1997 LAKE STEVENS SURVEY: THE WARMWATER FISH COMMUNITY AFTER IMPLEMENTATION OF A MINIMUM LENGTH LIMIT ON LARGEMOUTH AND SMALLMOUTH BASS

by

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INTRODUCTION AND BACKGROUND

Lake Stevens is a deep (maximum depth = 45.7 m), moderate size (surface area = 433 ha) body of water located approximately 6 km east of the City of Everett. It is the largest natural recreational lake in Snohomish County. Lake Stevens is fed by Stitch Creek from the south and Lundeen and Kokanee (or Mitchell) Creeks from the north. Surface water exits the lake at the northeast corner, through Stevens Creek, eventually discharging into the Pilchuck River.

Because of its depth, Lake Stevens stratifies readily as surface water temperatures increase. In the past, during the warmer spring and summer months, the lake's hypolimnion (the cold, deep layer of water in a stratified lake) became hypoxic - even anoxic, effectively reducing the amount of habitat hospitable to fishes and their prey. Furthermore, the low dissolved oxygen levels exacerbated the release of nutrients (phosphorous) from the lake bottom causing eutrophication and nuisance blue-green algal blooms (KCM 1992; KCM *undated*). To rectify the situation, the City of Lake Stevens and the Drainage Improvement District No. 8, with funding from the Washington Department of Ecology (WDE), began operating the world's largest hypolimnetic aeration system in the northwest basin of the lake on May 19, 1994. The system uses compressed air to increase the dissolved oxygen content in the deepest part of the lake, thereby increasing the habitat available to fishes and their prey, while reducing the phosphorous load and occurrence and intensity of algal blooms (KCM *undated*).

In addition to its water quality problems, Lake Stevens has endured invasions by Eurasian watermilfoil (*Myriophyllum spicatum*) and a top-level predator, the smallmouth bass (*Micropterus dolomieu*). In 1994, Eurasian watermilfoil (EWM) was patchily distributed throughout the lake. However, a routine survey by WDE in 1997 showed that EWM had died back; in fact, all submersed aquatic vegetation in the lake was unhealthy, possibly due to disease or herbivory by insects (Parsons 1998). Sometime during the early 1980's, smallmouth bass were illegally introduced into Lake Stevens. The first record of the species was noted in 1985. By the late 1980's, smallmouth bass were fairly abundant in the lake and their growth was rapid [Curt Kraemer, Washington Department of Fish and Wildlife (WDFW), personal communication]. Although colonization by Eurasian watermilfoil has the potential for serious impacts at the lake, the introduction of smallmouth bass has, fortunately, benefitted the recreational fishery.

Given the expanding population of smallmouth bass in Lake Stevens, biologists from WDFW proposed a minimum length limit regulation in order to create a trophy fishery for the predator. In 1990, a new fishing rule was implemented which allows anglers to retain only one smallmouth bass or one largemouth bass (*Micropterus salmoides*) per day with a minimum length of 457 mm (18") total length. Little or no information exists regarding the resident fish community of Lake Stevens after implementation of the minimum length rule. Therefore, in an effort to assess the warmwater fishery of the lake, as well as to monitor the success of the restoration plan, personnel from WDFW's Warmwater Enhancement Program conducted a fisheries survey at Lake Stevens in early fall 1997.

MATERIALS AND METHODS

Lake Stevens was surveyed by a three-person team during September 8 - 11, 1997. Fish were captured using two sampling techniques: electrofishing and gill netting. The electrofishing unit consisted of a 5.5 m Smith-Root 5.0 GPP 'shock boat' using a DC current of 120 cycles/sec at 3 to 4 amps power. Experimental gill nets (45.7 m long × 2.4 m deep) were constructed of four sinking panels (two each at 7.6 m and 15.2 m long) of variable-size (13, 19, 25, and 51 mm stretched) monofilament mesh.

Sampling locations were selected by dividing the shoreline into 62 consecutively numbered sections of about 183 m each (determined visually from a map). Using the random numbers table from Zar (1984), 15 of these sections were then randomly selected as sampling locations. While electrofishing, the boat was maneuvered through the shallows (depth range: 0.2 - 1.5 m), adjacent to the shoreline, at a rate of approximately 18.3 m/minute. Gill nets were set perpendicular to the shoreline. The small-mesh end was attached onshore while the large-mesh end was anchored offshore. Sampling occurred during evening hours to maximize the type and number of fish captured. Nighttime electrofishing occurred along 14.5% (~ 1.6 km) of the available shoreline, whereas gill nets were set overnight at six locations (= 6 'net nights') around the lake (Figure 1). In order to reduce bias between techniques, the sampling time for each gear type was standardized so that the ratio of electrofishing to gill netting was 1:1 (Fletcher et al. 1993). Total electrofishing time was 5,440 sec (actual pedal-down time), or roughly three units of 1,800 sec each; total gill netting time was 86.1 h, or roughly three units of 24 h each.

With the exception of sculpins (family Cottidae), all fish captured were identified to the species level. Each fish was measured to the nearest 1 mm and assigned to a 10-mm size class based on total length (TL). For example, a fish measuring 156 mm TL was assigned to the 150-mm size class for that species, a fish measuring 113 mm TL was assigned to the 110-mm size class, and so on. When possible, up to 10 fish from each size class were weighed to the nearest 1 g. However, if a sample included several hundred individuals of a given species, then a sub-sample ($n \geq 100$ fish) was measured and weighed while the remainder was counted overboard. The length frequency distribution of the sub-sample was then applied to the total number collected. Weights of individuals counted overboard were estimated using a simple linear regression of $\log_{10}$-length on $\log_{10}$-weight of fish from the sub-sample. Scales were removed from up to 10 fish from each size class for aging. Scale samples were mounted, pressed, and the fish aged according to Jearld (1983) and Fletcher et al. (1993). However, a lack of technical resources precluded aging members of the family Ictaluridae (catfish). Furthermore, given the narrow scope of this study, salmonid and non-game fish were not aged.

Water quality data was collected during midday from two locations on September 10, 1997 (Figure 1). Using a Hydrolab® probe and digital recorder, information was gathered on dissolved oxygen, redox, temperature, pH, and specific conductance. Secchi disc readings were recorded in feet and then converted to m (Table 1).

TABLE 1.---Water quality from two locations (northeast and south end) at Lake Stevens (Snohomish County). Samples were collected midday on September 10, 1997.

		Parameter					
Location	Secchi (m)	Depth (m)	DO	Temp (°C)	pH	Conductance	Redox
Northeast end	5 m	1	8.6	21.8	7.8	90	357
		3	9.0	21.5	7.9	90	362
		6	8.8	21.0	7.8	88	372
		9	6.4	13.1	7.0	94	421
		11	5.4	8.5	6.8	95	430
South end	5 m	1	8.6	21.4	7.9	89	382
		3	8.7	21.3	7.9	87	390
		6	8.7	20.1	7.7	88	397
		9	7.1	14.0	7.2	90	438
		12	6.1	8.5	6.8	91	454
		15	6.4	7.7	6.7	91	456
		18	6.6	7.3	6.7	90	457

Data analysis

Balancing predator and prey fish populations is the hallmark of warmwater fisheries management. According to Bennett (1962), the term 'balance' is used loosely to describe a system in which omnivorous forage fish or prey maximize food resources to produce harvestable-size stocks for fishermen and an adequate forage base for piscivorous fish or predators. Predators must reproduce and grow to control overproduction of both prey and predator species, as well as provide adequate fishing. To maintain balance, predator and prey fish must be able to forage effectively. Evaluations of species composition, size structure, growth, and condition (plumpness or robustness) of fish provide useful information on the adequacy of the food supply (Kohler and Kelly 1991), as well as the balance and productivity of the community (Swingle 1950; Bennett 1962).

Species composition by weight (kg) of fish captured was determined using procedures adapted from Swingle (1950). The species composition by number of fish captured was also determined, but using procedures outlined in Fletcher et al. (1993). Only fish estimated to be at least one year old were used to determine species composition. These were inferred from the length frequency distributions described below, in conjunction with the results of the aging process. Young-of-year or small juveniles were not considered because large fluctuations in their numbers may cause distorted results (Fletcher et al. 1993). For example, the length frequency distribution of largemouth bass may suggest successful spawning during a given year, as indicated by a preponderance of fish in the smallest size classes. However, most of these fish would be subject to natural attrition during their first winter (Chew 1974), resulting in a different size distribution by the following year.

Catch per unit effort (CPUE) by gear type was determined for each warmwater fish species (number of fish/hour electrofishing and number of fish/net night). Only stock size fish and larger were used to determine CPUE. Stock length, which varies by species (see Table 2 and discussion below), refers to the minimum size of fish having recreational value. Since sample locations were randomly selected, which might introduce high variability due to habitat differences within the lake, 80% confidence intervals (CI) were determined for each mean CPUE by species and gear type. CI was calculated as the mean $\pm t_{(\alpha, N\text{-}1)} \times SE$, where t = Student's t for α confidence level with N-1 degrees of freedom (two-tailed) and SE = standard error of the mean. Since it is standardized, CPUE is a useful index for comparing relative abundance of stocks between lakes.

With the exception of sculpin, mountain whitefish (*Prosopium williamsoni*), coho salmon (*Oncorhynchus kisutch*), black crappie (*Pomoxis nigromaculatus*), and unidentified trout (*Oncorhynchus* sp.), the size structures of all fishes captured were evaluated by constructing length frequency histograms (number of fish captured by gear type per size class). Absolute numbers of individuals in each size class were standardized to CPUE by gear type (number of fish/hour electrofishing and number of fish/net night). Standardization adjusts for differences in sampling effort between sampling times or locations (Anderson and Neumann 1996). For the same reasons described above, only fish estimated to be at least one year old were used when constructing length frequency histograms. These were inferred from the results of the aging process.

The proportional stock density (PSD) of each warmwater fish species was determined following procedures outlined in Anderson and Neumann (1996). PSD, which was calculated as the number of fish≥quality length/number of fish≥stock length×100, is a numerical descriptor of length frequency data that provides useful information about population dynamics. Stock and quality lengths, which vary by species, are based on percentages of world-record lengths. Again, stock length (20-26% of world-record length) refers to the minimum size fish with recreational value, whereas quality length (36-41% of world-record length) refers to the minimum size fish most anglers like to catch.

The relative stock density (RSD) of each warmwater fish species was examined using the five-cell model proposed by Gabelhouse (1984). In addition to stock and quality length, Gabelhouse (1984) introduced preferred, memorable, and trophy length categories (Table 2). Preferred length (45-55% of world-record length) refers to the minimum size fish anglers would prefer to catch when given a choice. Memorable length (59-64% of world-record length) refers to the minimum size fish most anglers remember catching, whereas trophy length (74-80% of world-record length) refers to the minimum size fish considered worthy of acknowledgment. Like PSD, RSD provides useful information regarding population dynamics, but is more sensitive to changes in year-class strength. RSD was calculated as the number of fish≥specified length/number of fish≥stock length×100. For example, RSD P was the percentage of stock length fish that also were longer than preferred length, RSD M, the percentage of stock length fish that also were longer than memorable length, and so on. Eighty-percent confidence intervals for PSD and RSD were selected from tables in Gustafson (1988).

TABLE 2.---Length categories for warmwater fish species captured at Lake Stevens (Snohomish County) during early fall 1997. Measurements are minimum total lengths (mm) for each category (Willis et al. 1993).

	Size				
Type of fish	Stock	Quality	Preferred	Memorable	Trophy
Yellow perch	130	200	250	300	380
Brown bullhead	150	230	---	---	---
Smallmouth bass	180	280	350	430	510
Pumpkinseed	80	150	200	250	300
Largemouth bass	200	300	380	510	630
Black crappie	130	200	250	300	380

Age and growth of warmwater fishes in Lake Stevens were evaluated using the direct proportion method (Jearld 1983; 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,

L_n, was back-calculated as $L_n = (A \times TL)/S$, where A is the radius of the fish scale at age n, TL is the total length of the fish captured, and S is 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 is 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 Lake Stevens fish and the state average (listed in Fletcher et al. 1993) for the same species.

A relative weight (W_r) index was used to evaluate the condition of fish in the lake. A W_r value of 100 generally indicates that a fish is in good condition when compared to the national standard (75^{th} percentile) for that species. Furthermore, W_r is useful for comparing the condition of different size groups within a single population to determine if all sizes are finding adequate forage or food (ODFW 1997). Following Murphy and Willis (1991), the index was calculated as $W_r = W/W_s \times 100$, 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 is calculated from a standard $\log_{10}$weight-$\log_{10}$length relationship defined for the species of interest. The parameters for the W_s equations of many cold- and warmwater fish species, including the minimum length recommendations for their application, are listed in Anderson and Neumann (1996). With the exception of brown bullhead (*Ameiurus nebulosus*), salmonids, and non-game fish, the W_r values from this study were compared to the national standard ($W_r = 100$) and the average W_r values from 25 western Washington warmwater lakes sampled during 1997 and 1998 (Steve Caromile, WDFW, unpublished data). Because W_s has not been defined for brown bullhead, a Fulton-type condition factor (C) was used instead of W_r. The alternate index was calculated as $C = (W/TL^3) \times 10^4$, where W is the weight of an individual fish (pounds) and TL is the total length (inches) of the same fish (Anderson and Neumann 1996). Using C allowed comparisons between Lake Stevens brown bullhead and the Washington State average for the species (listed as C in Fletcher et al. 1993). Since average W_r values for rainbow and cutthroat trouts (*Oncorhynchus mykiss* and *O. clarki*, respectively) were lacking, their W_r values were compared to the national standard only.

RESULTS AND DISCUSSION

During early fall 1997, Lake Stevens showed some indications of having an unbalanced fish community. Characteristics of unbalanced populations include slow growth, poor condition, and low recruitment (Swingle 1950, 1956; Kohler and Kelly 1991; Masser *undated*). In terms of biomass and the number of fish captured, Lake Stevens was clearly dominated by a superabundant population of small, slow-growing yellow perch (*Perca flavescens*). This was not surprising given the lake's physical characteristics. Because of its depth, Lake Stevens remains relatively cool compared to shallower lakes. In general, percids (e.g., yellow perch) fare better than centrarchids (e.g., largemouth bass) under these conditions. Still, most fish captured had relative weights that were consistent with those of similar fish throughout western Washington, which suggests that food was not limited during early fall 1997. Yet the size structure and growth pattern of largemouth and smallmouth bass suggest that these predators were unable to reach an adequate size to control overproduction of yellow perch. Few quality size fish were captured, and some year classes were lacking or altogether absent. Whether these conditions were natural or an artifact of sampling bias remains unknown. For instance, electrofishing or gill netting the shallows might not garner a truly representative sample of bathyphilic smallmouth bass.

Species composition

During early fall 1997, the fish community of Lake Stevens was dominated by warmwater species, primarily yellow perch (Table 3). Together, brown bullhead, pumpkinseed (*Lepomis gibbosus*), and largemouth bass accounted for about one-third of the biomass and number captured, whereas smallmouth bass accounted for 10% of the biomass captured, but less than 3% by number. A single, age 1+ black crappie (*Pomoxis nigromaculatus*) was captured while gill netting. The fish measured 84 mm TL and weighed 9 g. Length at first annulus formation was 48 mm TL by the direct proportion method, and 63 mm TL using Lee's modification of the direct proportion method. Species other than the warmwater variety comprised about 12% of the biomass and 7% of the number of fish captured. Of these, rainbow trout and sculpin were dominant (Table 3).

TABLE 3.---Species composition (excluding young-of-year) by weight (kg) and number of fish captured at Lake Stevens (Snohomish County) during an early fall 1997 survey of warmwater fish.

	Species composition				
	by weight		by number		
Type of fish	(kg)	(%)	(#)	(%)	Size range (mm TL)
Yellow perch (*Perca flavescens*)	25.32	42.96	964	58.35	80 - 275
Brown bullhead (*Ameiurus nebulosus*)	10.60	17.98	96	5.81	93 - 342
Smallmouth bass (*Micropterus dolomieu*)	5.91	10.03	36	2.18	91 - 435
Pumpkinseed (*Lepomis gibbosus*)	5.86	9.95	198	11.99	50 - 150
Largemouth bass (*Micropterus salmoides*)	4.42	7.50	241	14.59	80 - 200
Rainbow trout (*Oncorhynchus mykiss*)	4.05	6.87	32	1.94	167 - 255
Sculpin (*Cottus* sp.)	1.08	1.83	70	4.24	---
Kokanee (*Oncorhynchus nerka*)	0.76	1.28	3	0.18	300 - 362
Cutthroat trout (*Oncorhynchus clarki*)	0.72	1.22	8	0.48	117 - 255
Mountain whitefish (*Prosopium williamsoni*)	0.19	0.33	1	0.06	271
Coho salmon (*Oncorhynchus kisutch*)	0.02	0.03	1	0.06	109
Black crappie (*Pomoxis nigromaculatus*)	0.01	0.02	1	0.06	84
Unidentified trout (*Oncorhynchus* sp.)	---	---	1	0.06	107
Total	58.95		1,652		

CPUE

While electrofishing, catch rates were highest for stock-size yellow perch and pumpkinseed, whereas low numbers of stock-size predators were captured (Table 4). With the exception of brown bullhead, the catch rates for stock-size forage fish were much lower when gill netting compared to electrofishing. Catch rates for stock-size brown bullhead were similar between gear types (Table 4).

TABLE 4.---Mean catch per unit effort (number of fish /hour electrofishing and number of fish/net night), including 80% confidence intervals, for stock size warmwater fish collected from Lake Stevens (Snohomish County) while electrofishing and gill netting during early fall 1997.

	Gear type			
Type of fish	Electrofishing (# fish/hour)	Shock sites	Gill netting (# fish/net night)	Net nights
Yellow perch	98.0 ± 26.8	9	21.7 ± 13.5	6
Brown bullhead	10.7 ± 10.3	9	12.5 ± 8.6	6
Smallmouth bass	2.0 ± 1.4	9	1.3 ± 1.2	6
Pumpkinseed	101.3 ± 32.9	9	6.7 ± 3.5	6
Largemouth bass	0.7 [a]	9	0.2 [a]	6
Black crappie	None captured	9	None captured	6

[a] sample size was insufficient to calculate confidence intervals.

Stock density indices

Except for yellow perch and brown bullhead, few quality or preferred size warmwater fish were captured. The only memorable length fish captured was a 435 mm TL smallmouth bass, which resulted in a RSD M of 12 for this species (Table 5). However, the PSD and RSD for largemouth and smallmouth bass should be viewed with caution, especially given the low catch rates and small sample sizes used to determine these indices. Still, the gill netting PSD and RSD for smallmouth bass and yellow perch (Table 5) were close to, or within, the stock density index objective ranges for a body of water managed for balance between predator and prey species (Willis et al. 1993).

TABLE 5.---Traditional stock density indices, including 80% confidence intervals, for warmwater fishes collected from Lake Stevens (Snohomish County) while electrofishing and gill netting during early fall 1997. PSD = proportional stock density, whereas RSD = relative stock density of preferred length fish (RSD P), memorable length fish (RSD M), and trophy length fish (RSD T).

Type of fish	Number of stock length fish captured	Stock density index: PSD	RSD P	RSD M	RSD T
Electrofishing					
Yellow perch	147	10 ± 6	0	0	0
Brown bullhead	14	14 [a]	0	0	0
Smallmouth bass	3	0	0	0	0
Pumpkinseed	152	1 [a]	0	0	0
Largemouth bass	1	0	0	0	0
Black crappie	0	0	0	0	0
Gill netting					
Yellow perch	130	25 ± 9	2 [a]	0	0
Brown bullhead	73	19 ± 11	0	0	0
Smallmouth bass	8	37 [a]	37 [a]	12 [a]	0
Pumpkinseed	40	0	0	0	0
Largemouth bass	1	0	0	0	0
Black crappie	0	0	0	0	0

[a] sample size was insufficient to calculate confidence intervals.

Yellow perch

Lake Stevens yellow perch ranged from 44 to 275 mm TL (age 0+ to 10+). Nearly 900 young-of-year (biomass = 3.06 kg) measuring less than 80 mm TL were captured while electrofishing. Of the older fish, individuals measuring ~ 80 to 110 mm TL (age 1+ to 3+) were dominant (Figure 2). Growth of the superabundant yellow perch in Lake Stevens was below average when compared to yellow perch statewide (Table 6), yet their condition was consistent with the average relative weights of yellow perch from 17 western Washington warmwater lakes (Figure 3).

TABLE 6.---Age and growth of yellow perch (*Perca flavescens*) captured at Lake Stevens (Snohomish County) during early fall 1997. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean length (mm) at age									
Year class	# fish	1	2	3	4	5	6	7	8	9	10
1997	10	79.6 85.0									
1996	11	71.5 82.5	97.9 102.5								
1995	10	60.5 77.2	88.8 99.3	115.9 120.5							
1994	16	56.5 75.9	86.8 100.6	117.1 125.2	144.6 147.6						
1993	19	59.2 79.5	86.3 102.3	115.0 126.3	139.9 147.1	166.4 169.2					
1992	13	61.1 82.6	90.6 108.0	126.9 139.2	155.4 163.7	179.2 184.2	199.1 201.3				
1991	5	59.9 82.3	94.3 112.3	128.1 141.8	155.4 165.6	183.4 190.0	205.8 209.6	220.9 222.6			
1990	2	61.1 83.5	86.2 105.5	134.1 147.5	160.6 170.8	196.9 202.5	210.5 214.5	220.8 223.5	232.5 233.8		
1989	0										
1988	1	59.9 83.3	117.3 134.3	138.1 152.8	169.4 180.6	195.4 203.8	208.5 215.4	226.7 231.6	237.1 240.9	244.9 247.8	255.4 257.1
Overall mean		63.1 80.4	90.0 103.7	119.9 129.9	147.5 154.2	174.9 179.2	202.2 205.2	221.6 224.0	234.0 236.1	244.9 247.8	255.4 257.1
State average		59.7	119.9	152.1	192.5	206.0	---	---	---	---	---

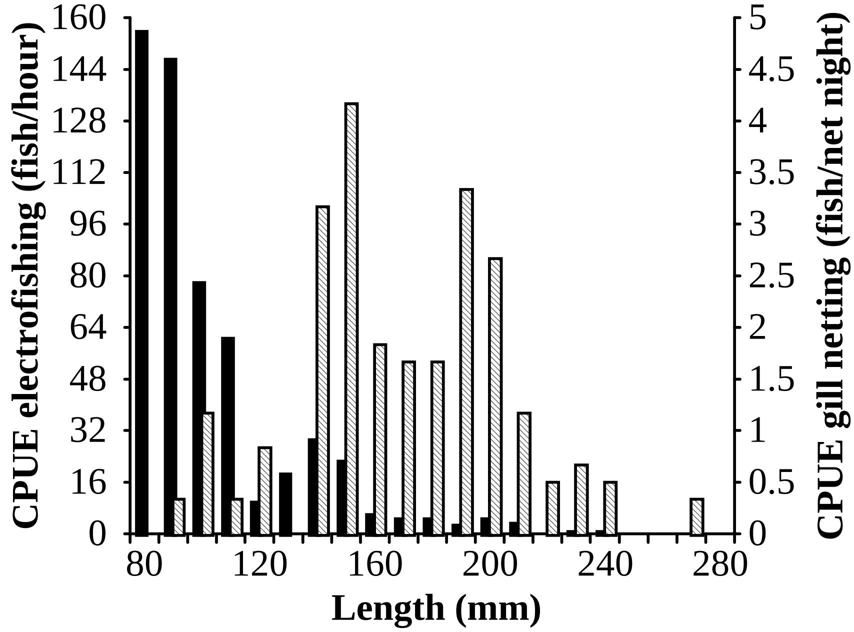

FIGURE 2.---Relationship between total length and catch per unit effort of electrofishing (solid bars) and gill netting (hatched bars) for yellow perch (*Perca flavescens*) at Lake Stevens (Snohomish County) during early fall 1997.

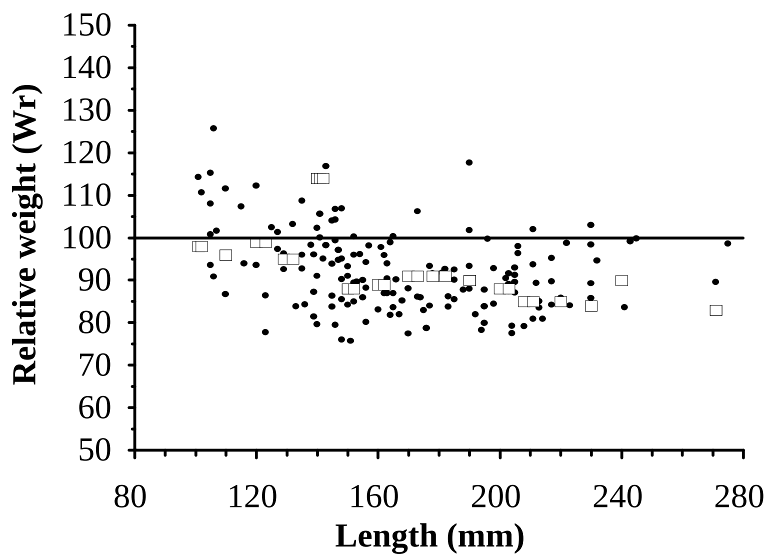

FIGURE 3.---Relationship between total length and relative weight (W_r) of yellow perch, *Perca flavescens* (n = 167), from Lake Stevens, Snohomish County (closed, black circles), compared to the average W_r from 17 western Washington warmwater lakes (open, clear rectangles) and the national standard (horizontal line at 100).

Brown bullhead

Brown bullhead in Lake Stevens ranged from 93 to 342 mm TL. The dominant size classes were 170 to 190 mm TL (Figure 4). These fish were not aged. The condition of fish below 200 mm TL was consistent with brown bullhead statewide; however, the condition of fish above 200 mm TL was below average (Figure 5).

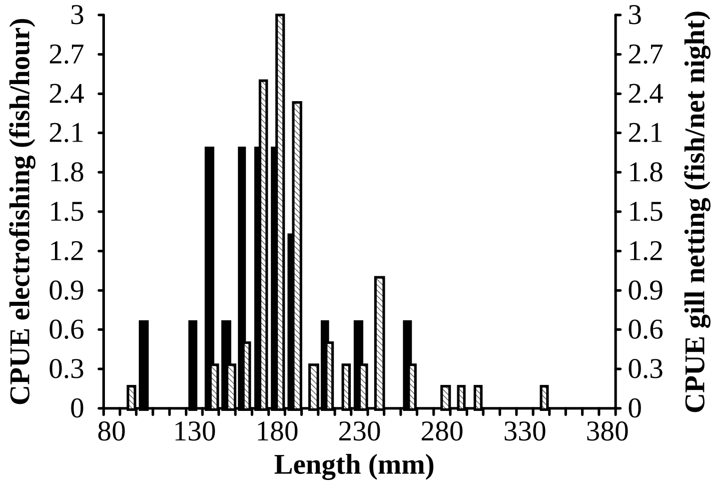

FIGURE 4.---Relationship between total length and catch per unit effort of electrofishing (solid bars) and gill netting (hatched bars) for brown bullhead (*Ameiurus nebulosus*) at Lake Stevens (Snohomish County) during early fall 1997.

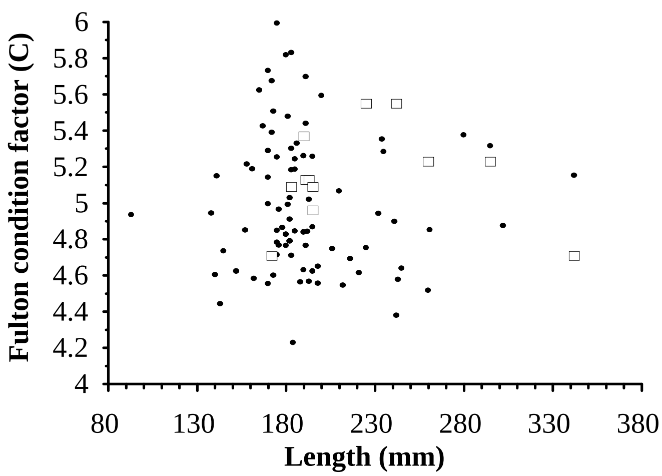

FIGURE 5.---Relationship between total length andcondition factor (*C*) of brown bullhead, *Ameiurus nebulosus* (n = 92), from Lake Stevens, Snohomish County (closed, black circles), compared to the Washington State average (open, clear rectangles).

Smallmouth bass

Smallmouth bass ranged from 61 to 435 mm TL (age 0+ to 7+). Smallmouth bass showed variable year-class strength. For example, although the 1997 year-class was dominant, only two young-of-year (< 70 mm TL each) were captured while electrofishing, and three year-classes (1993 - 1995) were conspicuously absent (Table 7, Figure 6). Growth of Lake Stevens smallmouth bass was above average when compared to smallmouth bass statewide (Table 7). The condition of smaller fish was consistent with the national standard and the average relative weights of smallmouth bass from three western Washington warmwater lakes; however, the relative weights of the largest individuals were above average (Figure 7).

TABLE 7.---Age and growth of smallmouth bass (*Micropterus dolomieu*) captured at Lake Stevens (Snohomish County) during early fall 1997. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

		Mean length (mm) at age						
Year class	# fish	1	2	3	4	5	6	7
1997	23	66.1 86.3						
1996	4	67.3 90.7	178.5 182.6					
1995	0							
1994	0							
1993	0							
1992	2	55.4 85.7	173.1 193.3	229.9 245.3	274.1 285.7	339.4 345.4	380.1 382.6	
1991	1	67.8 97.3	175.1 196.0	228.8 245.4	282.5 294.7	344.6 351.9	381.3 385.6	412.4 414.2
	Overall mean	65.6 87.2	176.5 187.6	229.5 245.3	276.9 288.7	341.1 347.5	380.5 383.6	412.4 414.2
	State average	70.4	146.3	211.8	268.0	334.0	356.1	392.7

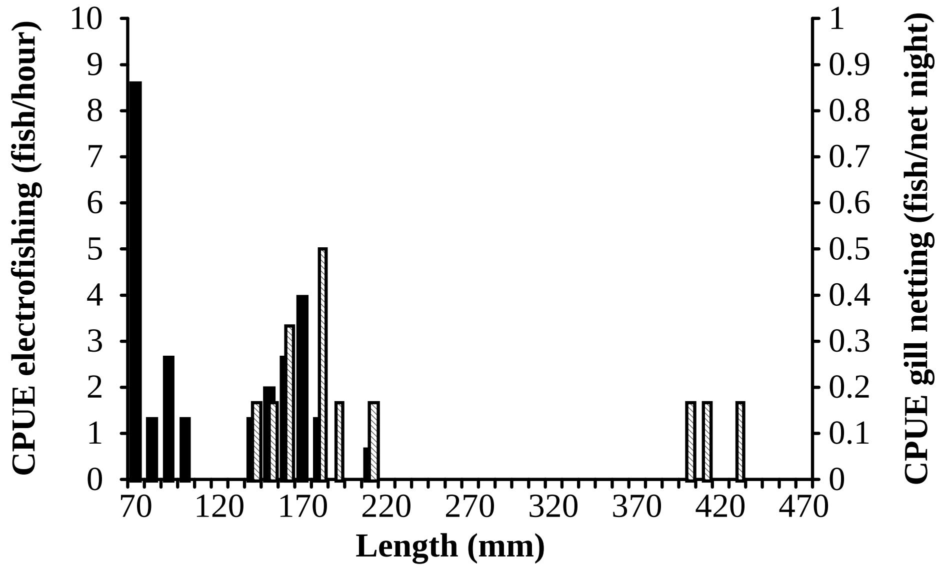

FIGURE 6.---Relationship between total length and catch per unit effort of electrofishing (solid bars) and gill netting (hatched bars) for smallmouth bass (*Micropterus dolomieu*) at Lake Stevens (Snohomish County) during early fall 1997.

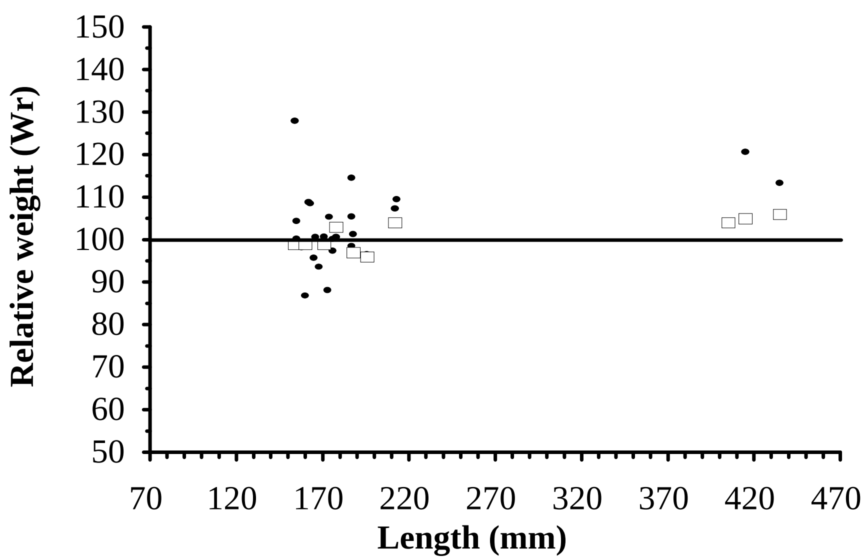

FIGURE 7.---Relationship between total length and relative weight (W_r) of smallmouth bass, *Micropterus dolomieu* (n = 27), from Lake Stevens, Snohomish County (closed, black circles), compared to the average W_r from three western Washington warmwater lakes (open, clear rectangles) and the national standard (horizontal line at 100).

Pumpkinseed

Lake Stevens pumpkinseed ranged from 27 to 150 mm TL (age 0+ to 6+). Like smallmouth bass, pumpkinseed showed variable year-class strength. The 1994 and 1995 year-classes were dominant, whereas the 1997 year-class was not observed (Table 8, Figure 8). Furthermore, only one young-of-year (27 mm TL) was captured while electrofishing. During their first two years, growth of Lake Stevens pumpkinseed was consistent with or slightly above the state average. However, after age 3, growth was slower than pumpkinseed statewide (Table 8). Relative weights were generally above the national standard for the species, yet consistent with, or above, the average relative weights of pumpkinseed from 17 western Washington warmwater lakes (Figure 9).

TABLE 8.---Age and growth of pumpkinseed (*Lepomis gibbosus*) captured at Lake Stevens (Snohomish County) during early fall 1997. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

Year class	# fish	Mean length (mm) at age					
		1	2	3	4	5	6
1997	0						
1996	4	39.9 53.6	73.0 77.4				
1995	11	39.6 54.7	66.1 74.5	83.5 87.5			
1994	13	43.5 59.6	64.7 76.5	87.1 94.3	108.9 111.7		
1993	6	41.5 58.8	66.4 78.9	84.2 93.4	103.4 109.0	121.4 123.7	
1992	1	38.8 57.3	59.5 74.6	81.5 92.9	94.4 103.7	116.4 122.0	133.2 136.0
	Overall mean	41.4 57.2	66.3 76.3	85.0 91.7	106.5 110.5	120.6 123.4	133.2 136.0
	State average	23.6	72.1	101.6	122.7	139.4	---

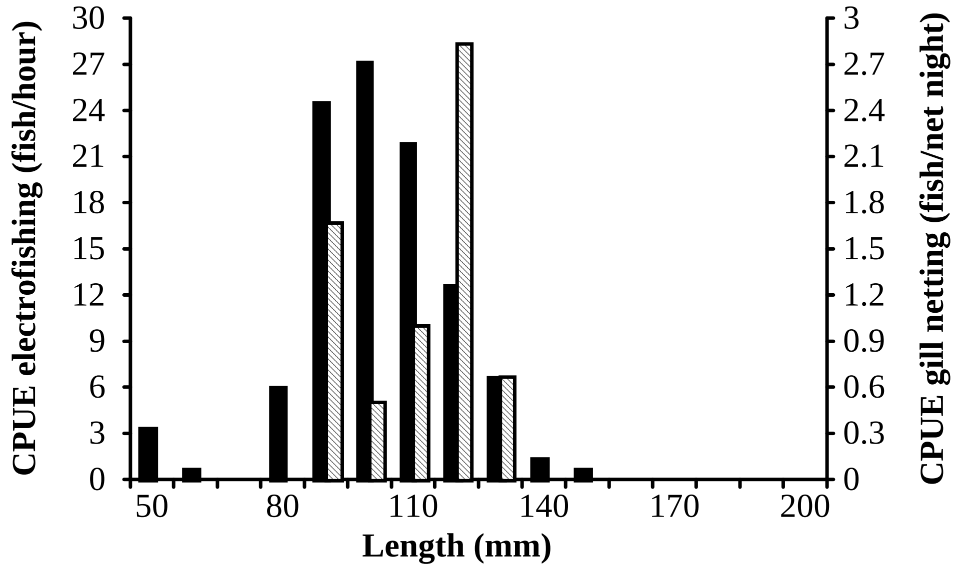

FIGURE 8.---Relationship between total length and catch per unit effort of electrofishing (solid bars) and gill netting (hatched bars) for pumpkinseed (*Lepomis gibbosus*) at Lake Stevens (Snohomish County) during early fall 1997.

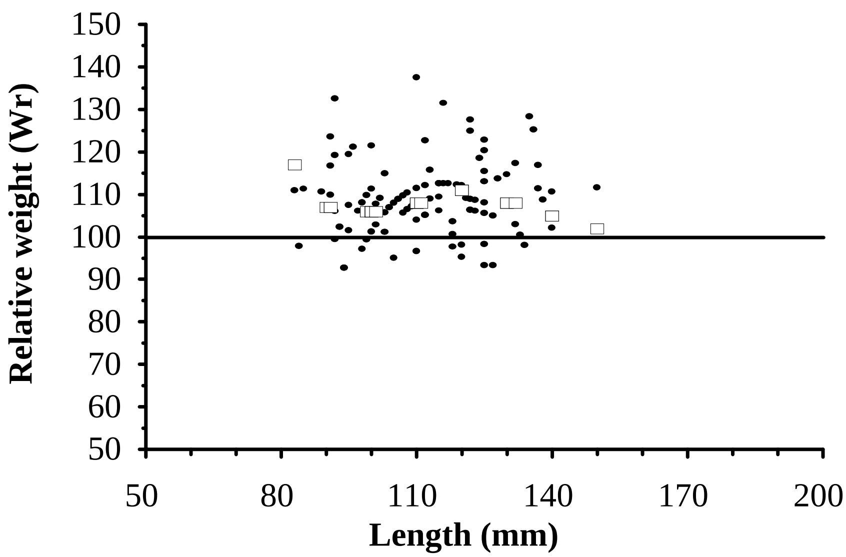

FIGURE 9.---Relationship between total length and relative weight (W_r) of pumpkinseed, *Lepomis gibbosus* (n = 116), from Lake Stevens, Snohomish County (closed, black circles), compared to the average W_r from 17 western Washington warmwater lakes (open, clear rectangles) and the national standard (horizontal line at 100).

Largemouth bass

Lake Stevens largemouth bass ranged from 66 to 200 mm TL (age 0+ to 5+). Small (< 110 mm TL), young (≤ age 3+) fish were dominant (Figure 10). Five young-of-year (< 80 mm TL) were captured while electrofishing, whereas only two quality size (≥ 200 mm TL) fish were observed. With the exception of age 1+ fish, growth of largemouth bass was slow when compared to the average growth of other western Washington largemouth bass (Table 9). Still, the condition of these fish was well above the national standard for the species, and above the average relative weights of largemouth bass from 20 western Washington warmwater lakes (Figure 11).

TABLE 9.---Age and growth of largemouth bass (*Micropterus salmoides*) captured at Lake Stevens (Snohomish County) during early fall 1997. Unshaded values are mean back-calculated lengths at annulus formation using the direct proportion method (Fletcher et al. 1993). Shaded values are mean back-calculated lengths using Lee's modification of the direct proportion method (Carlander 1982).

Year class	# fish	Mean length (mm) at age				
		1	2	3	4	5
1997	18	75.9 79.8				
1996	9	70.1 78.5	101.8 104.9			
1995	16	69.6 79.9	97.5 103.8	121.2 124.1		
1994	4	71.3 83.1	99.2 107.8	135.1 139.6	155.1 157.3	
1993	3	58.4 72.5	83.0 94.7	109.8 118.7	135.9 142.2	181.8 183.4
	Overall mean	71.4 79.4	97.6 103.7	122.1 126.1	146.9 150.8	181.8 183.4
Western Washington average		60.4	145.5	222.2	261.1	289.3

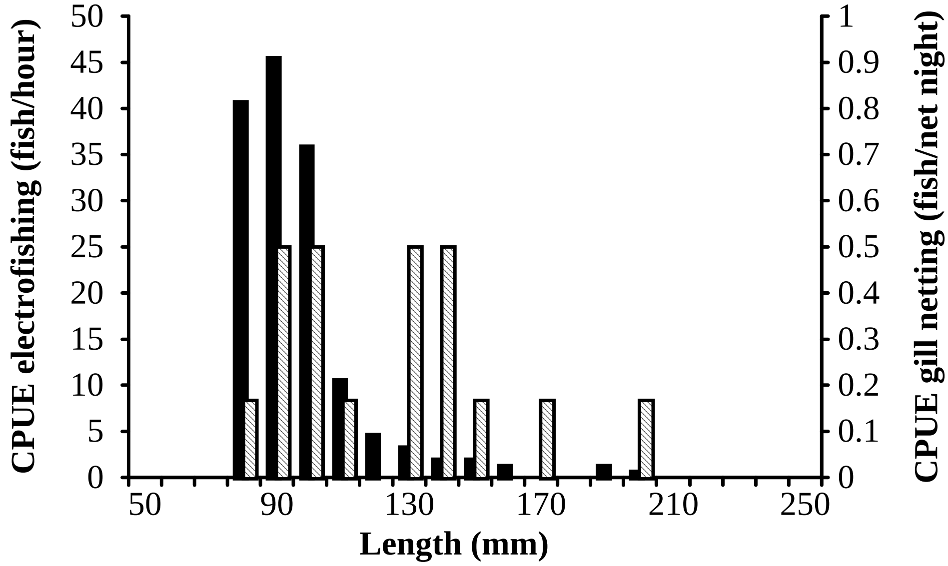

FIGURE 10.---Relationship between total length and catch per unit effort of electrofishing (solid bars) and gill netting (hatched bars) for largemouth bass (*Micropterus salmoides*) at Lake Stevens (Snohomish County) during early fall 1997.

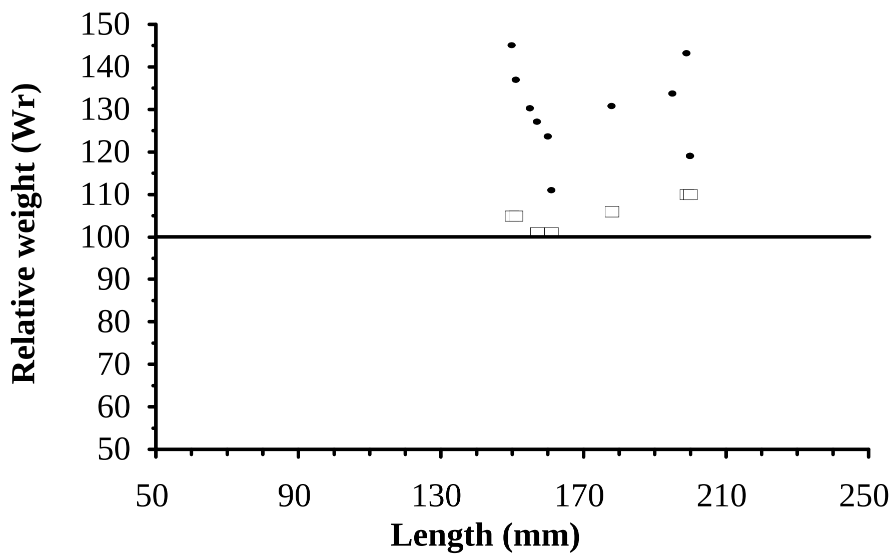

FIGURE 11.---Relationship between total length and relative weight (W_r) of largemouth bass, *Micropterus salmoides* (n = 11), from Lake Stevens, Snohomish County (closed, black circles), compared to the average W_r from 20 western Washington warmwater lakes (open, clear rectangles) and the national standard (horizontal line at 100).

Members of the family Salmonidae and non-game fish

Rainbow trout ranged from 167 to 255 mm TL and comprised nearly 7% of the biomass captured at Lake Stevens, but less than 2% by number (Table 3). The largest individuals were captured while gill netting (Figure 12); their condition was slightly below the national standard (Figure 13). Three kokanee (*Oncorhynchus nerka*) were captured while gill netting along the southeastern shore. These fish ranged from 300 to 362 mm TL. Sculpin were captured while electrofishing only, and comprised nearly 2% of the biomass and 5% of the number of fish captured (Table 3).

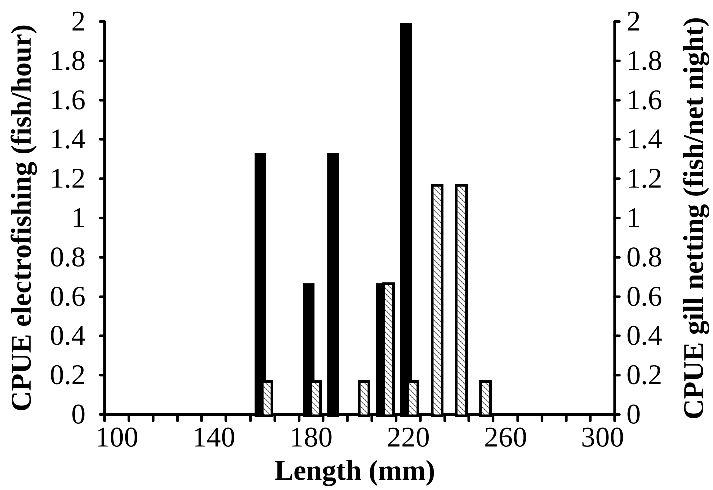

FIGURE 12.---Relationship between total length and catch per unit effort of electrofishing (solid bars) and gill netting (hatched bars) for rainbow trout (*Oncorhynchus mykiss*) at Lake Stevens (Snohomish County) during early fall 1997.

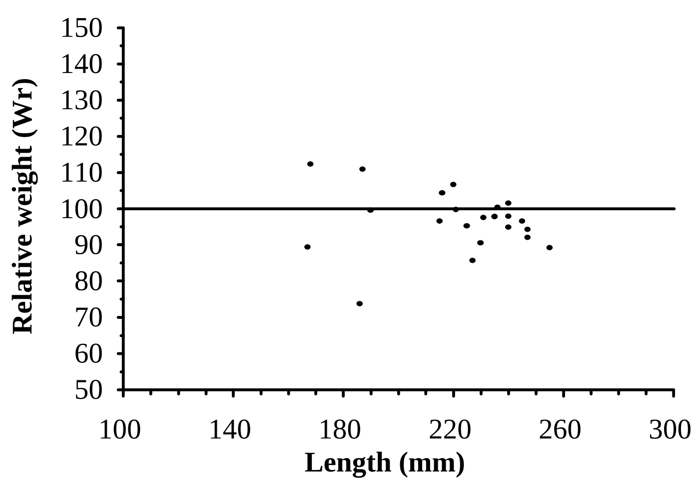

FIGURE 13.---Relationship between total length and relative weight (W_r) of rainbow trout, *Oncorhynchus mykiss* (n = 24), from Lake Stevens, Snohomish County (closed, black circles), compared to the national standard (horizontal line at 100).

Two year-classes of cutthroat trout were evident from the length frequencies (Figure 14); however, these fish were not aged. The smaller fish were captured while electrofishing, whereas the larger fish were captured while gill netting (Figure 14). Their condition was above average when compared to the national standard for the species (Figure 15). In addition to the above, one each of the following were captured: mountain whitefish, coho salmon, and unidentified trout. The mountain whitefish (271 mm TL, 193 g) was captured while gill netting along the southwest shoreline, whereas the others (109 and 107 mm TL, respectively) were captured while electrofishing along the steep shoreline located at the northwest corner of the lake.

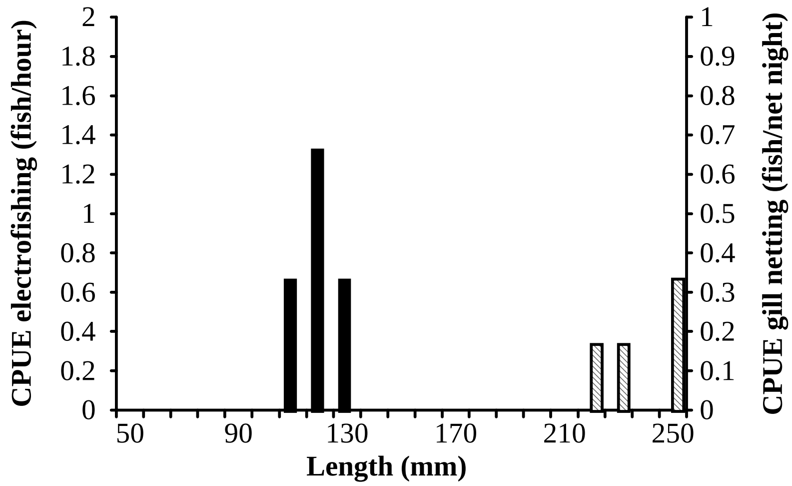

FIGURE 14.-- -Relationship between total length and catch per unit effort of electrofishing (solid bars) and gill netting (hatched bars) for cutthroat trout (*Oncorhynchus clarki*) at Lake Stevens (Snohomish County) during early fall 1997.

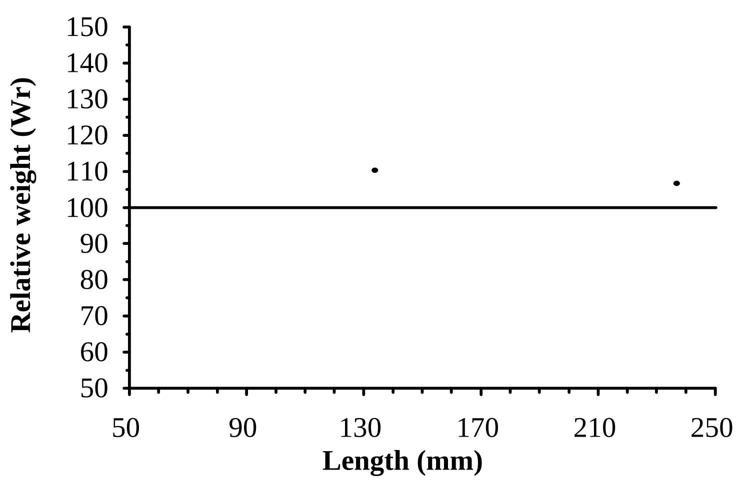

FIGURE 15.---Relationship between total length and relative weight (W_r) of cutthroat trout, *Oncorhynchus clarki* (n = 2), from Lake Stevens, Snohomish County (closed, black circles), compared to the national standard (horizontal line at 100).

WARMWATER ENHANCEMENT OPTIONS

Causes for the variation described above are complex and difficult to isolate from a single survey; however, some inferences can be drawn from previous studies. For example, the conditions observed in 1997 resemble those described by Swingle (1956) and Masser (*undated*) for populations experiencing inter- and intraspecific competition because of crowding. According to Swingle (1956), crowding in fish populations results in slow growth (less food per individual) and reduced or inhibited reproduction. This was evident in the warmwater fishes at Lake Stevens. Their size structures and growth patterns suggest that these fishes were not able to forage effectively, possibly due to overcrowding and competition with the dominant yellow perch. Moreover, the intermediate size classes (203 - 305 mm or 8 - 12" TL) of largemouth and smallmouth bass, those fish needed to maintain balance within Lake Stevens, were lacking. Management strategies that might improve the warmwater fishery at Lake Stevens include, but are not limited to, the following:

Conduct creel or angler survey to augment findings of 1997 field study

Lake Stevens is considered to be one of the finest fishing waters in Snohomish County. Depending on the season, it is not unusual for a competent angler to catch up to three preferred size (≥350 mm or 14" TL) smallmouth bass per hour, with at least one fish measuring ≥ 457 mm or 18" TL (Curt Kraemer, WDFW, personal communication). However, the results of the present study are incongruous with anecdotal reports for the lake. Therefore, a short-term (≤ 1 year) creel or angler survey might reveal additional information concerning the fishery, the minimum length rule, and angler satisfaction at Lake Stevens.

Change existing fishing rules to alter size structure of largemouth bass

Currently, Lake Stevens anglers are allowed to retain one largemouth bass or one smallmouth bass daily with a minimum length of 457 mm TL (18"). A minimum length limit should allow more largemouth or smallmouth bass to reach their full growth potential (Willis 1989), but the size structure of largemouth bass observed during early fall 1997 suggest that the rule is not working as intended. For example, although growth of smallmouth bass was rapid, growth of largemouth bass was slow. Similarly, although PSD and RSD values for smallmouth bass were reasonable when gill netting, those of largemouth bass were poor irrespective of sampling method. Yet the high relative weights of these fishes indicate that food was not limited. Still, over 90% of the largemouth and smallmouth bass captured measured less than 203 mm TL (8"); the CPUE for stock length fish was low.

Implementing a 254 - 457 mm (10 - 18") slot limit for largemouth bass at Lake Stevens might succeed where the minimum length limit failed (Willis 1989). Under this rule, only fish less than 254 or greater than 457 mm TL may be kept. Increasing the daily creel limit from one fish to five fish, of which only one can measure over 457 mm TL, would stimulate harvest of small fish while still protecting large fish. A reduction of small fish may improve growth and production of predator and prey species alike (McHugh 1990). An outstanding largemouth bass fishery was developed in Arkansas using this type of regulation (Turman and Dennis 1998); similar rule changes were proposed in Texas as well (Anonymous 1998).

However, the success of any rule changes depends upon angler compliance. Reasons for non-compliance include lack of angler knowledge of the rules for a particular lake, a poor understanding of the purpose of the rules, and inadequate enforcement (Glass 1984). Therefore, clear and concise multilingual posters or signs should be placed at Lake Stevens describing the fishing rules for the lake. Press releases should be sent to local papers, magazines, and sport fishing groups detailing the changes to, and purpose of, the rules. Furthermore, non-compliance may be reduced by increasing the presence of WDFW enforcement personnel at Lake Stevens during peak harvest periods.

Promote juvenile fishing derby for yellow perch and other panfish

Besides increased predation by largemouth bass, panfish numbers might be reduced by tournament anglers. Yellow perch and pumpkinseed can provide hours of enjoyment for eager, young anglers. Although significant control of these prolific fishes is nominal from such events, the opportunity for increased angler awareness and recreation is excellent.

Manage Lake Stevens for panfish

The original goal of the 457 mm (18") TL minimum length limit at Lake Stevens was to create trophy fisheries for largemouth and smallmouth bass. The main objectives were to improve the size structures of both species while increasing the catch of larger fish. If the results of this study are any indication, the objectives have not been met. However, the panfish populations at Lake Stevens are thriving. Not surprisingly, minimum length limits on predators, such as smallmouth or largemouth bass, are often used to develop quality panfish fisheries (Willis 1989). Therefore, the simplest management strategy might be developing the panfish fishery at the lake. A minimum length limit on predators would then be an appropriate management tool.

Support investigation of anomalous aquatic plant senescence

A healthy aquatic plant community is essential for the well-being of many warmwater fish species, which are more likely to be found in areas with aquatic plants than in areas without them (Killgore et al. 1989). Submersed aquatic vegetation provides important foraging, refuge, and spawning habitat (see review by Willis et al. 1997), improving survival and recruitment to harvestable sizes (Durocher et al. 1984). Changes in the standing crop of aquatic plants can alter fish production (Wiley et al. 1984) as well as the structure of the fish community itself (Bettoli et al. 1993). For these reasons, it is important to monitor the aquatic plant community in Lake Stevens, especially given the unusual die-back of submersed vegetation reported by Parsons (1998). Additional studies should be conducted to rule out disease or herbivory by aquatic insects as the cause of the anomalous senescence.

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