1999 Lake Terrell Survey: Potential Trophy Largemouth Bass and Channel Catfish Fisheries in a Lowland Western Washington Lake Preserve

by Mark R. Downen and Karl W. Mueller

Washington Department of Fish and Wildlife
Fish Program
Warmwater Enhancement Program
600 Capitol Way North
Olympia, WA 98501-1091

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Abstract

The presence of a robust warmwater fishery on Lake Terrell and potential for increasing access to this fishery resulted in a stock assessment by the WDFW Warmwater Enhancement Program in spring 1999. We assessed species composition, abundance, size structure, growth, and condition of fish in the lake. We then evaluated habitat, access, and the effects of current fishing rules, and outlined options for enhancing the fishery and fishing opportunity on the lake. Warmwater species in Lake Terrell were characterized by high growth rates, but recruitment of forage fish appeared to be low. The PSD values for largemouth bass were consistent with those generally accepted for trophy fisheries but densities were assumed to be low as indicated by low CPUE. Channel catfish survival in Lake Terrell appeared to be better than in many other western Washington lakes, but based on the fish sampled we concluded that they may not be maximizing their potential for growth. Based on these assessments, we outlined options for Lake Terrell that balance an increase in access and fishing opportunity with reductions in harvest to maintain current fishery quality. We propose rule changes for largemouth bass, channel catfish and forage fish species which we believe will accomplish these objectives.

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Introduction and Background

In the late 1940s, the Washington Department of Fish and Wildlife (WDFW) [then Washington Department of Game (WDG)] purchased four diary farms in west Whatcom County with Federal Aid in Wildlife Restoration Funds. In restoring these lands for a waterfowl preserve, WDG dammed Terrell Creek (Whatcom County), creating a 175 ha lake with a drainage area of 738 ha, a mean depth of 2.1 meters and a maximum depth of 3.1 meters. Sedimentary and metamorphic materials characterize basin geology, and approximately 75 percent of the drainage basin is farmland, while 25 percent is second growth forest or fallow. Although Terrell Creek was originally dammed to create an impoundment and restore wetlands to preserve waterfowl, the resulting water body provided ideal habitat for a number of introduced fish species.

Habitat along the shoreline of Lake Terrell is rimmed by undeveloped second growth forest, grasslands, and marshes. The littoral zone includes most of the lake bottom, and shallow channels and artificial islands add substantially to shoreline complexity. Uniform emergent plant communities of cattail, rushes, sedges, and willow occur along approximately 85 percent of the shoreline. Patchy, floating plant communities of water lily, potamogitan, and watershield occur along approximately 25 percent of the shoreline and submergent plant species including spirogira and coontail are patchily distributed throughout the littoral zone. The lake substrate is composed of combinations of sand, clay, peat, and detritus, and natural coarse woody debris occurs along 90 percent of the lake shoreline. Additionally, several artificial snags have been installed in the lake to further enhance this important habitat feature.

Regulation of water levels dominates environmental disturbance regimes in Lake Terrell, influencing approximately 50 ha of marginal aquatic habitats and the fish populations that utilize them. Since the late 1970s, WDG personnel have sought to reduce predation on nesting waterfowl and maximize spawning habitat for warmwater fish species by allowing the lake to reach its maximum level by mid–April after several months of maintaining slightly lower levels that provide winter flood control. From March through June, large areas of the lake are closed to fishing in order to promote and protect nesting activity of waterfowl from human disturbance. These closures may also affect warmwater fish species that spawn during these months.

Records of the historical fish community in Lake Terrell are incomplete, but anecdotal information suggests that brown bullhead became established shortly after the lake was created. Rainbow and cutthroat trout were stocked by the WDG in following decades. Largemouth bass were stocked in the mid–1960s and again in the 1970s, and during this time illegally introduced yellow perch also became established. In the 1980s, WDG began stocking channel catfish, while additional unauthorized introductions resulted in the establishment of reproducing bluegill, pumpkinseed, and black crappie populations in the lake. Currently, cutthroat are stocked annually in February, and 4,000 to 7,000 150 mm channel catfish are stocked each fall. Recent data enumerating fishing pressure on Lake Terrell does not exist but anecdotal information suggests the lake receives a number of anglers beginning in March who fish from two piers for cutthroat trout, yellow perch, sunfish, channel catfish, brown bullhead, and largemouth bass. After closures on the lake are lifted, anglers fish the lake extensively by boat throughout the summer and fall.

The presence of a robust warmwater fishery on Lake Terrell and potential for increasing access to this fishery resulted in a stock assessment by the WDFW Warmwater Enhancement Program in spring 1999. We assessed species composition, abundance, size structure, growth, and condition of fish in the lake, evaluated habitat, access, and the effects of current fishing rules, and outlined options for enhancing the fishery and fishing opportunity on the lake.

Materials and Methods

Two WDFW biologists and one scientific technician surveyed Lake Terrell during May 20-23, 1999. Fish were captured using three sampling techniques: electrofishing; gill netting; and fyke netting. The electrofishing unit consisted of a 4.9–meter Smith-Root 5.0 GPP electrofishing boat set to a DC current of 120 cycles/second at 6 AMPS current. Experimental gill nets (45.7 meters long × 2.4 meters deep) were constructed of four sinking panels (two each at 7.6 meters and 15.2 meters long) of variable-size (13, 19, 25, and 51 millimeters stretched) monofilament mesh. Fyke nets were constructed of a single 30.4–meter lead and two 15.2–meter wings of 130 millimeter nylon mesh with the body of the nets stretched around four 1.2–meter aluminum rings in each of two sections.

Sampling locations were selected by dividing the shoreline into 18 consecutively numbered sections of about 400 meters each as determined from a 1:24,000 USGS map (Figure 1). A portion of the shoreline was sampled by electrofishing six randomly selected sections for a total of 5,400 seconds. While electrofishing, the boat was maneuvered through the shallows (depth range: 0.2 - 1.5 meters), adjacent to the shoreline, at a rate of 18 meters/minute. Four gill nets were set perpendicular to the shoreline with the small–mesh end attached onshore and the large–mesh end anchored offshore. Four fyke nets were set in water less than three meters deep, perpendicular to the shoreline with wings extended at 70° angles from the lead. Sampling

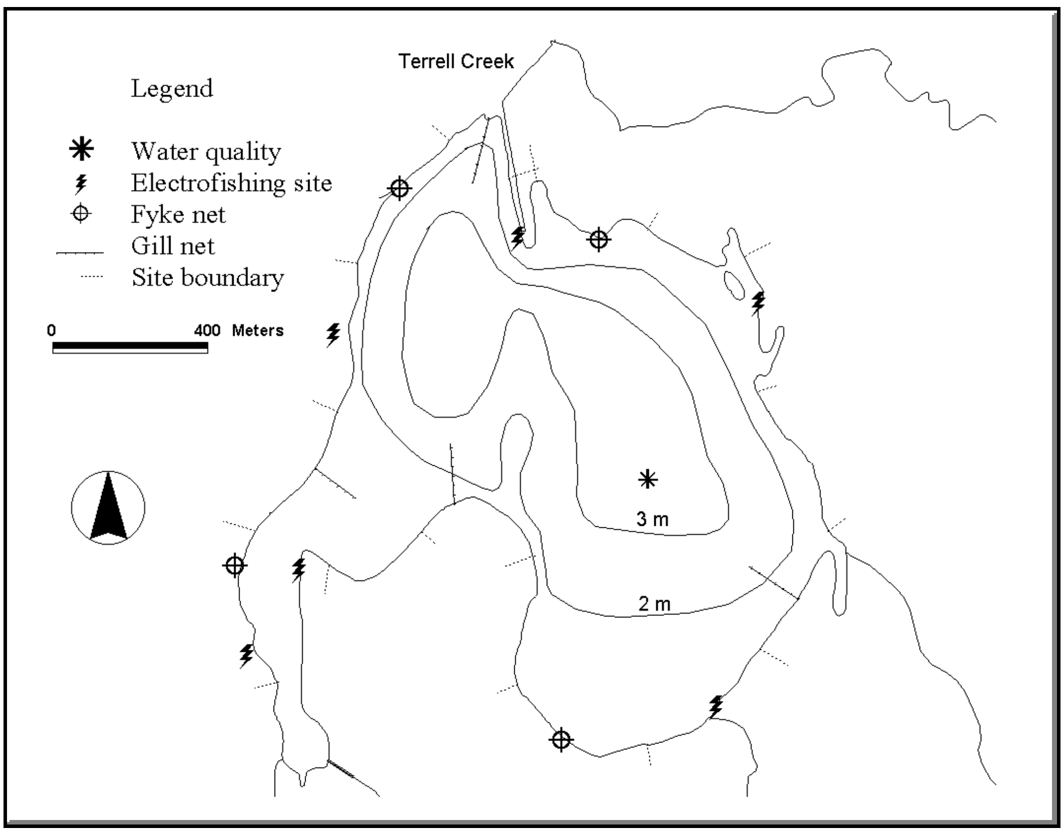

Figure 1. Hydrology, bathymetry, and 1999 sampling sites on Terrell Lake (Whatcom County).

occurred during evening hours to maximize the type and number of fish captured. In order to reduce bias between techniques and to standardize effort, the sampling time for each gear type was standardized to a ratio of 1:1:1 (Fletcher et al. 1993). One unit of electrofishing time equal to three 600–second sections (actual pedal–down time) was applied for each 24 hour unit (= 2 net nights) of gill netting time and fyke netting time so that three sites were electrofished for every two sites of gill netting and fyke netting.

All fish captured were identified to species. Each fish was measured to the nearest millimeter (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. Fish were weighed to the nearest 0.5 gram. 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 the linear regression of $\log_{10}$-length on $\log_{10}$-weight of fish from the sub–sample. Scales were removed from up to five 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). Scales were also measured for standard back–calculation of growth. However, a lack of technical resources precluded aging members of the family *Ictaluridae* (catfish).

Water quality data was collected during mid–day from one site on May 20, 1999, using a Hydrolab® probe and digital recorder. We measured dissolved oxygen, total dissolved solids, temperature, pH, and specific conductance and recorded secchi disc readings in meters (Table 1).

Table 1. Water quality from the deepest location on Lake Terrell (Whatcom County) collected at mid–day on May 20, 1999. Secchi depth = 0.9 m.

Depth (m)	Temp (EC)	DO (mg/L)	pH	Conductance (uS/cm)	TDS (g/L)
0	13.92	8.81	7.78	48.5	0.0311
1	13.88	8.59	7.63	48.7	0.0311
2	13.84	8.40	7.55	48.6	0.0312
3	13.83	8.41	7.45	48.7	0.0311

In addition to analyzing data collected from this stock assessment, we analyzed data collected by a local bass club. Largemouth bass captured during this contest, held May 5 and 6, 1999, were measured and weighed, and angler hours were recorded. From this data we report length frequency distribution, relative weights, proportional stock density, and catch per unit effort as described in the following sections.

Data Analysis

Balancing predator and prey fish populations is an important axiom of managing warmwater fisheries. 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 anglers while maintaining 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 population age class structures, relative species abundances, the potential for species interactions, and the adequacy of the food supplies for various foraging niches (Ricker 1975; Kohler and Kelly 1991; Olson et al. 1995). Balance and productivity of the community may also be addressed based upon these evaluations (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.

CPUE by gear type was determined for all fish species (number of fish/hour electrofishing and number of fish/net night). Only stock size fish and larger were used to determine CPUE for warmwater and other game species. Stock length, which varies by species (see Table 3 and discussion below), refers to the minimum size of fish having recreational value. Since sample locations were randomly selected, which can introduce high variability due to habitat differences within the lake, 80 percent 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 and the confidence intervals express the relative uniformity of species distributions throughout a given lake. CPUE values for Lake Terrell were then compared to western Washington State averages compiled by the WDFW Inland Fisheries Research Unit (Table 2).

Table 2. Mean catch per unit effort (number of fish /hour electrofishing and number of fish/net night) for stock size fish collected from several western Washington lakes while electrofishing, gill netting, and fyke netting during 1997 and 1998.

	Gear type					
Species	**Electrofishing (fish/hr)**	**n (lakes)**	**Gillnetting (fish/hr)**	**n (lakes)**	**Fyke netting (fish/hr)**	**n (lakes)**
Largemouth Bass	41.6	12	1.9	8	0.3	1
Bluegill	169.1	7	1.6	4	20.7	5
Pumpkinseed	70.8	11	3.8	9	7.9	4
Yellow Perch	97.5	8	13.7	6	0.2	2
Brown Bullhead	7.8	10	14.4	7	12.7	6

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.

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 $\geq$quality length/number of fish $\geq$stock length$\times$100, is a numerical descriptor of length frequency data that provides useful information about size class structure. Stock and quality lengths, which vary by species, are based on percentages of world–record lengths. Again, stock length (20-26 percent of world–record length) refers to the minimum size fish with recreational value, whereas quality length (36-41 percent 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 3). Preferred length (45-55 percent of world–record length) refers to the minimum size fish anglers would prefer to catch. Memorable length (59-64 percent of world–record length) refers to the minimum size fish most anglers are likely to remember catching, whereas trophy length (74-80 percent of world–record length) refers to the minimum size fish considered worthy of acknowledgment. Like PSD, RSD provides useful information regarding size class structure, but is more sensitive to changes in year–class strength. RSD was calculated as the number of fish $\geq$specified length/number of fish $\geq$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 4).

We compared PSD and RSD values for warmwater species in Lake Terrell with western Washington State averages compiled by the WDFW Inland Fisheries Research Unit (Table 5).

Table 3. Length categories for warmwater fish species by Gabelhouse (1984) used to calculate stock density indices (PSD, RSD) for fish captured at Lake Terrell (Whatcom County) during spring 1999 based on numbers from Anderson and Neumann (1996) and Bister et al. (unpublished data).*

	Total Length (mm)				
Species	**Stock**	**Quality**	**Preferred**	**Memorable**	**Trophy**
Largemouth bass	200	300	380	510	630
Bluegill	80	150	200	250	300
Pumpkinseed	80	150	200	250	300
Yellow perch	130	200	250	300	380
Brown bullhead	130	200	280	360	430
Channel catfish	280	410	610	710	910

- Bister et al. Dept. of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, South Dakota 57007.

Table 4. Stock density index ranges for largemouth bass and bluegills under three commonly implemented management options (from Willis et al. 1993).

	Largemouth bass			Bluegill	
Option	**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

Table 5. Mean stock density indices for available warmwater fishes from western Washington lakes with the most effective sampling method for a given species during 1997 and 1998 (WDFW Inland Fisheries Research Unit, unpublished data). 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.

Species	Gear Type	n (lakes)	PSD	RSD-P	RSD-M	RSD-T
Largemouth bass	EB	12	29	17	0	0
Bluegill	EB	9	16	0	0	0
Pumpkinseed	EB	12	8	0	0	0
Yellow Perch	GN	12	53	1	0	0

Age and growth of warmwater fishes in Lake Terrell 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 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 Terrell fish and the western Washington 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 has a condition value equal to the national standard (75^{th} percentile) for that species. Furthermore, W_r is useful for comparing the condition of different size classes within a single population to determine if all sizes are finding adequate forage (ODFW 1997). Following Murphy et al. (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). The W_r values from this study were compared to the national standard ($W_r = 100$) and where available, with mean W_r values from up to 25 western Washington warmwater lakes sampled during 1997 and 1998 (Steve Caromile, WDFW, unpublished data). Trends in the dispersion of points on the relative weight graph have been used to infer ecological dynamics of fish populations (Willis 1999). For example, a decrease in relative weight with increasing total length often occurs where competition is high among larger size classes. Conversely, lower relative weights occurring with smaller fish suggests competition and crowding for these fish. Testing the statistical significance of the relationship between total length and relative weight, standard transformation failed to normalize the length data. Moreover, we make no assumption that relationships would be linear. We therefore used a nonparametric correlation, Spearman's Rho (Zar 1984), to assess the significance of correlations between total length and relative weight where relationships were suggested by the graphs.

Results and Discussion

Species Composition

During spring 1999, our sample from the fish community of Lake Terrell was dominated by largemouth bass by biomass and by bluegill and yellow perch by number (Table 6). Together, bluegill and yellow perch accounted for more than 80 percent of the number of fish captured. Together, channel catfish and brown bullhead made up 35 percent by biomass but only 7 percent by number.

Table 6. Species composition by weight (kg) and number of fish captured at Lake Terrell (Whatcom County) during spring 1999.

	Species composition				
	by weight		**by number**		**Size range**
Species	**(kg)**	**(%) weight**	**(#)**	**(%) n**	**(mm TL)**
Largemouth Bass (*Micropterus salmoides*)	37.103	51.078	58	9.163	67 - 534
Bluegill (*Lepomis macrochirus*)	1.314	1.810	140	22.117	30 - 177
Pumpkinseed Sunfish (*Lepomis gibbosus*)	0.399	0.549	8	1.264	56 - 183
Yellow Perch (*Perca flavescens*)	9.103	12.531	383	60.506	49 - 216
Channel Catfish (*Ictalurus punctatus*)	10.866	14.959	11	1.738	419 - 524
Brown Bullhead (*Ameiurus nebulosus*)	13.855	19.074	33	5.213	65 - 345
Total	**72.639**		**633**		

CPUE

Catch rates for stock–length largemouth bass were highest with electrofishing, but below the western Washington State average (Tables 2 and 7). While electrofishing, catch rates were well below the average for stock–length bluegill and pumpkinseed and consistent with the average for yellow perch. Catch rates for stock–length channel catfish highest while gill netting. Catch rates for brown bullhead were highest while electrofishing and above average.

Table 7. Mean catch per unit effort (number of fish /hour electrofishing and number of fish/net night), including 80 percent confidence intervals, for stock size fish collected from Lake Terrell (Whatcom County) while electrofishing, gill netting, and fyke netting during spring 1999.

	Gear type					
	Electrofishing		**Gillnetting**		**Fyke netting**	
Species	**(fish/hr)**	**n (sites)**	**(fish/hr)**	**n (net nights)**	**(fish/hr)**	**n (net nights)**
Largemouth Bass	32.71± 12.76	6	1.25± 0.96	4	0	4
Bluegill	29.75± 15.42	6	0	4	0	4
Pumpkinseed	4.96± 3.06	6	0	4	0	4
Yellow Perch	108.18± 45.84	6	6.25± 1.42	4	0.25 [a]	4
Channel Catfish	1 [a]	6	2.5 [a]	4	0 [a]	4
Brown Bullhead	25.75± 10.92	6	1.25± 0.61	4	0.25	4

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

Stock Density Indices

Proportional stock density indices (PSD) and relative stock density indices (RSD) for largemouth bass were above those reported in other Western Washington lakes (Mueller 1998, Downen and Mueller 1999a), above state averages for largemouth bass (see Table 5), consistent with values generally accepted for trophy waters (Willis et al. 1993), and consistent with PSD calculated from angler data collected the previous week (Table 8). However, PSD values for bluegill and yellow perch were low compared to western Washington State averages and to generally accepted ranges for either balanced communities or trophy waters (Willis et al. 1993). High PSD for pumpkinseed should be viewed with caution due to low sample size (Divens et al. 1998). While PSD values for channel catfish and brown bullhead were 100, RSD for channel catfish were zero, the RSD-P values for brown bullhead were very high for both electrofishing and gill netting.

Table 8. Traditional stock density indices, including 80 percent confidence intervals, for warmwater fishes collected from Lake Terrell (Whatcom County) while electrofishing, gill netting, and fyke netting during 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, FN = fyke netting, and AN = angling.

Species	Gear Type	n	PSD	RSD-P	RSD-M	RSD-T
Largemouth Bass	EB	33	79±9	58±11	3[a]	0
	GN	5	100	60±28	0	0
	FN	0	0	0	0	0
	AN	76	80±6	61±7	1[a]	0
Bluegill	EB	30	7±6	0	0	0
	GN	0	0	0	0	0
	FN	0	0	0	0	0
Pumpkinseed	EB	5	40±28	0	0	0
	GN	0	0	0	0	0
	FN	0	0	0	0	0
Yellow Perch	EB	109	4±2	0	0	0
	GN	25	0	0	0	0
	FN	1	0	0	0	0
Channel Catfish	EB	1	100	0	0	0
	GN	10	100	0	0	0
	FN	0	0	0	0	0
Brown Bullhead	EB	26	100	65±12	0	0
	GN	5	100	80±23	0	0
	FN	1	100	10	0	0

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

Largemouth Bass

Largemouth bass ranged from 67 to 534 mm (age 0+ to 12+) (Table 9, Figure 2). Age–1+ and 3+ fish were relatively abundant, and several older age classes were well represented in our sample. Growth of largemouth bass collected from Lake Terrell was above the western Washington State average. Comparison of these growth rates with a survey carried out by Fletcher (1981) suggested growth rates have improved since that survey. Relative weights were below western Washington State averages with no statistical relationship between W_r values and size (Figure 4). The Spearman correlation coefficient (Rho) for largemouth bass length and relative weight captured during our survey was 0.249 (p = 0.127). Fish captured by anglers during the previous week came from the same length frequency distribution as stock length fish captured during our survey (see Table 8). However, the fish captured by anglers had higher relative weights.

Table 9. Age and growth of largemouth bass captured at Lake Terrell (Whatcom County) during spring 1999. 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 Total Length at Age											
Year Class	**# Fish**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1998	16	114.0											
		115.0											
1997	2	48.4	171.0										
		62.8	171.0										
1996	12	52.4	175.0	271.0									
		68.8	183.0	273.0									
1995	5	50.0	170.0	282.0	346.9								
		67.2	181.0	286.0	347.6								
1994	1	28.1	140.0	275.0	355.7	391.0							
		46.8	153.0	281.0	358.4	392.0							
1993	2	102.0	221.0	296.0	339.8	376.0	409.3						
		117.0	231.0	302.0	343.9	378.0	410.1						
1992	4	89.0	166.0	248.0	302.1	359.0	397.9	431.0					
		105.0	179.0	257.0	308.5	363.0	400.0	431.0					
1991	6	81.8	158.0	234.0	300.3	350.0	392.3	414.0	435.2				
		98.1	171.0	243.0	306.8	354.0	394.6	416.0	435.6				
1990	5	86.7	154.0	235.0	287.3	33.0	371.2	398.0	433.2	455.0			
		103.0	168.0	245.0	295.0	339.0	375.2	401.0	434.6	455.0			
1989	1	97.0	143.0	212.0	290.9	355.0	383.2	415.0	434.0	466.0	480.0		
		113.0	157.0	223.0	299.1	361.0	387.7	418.0	436.4	467.0	480.0		
1988	0												
1987	1	90.4	137.0	193.0	228.2	314.0	344.5	391.0	413.4	447.0	478.0	499.0	521.1
		107.0	152.0	206.0	239.7	322.0	351.6	397.0	417.9	451.0	480.0	500.0	521.6
Overall mean		76.4	164.0	249.0	306.4	354.0	383.1	410.0	429.0	456.0	479.0	499.0	521.1
Weighted mean		93.8	178.0	263.0	314.9	355.0	389.6	414.0	433.9	456.0	480.0	500.0	521.6
Western WA Average		60.4	145.0	222.0	261.1	289.0	319.0	367.0	396.0	439.0	484.0	471.0	495.6

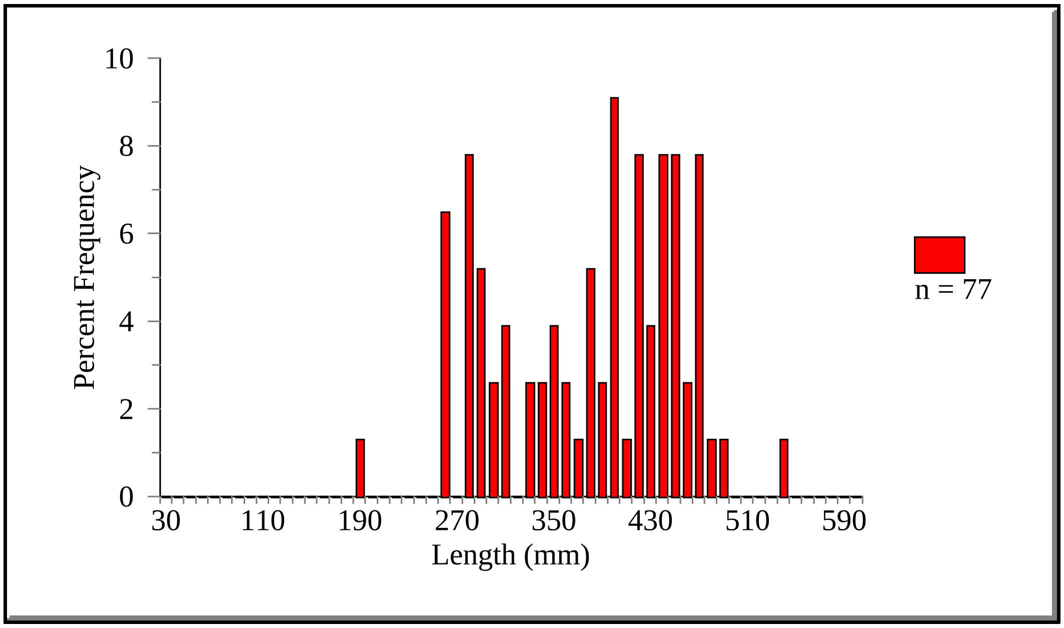

Figure 4. Length frequency histogram of largemouth bass sampled by anglers from Lake Terrell during spring 1999.

1999. 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.

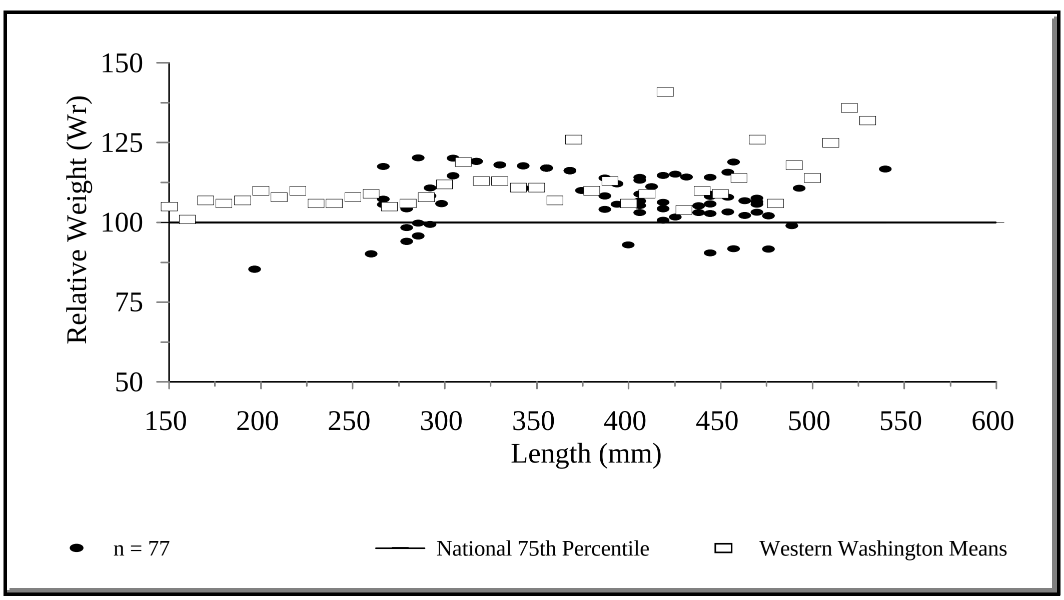

Figure 3. Relationship between total length and relative weight (**W_r**) **of largemouth bass** sampled by anglers from Lake Terrell (Whatcom County), compared with means from up to 25 western Washington lakes and the national 75th percentile.

from Lake Terrell (Whatcom County), compared with means from up to 25 western Washington lakes and the national 75th percentile.

Bluegill

Bluegill ranged from 30 to 177 mm (TL) (age 1+ to 3+) (Table 10, Figure 6). Growth rates for bluegill in Lake Terrell were generally consistent with the western Washington State average for age 1 and 2 fish. We sampled one age 3+ individual that demonstrated a dramatic increase in growth from age 2 to 3. While W_r values were consistent with the Washington State average, a upward trend appeared with increasing length (Figure 7). The Spearman correlation coefficient (Rho) for bluegill total length and relative weight was 0.370 (p = 0.044).

Table 10. Age and growth of black crappie captured at Lake Terrell (Whatcom County) during spring 1999. 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 Total Length (mm) at Age		
Year Class	**# Fish**	**1**	**2**	**3**
1998	17	58.2		
		62.1		
1997	17	26.1	102.0	
		41.6	104.0	
1996	1	18.6	77.6	168.7
		36.5	88.9	169.7
Overall mean		34.3	89.8	168.7
Weighted mean		51.4	103.0	169.7
State Average		37.3	96.8	132.1

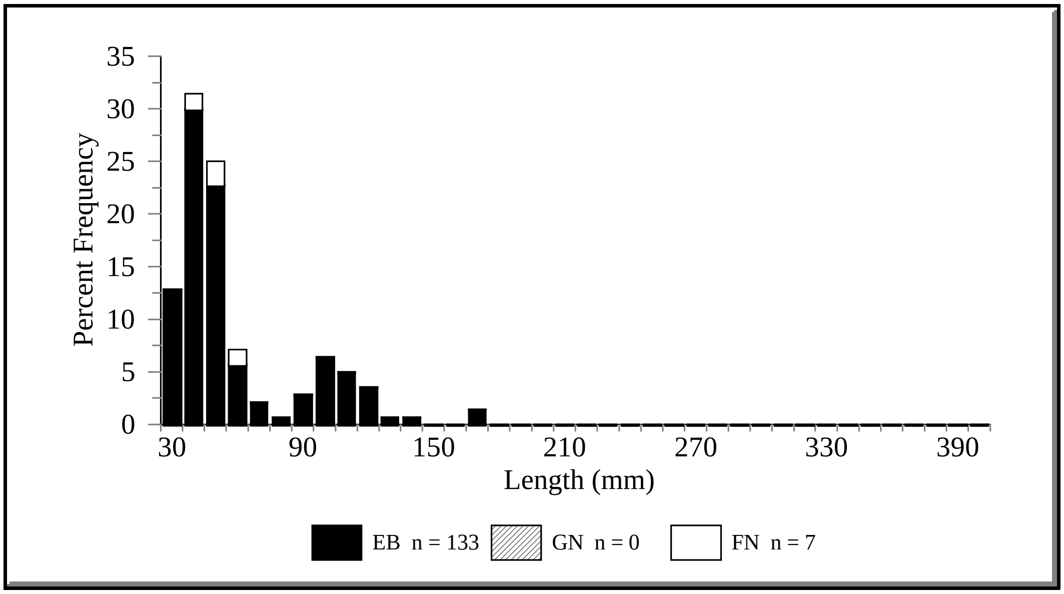

Figure 6. Length frequency histogram of bluegill sampled from Lake Terrell in spring 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

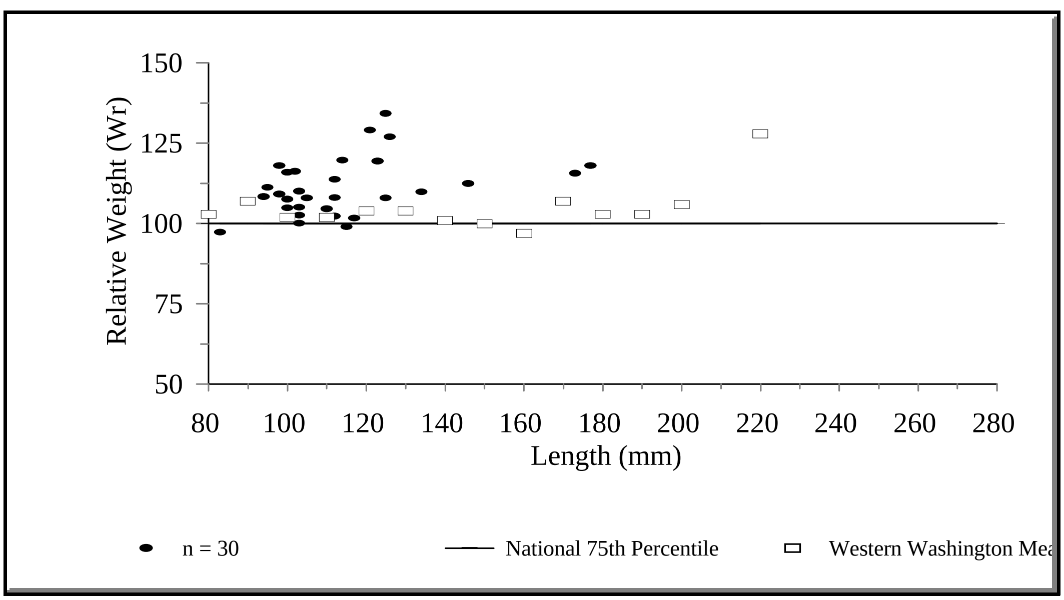

Figure 7. Relationship between total length and relative weight (W_r) of bluegill from Lake Terrell (Whatcom County), compared with means from up to 25 western Washington lakes and the national 75th percentile.

Pumpkinseed

Pumpkinseed ranged from 56 to 183 mm (TL) (age 1+ to 5+) (Table 11, Figure 8). However, only one fish older than age 2+ was captured. Growth rates for pumpkinseed in Lake Terrell were generally above the western Washington State average, particularly after age 1. While W_r values were consistent with the Washington State average, an upward trend appeared with increasing length (Figure 9). The Spearman correlation coefficient (Rho) for pumpkinseed length and relative weight was 0.881 (p = 0.041), significant despite low *n* size.

Table 11. Age and growth of pumpkinseed captured at Lake Terrell (Whatcom County) during spring 1999. 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 Total Length (mm) at Age				
Year Class	**# Fish**	**1**	**2**	**3**	**4**	**5**
1998	3	57.4				
		62.9				
1997	3	40.7	120.0			
		58.5	124.0			
1996	0					
1995	0					
1994	1	36.6	65.9	135.4	151.0	178.0
		56.6	81.9	141.9	155.0	178.0
Overall mean		44.9	93.2	135.4	151.0	178.0
Weighted mean		60.1	113.0	141.9	155.0	178.0
State Average		23.6	72.1	101.6	122.0	139.0

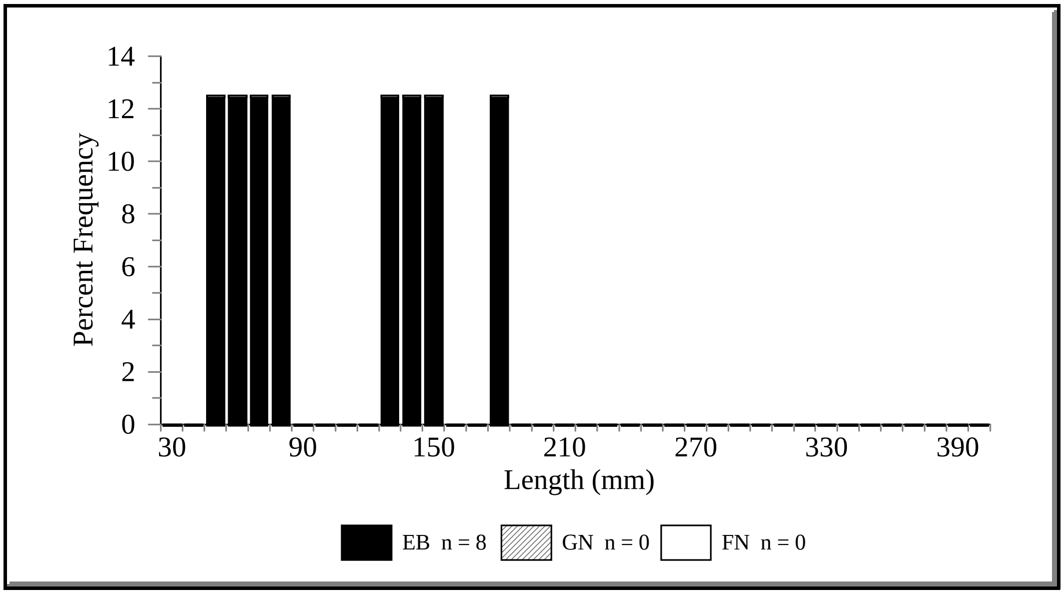

Figure 8. Length frequency histogram of pumpkinseed sampled from Lake Terrell in spring 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

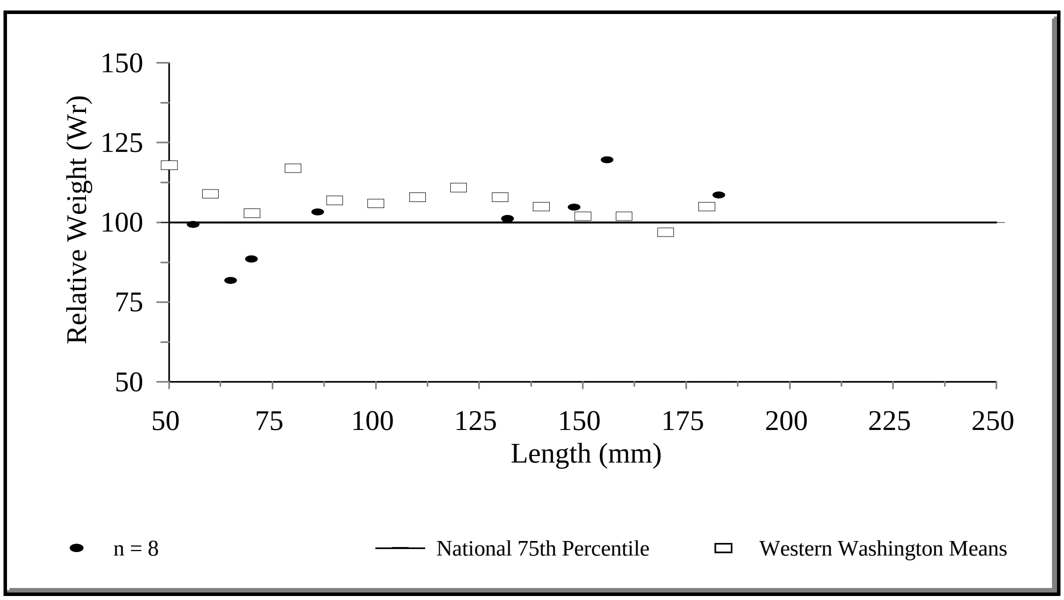

Figure 9. Relationship between total length and relative weight (W_r) of pumpkinseed from Lake Terrell (Whatcom County), compared with means from up to 25 western Washington lakes and the national 75th percentile.

Yellow Perch

Yellow perch ranged from 49 to 216 mm (TL) (age 1+ to 7+) (Table 12, Figure 10). Growth rates for yellow perch in Lake Terrell were below the Washington State average during their first two years. Although total lengths remained below average, growth rates as evidenced by annual changes in total length were above average thereafter. Relative weight values (W_r) were above the Washington State average with an apparent downward trend with increasing total length (Figure 11). The Spearman correlation coefficient (Rho) for yellow perch length and relative weight was –0.576 ($p < 0.01$).

Table 12. Age and growth of yellow perch captured at Lake Terrell (Whatcom County) during spring 1999. 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 Total Length (mm) at Age						
Year class	**# Fish**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1998	23	55.8						
		63.6						
1997	25	44.8	108.0					
		64.2	113.0					
1996	12	45.8	106.0	148.0				
		67.2	116.0	150.0				
1995	12	49.3	106.0	147.0	177.1			
		71.2	118.0	153.0	177.9			
1994	6	49.2	102.0	124.0	161.8	191.0		
		71.8	117.0	135.0	167.7	193.0		
1993	0							
1992	1	40.9	84.0	107.0	122.7	152.0	169.0	184.0
		64.4	100.0	120.0	133.2	158.0	172.0	185.0
Overall mean		47.6	101.0	131.0	153.9	172.0	169.0	184.0
Weighted mean		66.1	115.0	147.0	172.3	188.0	172.0	185.0
State Average		59.7	119.0	152.0	192.5	20.0		

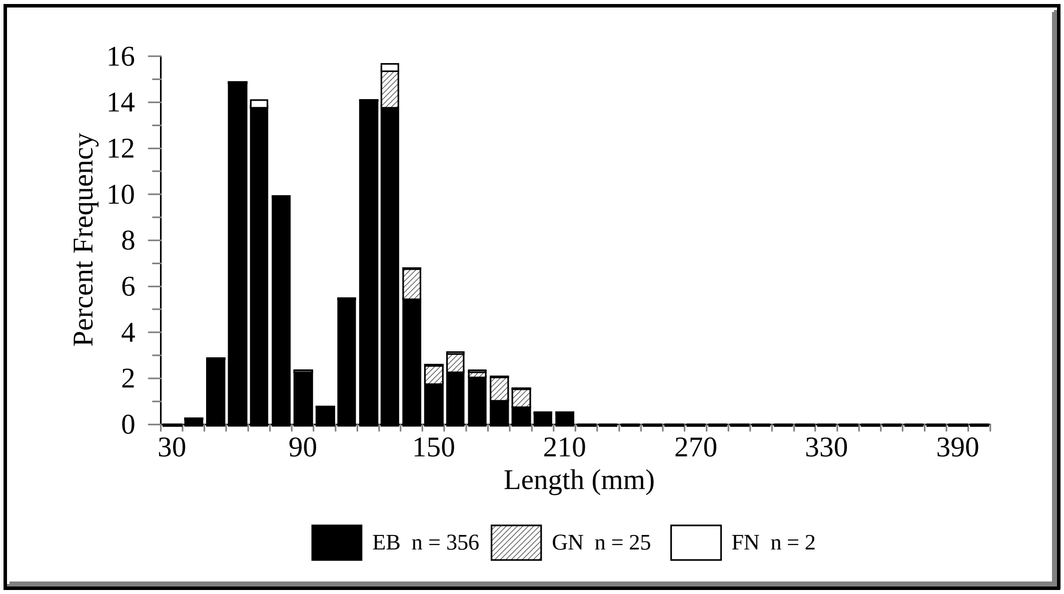

Figure 10. Length frequency histogram of yellow perch sampled from Lake Terrell in spring 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

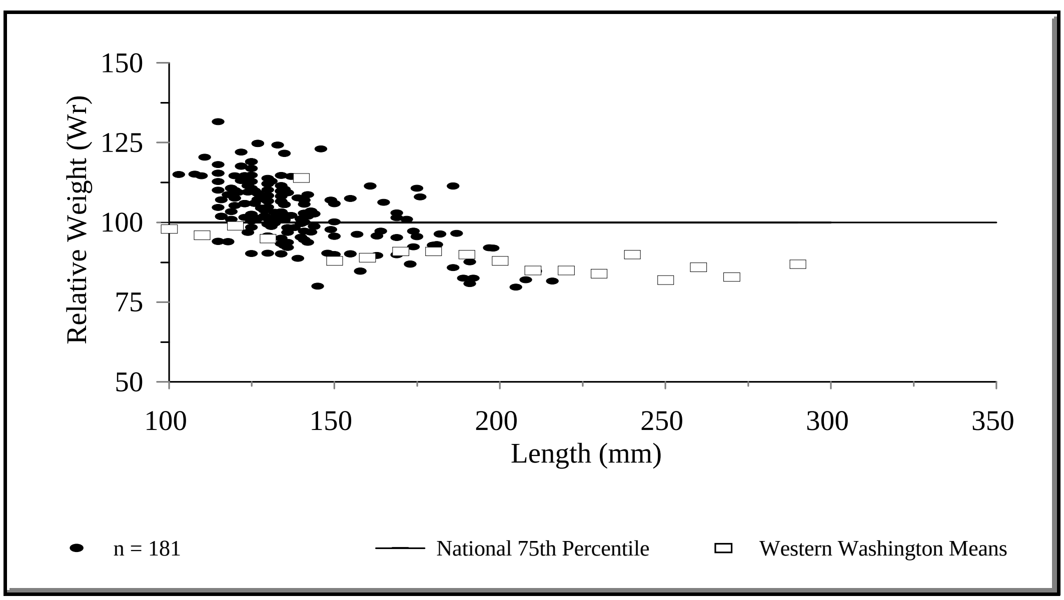

Figure 11. Relationship between total length and relative weight (W_r) of yellow perch from Lake Terrell (Whatcom County), compared with means from up to 25 western Washington lakes and the national 75^{th} percentile.

Channel Catfish

Channel catfish ranged from 419 to 524 mm TL (Table 6, Figure 12) and appeared to be from the same stocking. Relative weight values were consistent with the national 75th percentile, but appeared to be below the Washington State average (Figure 13). However, no state averages were available for the size classes in our sample. The Spearman correlation coefficient (Rho) for channel catfish length and relative weight was 0.455 (p = 0.159).

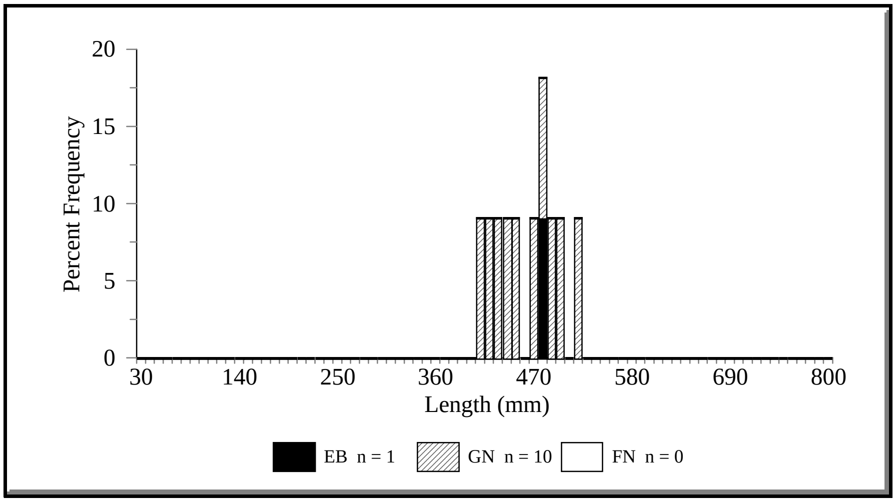

Figure 12. Length frequency histogram of channel catfish sampled from Lake Terrell in spring 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

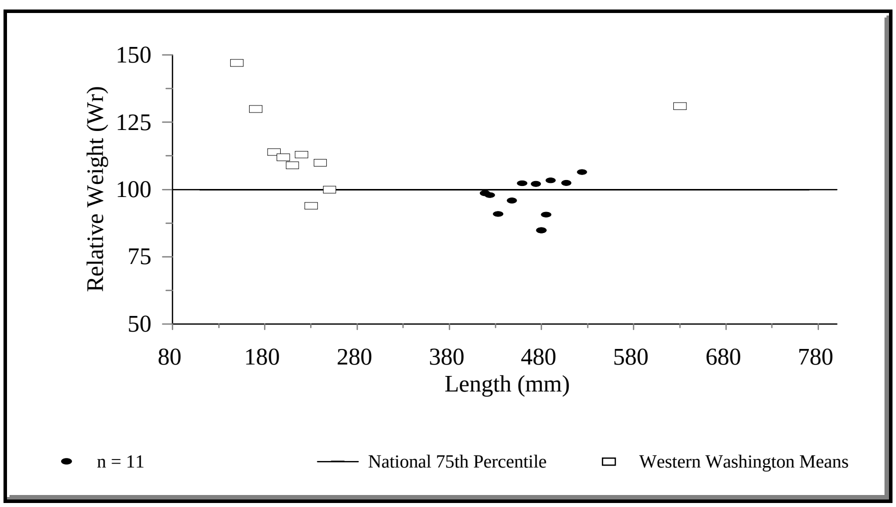

Figure 13. Relationship between total length and relative weight (W_r) of channel catfish from Lake Terrell (Whatcom County), compared with means from up to 25 western Washington lakes and the national 75th percentile.

Brown Bullhead

Brown bullhead ranged from 65 to 345 mm TL (Table 6, Figure 14). We did not sample any individuals between 65 and 240 mm TL. Relative weights for brown bullhead were consistent with the national 75th percentile (Figure 15) with no apparent trend. The Spearman correlation coefficient for relative weight and total length was 0.215 (p = 0.238).

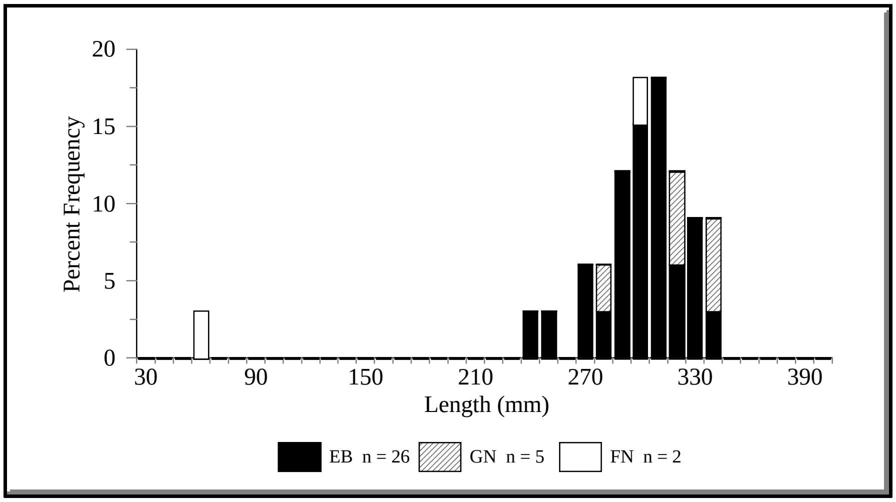

Figure 14. Length frequency histogram of brown bullhead sampled from Lake Terrell in spring 1999. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

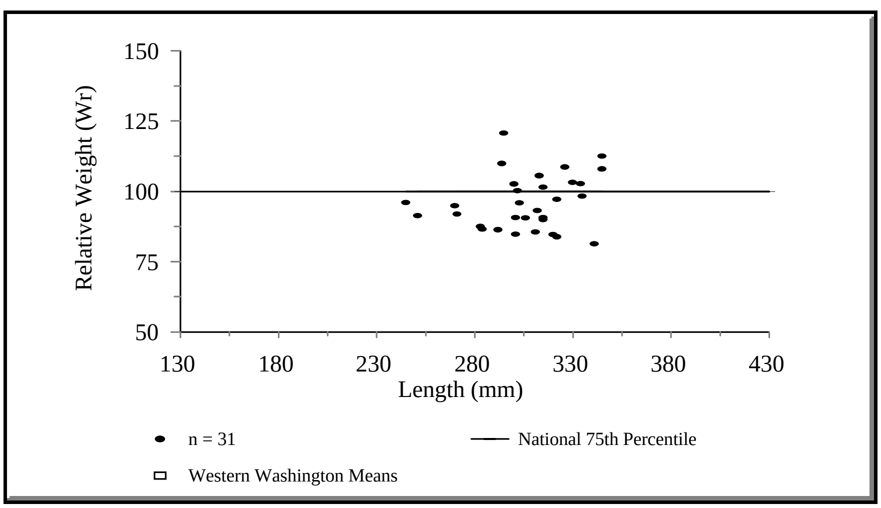

Figure 15. Relationship between total length and relative weight (Wr) of brown bullhead from Lake Terrell (Whatcom County), compared the national 75th percentile.

Warmwater Enhancement Options

During spring 1999, the fish community of Lake Terrell was dominated by warmwater species. Growth rates for largemouth bass, bluegill, and pumpkinseed well above western Washington State averages. The size structure of the largemouth bass population was robust, as evidenced by PSD values lying at the upper end of generally accepted values for a fishery managed for "big" bass (Willis 1997). However, our sample size was modest and our CPUE was below the state average. Moreover, spring sampling may have contributed to high PSD. Numbers of bluegill and pumpkinseed were very low; however, abundant slower growing yellow perch appear to provide an adequate forage base for largemouth bass. A strong downward trend in relative weights for yellow perch with increasing length suggest abundant resources for smaller yellow perch at the time of sampling. Recent spawning activity may also have influenced relative weights of mature fish. However, slow growth rates for age 1 and 2 yellow perch over all suggest resource abundance is highly seasonal for these fish. Channel catfish and brown bullhead were somewhat abundant and should provide good opportunity for catfish anglers in Lake Terrell. Both species demonstrated relative weight values consistent with the national 75th percentile. However, while RSD-P for brown bullhead was high, preferred length channel catfish were absent from our sample.

Based upon our assessment of the warmwater fish community in Lake Terrell, we outlined management options that follow two related strategies. First, we consider options that enumerate and expand angling on the lake. Second, we suggest rule changes that, in combination, may help preserve current quality fisheries in the face of increased fishing pressure. Management strategies that might improve the warmwater fishery at Lake Terrell include, but are not limited to, the following:

Conduct a Standardized Creel Survey on the Lake

Historically, Lake Terrell has been managed as a mixed–species fishery. Since the 1970s limited creel census data have been collected to help fisheries managers make management decisions for the lake. Furthermore, limitations on resources have prevented a formal creel census in recent years. With increasing public interest in warmwater fisheries, biologists have begun recommending standardized creels surveys on lakes where warmwater fishery enhancement options are practical (Downen and Mueller 1999b). These surveys would allow fisheries managers to assess usage, target species, and harvest rates, and assess the impacts of fishing pressure on community and population characteristics of warmwater fish species. Standardized surveys also would allow for comparison of these parameters between lakes or between years, and strengthen correlations between rule changes and population size structures over time.

Improve Fishing Access

Currently, one boat launch and two piers exist along the southwest shore of Lake Terrell. The pier associated with the boat ramp could be extended and widened. Improvements and minor repairs to the ramp itself might also be practical. The large fishing pier north of the boat launch provides the only substantial shore access to the lake, and during summer months often provides insufficient access for the number of anglers at the lake. An additional pier of similar size would greatly increase access to the lake. Such a project has already been recommended in the Lake Terrell, Tennant Lake Management Plan (1998).

Change Existing Fishing Rules to Preserve Size Structure and Increase Numbers of Stock–length Largemouth Bass

Currently, a 305 – 381 mm (12 – 15 inch) slot limit makes it illegal to retain largemouth bass between 305 and 381 mm from Lake Terrell. This limit is designed to protect largemouth bass for about two years. Of the fish retained outside the slot, no more than three of the five fish allowed per person per day can measure over 381 mm TL. These slot and creel limits are intended to protect fish required for a balance within the lake, and our data suggests the rule has been working as intended. However, a number of lakes in western Washington with the same rule have failed to maintain adequate numbers of larger fish (Mueller 1998, Downen and Mueller 1999a, Mueller and Downen 1999). This phenomenon has occurred in conjunction with increasing public interest in fishing for warmwater species (Kraemer 1992). We have postulated that these failures may be a result of overharvest which either occur through illegal fishing or, if fishing pressure is high, as a result of large creel limits. While there is currently no evidence for overharvest of larger largemouth bass in Lake Terrell we believe slight adjustments in the current rule would reduce impacts of future increases in fishing pressure and possibly increase numbers of stock length fish.

Widening the slot limit to 305 – 457 mm TL (12 – 18 inches), and reducing the daily creel limit from five to three fish with only one taken above the slot may increase numbers of quality length fish and preserve the size structure of largemouth bass. This limit would protect these fish for four to five years and may improve recruitment into the RSD-M length category. 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 reduction in small fish may improve growth and production of predator and prey species (McHugh 1990).

The success of any rule on the lake will depend upon angler compliance with the rules. Reasons for illegal harvest 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). Public access to Lake Terrell is gained through WDFW piers and boat launch facilities. Rules and their purpose should be posted there to inform and encourage anglers in the active management of their resource. The presence of WDFW enforcement personnel during peak harvest periods may currently reduce the possibility of illegal harvest on Lake Terrell. Another important consideration in assessing the impact of fishing pressure and rules on largemouth bass in Lake Terrell is the fact that extensive reaches of the lake are closed from March through June. Although the purpose of this closure is primarily to protect nesting waterfowl from human disturbance, it may also protect mature largemouth bass from fishing pressure through the course of their spawning activities. The effects of these closures merit further investigation.

Change Existing Fishing Rules to Improve the Size Structure of Channel Catfish

Growth of channel catfish in the Pacific Northwest is comparable to growth in other regions of the country (Bonar et al. 1995) where this long–lived species can reach 900 mm in total length (DeRoth 1965, Downen and Mueller 1999b). Channel catfish sampled from Lake Terrell ranged from 419 to 524 mm with no individuals above the RSD-P preferred length threshold of 610 mm. While the PSD for channel catfish in the lake was 100, RSD values were zero, suggesting fish are not recruiting into larger size classes despite survival to recruitment into the fishery.

Currently, a minimum length limit makes it illegal to retain channel catfish smaller than 305 mm from Lake Terrell. Of the daily limit of five fish, only one can measure over 610 mm (24 inches). However, the current rule does not appear to allow channel catfish to maximize their growth potential in Lake Terrell. We suggest increasing the minimum length from 305 mm to the RSD-Q criterion value of 410 mm (16 inches) to increase the relative stock indices for Lake Terrell and protect fish for an additional year (Bonar et al. 1995). Moreover, we suggest reducing the daily limit from five to three fish since large brown bullhead (>305 mm) are abundant in the lake, and could be taken instead.

Change Existing Fishing Rules to Increase Populations of Forage Fish

Generally, fish communities, unbalanced with respect to predator and prey, fall into one of two categories: the predator–crowded community or the prey–crowded community (Swingle and Smith 1947). Rule changes are commonly implemented by fisheries managers in either of these situations to affect changes in the number or size structure of the predator species to achieve balance (Anderson 1976, Novinger 1984). Lake Terrell does not demonstrate strong tendencies toward imbalance with the possible exceptions of low growth rates of yellow perch or low abundance of panfish. However, increased numbers of stock length largemouth bass and larger channel catfish as a result of rule changes mentioned above may require an increase in forage to prevent predator crowding. Moreover, low numbers of panfish in our sample were of some concern. Low numbers of these species in Lake Terrell may be related to overharvest. Anecdotal information suggests that some anglers take large numbers of no–limit fish from the lake. To address these issues, we suggest a rule change for panfish that may increase numbers of these important forage species.

Currently, Lake Terrell falls under the statewide rule for bluegill and pumpkinseed of no size limit and no daily limit. These fish are an important forage species for largemouth bass (Carlander 1977). Therefore, we suggest altering the rule to include a ten fish per day limit to prevent harvesting rates that may have long–term impacts other fish populations in the lake, particularly largemouth bass and larger channel catfish.

Coordinate Sampling Efforts with Department of Ecology to Link Lake Productivity and Zooplankton Dynamics to Fish Populations

Lake productivity, as determined from accurate assessment of water quality data (Carlson 1977), is directly related to fish production (Downing et al 1990, Downing and Plante 1993), primarily through the dynamics of zooplankton populations that most warmwater fish exploit at some stage of their life history (Carlander 1977; Keast 1979; Paszkowski and Tonn 1994; Bonar et al. 1994). Currently, the Washington Department of Ecology is analyzing water quality and zooplankton data collected at Lake Terrell during the time period of our stock assessment, and some effort is being made to correlate fish condition with zooplankton abundance. Coordinating sampling efforts between our agencies might increase our knowledge of the resource base that ultimately supports the fish community in Lake Terrell. Lake Terrell provides a number of opportunities for research related to warmwater fish community ecology and stock responses to fishing regulation changes. Synchronized sampling and collaboration with DOE and other relevant agencies might help us learn more about factors that determine the growth rates, condition, and carrying capacities of warmwater fish populations in western Washington lakes.

Encourage the Collection of Data by Bass Clubs

During this sampling period, we were fortunate in having a bass club tournament occurring the previous week. Members were willing to collect length and weight data from their fish following our protocol that we could compare to our electrofishing data. The similarities in the two data sets were striking. We would like to encourage such cooperation in the future since angling is a valid and important sampling technique, the data from which can then be compared to other sampling methods or to data collected similarly from other lakes. Encouraging the practice of keeping volunteer angler diaries would also benefit fisheries managers.

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