Whitestone Lake, Washington in 1979 (Williams 1979), 1986 (Walton and Wirt 1989), and 1998 (Jackson 1998 - unpublished).

	Species Composition					
	1979		1986		1998	
Species	**No.**	**%**	**No.**	**%**	**No.**	**%**
brown bullhead	122	29.6	134	41.7	1	0.2
black crappie	29	7.0	169	52.6	—	—
bluegill	—	—	—	—	179	44.4
channel catfish	—	—	—	—	—	—
carp	—	—	—	—	9	2.2
largemouth bass	258	62.6	15	4.7	137	34.0
pumpkinseed	—	—	3	0.9	74	18.3
smallmouth bass	2	0.56	—	—	—	—
suckers (spp.)	1	0.24	—	—	—	—
yellow perch	—	—	—	—	4	0.9

Although largemouth bass were observed on all four sampling dates (1979, 1986, 1998, and 2000), their abundance greatly varied (Table 3, Table 4). Williams (1979) observed 258 largemouth bass in 1979 whereas Walton and Wirt (1989) observed only 15 in 1986. Jackson (1998 - unpublished) observed 137 largemouth bass in 1998. However, Jackson sampled the lake only during daylight hours using electrofishing. Had he sampled at night, the abundance of littoral species such as bluegill and largemouth bass in his samples would most likely have been even higher.

Catch per Unit Effort (CPUE)

When using either active (electrofishing) or passive (gill or fyke nets) sampling techniques, CPUE can be used as an index to monitor size structure and relative abundance of fish species in a lake or reservoir (Hubert 1996). Although Whitestone Lake was sampled in 1998 (Jackson 1998), electrofishing was the sole sampling technique and was conducted only during daylight hours. CPUE from 2000 provides baseline information that can be used to monitor the effectiveness of future management techniques on the lake.

With the exception of yellow perch, electrofishing captured more fish in Whitestone Lake than did gill nets or fyke nets. Catch rates of bluegill were higher than any other species sampled by electrofishing, gill netting, or fyke netting (Table 5). Yellow perch were the only species sampled most effectively by gill nets.

Table 5. Mean catch per unit effort and 80% confidence intervals (CI), by gear type, of fish (excluding YOY) sampled at Whitestone Lake, Washington in June 2000.

	Gear Type								
	Electrofish			Gill Net			Fyke Net		
	No./hour	CI (+/-)	No. sites	No./hour	CI (+/-)	No. sites	No./hour	CI (+/-)	No. sites
bluegill	1,334.4	216.0	12	14.6	4.7	8	143.5	39.4	8
brown bullhead	1.0	0.9	12	0.0	—	8	0.0	—	8
carp	3.0	2.6	12	0.1	0.2	8	0.0	—	8
channel catfish	0.0	—	12	0.8	0.3	8	0.0	—	8
largemouth bass	42.8	14.6	12	1.6	0.5	8	0.0	—	8
pumpkinseed	96.5	18.2	12	2.6	1.0	8	12.5	3.3	8
smallmouth bass	0.0	—	12	0.1	0.2	8	0.0	—	8
yellow perch	1.5	1.0	12	10.0	4.4	8	1.6	1.0	8

In most cases, electrofishing captured the same size fish than did gill nets or fyke nets (refer to length-frequency histograms under species sections). As expected, gill nets captured larger yellow perch than electrofishing and fyke nets. Adult yellow perch inhabit pelagic water and are, under most circumstances, sampled more effectively using gill nets. Compared to gill nets and fyke nets, electrofishing tended to capture smaller (70-150 mm) and larger (430-560 mm) largemouth bass.

The major differences in CPUE between 1998 and 2000 occurred on largemouth bass and bluegill. In 1998, CPUE of largemouth bass sampled with electrofishing was 99 fish per hour (fish/hr) whereas in 2000 the CPUE was approximately 43 fish/hr. Had the lake been electrofished at night, the CPUE of largemouth bass in 1998 would likely have been higher. The CPUE of bluegill sampled with electrofishing in 1998 was 130 fish/hr whereas in 2000 the CPUE was 1,334 fish/hr; about 10 times higher.

Stock Density Indices

The PSD for largemouth bass sampled by electrofishing was 76 ± 6 (Table 6). Of the number of stock length largemouth bass collected by electrofishing (n = 86), 31 ± 6% and 6 ± 3% were of preferred and memorable size, respectively. The PSD for bluegill collected using electrofishing, gill netting, and fyke netting were 6 ± 1, 3 ± 2, and 5 ± 1, respectively. With the exception of largemouth bass, no warmwater gamefish were larger than quality size.

Largemouth bass were represented in all RSD categories except the RSD-T (Trophy). Moreover, relatively few stock length panfish in Whitestone Lake are recruiting to quality size or larger. This is most likely due to competition for food and space between the bluegill, pumpkinseed, yellow perch, and smaller size largemouth bass in the lake. Jackson's (1998) findings indicated that a decent proportion of the largemouth bass sampled in 1998 were larger than 380 mm and that bluegill density was at moderate levels. In 2000, bluegill density was much higher than what was seen in 1998 and most of the larger size largemouth bass observed in 2000 were likely those large fish observed in 1998. Bonar et al. (2000) reported that a minimum sample size of 55 stock length fish is required for a sound PSD estimate. Certain species were collected in inadequate sample sizes, so their PSD values should be viewed with caution.

Table 6. Proportional (PSD) and relative (RSD, P = preferred, M = memorable, T = trophy) stock densities, by gear type, including 80% confidence intervals, of fish collected from Whitestone Lake, Washington. Fish were sampled in June 2000.

Species	# Stock Length	PSD	RSD-P	RSD-M	RSD-T
		Electrofishing			
bluegill	2,688	6 ± 1	0	0	0
largemouth bass	86	76 ± 6	31 ± 6	6 ± 3	0
pumpkinseed sunfish	194	3 ± 2	0	0	0
yellow perch	3	33 ± 34	0	0	0
		Gill Netting			
bluegill	117	3 ± 2	0	0	0
largemouth bass	13	69 ±16	31 ± 16	0	0
pumpkinseed sunfish	21	0	0	0	0
yellow perch	80	26 ± 6	0	0	0
		Fyke Netting			
bluegill	1,148	5 ± 1	0	0	0
pumpkinseed sunfish	100	4 ± 3	0	0	0
yellow perch	13	8 ± 9	0	0	0

Water Chemistry

Whitestone Lake was relatively homogeneous in terms of temperature, dissolved oxygen, pH, and conductivity throughout the entire water column (Table 7). This is probably due to the time of sampling. Water chemistry was sampled in June and the lake had not been influenced by warm summer temperatures that can lead to low dissolved oxygen concentrations. Due to the shallow depth of the basin and the high quantity of aquatic vegetation present in the lake, Whitestone Lake has a history of dissolved oxygen depletion and frequent partial fish kills (Williams 1979). However, water chemistry parameters measured in June 2000 were within acceptable ranges for fish inhabitants. Water temperatures ranged from 22.2 to 24.3 EC. Dissolved oxygen ranged from 5.1 to 6.1 mg/l. The pH levels of Whitestone Lake were only slightly higher than the range (6.5 - 9) desirable for warmwater fish as reported by Swingle (1969).

Table 7. Water chemistry data collected from Whitestone Lake, Washington in June, 2000.					
Location	**Depth (m)**	**Temp (EC)**	**pH**	**Dissolved O_2 (mg/l)**	**Conductivity (FS/cm)**
Main Body	Surface	24.30	9.01	5.10	509.0
	1	23.96	9.05	5.36	508.4
	2	23.36	9.04	5.83	504.3
	3	22.21	9.04	6.11	495.6

Largemouth Bass

Largemouth bass ranged in age from 1 to 12 years with age 4 fish being the most abundant of those analyzed for age and growth (Table 8). Growth of Whitestone Lake largemouth bass was above the statewide average at most ages. However, the sample sizes of largemouth bass older than 5 years were too small for accurate analyses. Total lengths of largemouth bass sampled at Whitestone Lake ranged from 69 to 562 mm in 2000 (Table 3, Figure 2) and from 70 to 530 mm in 1998 (Figure 3). Age 1 (70-115 mm) largemouth bass observed in 2000 appear to be the dominant year class (Figure 2). Higher numbers of age 1 and age 2 largemouth bass were expected in 2000 due to the relatively high number of mature fish observed in 1998. No YOY largemouth bass were expected because those fish would not likely have recruited to the sampling gears at the time of sampling.

Although largemouth bass less than 300 mm observed in 2000 (Figure 4) were in better condition than those observed in 1998 (Figure 5), most had relative weights less than the national average (100) indicating that those fish are likely limited by food or space. Conversely, largemouth bass greater than 300 mm observed in 2000 and 1998 were in relatively good condition. Most fish had relative weights greater than 90. Largemouth bass greater than 300 mm may be capable of utilizing the size of prey (bluegill and pumpkinseed) that is present whereas largemouth bass smaller than 300 mm are forced to compete with the bluegill and pumpkinseed for food.

The largemouth bass fishery in Whitestone Lake is similar to the outcome sought under a big bass management option (Willis et al. 1993). Under the big bass option largemouth bass PSD should be 50 to 80 (RSD-P of 30 to 60) and bluegill PSD should be less than 50 (RSD-P of 0 to 10). The PSD of largemouth bass sampled by electrofishing was 76 ± 6 and the RSD-P was 31 ± 6 (Table 6). The highest PSD of bluegill sampled by any gear was 6 ± 1 and the RSD-P was 0. The strategy of the big bass option is to produce fewer, larger bass and a smaller size structure of bluegill. Although natural reproduction is evident with the presence of age 1 fish, reproductive success of largemouth bass was likely limited due to the high density of bluegill present in the lake. Dense populations of bluegill may have limited spawning success by invading largemouth bass nests and consuming the eggs. Low relative weights of the smaller size largemouth bass are likely due to food competition with the bluegill and pumpkinseed in the lake. Competition for food and space not only can result in poor condition of the smaller largemouth bass, but may also limit juvenile survival. High competition and low reproductive success may lead to low recruitment of largemouth bass to larger sizes. Present conditions of the largemouth bass fishery may be desirable, but may only be sustained until the mortality exceeds recruitment.

Table 8. Back calculated length at age (mm) of largemouth bass sampled at Whitestone Lake, Washington, during June 2000. Shaded values represent length at age calculated using the direct proportion method (Fletcher et al. 1993). Unshaded values represent length at age calculated using Lee's modification of the direct proportion method (Carlander 1982).

Year class	# fish	Mean total length (mm) at age 1	2	3	4	5	6	7	8	9	10	11	12
1999	16	67.9											
		72.8											
1998	16	65.3	124.8										
		75.2	125.6										
1997	19	63.8	139.2	206.4									
		78.0	146.7	207.9									
1996	26	61.7	123.1	197.4	291.2								
		77.7	135.2	204.7	292.5								
1995	16	58.7	111.2	179.3	273.3	359.4							
		75.4	125.1	189.4	278.2	359.6							
1994	9	60.6	119.7	187.3	253.7	343.1	397.3						
		77.5	133.7	197.9	260.9	345.9	397.3						
1993	4	68.0	116.4	201.2	273.1	260.2	409.3	435.1					
		84.9	131.1	212.0	280.6	363.7	410.5	435.1					
1992	5	58.4	114.9	180.3	242.6	330.0	390.0	427.7	452.1				
		75.9	129.8	192.3	251.9	335.4	392.7	428.8	452.1				
1991	2	76.7	186.4	259.6	338.7	391.9	415.9	439.7	458.0	472.0			
		93.5	198.6	268.7	344.3	395.4	418.3	441.1	458.6	472.0			
1990	3	70.8	157.7	223.0	303.3	376.5	414.5	449.8	472.1	487.6	505.0		
		88.0	171.5	234.2	311.3	381.6	418.1	452.0	473.4	488.3	505.0		
1989	1	56.9	124.5	229.0	273.5	336.5	388.8	425.7	439.5	453.3	468.7	481.0	
		74.5	139.3	239.5	282.2	342.6	392.6	428.0	441.2	454.5	469.2	481.0	

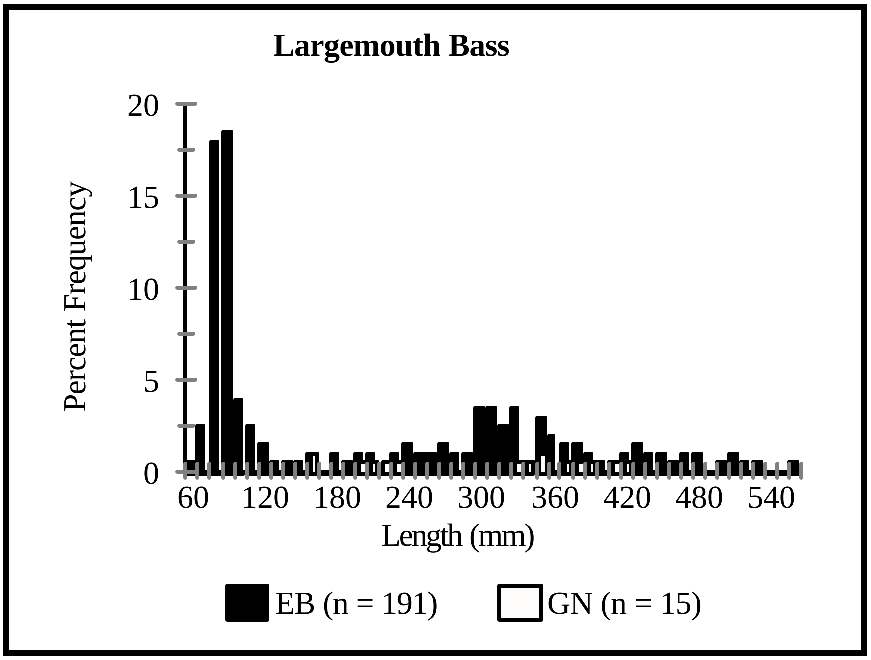

Figure 2. Length frequency distribution of largemouth bass sampled at Whitestone Lake, Washington, during June 2000 using electrofishing (EB) and gill netting (GN).

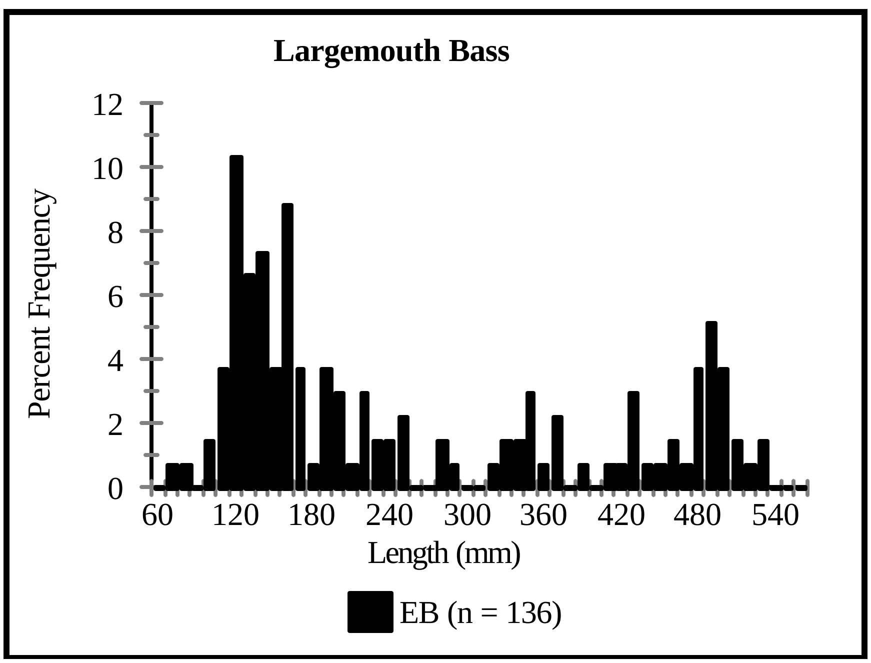

Figure 3. Length frequency distribution of largemouth bass sampled at Whitestone Lake, Washington, during May 1998 using electrofishing (EB).

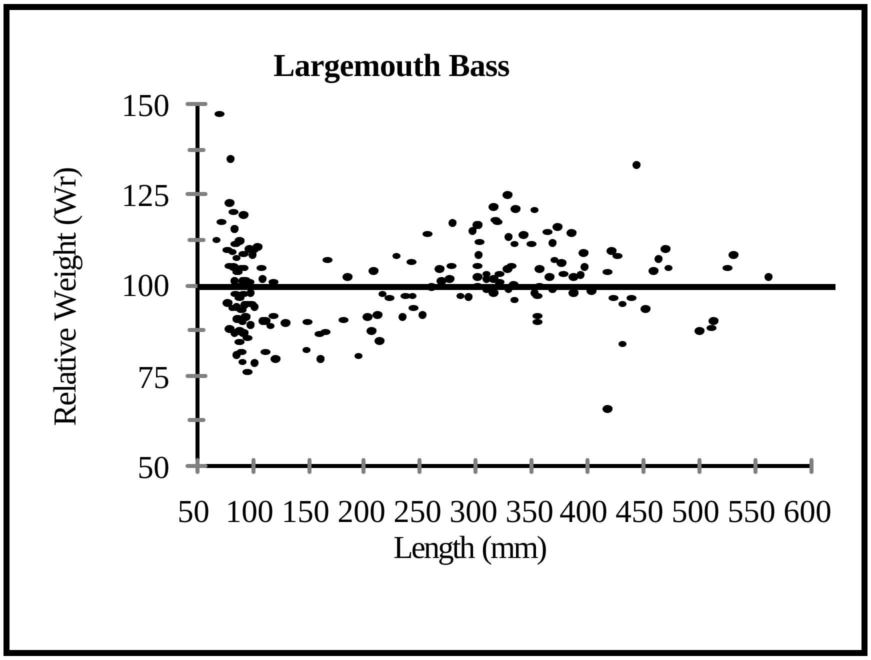

Figure 4. Relative weights of largemouth bass (n = 203) sampled at Whitestone Lake, Washington during June 2000, as compared to the national average, W_r=100 (Anderson and Neumann 1996).

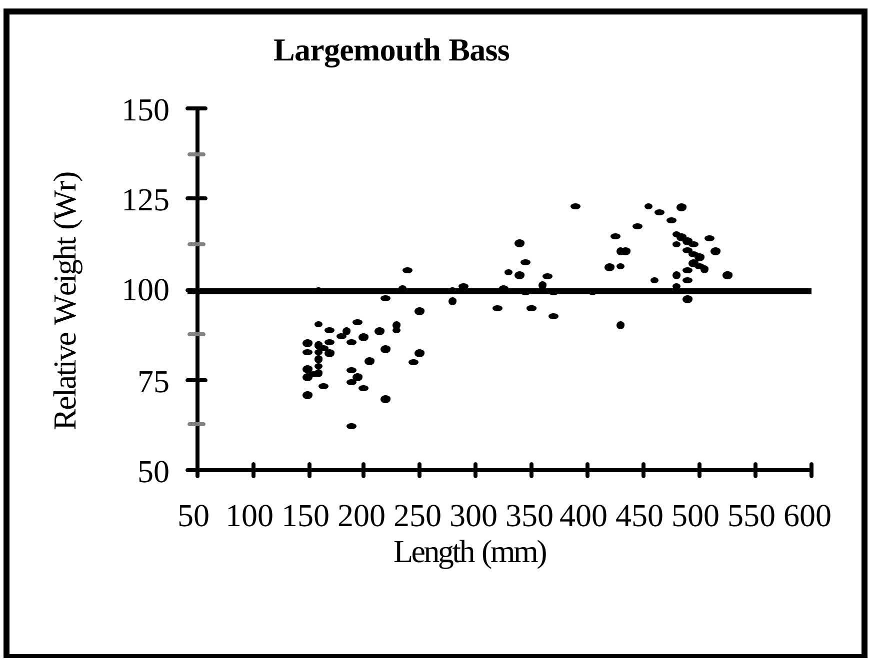

Figure 5. Relative weights of largemouth bass (n = 94) sampled at Whitestone Lake, Washington during May 1998, as compared to the national average, W_r=100 (Anderson and Neumann 1996).

Smallmouth Bass

Only one smallmouth bass was observed in Whitestone Lake during June 2000 (Table 3). That fish was 401 mm in length, weighed 905 g, had a relative weight of 90, and was five years old. Smallmouth bass were last stocked in the lake in 1972 and it is uncertain whether this fish was naturally reproduced or a result of an unauthorized release. No smallmouth bass were observed in 1986 or 1998 (Table 4) and only 2 were observed in 1979. Historically, smallmouth bass have done poorly in this lake (Williams 1979). Ecological conditions are less than ideal for this species and the smallmouth bass that are present are likely confined to the minimal quantity of rocky habitat in the lake. No YOY smallmouth bass were expected because those fish would not likely have recruited to the sampling gears at the time of the survey.

Bluegill

A total of 4,447 bluegill were sampled at Whitestone Lake in June 2000 (Table 3) which was significantly more than expected given the abundance observed in 1998 (Table 4). Bluegill ranged in age from 1 to 10 years with age 5 being the most abundant of those fish analyzed for age and growth (Table 9). Growth of Whitestone Lake bluegill was below the statewide average at all ages. However, samples sizes for the 1999 and 1990-1993 year classes were too small for accurate analyses. No YOY bluegill were expected because those fish would not likely have recruited to the sampling gears at the time of sampling.

Total lengths of bluegill sampled at Whitestone Lake ranged from 40 to 224 mm in 2000 (Table 3, Figure 6) and from approximately 80 to 200 mm in 1998 (Figure 7). Bluegill 70 to 110 mm dominated the 2000 samples. These fish were most likely age 1 and age 2. However, size ranges from these age classes overlapped significantly and proportions of fish from each age class could not be determined.

Overall, bluegill sampled in 2000 (Figure 8) were in better condition than those observed in 1998 (Figure 9). In 2000, condition of bluegill less than 100 mm and greater than 180 mm was good (Figure 8). Conversely, the condition of bluegill between 100 and 180 mm was poor with few fish having relative weights greater than 100. Typically, average to high relative weights indicate food or space are appropriate for fish. The density of bluegill in Whitestone Lake was very high and coupled with good relative weights, contradicts the relative weight analyses. Although this occurrence is not fully understood, bluegill in Whitestone Lake were spawning at the time of sampling. A proportion of bluegill in our samples may not have spawned. Those that hadn't would tend to be more robust for their length than those that had. Moreover, nest invasion was likely prevalent throughout the population; particularly by the abundant smaller bluegill and the larger, more dominant bluegill.

The PSD values for bluegill were low suggesting few fish are reaching quality size (Table 6). The high relative abundance, low PSD values, and slow growth rates suggest that the bluegill in

Whitestone Lake are overpopulated. Although largemouth bass most likely forage on the bluegill in the lake, dense aquatic macrophytes, such as Chara and water milfoil may have contributed to bluegill overpopulation. Dense aquatic vegetation may reduce the ability of predators to effectively forage (Bettoli et al. 1992, Olson et al. 1998) which can ultimately lead to stunted prey populations and may reduce panfish feeding efficiency which could result in below average condition (Crowder and Cooper 1982).

Table 9. Back calculated length at age (mm) of bluegill sampled at Whitestone Lake, Washington, during June 2000. Shaded values represent length at age calculated using the direct proportion method (Fletcher et al. 1993). Unshaded values represent length at age calculated using Lee's modification of the direct proportion method (Carlander 1982).

Year class	# fish	Mean total length (mm) at age									
		1	2	3	4	5	6	7	8	9	10
1999	1	36.1									
		42.5									
1998	14	26.8	58.4								
		39.3	61.9								
1997	13	24.6	64.3	91.1							
		39.4	70.9	92.1							
1996	8	22.3	63.8	95.4	112.7						
		38.4	72.7	98.7	113.0						
1995	17	23.3	64.3	97.5	122.2	143.0					
		40.1	75.5	104.1	125.5	143.6					
1994	12	26.4	75.1	108.3	132.1	149.6	163.1				
		43.2	85.9	115.0	135.9	151.2	163.1				
1993	2	26.8	71.7	105.9	134.4	156.1	167.7	177.0			
		43.7	83.5	113.8	139.1	158.5	168.8	177.0			
1992	3	24.6	66.2	105.6	132.0	163.0	181.2	191.8	201.3		
		42.2	79.6	115.1	138.9	166.8	183.2	192.7	201.3		
1991	2	24.5	71.4	108.7	145.0	165.2	175.4	184.4	193.9	204.0	
		42.0	84.2	117.8	150.4	168.6	177.8	185.9	194.5	204.0	
1990	3	26.6	75.2	111.3	137.2	164.9	183.6	194.3	201.8	208.2	213.7
		44.1	88.2	120.9	144.3	169.4	186.4	196.1	202.9	208.7	213.7
Weighted Mean		25.1	65.8	99.7	126.2	150.1	169.9	188.1	199.7	206.5	213.7
WA State Avg		37.3	96.8	132.1	148.3	169.9	200.9	195.8	—	—	—

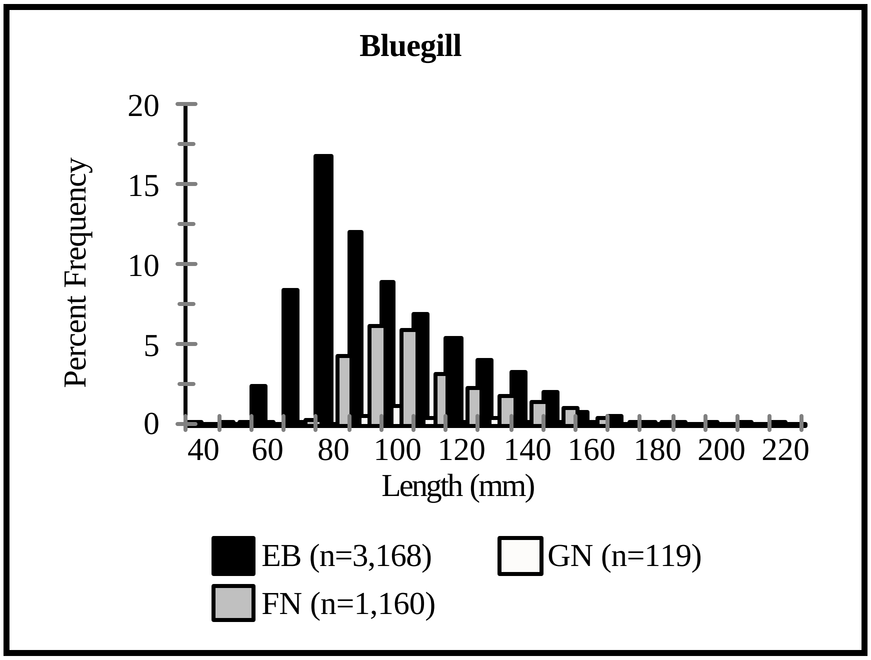

Figure 6. Length frequency distribution of bluegill sampled at Whitestone Lake, Washington, during June 2000 using electrofishing (EB), gill netting (GN), and fyke netting (FN).

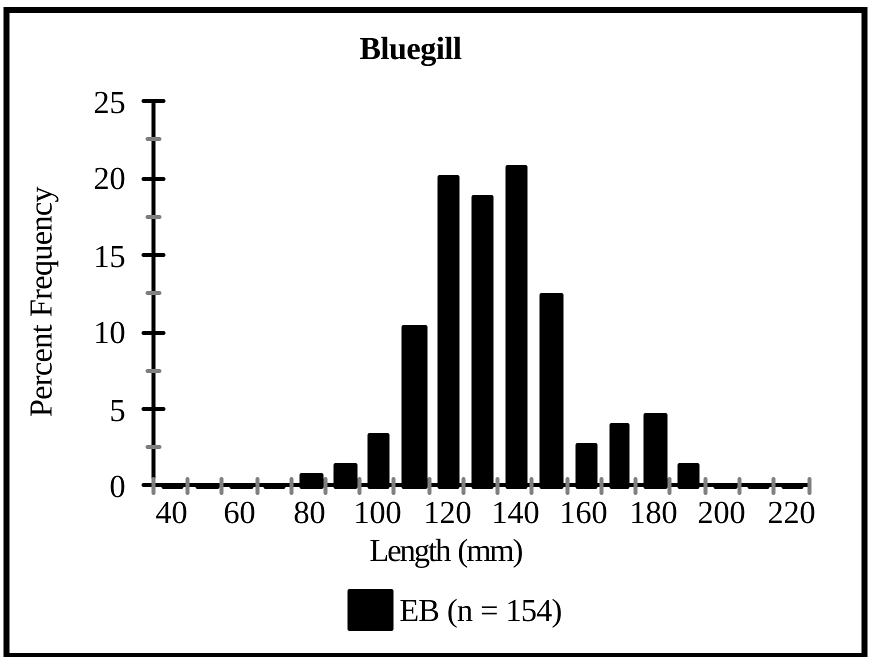

Figure 7. Length frequency distribution of bluegill sampled at Whitestone Lake, Washington, during May 1998 using electrofishing (EB).

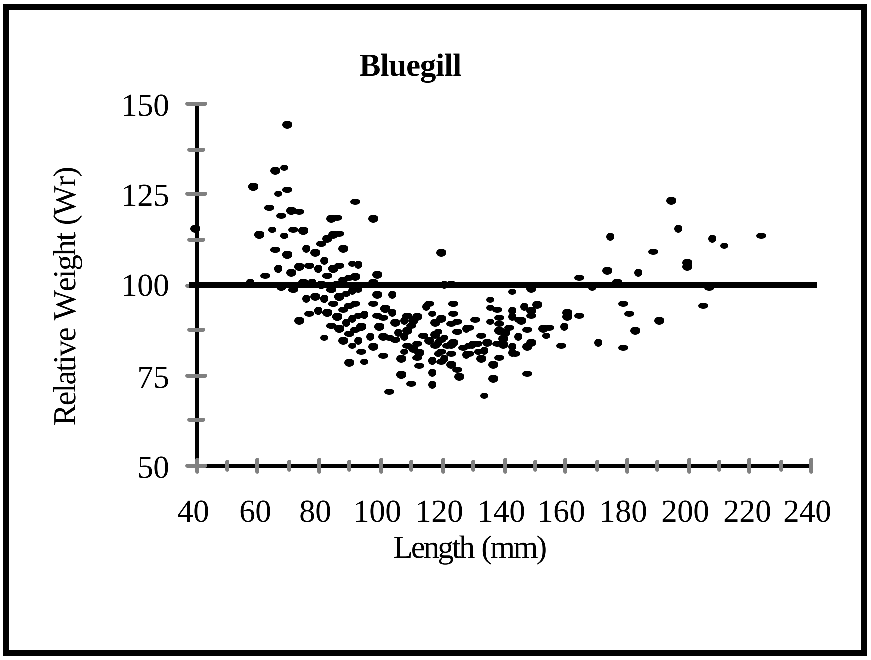

Figure 8. Relative weights of bluegill (n = 324) sampled at Whitestone Lake, Washington during June 2000, as compared to the national average, W_r=100 (Anderson and Neumann 1996).

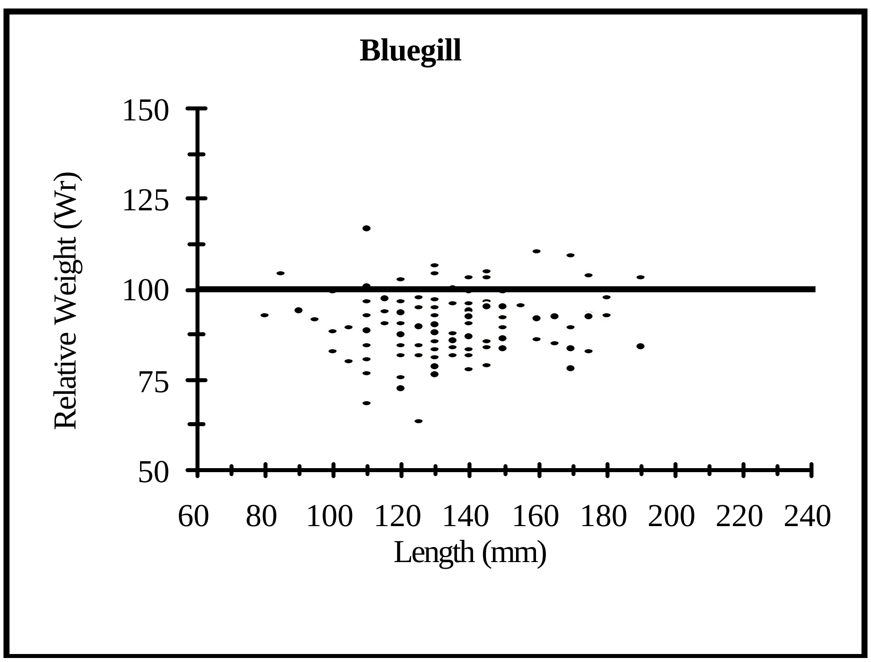

Figure 9. Relative weights of bluegill (n = 154) sampled at Whitestone Lake, Washington during May 1998, as compared to the national average, W_r=100 (Anderson and Neumann 1996).

Pumpkinseed

Scale samples were not collected from pumpkinseed thus age and growth information were not analyzed. A total of 326 pumpkinseed were sampled at Whitestone Lake in June 2000 (Table 3). This was more than expected given the abundance observed in 1998 (Table 4). Total lengths of pumpkinseed sampled at Whitestone Lake ranged from 70 to 167 mm in 2000 (Table 3, Figure 10) and from approximately 70 to 170 mm in 1998 (Figure 11). Although pumpkinseed 110 to 130 mm were most abundant in the 2000 samples, most 10 mm size classes between 70 and 170 mm were represented. No YOY pumpkinseed were expected because those fish would not likely have recruited to the sampling gears at the time of sampling.

Although pumpkinseed abundance has consistently increased since 1986 (Table 4), their density remains at moderate levels. This is likely due to the increase in bluegill density observed between 1998 and 2000. Pumpkinseed sampled in 2000 (Figure 12) were in worse condition than those observed in 1998 (Figure 13) with most fish having relative weights less than 100. Similar to largemouth bass, spawning success may be low due to nest invasion by bluegill. Moreover, decreased relative weights may have been caused by interspecific competition for food and space.

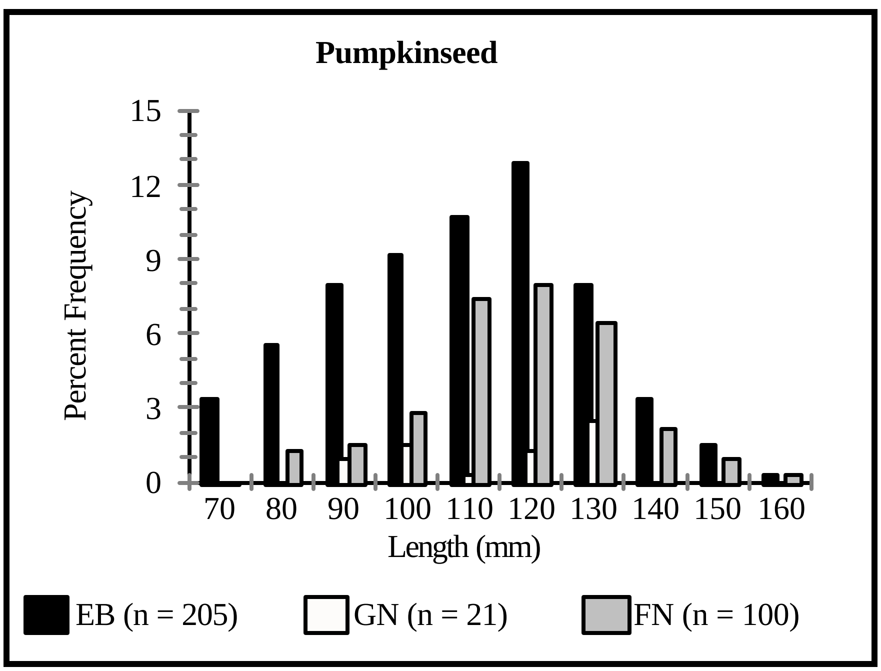

Figure 10. Length frequency distribution of pumpkinseed sampled at Whitestone Lake, Washington, during June 2000 using electrofishing (EB), gill netting (GN), and fyke netting (FN).

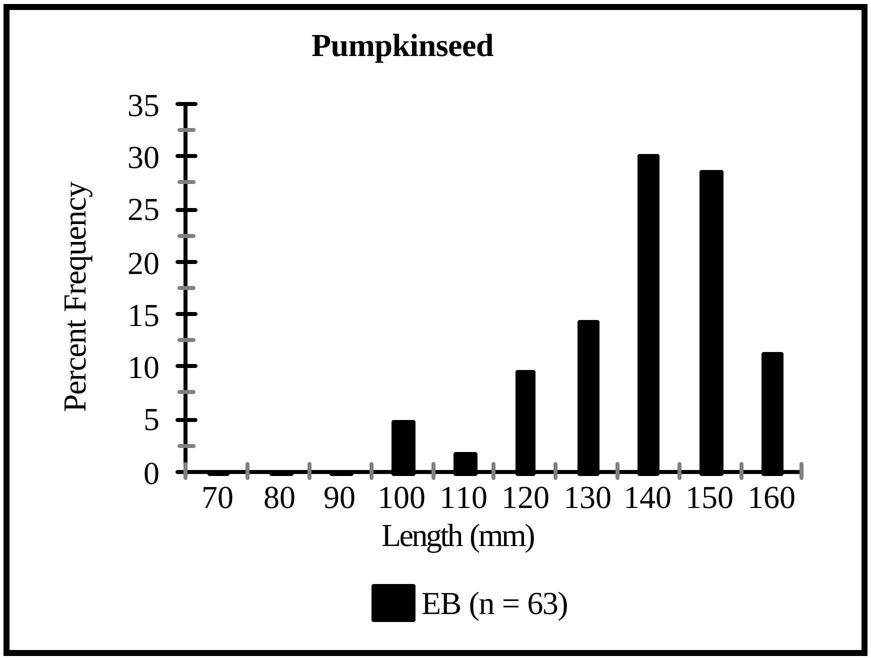

Figure 11. Length frequency distribution of pumpkinseed sampled at Whitestone Lake, Washington, during May 1998 using electrofishing (EB).

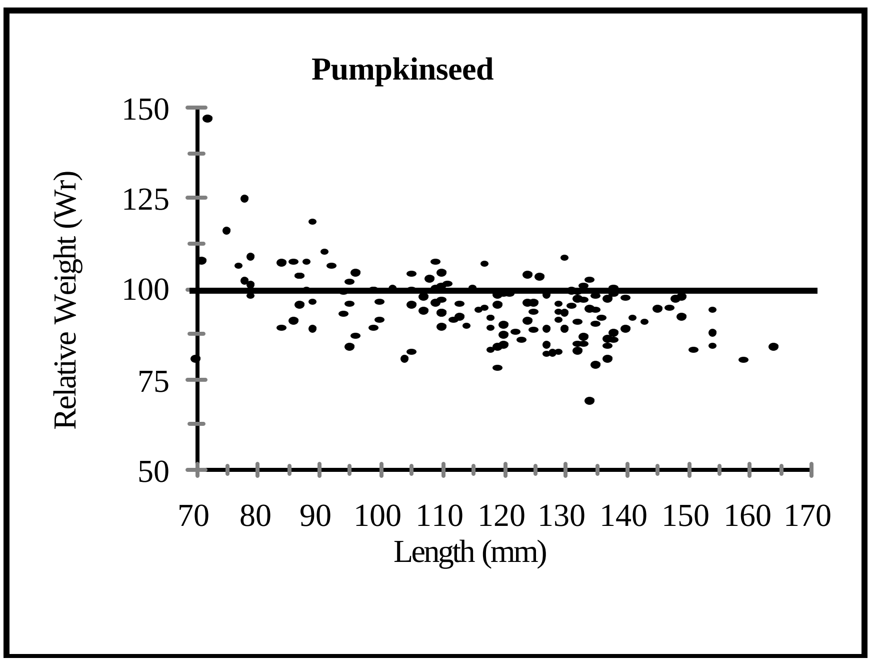

Figure 12. Relative weights of pumpkinseed (n = 142) sampled at Whitestone Lake, Washington during June 2000, as compared to the national average, W_r=100 (Anderson and Neumann 1996).

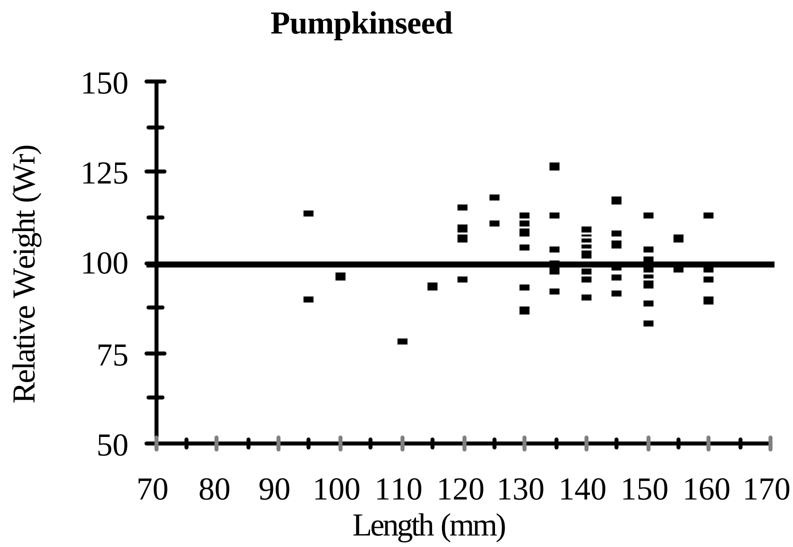

Figure 13. Relative weights of pumpkinseed (n = 63) sampled at Whitestone Lake, Washington during May 1998, as compared to the national average, W_r=100 (Anderson and Neumann 1996).

Yellow Perch

A total of 96 yellow perch were observed in 2000 (Table 3). Yellow perch ranged in age from 2 to 5 years (Table 10) with age 4 being the most abundant of those fish analyzed for age and growth. Wydoski and Whitney (1979) reported that yellow perch generally live less than 7 years. Growth of Whitestone Lake yellow perch was above the statewide average at all ages. However, no age 1 fish and only one age 5 fish were analyzed for age and growth. No YOY yellow perch were expected because those fish would not likely have recruited to the sampling gears at the time of sampling.

Total lengths of yellow perch sampled at Whitestone Lake ranged from 145 to 251 mm in 2000 (Table 3, Figure 14) and from approximately 145 to 155 mm in 1998 (Figure 15). Yellow perch 150 to 200 mm were most abundant in the 2000 samples. These fish were most likely age 2 and age 3. Similar to bluegill, size ranges from these age classes overlapped significantly and proportions of fish from each age class could not be determined.

Although yellow perch sampled in 2000 exhibited above average growth, none had relative weights exceeding 100. Wydoski and Whitney (1979) stated that small fish play an important role in the diet of adult yellow perch which may explain the good growth rates. Whitestone Lake bluegill are slow growing and small fish are likely present throughout most of the growing season. Although yellow perch relative weights did not exceed the national average (Wr = 100), perch may be in condition that can be attained in this specific lake. The absence of age 1 yellow perch in 2000 is coincident with the rapidly increasing bluegill population and may be evidence that the spawning success of yellow perch had been drastically reduced. Of the 96 yellow perch observed in 2000, all were stock size or larger (Table 6) indicating that the yellow perch population is likely comprised of older individuals. The absence of age 1 yellow perch was further evidence of the older age structure of perch in Whitestone Lake.

Table 10. Back calculated length at age (mm) of yellow perch sampled at Whitestone Lake, Washington, during June 2000. Shaded values represent length at age calculated using the direct proportion method (Fletcher et al. 1993). Unshaded values represent length at age calculated using Lee's modification of the direct proportion method (Carlander 1982).

		Mean total length (mm) at age				
Year class	**# fish**	**1**	**2**	**3**	**4**	**5**
1999	0	—				
		—				
1998	13	80.7	142.7			
		95.1	145.1			
1997	10	104.0	168.1	164.5		
		117.3	171.2	165.3		
1996	20	83.8	151.1	180.5	199.5	
		101.5	158.8	183.8	200.1	
1995	1	86.9	153.1	193.1	222.0	240.0
		106.5	164.8	200.0	225.5	241.3
Weighted Mean		87.6	152.5	175.7	200.6	240.0
WA State Average		59.7	119.9	152.1	192.5	206.0

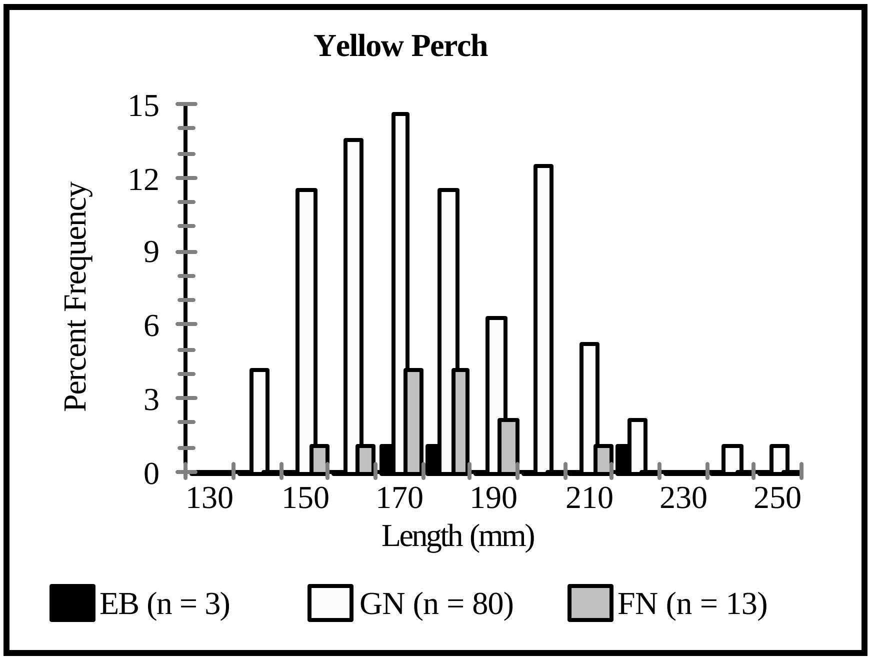

Figure 14. Length frequency distribution of yellow perch sampled at Whitestone Lake, Washington during June 2000 using electrofishing (EB), gill netting (GN), and fyke netting (FN).

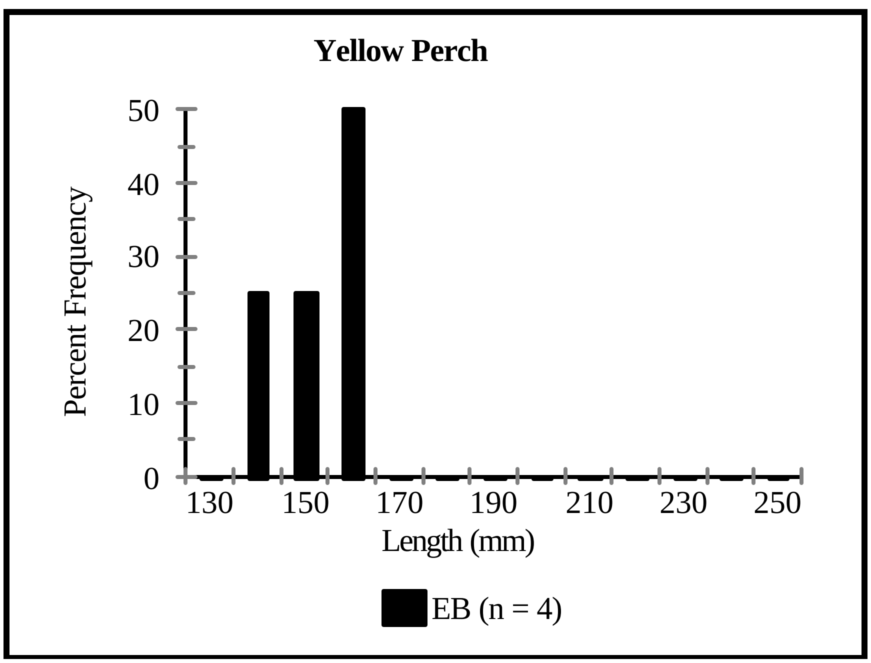

Figure 15. Length frequency distribution of yellow perch sampled at Whitestone Lake, Washington during May 1998 using electrofishing (EB).

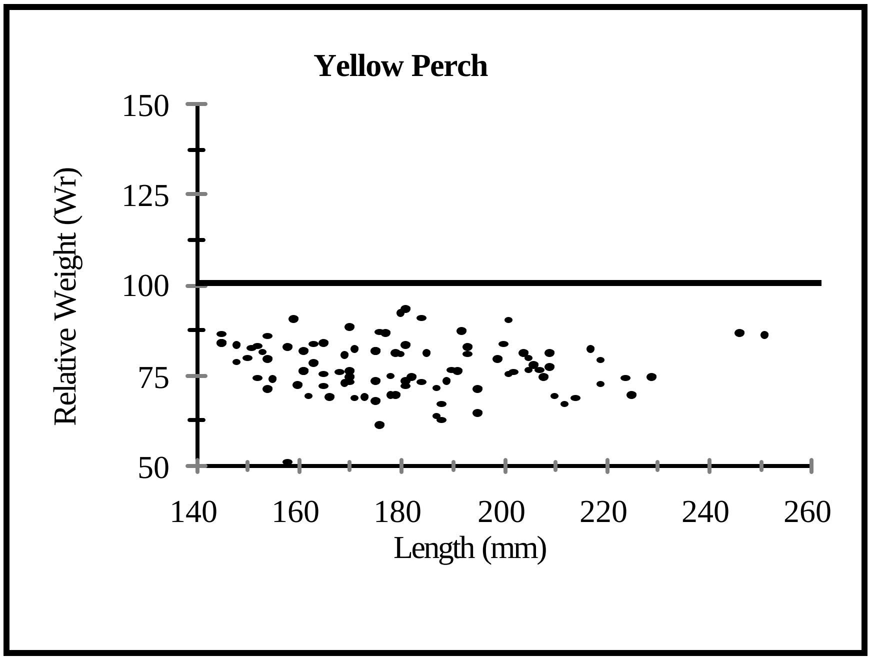

Figure 16. Relative weights of yellow perch (n = 94) sampled at Whitestone Lake, Washington during June 2000, as compared to the national average, W_r=100 (Anderson and Neumann 1996).

Black Crappie

Although abundance of black crappie in Whitestone Lake increased between 1979 and 1986 (Table 4), none were observed in either 1998 or 2000. A total of 10,132 black crappie fry were stocked in the lake in 1999 and although fish stocked as fry exhibit high mortality, at least low numbers were expected in 2000. Poor survival of those fish stocked in 1999 most likely was due to predation by the yellow perch and largemouth bass or interspecific competition.

A total of 1,733 black crappie (1,000 adults and 733 fry) were stocked in Whitestone Lake following the survey in 2000. Further investigation is required to evaluate the current status of the black crappie population in the lake.

Channel Catfish

A total of 11 channel catfish were sampled at Whitestone Lake in 2000 (Table 3). This was expected since 2,500 fingerlings were stocked in 1999 and 2,500 fingerlings were stocked in 1997. However, channel catfish less than 200 mm are vulnerable to predation (Heidinger 1999) and some of those stocked in 1997 and 1999 may have been preyed heavily upon by the largemouth bass in the lake. Stocking larger channel catfish, when possible, may increase juvenile survival. Angler exploitation may have also contributed to the low number of channel catfish observed. Of the channel catfish sampled in 2000, those ranging between 211 and 283 mm (n = 6) were most likely those stocked in 1999 (Table 1) whereas those ranging between 347 and 454 mm (n = 5) were those released in 1997.

Conclusions and Management Options

A total of eight different fish species were observed in Whitestone Lake in June 2000. Bluegill were, by far, the most abundant warmwater species present and had increased in abundance since 1998. Additionally, the bluegill in Whitestone Lake may have had a density advantage over the pumpkinseed and yellow perch and probably exploited most available resources typically used by younger fish. Relative weights of most yellow perch and pumpkinseed were below 100 indicating that these species were limited by food and/or space.

Although the largemouth bass fishery in Whitestone Lake is similar to the outcome sought under the big bass management option, the current bass size structure is seldom used to reduce panfish abundance. Natural reproduction of largemouth bass was evident but the high density of bluegill had likely limited spawning success of the bass. Low relative weights of the smaller size largemouth bass were likely a result of food competition with the bluegill. High competition and low reproductive success may lead to low recruitment of largemouth bass to larger sizes. Although the condition of the largemouth bass fishery may be currently desirable, it may only persist until mortality exceeds recruitment.

Channel catfish have been stocked in Whitestone Lake in two of the last three years. A total of 2,500 were stocked in 1997 and 2,500 were stocked in 1999. Those stocked in 2000 were done so following our survey. Although the condition of channel catfish sampled from Whitestone Lake appeared above average, their survival rates are questionable.

Although abundance of black crappie in Whitestone Lake increased between 1979 and 1986, none were observed in either 1998 or 2000. A total of 10,132 black crappie fry were stocked in the lake in 1999 and likely experienced low survival due to predation by the yellow perch and largemouth bass or interspecific competition. A total of 1,733 black crappie (1,000 adults and 733 fry) were stocked in 2000 following the survey and further investigation is required to evaluate the current status of the black crappie population in the lake.

Whitestone Lake currently provides the public with the opportunity to fish for sizeable largemouth bass. However, it appears that bluegill density has increased drastically since 1998 and measures should be taken to prevent negative impacts to the largemouth bass and other fish populations in the lake. The following are recommendations developed in response to the Warmwater Gamefish Enhancement Program's goal of increasing opportunities to fish for and to catch warmwater gamefish in Whitestone Lake. It is likely that these recommendations will need to be exercised in combination to reduce bluegill density to manageable levels.

Recommendation 1: Reduce bluegill density using regulations

Option 1: Panfish Option

This option requires the protection of all largemouth bass 16 inches in length and smaller, with a daily harvest limit of no more than 1 largemouth bass greater than 16 inches in length. Additionally, current statewide panfish regulations for Whitestone Lake would be maintained; no daily harvest or size limit. Regular warmwater surveys will be required to monitor the balance of panfish and largemouth bass for this option to be successful.

Overpopulation of bluegill often results in stunted panfish populations which can limit recruitment of largemouth bass. The panfish option is designed to prevent overpopulation of panfish by maintaining a high density of largemouth bass between 8 and 15 inches (Flickinger et al. 1999) thus allowing increased panfish growth. Although increased panfish growth may be a benefit, the primary objective of this option in Whitestone Lake would focus on reducing bluegill density. Although minimum length limits have been found to increase catch rates (Wilde 1996), angler satisfaction may sometimes be sacrificed due to the increased number of smaller bass in the lake (Flickinger et al. 1999). The success of this option is governed by the adherence by anglers to the largemouth bass minimum size harvest restriction.

Option 2: Largemouth bass and panfish option

This option continues with the current slot-length limit regulation on largemouth bass of a daily limit of 5 bass less than 12 inches or greater than 17 inches in length, with no more than 1 over 17 inches in length being retained. Current panfish regulations, as defined in Option 1, would remain in effect. As with Option 1, regular warmwater surveys would be required to monitor the balance of panfish and largemouth bass in Whitestone Lake.

Option 2 is similar to Option 1 in that both attempt to prevent overpopulation of panfish. However, the largemouth bass and panfish option allows anglers to harvest bass under 12 inches in length which would not be allowed under the panfish option. Managing a lake under a slot-length limit would protect sizes of largemouth bass that are highly predacious on panfish. It has been found that, in some cases, slot-length limits have failed to restructure largemouth bass populations due to lack of harvest of bass below the lower limit of the protected size range (Wilde 1996). In these cases, the slot-length limit acts as a minimum-length limit described in Option 1. Wilde (1996) reported that slot-length limits are useful in restructuring largemouth bass populations but often fail to increase angler catch rates.

Overall, Option 1 and 2 could both be used in an attempt to reduce panfish density, although each have their limitations. Option 1 (panfish) emphasizes larger panfish size structure and increases catch rates of largemouth bass, while allowing harvest of some larger size bass. Option 2 (largemouth bass and panfish) is similar to Option 1 in that it would enable panfish to grow to larger sizes but would also allow anglers to harvest small bass from the lake. Although fishery managers would prefer to increase angler catch rates and restructure largemouth bass populations, minimum-length (Option 1) and slot-length (Option 2) limits seldom accomplish both (Wilde 1996).

Recommendation 2: Reducing bluegill density using non-regulatory means

Option 1: Chemical treatments

Although rehabilitating the entire lake with rotenone would be costly, it is an option. However, even if largemouth bass salvage efforts were employed, a proportion would be sacrificed and reestablishment of a mature largemouth bass population would likely take years. Partial-lake rehabilitation, or spot treatments of rotenone, may be more feasible. Spot treatments could extirpate bluegill from areas in which they are congregated, such as nesting areas, or at least disrupt spawning with minimal impacts to the largemouth bass population. Areas where spot treatments are exercised could be monitored and non-targeted species could be recovered and relocated to other parts of the lake.

Option 2: Physical removal

Physical removal of bluegill from Whitestone Lake would be labor intensive but would provide additional benefits. Bluegill density may only be slightly reduced, but all fish could be retained and transplanted into waters in need of bluegill. The benefit-to-cost ratio of harvesting bluegill from Whitestone Lake would be high. Although exact figures would be difficult to calculate, large numbers of sub-adult and adult bluegill would be expensive to culture. In cooperation with WDFW’s Region 2 Hatchery Division, bluegill could be collected from juvenile fishing derbys in addition to intensive collection efforts by the Region 2 Warmwater Enhancement Team, other regional warmwater teams, Region 2 Area Biologists, or a combination thereof. Besides angling, bluegill removal would likely be conducted by electrofishing or seining. However, seining may be difficult due to the high content of aquatic vegetation present in the lake.

Recommendation 3: Fish stocking

We recommend stocking largemouth bass at a minimum length of 250 mm (~10 inches) and at a density of approximately five fish/acre in an attempt to reduce bluegill density in Whitestone Lake. The surface area of Whitestone Lake is 173 acres therefore approximately 850 largemouth bass would be required. If largemouth bass of that size were not available, transplanting largemouth bass from Davis Lake, Okanogan County, would be a feasible alternative. Largemouth bass in the 7 to 9 inch range are abundant in Davis Lake and transplant efforts would be cost effective due to reduced transport distance. We recommend stocking Davis Lake largemouth bass at a density of eight fish/acre (~1,300) due to the smaller size. In addition, largemouth bass could also be collected, with permission, from Alta and Rebecca lakes located on the Colville Reservation.

In addition to the largemouth bass, we recommend stocking channel catfish at densities similar to what has been stocked in previous years (14-17 fish/acre). Sizes of channel catfish previously stocked in the lake ranged from 6 to 14 inches. We do not recommend stocking channel catfish less than 9 inches since studies have shown that channel catfish smaller than 8 inches can be highly vulnerable to predation by largemouth bass. Stocking channel catfish, in addition to largemouth bass, will likely expedite bluegill density reduction.

Recommendation 4: Population monitoring

We recommend that warmwater fish surveys should be conducted every three to four years to monitor the size structure and condition of the largemouth bass, bluegill, and channel catfish in Whitestone Lake. In addition, future monitoring would likely forecast whether additional stocking of largemouth bass and channel catfish was needed, additional bluegill should be removed, and/or adjustments in regulations should be made.

Literature Cited

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

Bettoli, P. W., M. J. Maceina, R. L. Noble, and R. K. Betsill. 1992. Piscivory in largemouth bass as a function of aquatic vegetation abundance. North American Journal of Fisheries Management 12:509-516.

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

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

Crowder, L. B. and W. E. Cooper. 1982. Habitat complexity and the interactions between bluegill and their prey. Ecology 63:1802-1813.

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

Flickinger, S. A., F. J. Bulow, and D. W. Willis. 1999. Small impoundments. Pages 561-587 *in* C. C. Kohler and W. A. Hubert, editors. Inland Fisheries Management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

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

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

Heidinger, R. C. 1999. Stocking for sport fisheries enhancement. Pages 375-401 *in* C. C. Kohler and W. A. Hubert, editors. Inland Fisheries Management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

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

Jackson, C. 1998. 1998 Whitestone Lake survey: assessment of the warmwater fish community. Unpublished report. Washington Department of Fish and Wildlife, Region 2 files, Ephrata, Washington. 12 pp.

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

Swingle, H. S. 1969. Methods for the analysis of waters, organic matter, and pond bottom soils used in fisheries research. Auburn University, Auburn, Alabama. 119 pp.

Walton, J. M. and W. Wirt. 1989. Fish population assessments for four Eastern Washington lakes. Peninsula College Fisheries Technology Program, Port Angeles, Washington. 142 pp.

Wilde, G. R. 1996. Largemouth bass fishery responses to length limits. Fisheries 22(6):14-23.

Williams, K. R. 1979. Fisheries management report #81-15, Okanogan District, January 1 - December 31, 1979. Washington State Department of Game, Fisheries Management Division, Olympia, Washington. 76 pp.

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

Wydoski, R. S. and R. R. Whitney. 1979. Inland fishes of Washington. University of Washington Press, Seattle, Washington. 220 pp.

Glossary

Catch Per Unit Effort (CPUE): Is defined as the number of fish captured by a sampling method (electrofishing, gill netting, or fyke netting) divided by the amount of time sampled.

Confidence Interval (CI): Is defined as an estimated range of values which is likely to include an unknown population parameter with a percentage or degree of confidence.

Memorable Size: Is defined as fish anglers remember catching, and also identified as 59-64 percent of the world record length. Memorable length varies by species.

Preferred Size: Is defined as the size fish anglers preferred to catch when given a choice, and also identified as 45-55 percent of world record length. Preferred length varies by species.

Proportional Stock Density (PSD): Is defined as the number of quality length fish and larger, divided by the number of stock sized fish and larger, multiplied by 100.

Quality Length: Is defined as the length at which anglers begin keeping fish. Also identified as 36-41 percent of world record length. Quality length varies by species.

Relative Stock Density (RSD): Is defined as the number of fish of a specified length category (quality, preferred, memorable, or trophy) and larger, divided by the number of stock length fish and larger, multiplied by 100.

Relative Stock Density of Preferred Fish (RSD-P): Is defined as the number of fish in the preferred size category and larger, divided by the number of stock length fish and larger, multiplied by 100.

Relative Stock Density of Memorable Fish (RSD-M): Is defined as the number of fish in the memorable size category and larger, divided by the number of stock length fish and larger, multiplied by 100.

Relative Stock Density of Trophy Fish (RSD-T): Is defined as the number of fish in the trophy size category and larger, divided by the number of stock length fish and larger, multiplied by 100.

Relative Weight (W_r): The comparison of the weight of a fish at a given size to the national average weight (W_r = 100) of fish of the same species and size.

Standard Weight (W_s): Is defined as a standard or average weight of a fish species at a given length determined by a national length-weight regression.

Stock Length: Is defined by the following: 1) approximate length of fish species at maturity, 2) the minimum length effectively sampled by traditional sampling gears, 3) minimum length of fish that provide recreational value, and 4) 20-26 percent of world record length. Stock length varies by species.

Total Length (TL): Is defined as the length measurement from the anterior most part of the fish to the tip of the longest caudal (tail) fin ray (compressed).

Trophy Size: Considered a trophy, and also identified as 74-80 percent of world record length. Trophy length varies by species.