

***2000 Angle Lake Survey:
The Warmwater Fish Community
of a Heavily-fished,
Low-productivity Urban Lake***

by

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Abstract

Warmwater fish species dominated our catch from Angle Lake in late spring 2000. Growth of largemouth bass, pumpkinseed, rock bass, and yellow perch was consistent with or above western Washington State averages. However, CPUE for brown bullhead, largemouth bass, pumpkinseed and yellow perch were below average, suggesting low abundance of these species. Obvious gaps in the length frequency distribution of largemouth bass may be due to weather-related year-class failure, competition with the abundant yellow and rock bass, or overharvest of larger individuals. Conversely, rock bass in our sample were abundant and demonstrated high CPUE, strong growth, and relative weights consistent with state averages. Management options for Angle Lake include implementation of a slot limit for largemouth bass to improve size structure of that population, consider stocking channel catfish to increase angler opportunity and control abundant rock bass, or manage the lake for panfish.

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Introduction and Background

Angle Lake (Figure 1) is located within the city limits of the City of SeaTac (King County) at an elevation of 111 m (363 ft). This small lake has a surface area of about 41.3 ha (102 acres) with a small drainage basin of 207 ha (0.80 mi²) (Bortelson et al. 1976). Glacial in origin, Angle Lake formed during the Pleistocene about 25,000 years ago. The littoral zone substrate is mainly gravel with an overlay of flocculent mud of varying degrees from none to several inches deep. On most sides of the lake water depth increases rapidly away from the shore. The L-shaped lake has a volume of 3,210,990 m³ (2,600 acre-ft) and a maximum and mean depth of 15.9 m (52 ft) and 7.6 m (25 ft), respectively. Except for the city park with swimming beach, fishing pier, and boat launch areas on the southwest end of the lake, the shoreline of the lake is nearly completely developed with urban residences. There are approximately 195 homes within 100 meters of the lake shore.

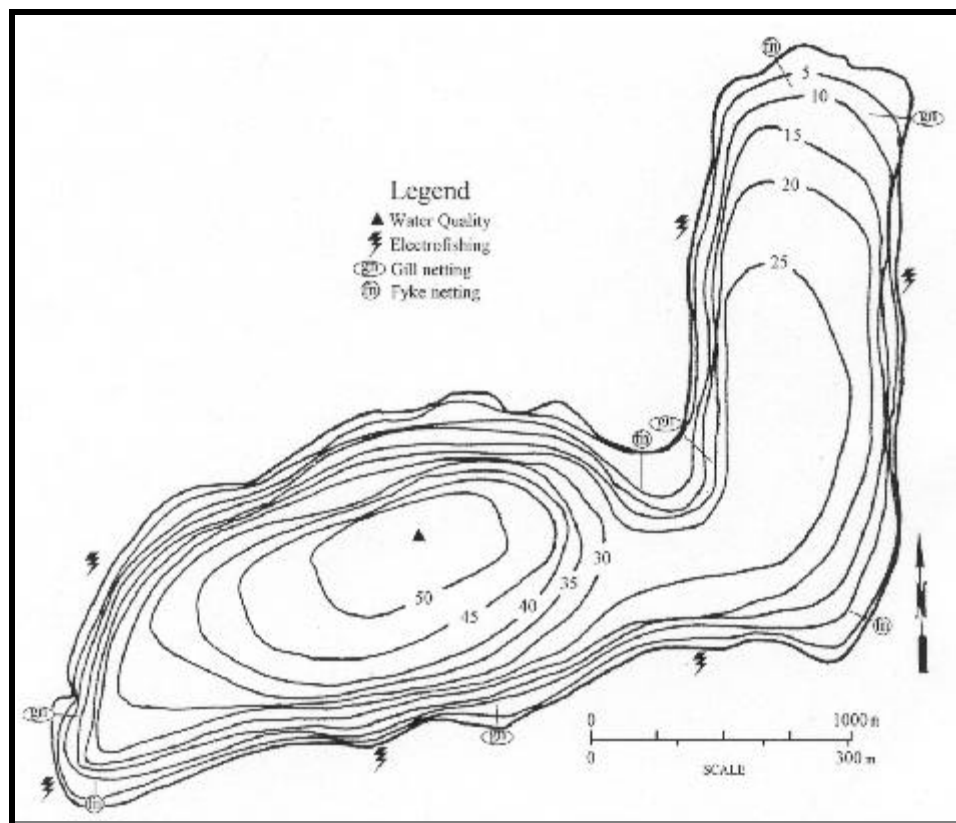


Figure 1. Map of Angle Lake (King County) showing sampling locations. Bolts indicate sections of shoreline where electrofishing occurred. Circled “fn” and “gn” symbols with lines extending into the lake represent fyke net and gill net sample locations, respectively. The triangle indicates the location of water quality sampling.

There are no stream inlets or outlets at the lake. Inflow is primarily from groundwater and rainfall while out flow is through groundwater seepage and, when water levels are high enough, a sewer system. The sewer system was installed around the perimeter of the lake in the late 1970s to prevent flooding of nearshore residences. Property owners successfully petitioned the courts to regulate outflow of Angle Lake in 1975, citing county and state development of streets and highways as the cause of increased inflow and limited outflow at the lake (KCSC 1975). The lake level changes with inflow and in 1998 fluctuated 0.98 m over the year (KCWLRD 1999). The highest water levels occur during the winter.

In 1998, summer secchi depths in Angle Lake averaged 6.6-m and was the second highest average transparency of 42 lakes monitored in King County (KCWLRD 1999). Chlorophyll *a*, total phosphorus, and total nitrogen values for Angle Lake fell generally at the low end or below the range of values observed on other lakes in King County. These low concentrations are indicative of low biological activity (oligotrophic conditions) and clean water quality. Based on Carlson's Trophic Status Index (TSI) which uses total phosphorus and chlorophyll *a* data to rate a lake's trophic status, Angle Lake is an oligotrophic body of water. Bacteria monitoring at Angle Lake on August 3, 1998 by King County's Lake Stewardship Program revealed fecal coliform counts in excess of 200 CFU/100 ml, which is considered high by most health officials. Goose droppings were speculated to be the major source of the bacteria. At the time of our survey, Angle Lake was thermally stratified with water temperatures of 18°C at the surface, 8°C at the bottom, and the metalimnion between 6 and 10 m (see Table 3). Dissolved oxygen decreased below 5 mg/L between 11 and 12-m of depth and was as low as 1.25 mg/L at the bottom of the lake. Water transparency was very high with a secchi disk reading of 7.3 m. These parameters were consistent with previous data compiled by King County Water and Land Management.

The aquatic plant community of Angle Lake is sparse and limited by its low productivity. Moreover, suitable habitat for submersed vegetation is limited, in part, because of the steep morphometry of the lake. Nearshore development has, in the past, included filling in shallows that further reduced available plant habitat (WDFW, unpublished data). We observed small patches of submergent, emergent and floating vegetation including sedges (Family Cyperaceae), pond weed (*Potamogeton sp.*) and pond lilies (Family Nymphaeaceae). Also, isolated patches of the weed, reed canary grass (*Phalaris arundinacea*) have been reported (KCWLRD 2000).

Sport fishing is an important activity at Angle Lake which has been stocked with rainbow trout for decades. Washington Department of Fish and Wildlife (WDFW), then acting as the Washington Department of Game (WDG), secured a public access area in 1952 with the condition that the department stock the lake with fish. Near shore shallows exist in the north arm of the lake and at the inside of the bend or angle of the lake. Because of its shallow slope and the presence of submersed plants in which small fish could hide and find food, this site was recommended as "the only good place" to release fish (WDFW, unpublished data). In September 1954, an estimated seven to nine thousand fingerling rainbow trout died after being released into the lake. The cause of the fish kill was never

determined, but some WDG staff blamed “toxic shock”, a condition observed in other stocking events but not well understood. The lake was rehabilitated in 1954 to remove yellow perch, pumpkinseed, and largemouth bass. Prior to rehabilitation, warmwater species dominated samples from the lake (Table 1).

Table 1. Fish species composition changes at Angle Lake (King County) since 1938 (Washington Department of Fish and Wildlife, unpublished data).

Date	Sample method	Sample size (# fish)	Species composition by number
Summer 1938	Angler survey (31 anglers)	89	84% yellow perch (<i>Perflavescens</i>), 7% bullhead (<i>Ameiurus</i> sp.), 7% largemouth bass (<i>Micropterus salmoides</i>)
Summer 1940	Angler reports (16 anglers)	118	50% largemouth bass, 45.8% kokanee, 4.2% rainbow trout (<i>Oncorhynchus mykiss</i>)
Summer 1952	Angler reports (160 anglers)	1,591	98.1% rainbow trout (<i>Oncorhynchus mykiss</i>), 1.26% yellow perch, 0.01% largemouth bass
Summer 1960-69	Angler reports (75 anglers)	992	99.4% rainbow trout, 0.6% yellow perch
Summer 1970-73	Angler reports (192)	451	98.2% rainbow trout, 1.1% bullhead, 0.7% yellow perch

Since the mid-1980's, the lake has been managed as a mixed species water open to angling year-round. Angle Lake continues to support an active sports fishery composed of seasonally stocked rainbow trout, kokanee (*Oncorhynchus nerka*), largemouth bass and yellow perch (*Perca flavescens*) (Tables 1 and 2). Angle Lake is a well known and popular trout fishing lake located close to home for many urban anglers. It is a kid-friendly lake with a county park, public fishing dock, shore access and modern restrooms (Rudnick 1978; Anonymous 2000). Furthermore, the lake has been noted as one of the top ten largemouth bass waters in King County (Johansen 1999). In order to manage these fisheries more effectively, the WDFW Warmwater Enhancement Program conducted a stock assessment in late spring 1999. We assessed species composition, abundance, size structure, growth, and condition of fish in the lake. We also evaluated habitat and access, then outlined options for enhancing the fishery and fishing opportunity on the lake.

Table 2. Opening day catch statistics at Angle Lake for 1996, 1997 and 1999.

Year	Species	# of fish	Total angler hours	CPUE (fish/hr.)
1996	Rainbow trout	27	61.8	0.44
1997	Rainbow trout	37	69.2	0.54
1999	Rainbow trout	5	42.5	0.12
1999	Kokanee	9	42.5	0.21

Materials and Methods

Angle Lake was surveyed during June 5 to June 7, 2000 by a three-person team consisting of two biologists and one scientific technician. Fish were captured using three sampling techniques: electrofishing, gill netting, and fyke netting. The electrofishing unit consisted of a 4.9 m Smith-Root 5.0 GPP 'shock boat' set to 250 volts of 6 amp pulsed DC (120 cycles/sec). 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. Fyke nets were constructed of a single 30.4 m lead and two 15.2 m wings of 130 mm nylon mesh. The bodies of the nets were stretched around four 1.2 m aluminum rings in each of two sections.

Sampling locations were selected by dividing the shoreline into 10 consecutively numbered sections of about 400 m each (determined visually from a map). Nine of these sections were then systematically sampled to maximize dispersion of gear types. While electrofishing, the boat was maneuvered through the shallows (depth range: 0.2 - 1.5 m), adjacent to the shoreline, at a rate of 18.3 m/minute. Gill nets and fyke nets were set overnight at four locations each (=4 net nights for each gear type). Gill nets were set perpendicular to the shoreline. The small-mesh end was attached onshore while the large-mesh end was anchored offshore. The fyke nets were set in water less than 3 m deep with wings extended at 70E angles from the lead. Sampling occurred during evening hours to maximize the type and number of fish captured. Nighttime electrofishing occurred along 30% (~2.4 km) of the available shoreline (Figure 1).

With the exception of sculpin (Family Cottidae), all fish captured were identified to the species level and aged. 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 ($n < 100$ 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). Brown bullhead (*Ameiurus nebulosus*) were not aged because of technical limitations.

Using a Hydrolab® probe and digital recorder, water quality data was collected during midday on June 7, 2000 (Figure 1). Table 3 summarizes the information gathered on dissolved oxygen, total dissolved solids, temperature, pH, and specific conductance from a point near the deepest part of the lake.

Table 3. Water quality at Angle Lake (King County). Samples were collected late-morning June 7, 2000. DO = dissolved oxygen, TDS = total dissolved solids.

Secchi depth	Depth (m)	DO (mg/L)	Temperature (EC)	pH	Conductance (µS/cm)	TDS (g/L)
7.3 m	1	9.89	18.3	7.01	56.3	0.0361
	2	9.06	18.3	7.00	56.7	0.0362
	3	8.67	18.3	7.03	56.3	0.0363
	4	8.49	18.3	7.05	56.6	0.0363
	5	8.55	18.3	7.07	56.5	0.0360
	6	8.49	17.4	7.08	56.5	0.0361
	7	8.43	17.3	7.07	56.5	0.0362
	8	8.05	13.6	6.98	56.7	0.0364
	9	7.22	12.5	6.89	56.7	0.0364
	10	6.50	10.8	6.80	57.4	0.0367
	11	5.10	9.5	6.71	57.9	0.0368
	12	3.83	8.7	6.62	58.6	0.0376
	13	2.13	8.5	6.54	59.9	0.0379
	14	1.25	8.2	6.44	68.3	0.0433

In order to characterize the trophic status of the lake we applied Carlson's Trophic Status Index (TSI) to total phosphorus and chlorophyll *a* data collected by the King County Water and Land Resources Division (KCWL RD 1999). The TSI rates a lake's trophic status on a continuous scale from 0 to 100 based upon Secchi depth, total phosphorus concentrations, and chlorophyll *a* abundance. Criteria derived from application of the TSI have led to classifications for oligotrophic lakes ranging between 0 and 40, mesotrophic lakes between 40 and 60, and eutrophic lakes ranging between 60 and 100. Carlson (1977) generated regression equations for chlorophyll *a* and total phosphorus which are as follows:

$$\text{TSI(Chl } a) = 9.81(\ln \text{Chl } a) + 30.6 \text{ where Chl } a \text{ is in } \mu\text{g/L}$$

$$\text{TSI(TP)} = 14.42(\ln \text{TP}) + 4.15 \text{ where TP is in } \mu\text{g/L}$$

We used mean monthly values of chlorophyll *a* and total phosphorus (Figure 2) which placed Angle Lake in the mid to upper oligotrophic class with mean TP and Chl *a* values of 7.76 µg/L and 2.27 µg/L respectively, and corresponding TSI values of 33.7 and 38.6, respectively.

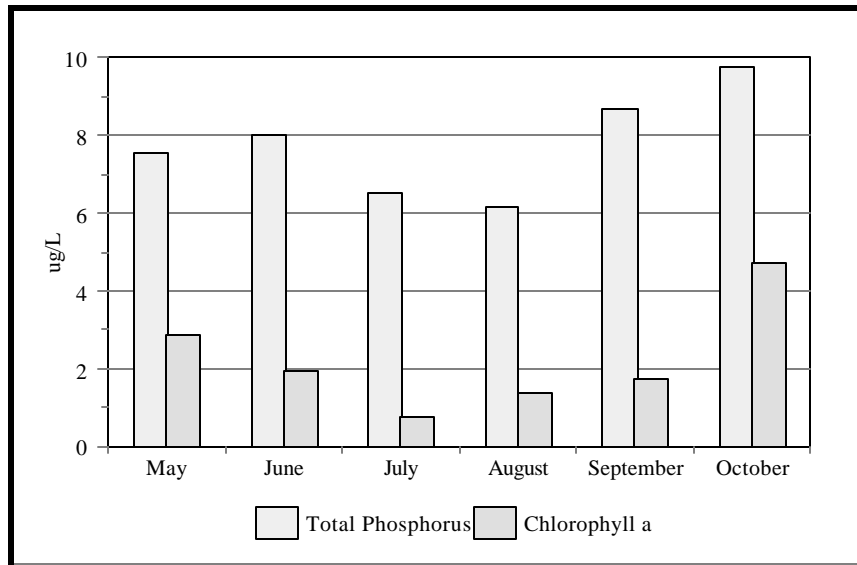


Figure 2. Epilimnetic total phosphorus and chlorophyll *a* concentrations for Angle Lake between May and October 1998 (Source: King County Water and Land Resources Division).

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, catch rates, 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).

We determined species composition by weight (kg) of fish captured using procedures adapted from Swingle (1950). The species composition by number of fish captured was determined using procedures outlined in Fletcher et al. (1993) with one exception. While young-of-year or small juveniles are often not considered because large fluctuations in their numbers may lead to misinterpretation of results (Fletcher et al. 1993), we chose to include them since their relative contribution to total species biomass was small. Moreover, the overall length frequency distribution of fish species may suggest successful spawning and initial survival during a given year, as indicated by a preponderance of fish in the smallest size classes. Many of these fish would be subject to natural attrition during their first winter (Chew 1974), resulting in a different length frequency distribution by the following year. However, the presence of these fish in the system relates directly to fecundity, forage

base for larger fish, and interspecific and intraspecific competition at lower trophic levels (Olson et al. 1995). We therefore rely on species composition as an ecological indicator and catch per unit effort (CPUE) and proportional stock density (PSD) as stock indicators.

The percent species composition by weight was calculated as the weight of fish captured of a given species divided by the total weight of all fish captured $\times 100$. The species composition by number was calculated as the number of fish captured of a given species divided by the total number of all fish captured $\times 100$.

Catch per unit effort (CPUE) by gear type was determined for all species (number of fish/hour electrofishing and number of fish/net night). Only stock size fish and larger were used to determine CPUE for the warmwater species and salmonids, whereas CPUE for non-game fish were calculated for all sizes. Stock length, which varies by species (Table 4), 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 $\pm t_{(\alpha, -1)} \times SE$, 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 and the confidence intervals express the relative uniformity of species distributions throughout a given lake. CPUE values for Angle Lake were then compared to western Washington State averages compiled by the WDFW Inland Fisheries Research Unit (Table 5).

Table 4. Length categories for cold- and warmwater fish species used to calculate stock density indices (PSD and RSD; Gablehouse 1984) of fish captured at Angle Lake (King County) during late spring 2000. Measurements are minimum total lengths (mm) for each category (Anderson and Neumann 1996; Bister et al. 2000; Hyatt and Hubert, Wyoming Cooperative Fish and Wildlife Unit, University of Wyoming, unpublished data).

Species	Minimum size (mm)				
	Stock	Quality	Preferred	Memorable	Trophy
Black crappie	130	200	250	300	380
Cutthroat trout	200	350	450	600	750
Kokanee	200	250	300	400	500
Largemouth bass	200	300	380	510	630
Pumpkinseed	80	150	200	250	300
Rainbow trout	250	400	500	650	800
Yellow perch	130	200	250	300	380

Table 5. Mean catch per unit effort (number of fish/hr electrofishing and number of fish/net night) for stock size fish collected from several western Washington State lakes while electrofishing, gill netting, and fyke netting during 1997 and 1998 (WDFW Inland Fisheries Research Unit, unpublished data).

Species	Gear Type					
	Electrofishing		Gillnetting		Fykenetting	
	(fish/hr)	# lakes	(fish/hr)	# lakes	(fish/hr)	# lakes
Brown bullhead	7.8	10	14.4	7	12.7	6
Largemouth bass	41.6	12	1.9	8	0.3	1
Black crappie	9.6	4	4.2	3	23.4	2
Pumpkinseed	70.8	11	3.8	9	7.9	4
Yellow perch	97.5	8	13.7	6	0.2	2

The proportional stock density (PSD) of each 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 $\times 100$, 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 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 5). 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 $\times 100$. 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).

PSD and RSD have become important tools for assessing size structures of warmwater fish populations and determining management options for warmwater fish communities (Willis et al. 1993). Three major management options commonly implemented for these communities include the panfish option, balanced predator-prey option, and big bass option and each of these has associated ranges of PSD and RSD values (Table 6).

Table 6. Stock density index ranges for largemouth bass and bluegill under three commonly implemented management strategies (from Willis et al. 1993). PSD = proportional stock density, whereas RSD = relative stock density of preferred length fish (RSD-P), and memorable length fish (RSD-M).

Option	Largemouth bass			Bluegill	
	PSD	RSD-P	RSD-M	PSD	RSD-P
Panfish	20 - 40	0 - 10		50 - 80	10 - 30
Balanced	40 - 70	10 - 40	0 - 10	20 - 60	5 - 20
Big bass	50 - 80	30 - 60	10 - 25	10 - 50	0 - 10

Age and growth of fishes in Angle Lake 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 Angle Lake fish and the state average for the same species (listed in Fletcher et al. 1993).

While total length at the end of a given age provides valuable information on relationships of length frequency to age of a population and gives some indication of overall growth, instantaneous growth is a better measure of actual growth (Ricker 1975). Because it is an incremental measure, instantaneous growth also allows for analysis of life stage-specific patterns in growth. For example, it is not uncommon for a population to display below average total length across all age classes even though growth rates were only below average during the first or second year of life (Downen and Mueller 2000). Generally, we see a pattern of growth characterized by initially higher values that decline each year in the form of an inverse exponential relationship. Sometimes growth is highest in the second year but thereafter the same general pattern ensues. Occasionally, instantaneous growth rate values averaged across a population or populations are negative for older age classes due to the propensity of long-lived individuals or populations to become stunted. However, this does not mean actual growth is negative, but rather that the optimum overall growth rates and subsequent length frequency distributions may occur at some level of exploitation. The utility of identifying these patterns becomes apparent when assessing the ecological constraints on growth with the objective of population manipulation as a means of influencing these rates. For example, the implementation of a slot limit eloquently addresses situations where competition limits growth in both younger and older age classes of relatively long-lived fish. Yet a maximum length rule might be more effective for thinning younger age classes and reducing competition of relatively short-lived fish and allowing those remaining to attain greater size.

Annual average instantaneous growth rates, G , are defined as the difference between the natural logarithms of successive sizes over a unit of time, and were calculated according to Ricker (1975). The working formula is $G = (\log_e Y_2 - \log_e Y_1) / (t_2 - t_1)$, where t_1 is the time at the beginning of an interval and t_2 the time at the end and Y_1 and Y_2 are the respective fish sizes at those times. Because the unit time expression is calculated for one year intervals and equals one, it drops out. For fish size, Y , we used weight, w , and with reorganization, the equation becomes $G = \ln(w_t/w_0)$, where w_t is the estimated average weight at time t and w_0 is the average estimated weight at time 0 . Fish weights were estimated from average total length using the linear regression of \log_{10} -length on \log_{10} -weight resulting in $w = 10^{(m \log(TL) + b)}$, where m is the standard slope and b is the standard intercept for a given species (Ricker 1975). These standardized weights represent the least biased estimate of average weight throughout the year since they are not influenced by seasonal fluctuations due to spawning, feeding, or overwintering. Mean annual G was then compared to the state average, G_{avg} , derived similarly from the data listed in Fletcher et al (1993).

The size structure of each species captured was evaluated by constructing a stacked length frequency histogram (percent frequency of fish in a given size class captured by each gear type). Although length frequencies are generally reported by gear type, we report the length frequency of our catch with combined gear types which is then broken down by the relative contribution each gear type makes to each size class. Selectivity of gear types not only biases species catch based on body form, and behavior, but also based on size classes and subsequent habitat use within species (Willis et al. 1993). Therefore, an unbiased assessment of length frequency is unlikely under any circumstance. Our standardized 1:1:1 gear type ratio adjusts for differences in sampling effort between sampling times and locations. Furthermore, differences in size selectivity of gear types may in some circumstances result in offsetting biases (Anderson and Neumann 1996). Length frequency proportions for each gear type are divided by the total numbers of fish caught by all gear types for each size class. This changes the scale but not the shape of the length frequency percentages by gear type. If concern arises that pooled gear does not represent the least biased assessment of length frequency for a given species, then the shape of the gear type-specific distributions is still represented on the graphs, and these may be interpreted independently.

A relative weight (W_r) index was used to evaluate the condition of all species except sculpin. A W_r value of 100 generally indicates that a fish is in good condition when compared to the national standard (75th 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 of the W_s equations for many cold- and warmwater fish species, including the minimum length recommendations for their application, have been compiled by Anderson and Neumann (1996), Bister et al. (2000), as well as Mathew W. Hyatt and Wayne A. Hubert (Wyoming

Cooperative Fish and Wildlife Research Unit, University of Wyoming, unpublished data). With the exception of sculpin, the W_r values from this study were compared to the national standard ($W_r = 100$) and, where available, the mean W_r values from up to 25 western Washington lakes sampled during 1997 and 1998 (Steve Caromile, WDFW, unpublished data).

Results and Discussion

Species Composition

During late spring 2000, our sample was dominated by rock bass and yellow perch in terms of biomass and number (Table 7 and Figure 3). Together these species accounted for 72% of the species composition by weight and 85% by number. Largemouth bass accounted for less than one percent of the species composition by number but more than 13% by weight, whereas pumpkinseed accounted for about 5% by species and biomass. This is the first official record of rock bass (*Ambloplites rupestris*) in Angle Lake. Although black crappie (*Pomoxis nigromaculatus*) have been reported anecdotally in years past (Rudnick 1978), no official records exist of their presence, suggesting that rock bass were misidentified as black crappie.

Table 7. Species composition by weight (kg) and number of fish captured at Angle Lake (King County) during late spring 2000.

Species	Species composition				
	by weight		by number		Size range
	(kg)	(%) weight	(#)	(%) n	(mm TL)
Brown bullhead (<i>Ameiurus nebulosus</i>)	2.332	5.93	2	0.34	375 - 416
Goldfish (<i>Carassius auratus</i>)	0.035	0.09	1	0.17	144 - 144
Largemouth bass (<i>Micropterus salmoides</i>)	5.228	13.29	5	0.85	115 - 515
Pumpkinseed (<i>Lepomis gibbosus</i>)	1.673	4.25	28	4.75	85 - 190
Rainbow trout (<i>Oncorhynchus mykiss</i>)	0.949	2.41	6	1.02	233 - 289
Rock bass (<i>Ambloplites rupestris</i>)	16.417	41.74	333	56.54	45 - 209
Sculpin (<i>Cottus</i> sp.)	0.813	2.07	41	6.96	56 - 171
Yellow perch (<i>Perca flavescens</i>)	11.889	30.22	173	29.32	92 - 260
Total	39.336		589		

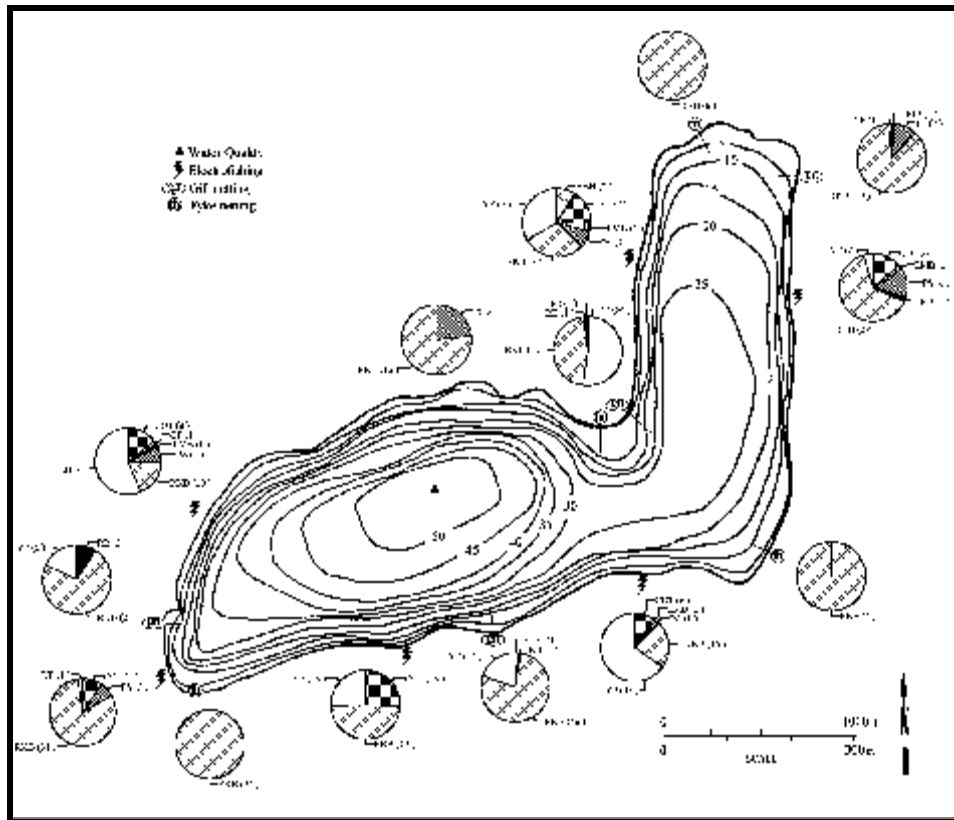


Figure 3. Map of Angle Lake (King County) showing fish counts by species for each sampling location. Catch data for each sample location, including species and number, is represented by adjacent pie-chart graphs. Species key: BBH = brown bullhead, COT = sculpin, GF = goldfish, LMB = largemouth bass, PS = pumpkinseed, RB = rainbow trout, RKB = rock bass, YP = yellow perch.

CPUE

Catch per unit effort for all gear types – electrofishing, gill netting, and fyke netting – was highest for stock-length rock bass (Table 8). While electrofishing rock bass catch rates were 100 fish/hour. Electrofishing catch rates for rock bass in other western Washington State lakes where they have been sampled include 37.7 fish/hour at Mason Lake in Mason County (Mueller 1999), 24.8 fish/hour at Green Lake in King County (Mueller 1998), and 142.2 fish/hour at American Lake in Pierce County (Mueller and Downen 1999). CPUE for largemouth bass for all gear types were a small fraction of averages observed in other western Washington State lakes (Table 3) indicating a low density population. Brown bullhead and pumpkinseed were also low compared to western Washington State averages for all gear types. Yellow perch catch rates while electrofishing and fyke netting were low compared to state averages but were above average for gill netting. For species other than the warmwater variety, electrofishing catch rates were highest for sculpin.

Table 8. Mean catch per unit effort (number of fish/hour electrofishing and number of fish/net night), including 80% confidence intervals for stock-length warmwater fish, salmonids, and non-game fish collected from Angle Lake (King County) while electrofishing, gill netting, and fyke netting during late spring 2000.

Species	Gear type					
	Electroshocking (#fish/hour)	Shock sites	Gill netting (# fish/hour)	n (net nights)	Fyke netting (# fish/hour)	n (net nights)
Brown bullhead	1.96 ^a	6	0	4	0	4
Goldfish	0.99 ^a	6	0	4	0	4
Largemouth bass	2.97 ± 1.7	6	0.25 ^a	4	0	4
	15.77 ± 6.75	6	2 ^a	4	1 ^a	4
Pumpkinseed	0	6	0.75 ± 0.61	4	0	4
Rainbow trout	100.6 ± 24.89	6	46 ± 9.86	4	6.5 ± 2.89	4
Rock bass	39.01 ± 9.86	6	0.25 ± 0.32	4	0	4
Sculpin	27.68 ± 26.8	6	18 ± 15.72	4	0	4
Yellow perch						

^a Sample size too small or catch rates too variable to permit calculation of reliable confidence intervals

Stock Density Indices

Proportional stock density indices for rock bass while electrofishing, gill netting, and fyke netting were consistent with PSD values generally accepted of a population managed for a balance between predator and prey species (Table 9). For yellow perch, PSD and RSD values while gill netting were similar to those of populations managed under the panfish option. Of the stock-length largemouth bass sampled in our survey, all were larger than the minimum for “preferred” sized fish and one was larger than the minimum for “memorable” sized fish. PSD and RSD values for largemouth bass and pumpkinseed were closest to those of populations generally accepted to be managed for big bass. This supports the popular opinion that Angle Lake can produce hefty bass (Johanson 1999). However, sample sizes of largemouth bass in our survey were too small to make a reliable determination. For predators such as largemouth bass, the generally accepted stock density index ranges for “big bass” option fish populations are PSD values of 50 to 80, RSD-P values of 30 to 60, and RSD-M values of 10 to 25. For balanced panfish populations, PSD values range from 30 to 60 (Gabelhouse 1984; Willis et al. 1993). The PSD and RSD values for brown bullhead, largemouth bass, and rainbow trout (Table 9) should be viewed with caution, especially given the low catch rates for stock-size fish and small sample sizes used to determine these indices (Divens et al. 1998).

Table 9. Traditional stock density indices including 80% confidence intervals for cold and warmwater fishes collected from Angle Lake (King County) while electrofishing, gill netting and fyke netting during late spring 1999. 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). EB = electrofishing, GN = gill netting and FN = fyke netting.

Species	Gear type	# Stock length fish	PSD	RSD-P	RSD-M	RSD-T
Brown bullhead	EB	2	100	100	50 ± 45	0
	GN	0	0	0	0	0
	FN	0	0	0	0	0
Largemouth bass	EB	3	100	100	33 ^a	0
	GN	1	100	0	0	0
	FN	0	0	0	0	0
Pumpkinseed	EB	16	19 ± 13	0	0	0
	GN	8	13 ± 15	0	0	0
	FN	4	0	0	0	0
Rainbow trout	EB	0	0	0	0	0
	GN	3	0	0	0	0
	FN	0	0	0	0	0
Rock bass	EB	103	34 ± 6	0	0	0
	GN	184	24 ± 4	0	0	0
	FN	26	19 ± 10	0	0	0
Yellow perch	EB	28	29 ± 11	0	0	0
	GN	72	74 ± 7	6 ± 3	0	0
	FN	0	0	0	0	0

^a Sample size too small or catch rates too variable to permit the calculation of reliable confidence intervals.

Brown bullhead

Two brown bullhead were captured while electrofishing the western shore of the north arm of the lake. These fish were 375 and 416 mm TL, respectively (Figure 4). Relative weights were above the national 75th percentile (Figure 5).

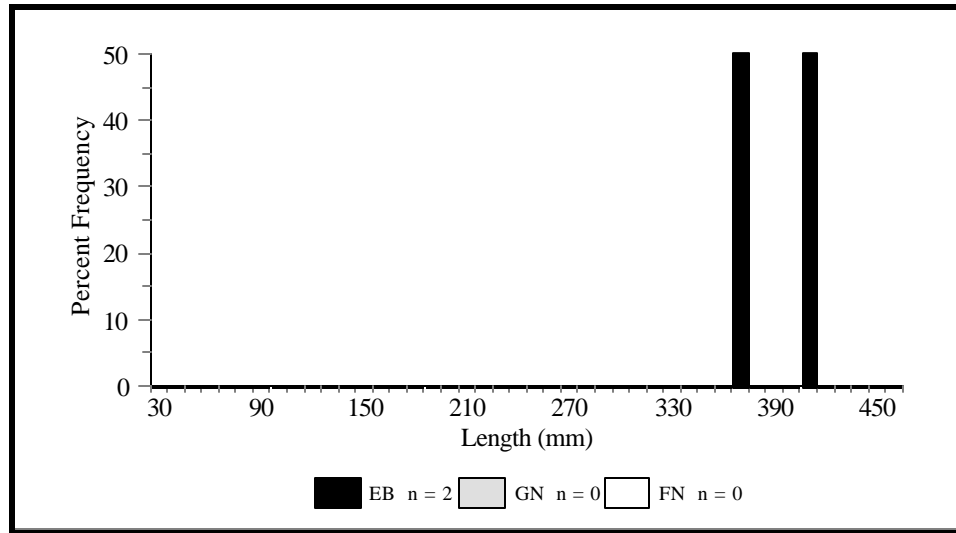


Figure 4. Length frequency histogram of brown bullhead sampled from Angle Lake (King County) in late spring 2000. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

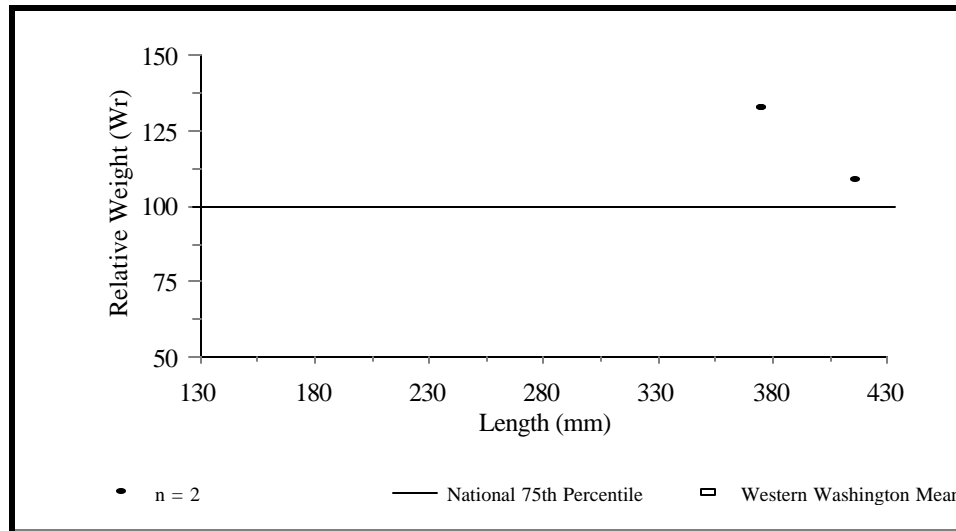


Figure 5. Relationship between total length and relative weight (W_r) of brown bullhead from Angle Lake (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Goldfish

One goldfish measuring 144 mm (age 3+) and weighing 35 g was captured while electrofishing. This fish was likely released into the lake from a private home aquarium.

Largemouth bass

Angle Lake largemouth bass ranged in size from 115 to 515 mm TL (age 1+ to 7+) and displayed variable year-class strength (Table 10). No fish were collected from the 1994, 1995 or 1998 year classes. Few quality size fish were captured. However, it is unknown whether this was due to natural factors or overharvest. Of the five largemouth bass captured, four were captured while electrofishing and the other while gill netting (Figure 6). Largemouth bass exhibited strong growth rates, especially during the first two years of life. For all sampled year classes, mean lengths at age of Angle Lake largemouth bass were marginally larger than western Washington State averages. Relative weights were consistent with state averages and, except for one 515 mm individual, exceeded the national 75th percentile (Figure 7).

Table 10. Age and growth of largemouth bass (*Micropterus salmoides*) captured at Angle Lake (King County) during late spring 2000. 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 total length (mm) at age						
		1	2	3	4	5	6	7
1999	1	97.8						
		100.8						
1998	0							
1997	2	118.5	308.5	382.0				
		132.4	312.3	382.0				
1996	1	55.9	259.0	382.0	422.0			
		73.3	266.7	383.9	422.0			
1995	0							
1994	0							
1993	1	112.1	209.0	295.4	398.4	440.8	489.3	515.0
		127.7	220.9	303.9	402.9	443.7	490.3	515.0
Overall mean		96.1	258.8	353.1	410.2	440.8	489.3	515.0
Weighted mean		113.3	278.1	363.0	412.4	443.7	490.3	515.0
Western WA average		60.4	145.5	222.2	261.1	289.3	319.0	367.8
<i>G</i>		3.597	3.062	0.96	0.463	0.222	0.322	0.158
<i>G_{avg}</i>		2.162	2.717	1.308	0.498	0.317	0.302	0.440

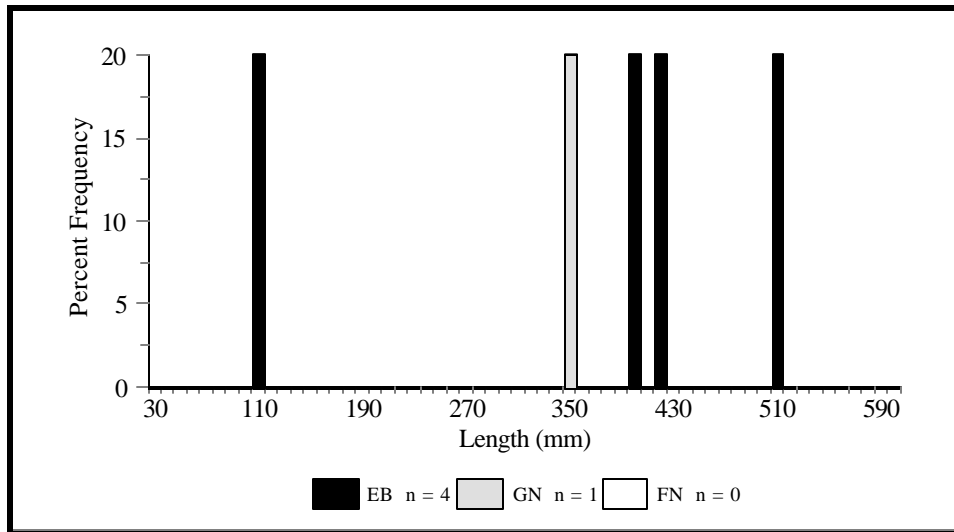


Figure 6. Length frequency histogram of largemouth bass sampled from Angle Lake (King County) in late spring 2000. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

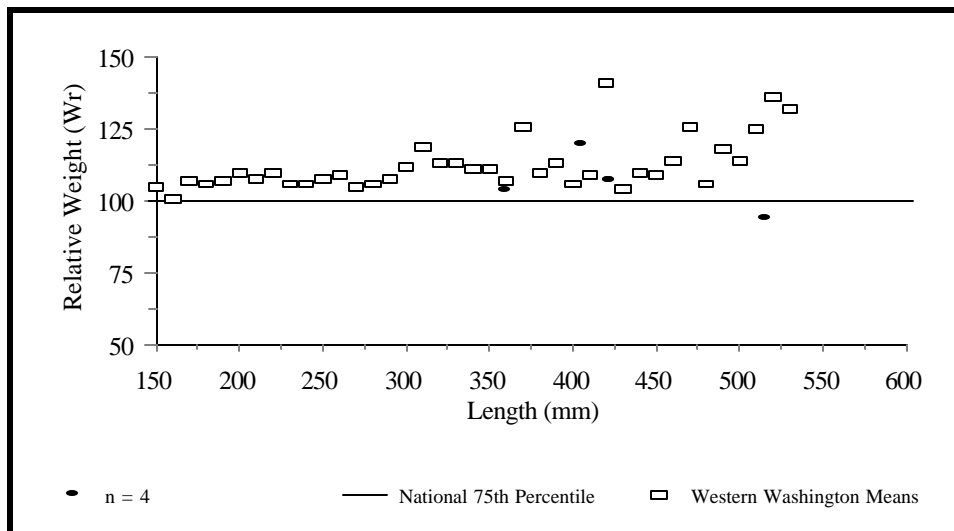


Figure 7. Relationship between total length and relative weight (W_r) of largemouth bass from Angle Lake (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Pumpkinseed

Angle Lake pumpkinseed ranged in size from 85 to 190 mm TL and demonstrated variable year-class strength (Table 11 and Figure 7). The 1998 year-class was well represented however no fish were collected from the 1996 or 1999 year-classes. Instantaneous growth rates, G , by age class were consistent with averages for western Washington. Relative weights generally exceeded western Washington State averages (Figure 9). Higher relative weights may be related to increased gonad weight during spawning (Blackwell et al. *In press*). Two gravid females, with total lengths of 133 and 185 mm respectively, were identified in our samples.

Table 11. Age and growth of pumpkinseed (*Lepomis gibosus*) captured at Angle Lake (King County) during late spring 2000. 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	# fish	Mean total length (mm) at age				
		1	2	3	4	5
1999	0					
1998	19	25.8	103.2			
		45.5	106.4			
1997	3	40.3	86.2	122.2		
		57.8	95.3	124.6		
1996	0					
1995	3	31.4	98.1	130.0	164.9	185.0
		52.2	109.9	137.4	167.6	185.0
Overall mean		32.5	95.8	126.1	164.9	185.0
Weighted mean		47.8	105.5	131.0	167.6	185.0
Western WA average		23.6	72.1	101.6	122.7	139.4
	G	1.461	3.256	0.825	0.807	0.347
	G_{avg}	0.498	3.362	1.032	0.568	0.384

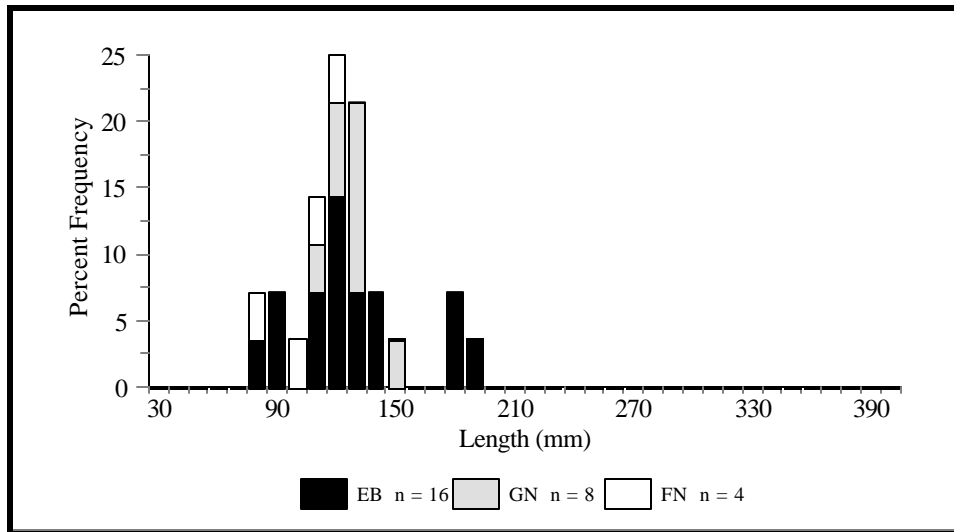


Figure 8. Length frequency histogram of pumpkinseed sampled from Angle Lake (King County) in late spring 2000. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gillnetting, and FN = fykenetting.

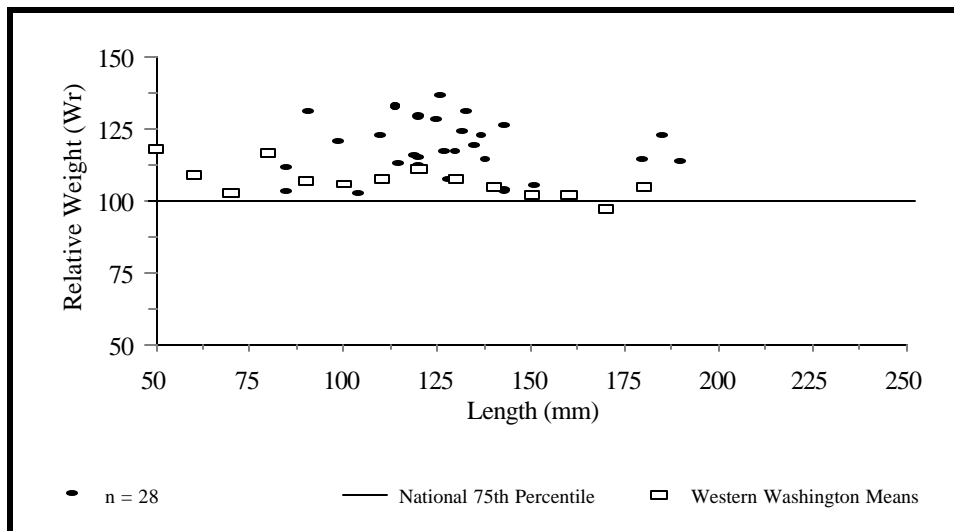


Figure 9. Relationship between total length and relative weight (W_r) of pumpkinseed from Angle Lake (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Rainbow trout

A total of six rainbow trout were captured while electrofishing and gill netting (Figure 10). These fish were similar in size and ranged between 233 and 289 mm TL. Scales were not taken for aging analysis as these fish were most likely stocked in the spring of 2000. Relative weights of rainbow trout were below the national 75th percentile (Figure 11).

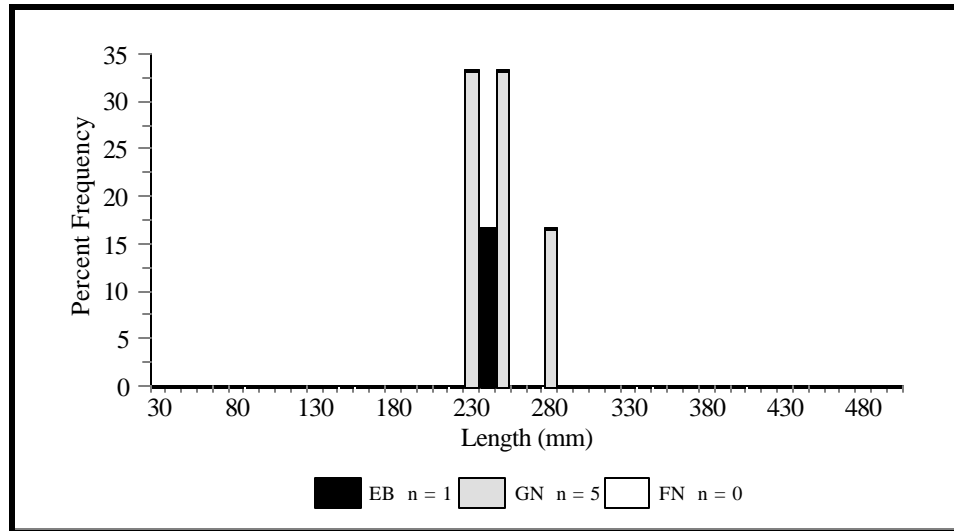


Figure 10. Length frequency histogram of rainbow trout sampled from Angle Lake (King County) in late spring 2000. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gillnetting, and FN = fykenetting.

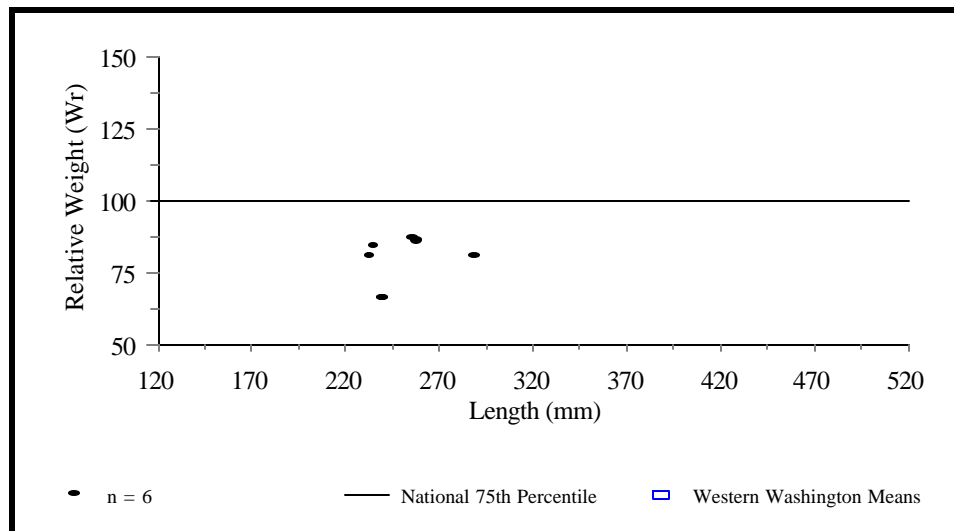


Figure 11. Relationship between total length and relative weight (W_r) of rainbow trout from Angle Lake (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Rock bass

Rock bass appear to be thriving at Angle Lake. Rock bass ranged in size from 45 to 209 mm TL (age 1+ to 5+) and were well represented in each year class sampled (Table 12, Figure 12). Growth, as indicated by length at age, exceeded western Washington State averages and decreased as fish reached age 4 and 5. Relative weights were consistent with state averages and the national 75th percentile for fish up to about 160 mm in size, then decreased with length (Figure 13).

Table 12. Age and growth of rock bass (*Ambloplites rupestris*) captured at Angle Lake (King County) during late spring 2000. 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 total length (mm) at age				
		1	2	3	4	5
1999	8	40.7				
		47.0				
1998	17	38.6	91.7			
		54.5	95.1			
1997	18	36.4	86.4	134.3		
		55.0	96.1	135.4		
1996	10	37.6	89.5	145.8	170.1	
		57.2	101.7	149.8	170.7	
1995	10	33.7	79.5	132.9	161.2	180.3
		54.0	93.5	139.6	164.0	180.5
Overall mean		37.4	86.8	137.7	165.7	180.3
Weighted mean		54.0	96.3	140.3	167.3	180.5
Western WA average		29.0	69.6	117.6	151.6	178.1

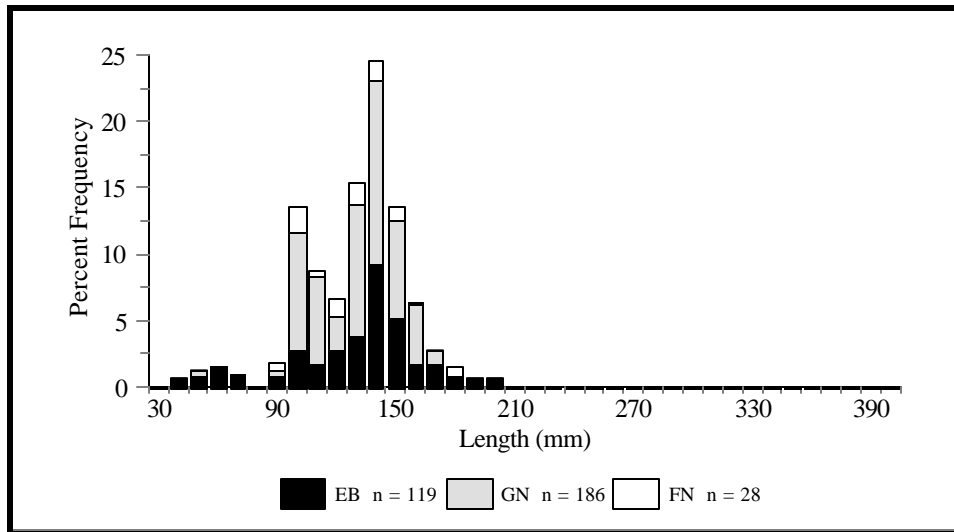


Figure 12. Length frequency histogram of rock bass sampled from Angle Lake (King County) in late spring 2000. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gillnetting, and FN = fykenetting.

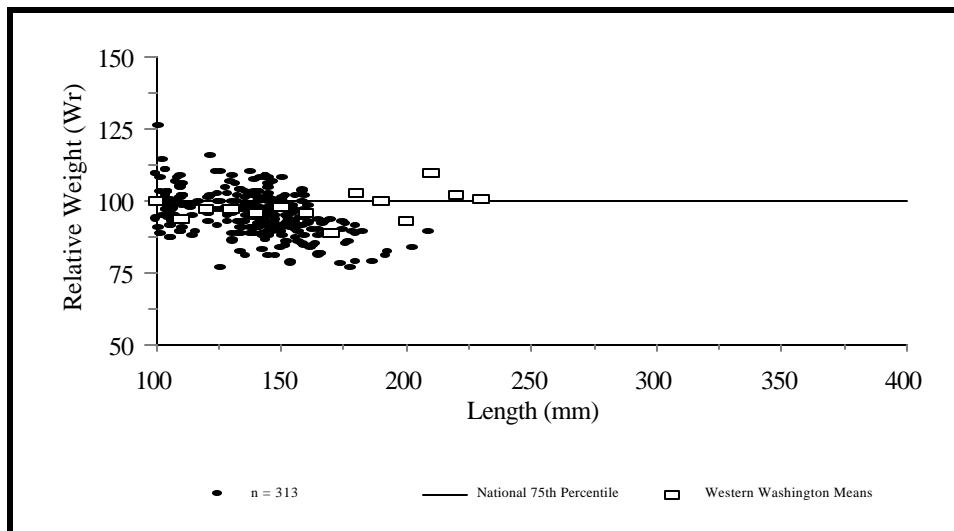


Figure 13. Relationship between total length and relative weight (W_r) of rock bass from Angle Lake (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Sculpin

We captured a total of 41 sculpin ranging in size from 56 to 171 mm (Figure 14). Sculpin were the third most abundant species sampled during our survey.

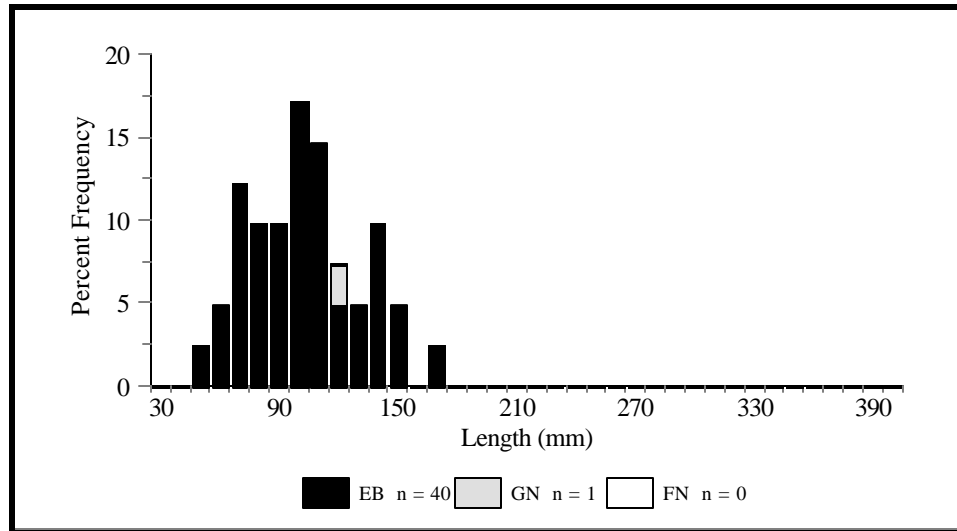


Figure 14. Length frequency histogram of sculpin sampled from Angle Lake (King County) in late spring 2000. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be view collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

Yellow perch

Yellow perch ranged in size from 92 to 260 mm (age 1+ to 4+) (Table 13, Figure 15). Age 1+ and 3+ fish were in greatest abundance while age 2+ and 4+ fish were less well represented. Growth rates of Angle Lake yellow perch consistently exceeded western Washington State averages across available age classes 1+ through 4+. Relative weights were low when compared with the national standard but consistent with western Washington averages (Figure 16).

Table 13. Age and growth of yellow perch (*Perca flavescens*) captured at Angle Lake (King County) during late spring 2000. 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 total length (mm) at age			
		1	2	3	4
1999	23	96.3			
		101.8			
1998	9	79.6	169.4		
		96.4	171.4		
1997	26	80.1	140.3	208.0	
		98.8	150.7	208.9	
1996	3	72.8	136.4	191.6	236.4
		93.5	149.1	197.5	236.9
Overall mean		82.2	148.7	199.8	236.4
Weighted mean		99.3	155.4	207.8	236.9
Western WA average		59.7	119.9	152.1	192.5
<i>G</i>		4.54	1.903	0.948	0.540
<i>G_{avg}</i>		3.51	2.238	0.764	0.756

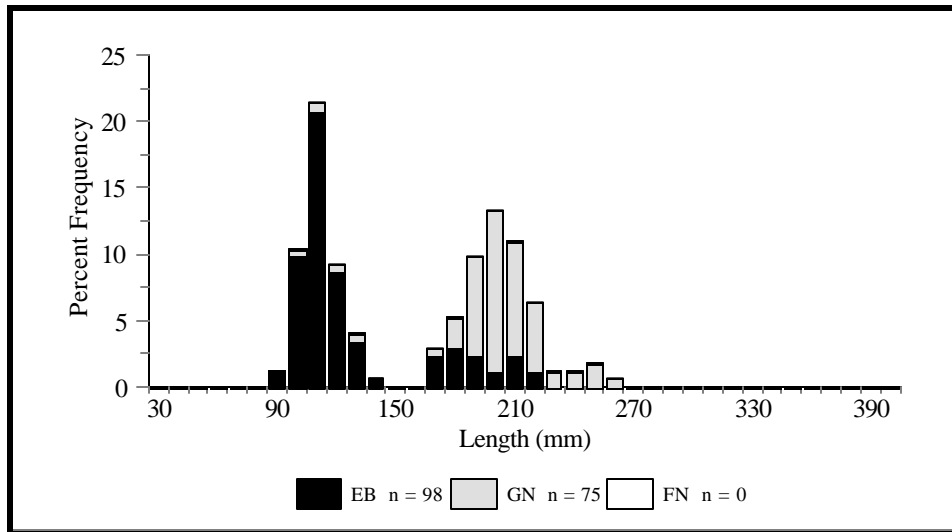


Figure 15. Length frequency histogram of yellow perch sampled from Angle Lake (King County) in late spring 2000. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, ad FN = fyke netting.

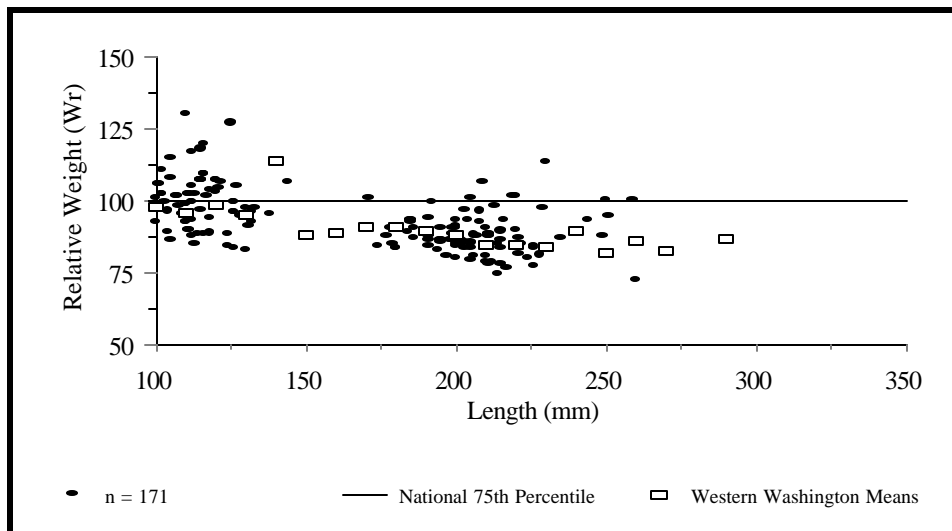


Figure 16. Relationship between total length and relative weight (W_r) of yellow perch from Angle Lake (King County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Warmwater Enhancement Options

Warmwater fish species dominated our catch from Angle Lake in late spring 2000. Growth of largemouth bass, pumpkinseed, rock bass, and yellow perch was consistent with or above western Washington State averages. However, CPUE for brown bullhead, largemouth bass, pumpkinseed and yellow perch were below average, suggesting low abundance of these species. Obvious gaps in the length frequency distribution of largemouth bass may be due to weather-related year-class failure, competition with the abundant yellow perch and rock bass, or overharvest of larger individuals. Conversely, rock bass in our sample were abundant and demonstrated high CPUE, strong growth, and relative weights consistent with state averages.

Change Existing Fishing Rules to Improve Size Structure of Largemouth Bass

Currently, Angle Lake anglers are allowed to harvest five largemouth bass daily. Although there is no minimum size limit, no more than three fish can measure over 381 mm (15") TL. During late spring 2000, electrofishing and gill netting PSD and RSD values (Table 8) suggest that a trophy fishery is evolving for largemouth bass (Gabelhouse 1984; Willis et al. 1993). One way of protecting and enhancing a trophy fishery is implementing a minimum length limit (Cornelius and Margenau 1999). Under this type of regulation, fish below a designated length must be released. A minimum length limit (e.g., 457 mm or 18" TL) with a reduced bag limit (e.g., one fish daily) should allow more fish to reach their full growth potential while protecting the resource (Maceina et al. 1998; Slipke et al. 1998). Since largemouth bass recruitment is very low in Angle Lake (i.e., few quality-sized fish were captured), whether due to natural or anthropogenic factors (e.g. delayed mortality from catch-and-release [Wilde 1998] or overharvest), a minimum length limit might benefit this species (Lucas 1986; Willis 1989). However, it should be noted that a minimum length limit may result in little or no change in largemouth bass size structures several years after implementation (Mueller 1999).

Alternatively, implementing a 305 – 432 mm (12 – 17") slot limit for largemouth bass might succeed should the current rule fail to achieve balance in Angle Lake. The main objective of a slot limit is to improve the size structure of largemouth bass. Under this rule, only fish less than 305 or greater than 432 mm TL may be kept. Decreasing the creel limit from three fish over 381 mm TL to one fish over 432 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). In Arkansas, an outstanding largemouth bass fishery was developed by adjusting the slot and the creel limits to stimulate harvest of small fish while protecting large fish (Turman and Dennis 1998).

A simpler alternative to protect largemouth bass would be to implement catch-and-release fishing on the lake. Under this rule, all largemouth bass captured must be released back into Angle Lake alive. Increased numbers of larger fish would act as a control on the abundant rock bass. Furthermore, since the rule is indisputable, it would be simpler to enforce.

The success of any rule change, though, 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 the lake describing the new regulations. Press releases should be sent to local papers, magazines, and sport fishing groups detailing the changes to, and purpose of, the rules. Furthermore, increasing the presence of WDFW enforcement personnel at Angle Lake during peak harvest periods would encourage compliance.

Consider Stocking Channel Catfish to Control Abundant Rock Bass

Temperature-sensitive channel catfish (*Ictalurus punctatus*) have been stocked into a number of Washington lakes in the past decade. These non-reproducing populations were introduced in an attempt to increase predation of over-abundant forage fish, such as yellow perch, and to add diversity to mixed-species fisheries (WDFW 1999). Angle Lake's abundant forage base (i.e., rock bass), low to moderate levels of aquatic vegetation, and clear water make it suitable for stocking channel catfish. However, the lake's trophic status makes it difficult to predict the success of stocking the predator (Bonar et al. 1995).

Manage Angle Lake for Panfish

The panfish populations at Angle Lake are thriving. Therefore, the simplest management strategy might be developing the panfish fishery at the lake. Minimum length limits on predators, such as largemouth bass, are often used to develop quality panfish fisheries (Willis 1989). Under a minimum length rule, all fish below a designated length must be released. For example, a minimum length limit of 432 mm (17") TL on largemouth bass in Angle Lake should increase the number of predators below 432 mm TL. Consequently, these fish would then thin out the abundant rock bass and yellow perch 'making room' for the remaining forage fish to achieve their full growth potential.

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