1998 Twin Lakes (Gissburg Ponds) Survey: Assessment and Comparison of the Warmwater Fish Communities in Two Small, Heavily Fished Ponds

by

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Introduction and Background

Twin Lakes (Snohomish County), aka Gissburg ponds, located north of Marysville, were formed from two borrow pits created during the construction of Interstate-5 in the 1960’s. These large (total surface area = 7 ha), moderately deep ponds (maximum depth = 9 m and 5.5 m, north and south, respectively) are somewhat rectangular in shape and nearly equal in size (Figure 1). Connected by a shallow canal, Twin Lakes are fed by a spring from below the north pond and drained by a small ephemeral stream at the southeast corner of the south pond. These ponds form the focus of Twin Lakes County Park which is bordered by Interstate-5 on the east and agricultural lands to the south and west.

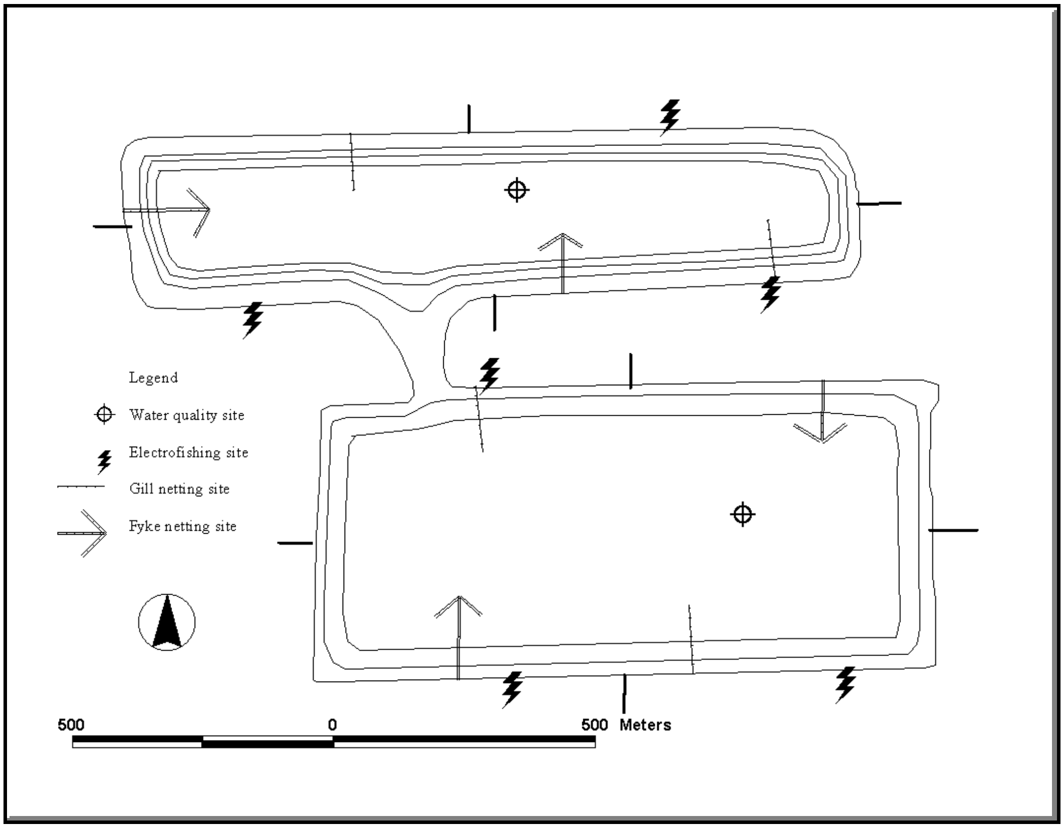

Figure 1. Hydrology, bathymetry, and 1998 sampling sites on Twin Lakes (Snohomish County). Bathymetric lines are drawn at 2 m intervals.

No water quality problems have, as yet, been identified for the ponds. However, data regarding lake productivity and seasonal temperature and dissolved oxygen concentrations are currently unavailable. During an October 1994 fisheries study, Bonar et al. (1995) found dissolved oxygen concentrations above 5 mg/L throughout the water column in both ponds. During this study they also estimated aquatic macrophyte volumes in each of the ponds as 2% for the north pond and 27% for the south pond.

The county park is used for a variety of recreational activities including swimming, canoeing, model boat racing, and fishing. Although no formal creel survey data exists for Twin Lakes, this water body receives heavy fishing pressure for stocked populations of rainbow trout (*Oncorhynchus mykiss*), channel catfish (*Ictalurus punctatus*), and naturalized centrarchid populations of largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), and pumpkinseed sunfish (*Lepomis gibbosus*). The Washington Department of Fish and Wildlife (WDFW) stocks between 8,000 and 10,000 legal-size rainbow trout in four equal plants in March, April, May, and June, annually. The WDFW also stocks between 500 and 1,000 channel catfish each year.

In fall 1994, Bonar et al. (1995) examined growth and survival of channel catfish over a fifteen month period in the north and south pond as part of a larger study including several Washington lakes. Growth of channel catfish in the north and south ponds was high with instantaneous growth rates of 2.1 and 2.2, respectively. Survival was 3.2% and 21.8%, respectively. The largemouth bass during this study were characterized by fewer fish in larger size classes relative to numerous smaller stock length fish. Largemouth bass in all size classes exhibited high relative weight (W_r) values suggesting competition was low and forage abundant.

Twin Lakes were selected for a warmwater fishery stock assessment by the WDFW due to the presence of warmwater populations, the absence of native salmonid populations, and due to the accessibility and popularity of these ponds with anglers. During early fall 1998, personnel from the WDFW Warmwater Enhancement Program surveyed the ponds in order to evaluate species composition, abundance, growth, size structure, and condition of fish in the north and south pond. We compared fish communities of each pond and discussed our results in context of earlier observations of Bonar et al. (1995).

Materials and Methods

Two WDFW biologists and one scientific technician surveyed Twin Lakes during 23 - 25 September 1998. 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 electrofishing boat set to a DC current of 120 cycles/sec at 6 amps. 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 body of the nets stretched around four 1.2 m aluminum rings in each of two sections.

Sampling locations were selected by dividing the shoreline of each pond into four consecutively numbered sections of about 400 m each as determined from a 1:24,000 USGS map (Figure 1). We sampled most of the shoreline by electrofishing three randomly selected sections for a total of 1,800 seconds on each pond. 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 m/minute. Two gill nets were set in each pond perpendicular to the shoreline. The small-mesh end was attached onshore while the large-mesh end was anchored offshore. Two fyke nets were set in each pond in water less than three meters deep, perpendicular to the shoreline with wings extended at 70º angles from the lead. Sampling occurred during evening hours to maximize the number of fish captured. In order to offset biases of the different sampling techniques and to standardize sampling effort among surveys, the sampling time for each gear type was arbitrarily 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. We applied one such sampling unit to each pond.

All fish captured were identified to species with the exception of sculpins which were identified to family. Each fish was measured to the nearest millimeter 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 g. However, if a sample included several hundred individuals of a given species, then a sub-sample ($n \geq 100$ fish) was measured and weighed while the remainder was counted overboard. The length frequency distribution of the sub-sample was then applied to the total number collected. Weights of individuals counted overboard were estimated using 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). Furthermore, given the emphasis of this study on warmwater species, growth was not assessed for salmonid and non-game fish.

Water quality data was collected during midday from mid-basin of each pond on 23 September 1998 using a Hydrolab® probe and digital recorder. We measured dissolved oxygen, toal dissolved solids, temperature, pH, and specific conductance and recorded Secchi disc readings in meters (Table 1).

Table 1. Water quality from the deepest locations on Twin Lakes (Snohomish County) collected at mid-day on 23 September 1998. Secchi depth = 1.5 m for south pond and 6.5 (bottom) for north pond.

Location	Depth (m)	Temp (°C)	DO (mg/L)	pH	Conductance (uS/cm)	TDS (g/L)
North Twin	1	20.40	8.54	8.12	170.9	0.1103
	2	20.24	8.86	7.95	172.6	0.1103
	3	20.07	8.55	7.82	172.6	0.1107
	4	20.00	8.61	7.73	172.1	0.1101
	5	19.97	8.65	7.71	171.9	0.1102
	6	19.91	8.62	7.69	172.8	0.1105
	7	19.84	8.52	7.65	173.8	0.1107
South Twin	1	19.89	7.24	8.29	147.7	0.0947
	2	19.64	6.71	8.14	148.5	0.0948
	3	19.57	6.85	7.82	148.7	0.0949
	4	19.53	6.72	7.81	148.2	0.0948

Data Analysis

Each pond was sampled with one standardized sampling unit and subsequently treated as a unique body of water for analysis. Species composition, catch per unit effort, PSD, age and growth, length frequency distribution, and relative weight are reported for each pond and compared qualitatively. The small size of the ponds and subsequent small sample size for CPUE and PSD prevented rigorous statistical analysis of differences for these indices. However, mean length, relative weight, and length frequency distribution were compared statistically.

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 fishermen 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 and potential for interaction, and the adequacy of the food supplies for various foraging niches (Ricker 1975, Kohler and Kelly 1991). The balance and productivity of the community may also be addressed based upon evaluation of these factors (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 size distribution by the following year. However, the presence of these fish in the system relates directly to fecundity, to the forage base for larger fish, and to questions of interspecific and intraspecific competition at lower trophic levels (Olson et al. 1995).

Mean catch per unit effort (CPUE) by gear type was determined for each warmwater fish species (number of fish/hour electrofishing and number of fish/net night). Only stock length fish and larger were used to determine CPUE. Stock length, which varies by species (see Table 2 and discussion below), refers to the minimum size of fish having recreational value. Since random selection of sample locations can introduce high variability into the data due to habitat differences within the lake, we determined 80% confidence intervals (CI) 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 the lakes. CPUE values for north and south Twin Lakes 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)**	**Gill netting (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
Pumpkinseen Sunfish	70.8	11	3.8	9	7.9	4

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 class 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. Salmonid size structures were evaluated with stacked length frequency histograms as well. Due to the distinct habitat and spatial separation of the two ponds, we compared length frequency distributions of warmwater fish species from the north and south pond with the two-sample Kolmogorov-Smirnov goodness-of-fit (GOF) test (Zar 1984, S-Plus 4.5, 1998).

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% of world-record length) refers to the minimum size fish with recreational value, whereas quality length (36-41% of world-record length) refers to the minimum size fish most anglers like to catch.

The relative stock density (RSD) of each warmwater fish species was examined using the five-cell model proposed by Gabelhouse (1984). In addition to stock and quality length, Gabelhouse (1984) introduced preferred, memorable, and trophy length categories (Table 3). Preferred length (45-55% of world-record length) refers to the minimum size fish anglers would prefer to catch. Memorable length (59-64% of world-record length) refers to the minimum size fish anglers would be likely to 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 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).

Table 3. Length categories for warmwater fish species by Gabelhouse (1984) used to calculate stock density indices (PSD,RSD) for fish captured at Twin Lakes (Snohomish County) during early fall 1998. Measurements are minimum total lengths (mm) for each category (Anderson and Neumann 1996).

Species	Size				
	Stock	Quality	Preferred	Memorable	Trophy
Largemouth bass	200	300	380	510	630
Bluegill	80	150	200	250	300
Pumpkinseed	80	150	200	250	300
Channel catfish	280	410	610	710	910

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 trophy bass option and each of these has associated ranges of PSD and RSD values (Table 4).

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	0 – 10	50 – 80	10 – 30
Balanced	40 – 70	10 – 40	10 – 25	20 – 60	5 – 20
Big bass	50 – 80	30 – 60		10 – 50	0 – 10

We compared PRD and RSD values for warmwater species in north and south Twin Lakes with western Washington State averages compiled by the WDFW Inland Fisheries Research Unit (Table 5).

Table 5. Mean stock density indices for available warmwater fishes collected from western Washington lakes while electrofishing, gill netting, and fyke netting 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, and FN = fyke netting.

Species	Gear Type	n (lakes)	PSD	RSD-P	RSM-M	RSD-T
Largemouth bass	EB	12	29	13	0	0
Bluegill	EB	9	16	0	0	0
Pumpkinseed	EB	12	8	0	0	0

Age and growth of warmwater fishes in Twin Lakes 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 $L_n = a \pm A \times (TL - a)/S$, 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 Twin Lakes fish and the state average (listed in Fletcher et al. 1993) for the same species.

A relative weight (W_r) index was used to evaluate the condition of fish in the lake. A W_r value of 100 generally indicates that a fish has a condition value equal 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 (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 or foraging efficiency is low among larger size classes. Conversely, lower relative weights occurring with smaller fish reflects increased competition for these fish or reduced competition in larger size classes (Willis 1999). These patterns can suggest differences in the seasonal abundance of forage for different size classes, crowding, or over harvest of larger fish. Testing the statistical significance of the relationship between total length and relative weight, standard transformation failed to normalize the length data. 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. Length frequency distributions and relative weights data from the ponds were not normally distributed so the Mann-Whitney test was used to compare means (Zar 1984).

Results and Discussion

Species Composition

North Twin

During early fall 1998, our sample from the fish community of the North Twin was dominated by largemouth bass by both biomass and number (Table 6). One channel catfish accounted of 14% of the biomass of our catch.

Table 6. Species composition by weight (kg) and number of fish captured at Twin Lakes (Snohomish County) during early fall 1998.

	Species Composition				
	by weight		by number		
Species	**(kg)**	**(%) weight**	**(kg)**	**(%) n**	**Size range (mm TL)**
Largemouth Bass (*Micropterus salmonides*)	10.778	44.9	241	49.5	56-413
Channel Catfish (*Ictalurus punctatus*)	3.554	14.8	1	0.2	635
Bluegill (*Lepomis macrochirus*)	4.545	18.6	122	25.1	32-175
Pumpkinseed (*Lepomis gibbosus*)	1.991	8.3	60	12.3	256-318
Rainbow Trout (*Oncorhynchus mykiss*)	2.192	9.1	9	1.8	37-160
Sculpin (*Cottus* spp.)	1.031	4.3	54	11.1	
Total	24.000		487		

South Twin

During early fall 1998, our sample from the fish community of the South Twin was dominated by largemouth bass by biomass and bluegill by number (Table 7). Together these species accounted for more than 80 % of the species composition by both number and biomass. Bluegill accounted for a much larger proportion of the biomass and number than for the North Twin. No channel catfish were captured in the South Twin.

Table 7. Species composition by weight (kg) and number of fish captured at Twin Lakes (Snohomish County) during early fall 1998.

	Species Composition				
	by weight		by number		
Species	**(kg)**	**(%) weight**	**(kg)**	**(%) n**	**Size range (mm TL)**
Largemouth Bass (*Micropterus salmonides*)	7.944	46.3	218	33.3	73-306
Bluegill (*Lepomis macrochirus*)	6.524	38.0	354	54.1	28-146
Rainbow Trout (*Oncorhynchus mykiss*)	2.132	12.4	77	11.8	79-137
	0.565	3.3	5	0.8	222-262
Total					

CPUE

North Twin

Catch rates for the north pond were highest for stock-length bluegill while electrofishing and were consistent with western Washington State averages (See Table 2). Catch rates for other species were considerably lower for all gear types (Table 8) and below western Washington State averages. However, fyke net sets captured bluegill and pumpkinseed at rates above average.

Table 8. Mean catch per unit effort (number of fish/hour electrofishing and number of fish/net night), including 80% confidence intervals, for stock size fish collected from North Twin Lakes (Snohomish County) while electrofishing, gill netting, and fyke netting during early fall 1998.

	Gear Type					
Species	**Electrofishing (fish/hr)**	**n (sites)**	**Gill netting (fish/hr)**	**n (net nights)**	**Fyke netting (fish/hr)**	**n (net nights)**
Largemouth Bass	17.97 ± 15.98	3	2.5 ± 1.92	2	0	2
Channel Catfish	0	3	0.5 [a]	2	0	2
Bluegill	127.56 ± 29.79	3	0.5 [a]	2	18 [a]	2
Pumpkinseed Sunfish	39.8 ± 18.41	3	2 ± 1.28	2	15 [a]	2
Rainbow Trout	7.99 [a]	3	2.5 ± 1.92	2	0	2
Sculpin	71.7 [a]	3	0	2	0	2

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

South Twin

Catch rates for the south pond were very high for bluegill both electrofishing and fyke netting. Catch rates were also high for pumpkinseed while electrofishing. Catch rates for both sunfish species were considerably higher than western Washington State averages. Stock-length rainbow trout were captured in low numbers in the south pond. Catch rates for largemouth bass were similar for both ponds among all gear types (Table 9) and below western Washington State averages.

Table 9. Mean catch per unit effort (number of fish/hour electrofishing and number of fish/net night), including 80% confidence intervals, for stock size fish collected from Twin Lakes (Snohomish County) while electrofishing, gill netting, and fyke netting during early fall 1998.

	Gear Type					
Species	**Electrofishing (fish/hr)**	**n (sites)**	**Gill netting (fish/hr)**	**n (net nights)**	**Fyke netting (fish/hr)**	**n (net nights)**
Largemouth Bass	19.87 ± 10.14	3	0	2	0	2
Bluegill	447.83 ±34.1	3	2.5 ± 1.92	2	32 ± 19.22	2
Pumpkinseed Sunfish	125.17 ± 84.95	3	6 ± 5.13	2	0.5 [a]	2
Rainbow Trout	0	3	0.5 [a]	2	0	2

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

Stock Density Indices

North Twin

Proportional stock density indices (PSD) and relative stock density indices (RSD) for largemouth bass (Table 10) were below those reported for other western Washington lakes (Mueller 1998, Downen and Mueller 1999), below western Washington State averages (See Table 5), and below values generally accepted for balanced predator/prey communities (Willis et al. 1993). However, sample sizes were small with values for largemouth bass being based upon only 15 stock length fish. Stock length bluegill and pumpkinseed were captured in moderate numbers while electrofishing, with PSD for bluegill consistent with the state average. However, PSD values for these fish were low compared to generally accepted ranges for panfish fisheries, balanced communities or trophy waters (Willis et al. 1993).

Table 10. Traditional stock density indices, including 80% confidence intervals, for warmwater fishes collected from north Twin Lakes (Snohomish County) while electrofishing, gill netting, and fyke netting during early fall 1998. 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	n	PSD	RSD-P	RSD-M	RSD-T
Largemouth Bass	EB	15	13 ± 11	7 [a]	0	0
	GN	5	0	0	0	0
	FN	0	0	0	0	0
Channel Catfish	EB	0	0	0	0	0
	GN	1	100	100	0	0
	FN	0	0	0	0	0
Bluegill	EB	65	17 ± 6	0	0	0
	GN	1	0	0	0	0
	FN	36	6 ± 5	0	0	0
Pumpkinseed	EB	22	0	0	0	0
	GN	4	0	0	0	0
	FN	0	3 [a]	0	0	0
Rainbow Trout	EB	4	0	0	0	0
	GN	5	0	0	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

South Twin

Proportional stock density indices (PSD) and relative stock density indices (RSD) for largemouth bass (Table 11) were below those reported in other Western Washington lakes (Mueller 1998, Downen and Mueller 1999), below Western Washington State averages, and below values generally accepted for balanced predator/prey populations (Willis et al. 1993). However, sample sizes were small with values for largemouth bass being based upon only 10 stock length fish (Table 9). Bluegill and pumpkinseed were captured in large numbers while electrofishing. However, PSD values for these fish were very low compared to the state averages, generally accepted ranges for panfish fisheries, balanced communities or trophy waters (Willis et al. 1993).

Table 11. Traditional stock density indices, including 80% confidence intervals, for warmwater fishes collected from south Twin Lakes (Snohomish County) while electrofishing, gill netting, and fyke netting during early fall 1998. 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	n	PSD	RSD-P	RSD-M	RSD-T
Largemouth Bass	EB	10	10 [a]	0	0	0
	GN	0	0	0	0	0
	FN	0	0	0	0	0
Bluegill	EB	225	0	0	0	0
	GN	5	0	0	0	0
	FN	64	0	0	0	0
Pumpkinseed	EB	63	0	0	0	0
	GN	12	0	0	0	0
	FN	1	0	0	0	0
Rainbow Trout	EB	4	0	0	0	0
	GN	5	0	0	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

Largemouth Bass

North Twin

Largemouth bass ranged from 56 to 413 mm TL (age 0+ to 8+) (Table 12, Figure 2). Age 1+, 2+, and 3+ fish were relatively abundant. Fish older than age 4+ were unsampled with the exception of two older individuals. Growth of largemouth bass collected from Twin Lakes was below the western Washington State average until age 3+ and consistent with the average thereafter. Relative weights were below western Washington State averages for small size classes with higher W_r values occurring with larger size classes (Figure 3). The Spearman correlation coefficient (Rho) for largemouth bass length and relative weight was 0.537 ($p < 0.01$).

Table 12. Age and growth of largemouth bass captured at north Twin Lakes (Snohomish County) during early fall 1998. 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**	**8**
1997	16	66.2							
		75.2							
1996	20	59.7	130.7						
		72.9	136.4						
1995	12	60.8	108.4	160.5					
		74.5	117.1	163.8					
1994	4	64.5	100.6	137.5	166.8				
		77.8	110.2	143.3	169.5				
1993	1	71.0	110.4	173.4	275.9	323.2			
		86.8	123.9	183.2	279.7	324.2			
1992	0								
1991	0								
1990	1	74.3	148.7	190.0	235.4	322.1	346.9	359.3	380.0
		90.7	161.5	200.8	244.0	326.5	350.1	361.9	381.6
Overall mean		66.1	119.8	165.4	226.0	322.7	346.9	359.3	380.0
Weighted mean		74.9	127.9	162.4	200.3	325.4	350.1	361.9	381.6
State Average		60.4	145.5	222.2	261.1	289.3	319	367.8	396

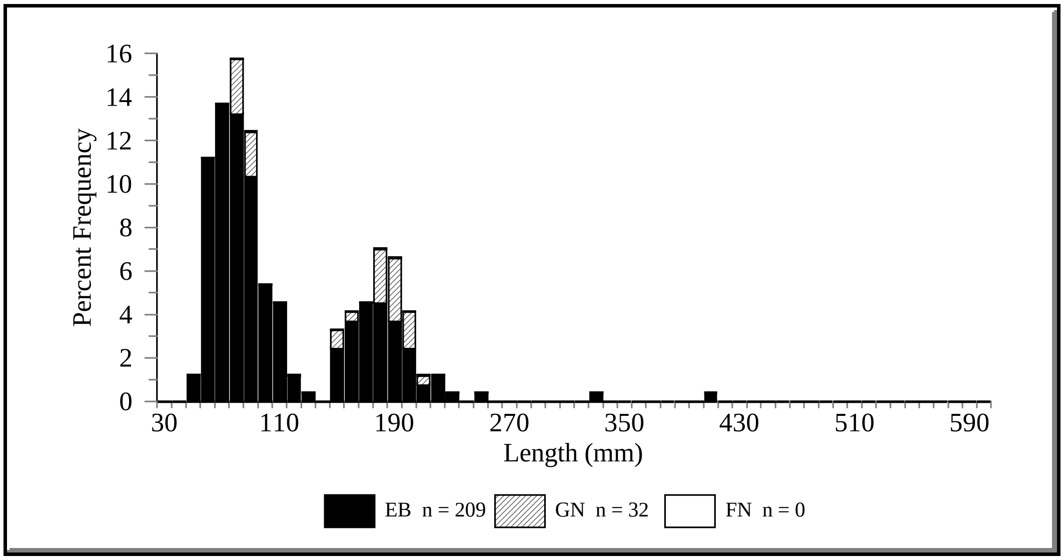

Figure 2. Length frequency histogram of largemouth bass sampled from north Twin Lakes in early fall 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

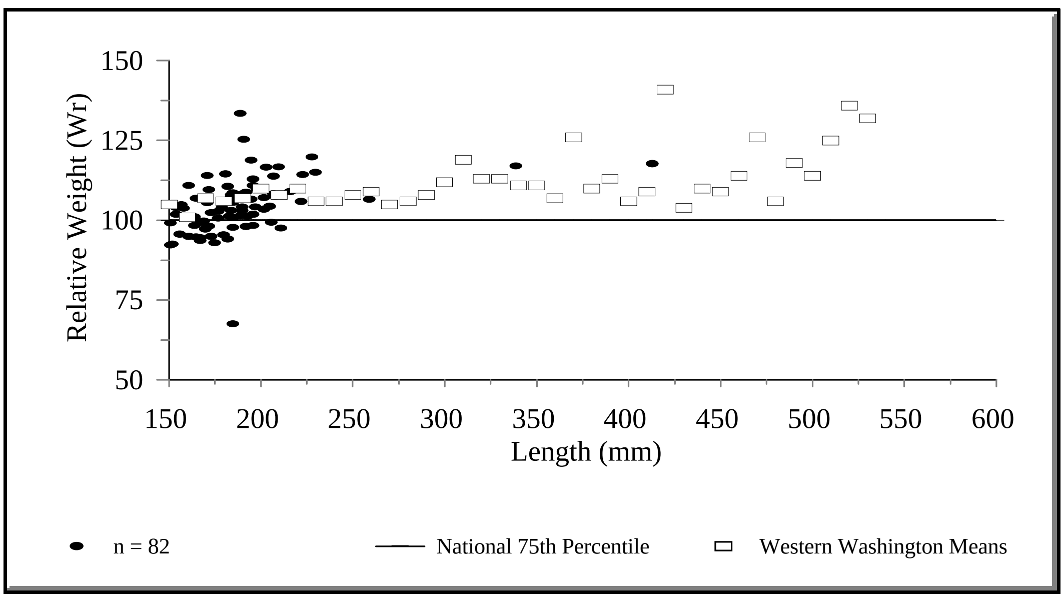

Figure 3. Relationship between total length and relative weight (W_r) of largemouth bass from north Twin Lakes, (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

South Twin

Largemouth bass ranged from 73 to 306 mm (age 0+ to 3+) (Table 13, Figure 4). Age 1+ and 2+ fish were relatively abundant. Fish older than age 3+ were not sampled. Growth of largemouth bass collected from south Twin Lakes was consistent with the western Washington State average. Relative weights were below western Washington State averages for small size classes with higher W_r values occurring with larger size classes (Figure 5). The Spearman correlation coefficient (Rho) for largemouth bass length and relative weight was 0.182 ($p = 0.121$). Length frequency distributions for largemouth bass from the north and south ponds were not significantly different ($D = 0.0984$ and $p = 0.933$). Mean length of stock-length largemouth bass in the south pond was not significantly different than the mean of those in the north pond ($p = 0.169$). However, mean relative weight was significantly higher for largemouth bass captured in the north pond ($p < 0.01$).

Table 13. Age and growth of largemouth bass captured at south Twin Lakes (Snohomish County) during early fall 1998. 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**
1997	15	66.4		
		78.6		
1996	16	59.5	151.4	
		73.2	155.4	
1995	2	56.6	131.2	211.4
		71.9	140.4	214.3
Overall mean		60.8	141.3	211.4
Weighted mean		75.6	153.8	214.3
State Average		60.4	145.5	222.2

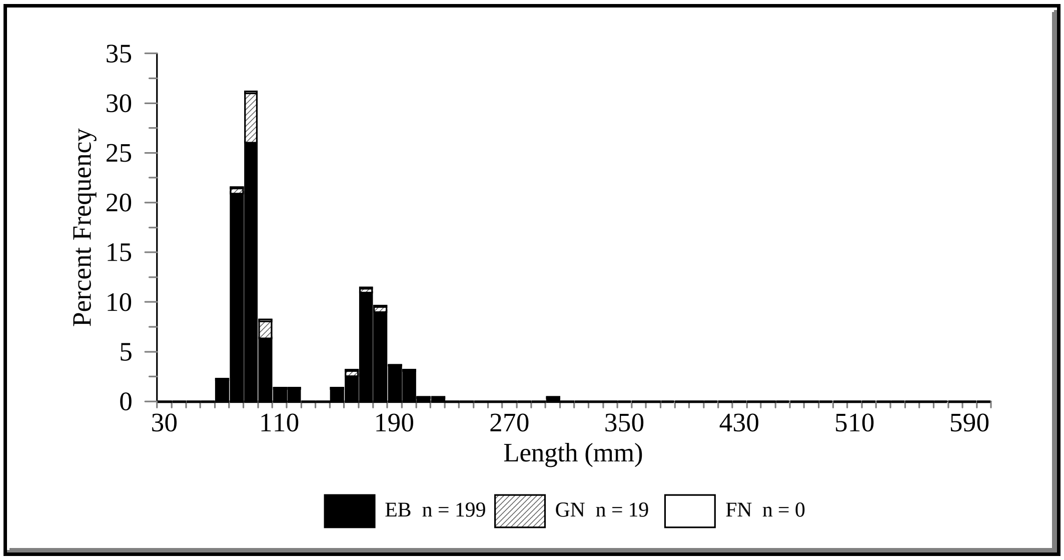

Figure 4. Length frequency histogram of largemouth bass sampled from south Twin Lakes in early fall 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

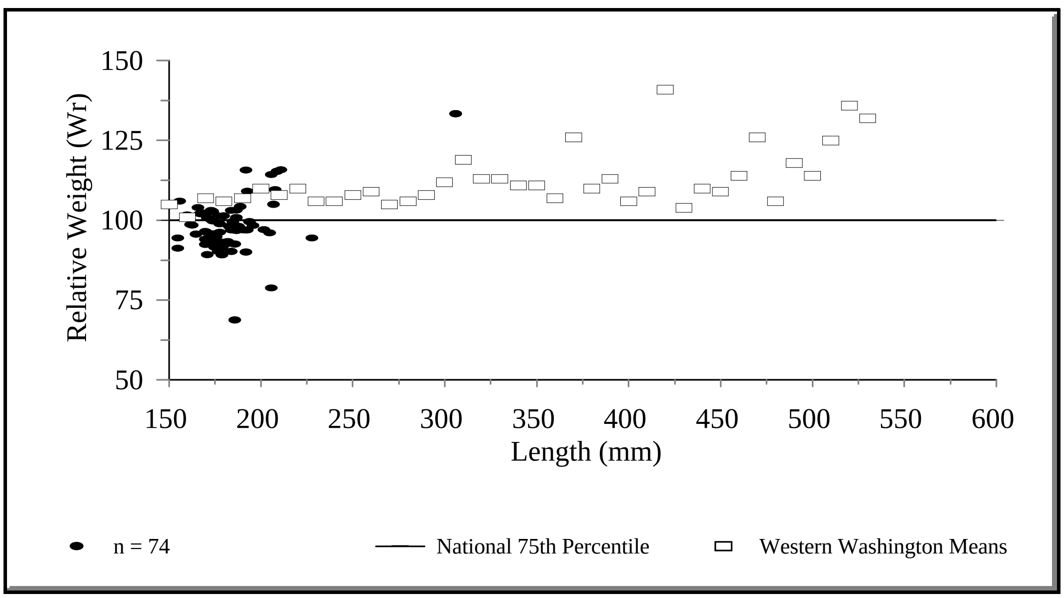

Figure 5. Relationship between total length and relative weight (W_r) of largemouth bass from south Twin Lakes, (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Bluegill

North Twin

Bluegill ranged from 32 to 175 mm TL (age 1+ to 5+) (Table 14, Figure 6). Growth rates for bluegill in north Twin Lakes were consistent with the Washington State average. Relative weight values were also consistent with the Washington State average (Figure 7). The Spearman coefficient (Rho) for bluegill length and relative weight was 0.614 ($p < 0.01$).

Table 14. Age and growth of bluegill captured at Twin Lakes (San Juan County) during early fall 1998. 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**
1997	22	55.9				
		66.0				
1996	9	62.9	115.1			
		73.7	118.4			
1995	5	62.1	110.0	131.5		
		73.4	114.6	133.2		
1994	0					
1993	3	62.7	107.8	121.5	139.3	151.5
		74.9	114.5	126.5	142.1	152.8
Overall mean		60.9	110.0	126.5	139.3	151.5
Weighted mean		69.4	116.6	130.7	142.1	152.8
State Average		37.3	96.8	132.1	148.3	169.9

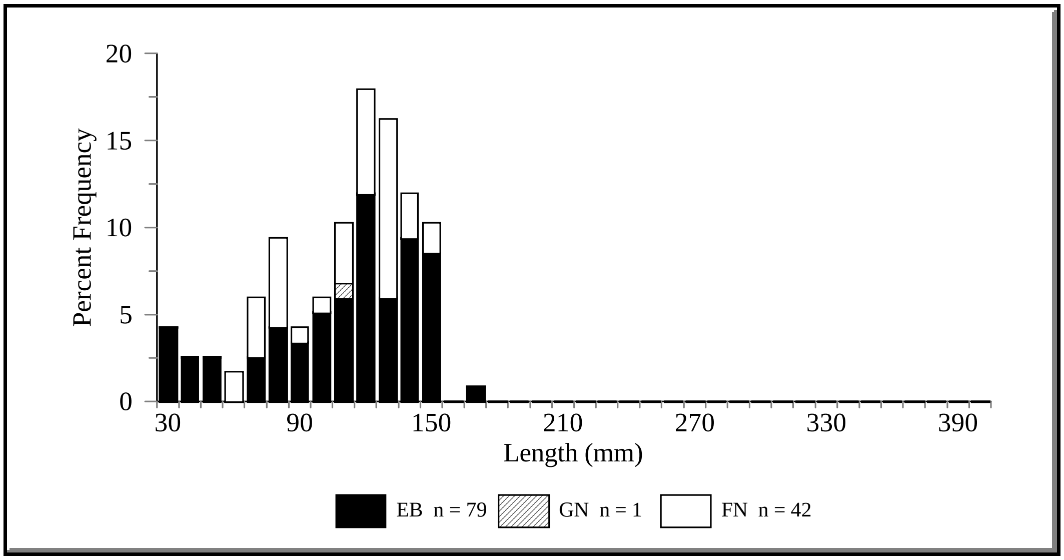

Figure 6. Length frequency histogram of bluegill sampled from north Twin Lakes in early fall 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

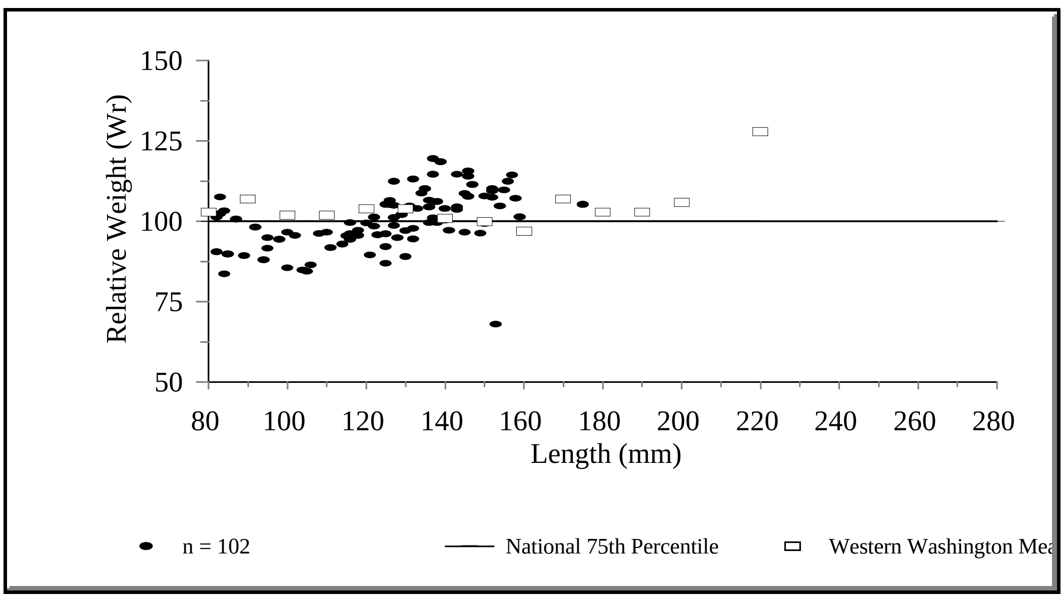

Figure 7. Relationship between total length and relative weight (W_r) of bluegill from north Twin Lakes, (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

South Twin

Bluegill ranged from 28 to 148 mm (TL) (age 0+ to 3+) (Table 15, Figure 8). Growth rates for bluegill in south Twin Lakes were consistent with the Washington State average and higher than those in the north pond, despite higher densities. Relative weight values were also consistent with the Washington State average (Figure 9). The Spearman coefficient (Rho) for bluegill length and relative weight was 0.090 ($p = 0.124$). Length frequency distributions for bluegill from the north and south ponds were not significantly different ($D = 0.222$ and $p = 0.527$). The mean length of stock-length fish was significantly greater for bluegill in the north pond ($p < 0.01$). However, the mean relative weights were not significantly different ($p = 0.650$).

Table 15. Age and growth of bluegill captured at south Twin Lakes (San Juan County) during early fall 1998. 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**
1997	19	54.5		
		64.3		
1996	7	63.0	109.8	
		73.4	112.9	
1995	1	71.8	127.0	136.7
		81.9	129.5	137.9
Overall mean		63.1	118.4	136.7
Weighted mean		67.3	115.0	137.9
State Average		37.3	96.8	132.1

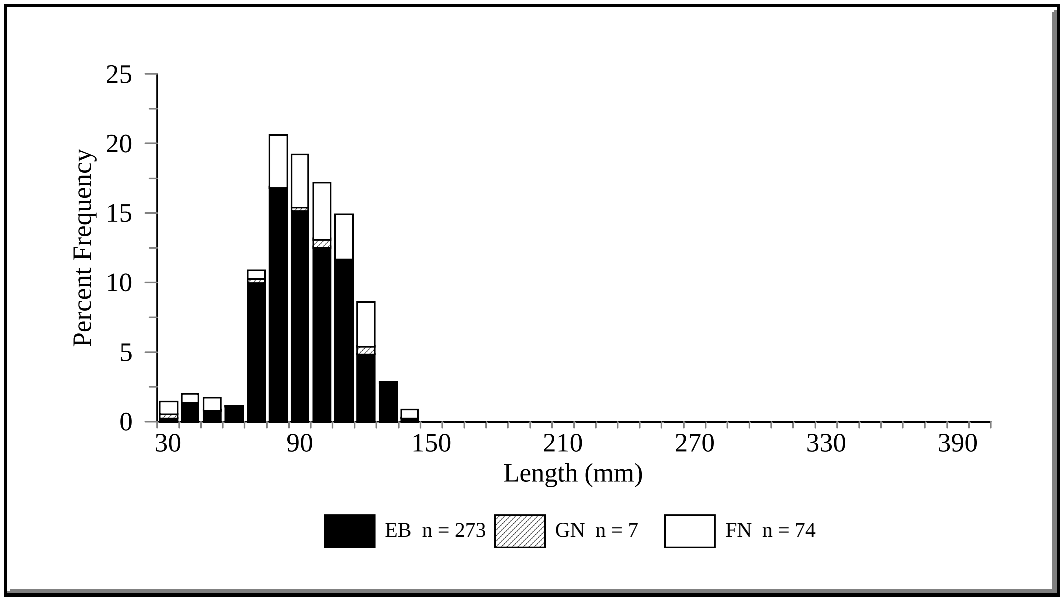

Figure 8. Length frequency histogram of bluegill sampled from south Twin Lakes in early fall 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

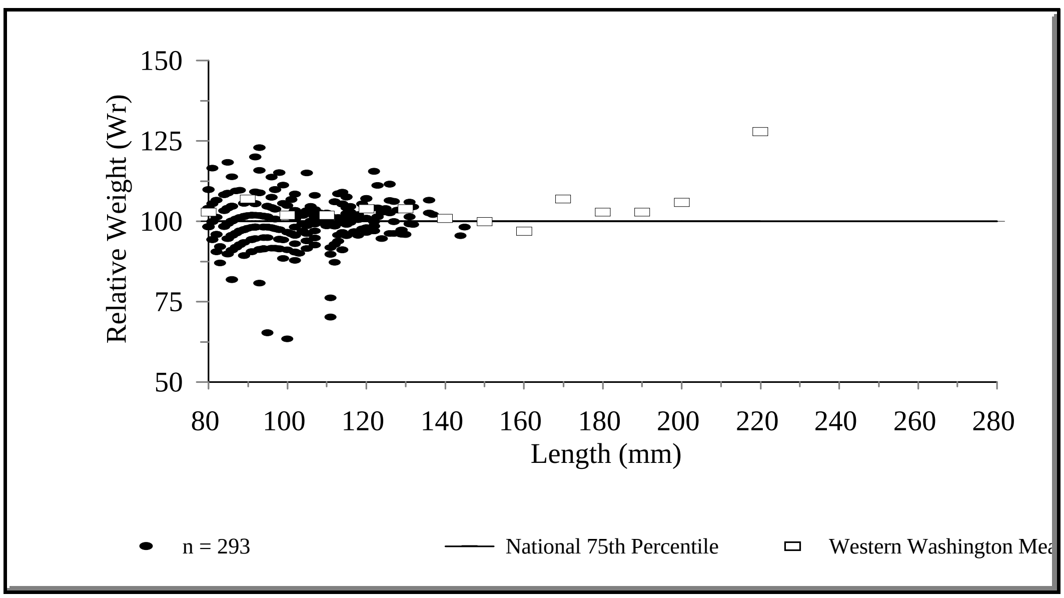

Figure 9. Relationship between total length and relative weight (W_r) of bluegill from south Twin Lakes, (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Pumpkinseed

North Twin

Pumpkinseed ranged from 72 to 152 mm (TL) (age 0+ to 5) (Table 16, Figure 10). Growth rates for pumpkinseed in north Twin Lakes were consistent with the Washington State average. Relative weight values were below the Washington State average (Figure 11). The Spearman correlation coefficient (Rho) for pumpkinseed length and relative weight was 0.784 ($p < 0.01$).

Table 16. Age and growth of pumpkinseed captured at Twin Lakes (Snohomish County) during early fall 1998. 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**
1997	13	43.8				
		57.7				
1996	5	42.2	84.3			
		58.1	91.0			
1995	9	44.5	77.4	104.9		
		60.8	87.4	109.5		
1994	1	35.8	68.0	89.5	114.6	
		54.5	81.0	98.7	119.4	
1993	4	37.8	67.8	91.7	112.1	133.8
		56.2	80.9	100.6	117.4	135.3
Overall mean		40.8	74.4	95.4	113.3	133.8
Weighted mean		58.4	86.6	106.2	117.8	135.3
State Average		23.6	72.1	101.6	122.7	139.4

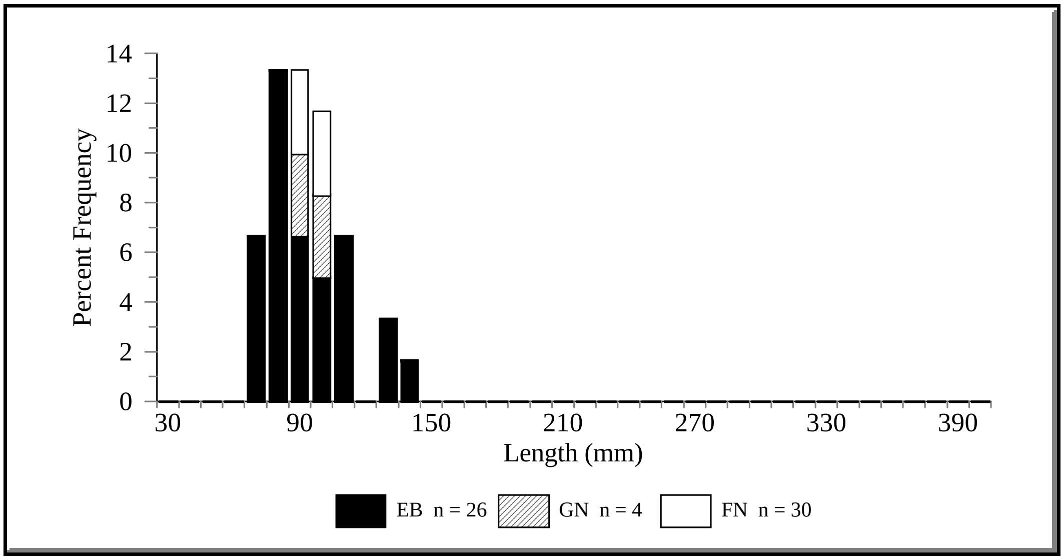

Figure 10. Length frequency histogram of pumpkinseed sampled from northTwin Lakes in early fall 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

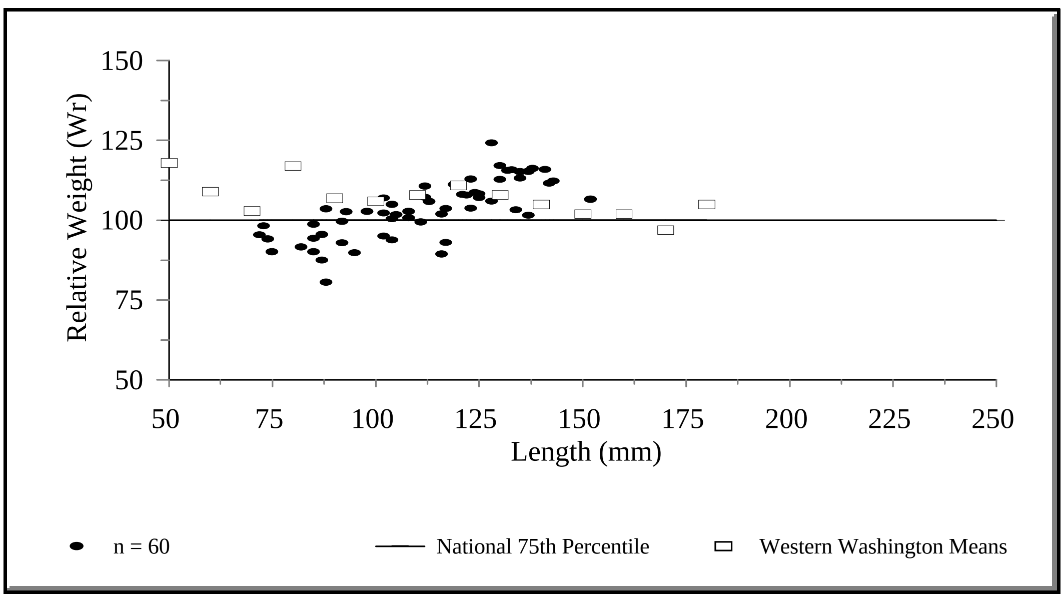

Figure 11. Relationship between total length and relative weight (W_r) of pumpkinseed from north Twin Lakes, (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

South Twin

Pumpkinseed ranged from 79 to 137 mm (TL) (age 1+ to 7+) (Table 17, Figure 12). Growth rates for pumpkinseed in Twin Lakes were above the Washington State average, and higher than those for the north pond, despite higher densities. Relative weight values were below the Washington State average (Figure 13). The Spearman correlation coefficient (Rho) for pumpkinseed length and relative weight was 0.350 (p = 0.002). Length frequency distributions for pumpkinseed from the north and south ponds were not significantly different (D = 0.185 and p = 0.754). Neither mean lengths nor mean relative weights of stock-length fish were significantly different between ponds (p = 0.111, p = 0.093, respectively).

Table 17. Age and growth of pumpkinseed captured at Twin Lakes (Snohomish County) during early fall 1998. 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**
1997	17	43.7		
		57.4		
1996	10	45.5	92.0	
		61.0	97.3	
1995	2	48.5	92.5	106.4
		64.4	100.3	111.5
Overall mean		45.9	92.3	106.4
Weighted mean		59.1	97.8	111.5
State Average		23.6	72.1	101.6

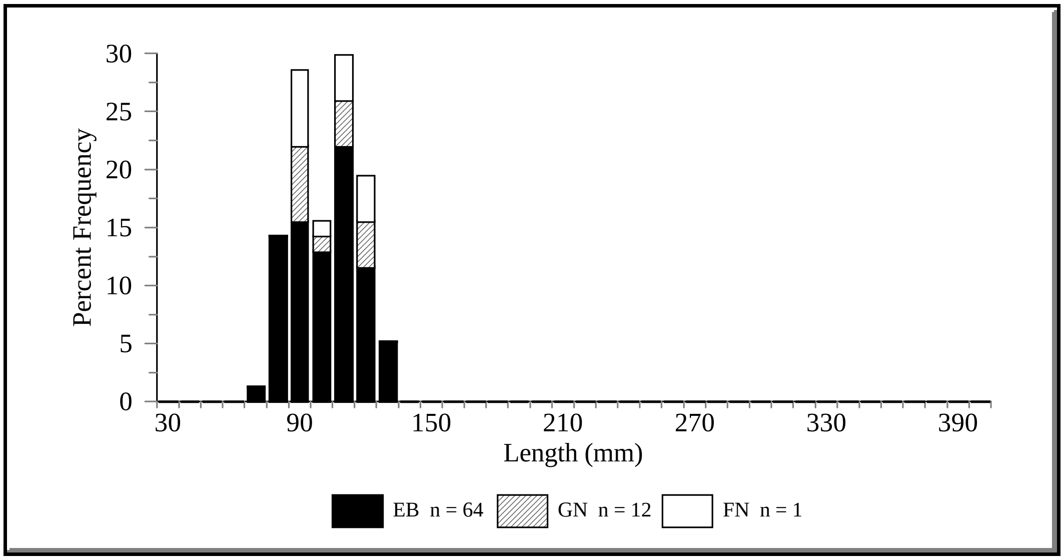

Figure 12. Length frequency histogram of pumpkinseed sampled from south Twin Lakes in early fall 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

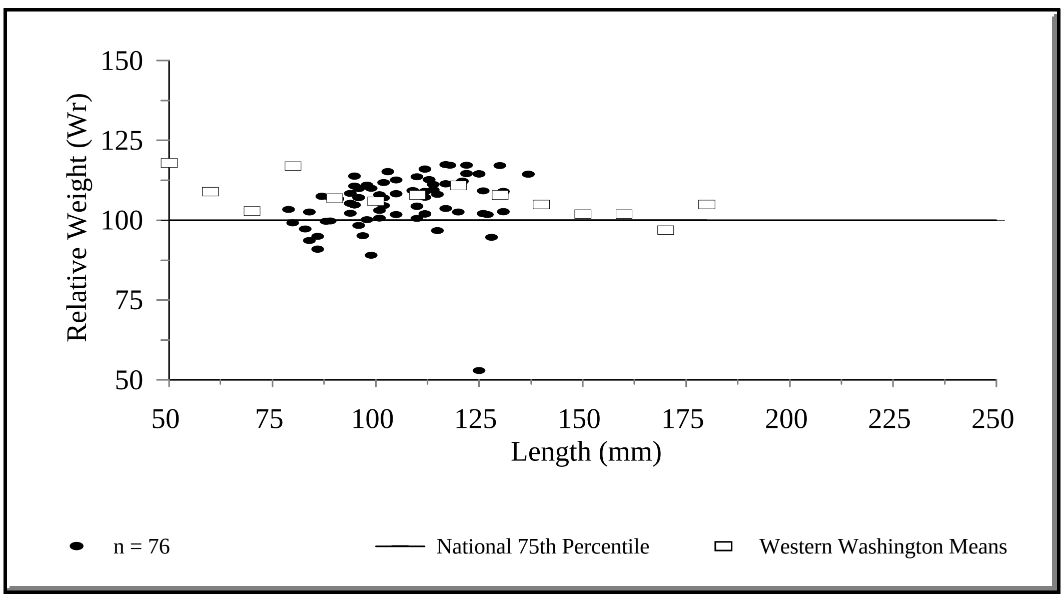

Figure 13. Relationship between total length and relative weight (W_r) of pumpkinseed from south Twin Lakes, (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Members of the Family Ictaluridae

North Twin

We captured one channel catfish in the north pond measuring 635 mm (TL), weighing 3.554 kg, with a relative weight of 131. Although we only captured one individual, another gill net sustained considerable damage from a large fish that had escaped before we retrieved the net. We suspect it was another large channel catfish.

South Twin

We did not sample any channel catfish in the south pond either by electrofishing or with nets. Poor visibility may have contributed to our low elctrofishing catch rate for this species.

Members of the Family Salmonidae

North Twin

We captured nine rainbow trout ranging from 256 to 318 mm fork length (FL) in the north pond (Figure 14). These individuals were probably stocked the previous spring. Relative weights for these fish were slightly below the 75th percentile but consistent with rainbow trout sampled in other western Washington lakes (Figure 15).

South Twin

We captured five rainbow trout ranging from 222 to 262 mm FL in the south pond (Figure 16). These fish were also probably from fish stocked the previous spring. Relative weights for these fish much lower than those sampled from the north pond (Figure 17).

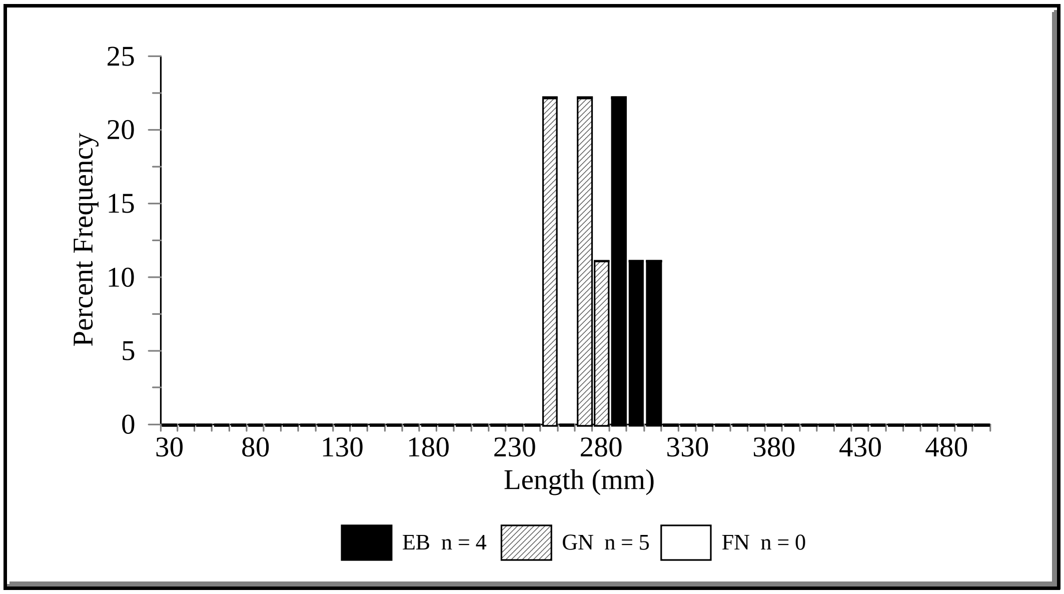

Figure 14. Length frequency histogram of rainbow trout sampled from north Twin Lakes in early fall 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

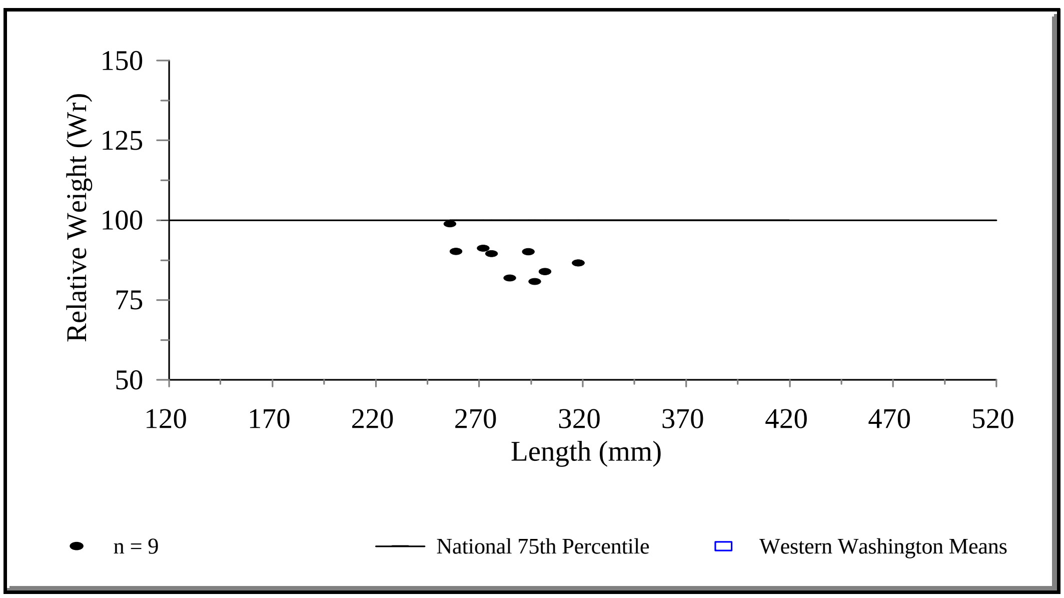

Figure 15. Relationship between total length and relative weight (W_r) of rainbow trout from north Twin Lakes, (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

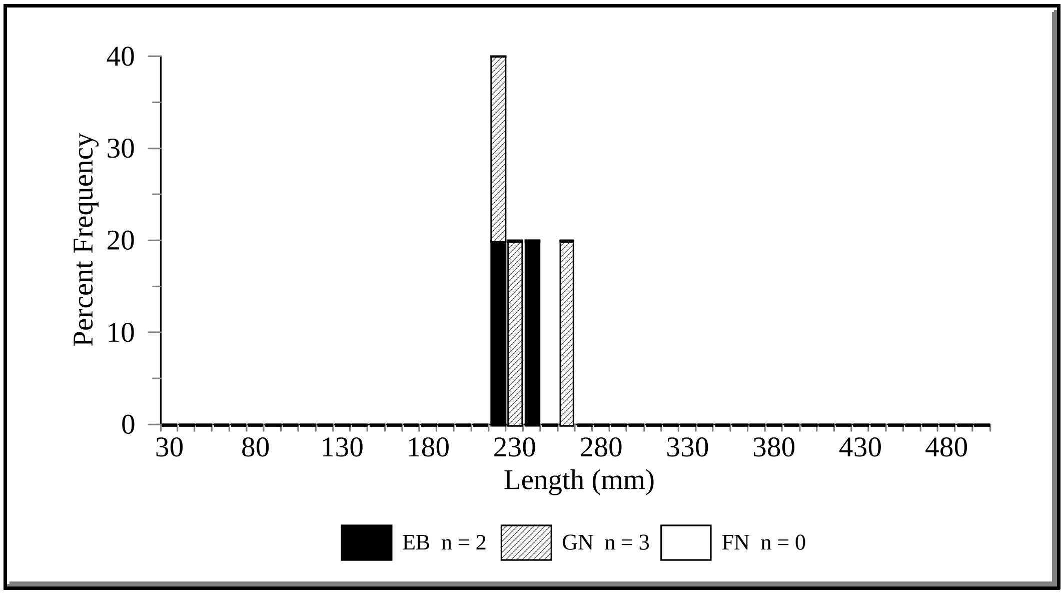

Figure 16. Length frequency histogram of rainbow trout sampled from south Twin Lakes in early fall 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

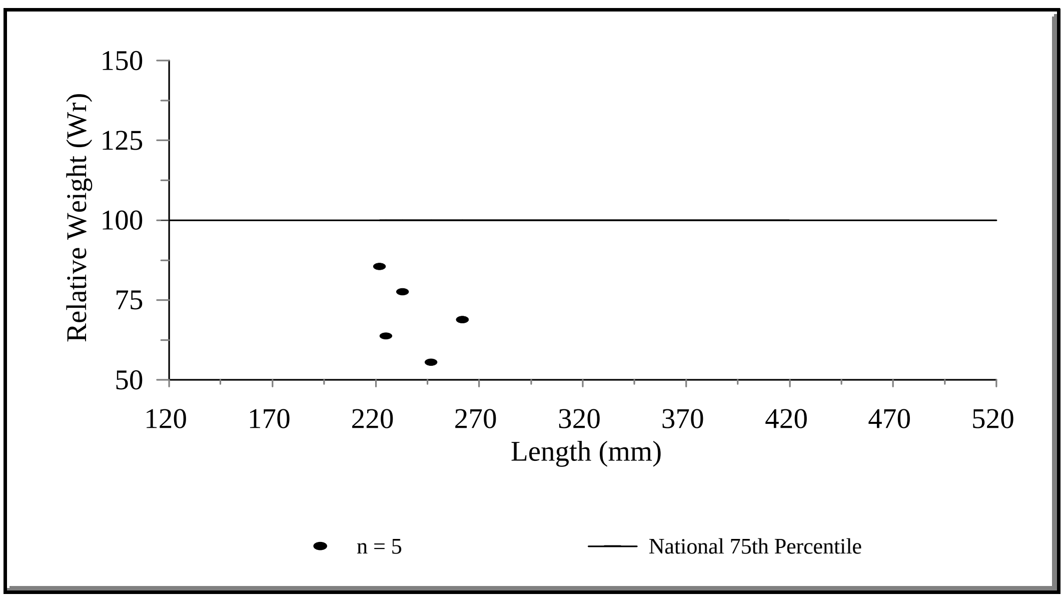

Figure 17. Relationship between total length and relative weight (W_r) of rainbow trout from south Twin Lakes, (Snohomish County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Warmwater Enhanement Options

Despite the connection of the ponds by a shallow canal, we noted distinct water quality differences between the north and south pond. We observed much higher visibility as well as higher dissolved oxygen concentrations in the north pond. Water quality in the south pond was characterized by high plankton growth. Higher productivity may be related to elevated nutrient levels or increased light in the south pond. However, a paucity of water quality data for these ponds prevents us from speculating beyond our own measurements and observations. During our survey we did not detect dissolved oxygen concentrations below 5 mg/L. However, lower concentrations in the south pond throughout the water column may be directly related to eutrophic conditions observed during our survey.

Habitat in both ponds was characterized by low densities of coarse woody debris and moderate densities of submerged vegetation. Emergent vegetation was only present in the south pond during the time of our survey and plant biomass in the south pond occupied a substantially greater volume. Our observations were consistent with habitat descriptions and assessment given by Bonar et al. (1995) in a previous WDFW study.

Differences in species composition between the ponds were subtle with the exception of the single channel catfish and numerous sculpin sampled from the north pond. These differences may have been influenced by environmental conditions associated with sampling, particularly visibility. Visibility may also have contributed to actual differences in community structure and population attributes of warmwater species. The fish communities inhabiting both ponds were dominated by largemouth bass by biomass. Although differences in length frequency distribution and mean total stock length were not significant, higher PSD and RSD in the north pond suggest a different size structure of these populations. The mean relative weight was significantly higher for largemouth bass in the north twin and there was a significant positive correlation in relative weight and total length for individuals captured in the north pond. However, growth was higher for largemouth bass in the south pond through age 3+ despite higher densities there. Growth of largemouth bass in the north pond was slow through age 3+ but increased thereafter. Higher growth rates of juveniles may be influenced by apparent differences in productivity, the transfer of energy through the food web, crowding relative to available resources. Differences in relative weight may reflect a seasonal difference in food availability. Reduced visibility during periodic phytoplankton blooms may reduce foraging efficiency and contribute to lower relative weights of largemouth bass in the south pond. Similar trends in abundance, size structure, and growth existed for bluegill and pumpkinseed, with fewer, larger, slower growing fish being sampled from the north pond.

While no formal creel surveys have been carried out at Twin Lakes, anecdotal information suggests these ponds receive intense fishing pressure, perhaps approaching the highest received anywhere in Snohomish County as measured in trips or anglers per ha (Curt Kreamer, WDFW, personal communication). Many of the anglers certainly target the 10,000 stock-length rainbow trout released into the ponds each spring or periodically stocked channel catfish. However, if anglers are not species specific, then such intense angling pressure would likely impact naturally reproducing populations. Based on this premise, the paucity of water quality data, and our assessment of habitat, some management options that might improve warmwater fishing in Twin Lakes include, but are not limited to, the following:

Implementing or Coordinating Water Quality Monitoring

Although no water quality problems have been identified with Twin Lakes, their small size and heavy recreational usage makes them sensitive to processes of eutrophication (Wetzel 1983). Water quality data on vertical temperature and dissolved oxygen profiles, as well as phosphorus and chlorophyll *a* levels would increase our understanding of how these factors relate to growth and production of warmwater fish in Twin Lakes. Total phosphorus and chlorophyll *a* provide economical indices of overall lake productivity (Calson 1977). Lake productivity, in turn, may be directly correlated with potential fish production (Downing et al. 1990). Implementing a water quality monitoring program for Twin Lakes or coordinating a program with Snohomish County Parks, Washington Department of Ecology, or other interested parties would provide valuable information for future fish management.

Enhancement of Habitat Structure

Robust warmwater fish communities depend upon habitat structure, particularly coarse woody debris, and intermediate densities of submerged vegetation (Stuber et al. 1983; Durocher et al. 1984; Wiley et al 1984). Although Hoyer and Canfield (1996) demonstrated that largemouth bass can exist without submerged or emergent vegetation, Colle et al. (1996) demonstrated that largemouth bass had significant preferences for natural and artificial structures, such as water tupelo (*Nyssa aquatica*) and piers, after removal of all submerged aquatic vegetation by grass carp.

Habitat structure mediates competition and predation among different species and age classes of warmwater fish. In a previous study, Bonar et al. (1995) identified lack of cover in the north pond as a possible explanation for low channel catfish survival. During our survey we also noted low quantities of coarse woody debris in both ponds and low densities of submerged vegetation in the north pond. We did, however, note the presence of undercut banks and overhanging terrestrial vegetation that may provide important cover to warmwater fish in the south pond. In addition to preserving these characteristics, natural structures such as native species of submerged vegetation, root wads or logs could also be considered (Mueller 1998a).

Access to limited areas of shoreline might also be restricted to provide refugia from intense angling. This may be particularly important for spawning habitat where larger fish are vulnerable to angling. Such restricted areas could be developed with natural buffers of vegetation. The north and south ponds might both benefit from the installation of coarse woody debris structures to increase cover for juveniles of all species and feeding stations for larger largemouth bass.

Conduct a Creel Census

Historically, Twin Lakes has been managed as a trout fishery and more recently as a mixed species fishery. While it has been postulated that Twin Lakes receive among the highest usages of any body of water in Snohomish County (expressed as anglers/ha or trips/ha), we have no hard data on fishing pressure. A survey following the methods of Kraemer (1993) would provide useful information about current angler effort, interest and harvest from the lake, which would benefit the management of both the trout and warmwater fisheries.

Change Rules to Alter Size Structure of Warmwater Species

The size structure, proportional stocking density, growth, and condition of warmwater fish populations in Twin Lakes are probably the result of overharvest and possibly the subsequent crowding of younger fishes (Mueller 1998b, Downen and Mueller 1999). Accessibility, heavy fishing pressure, small surface area, lack of supplemental stocking, and absence of adequate refuge may all contribute to this. Small surface area and heavy fishing pressure make Twin Lakes an excellent put-and-take trout fishery where stocking occurs regularly and harvest of hatchery fish is maximized. However, these factors make it difficult to sustain naturally reproducing populations of warmwater fish that cannot be feasibly stocked at catchable sizes. Currently, Twin Lakes falls under the statewide rule of five fish/day for largemouth bass. One way to improve the size structure of largemouth bass may be to change fishing regulations to reduce or terminate harvest of these fish.

Manage Twin Lakes for Panfish

Another option might be to manage Twin Lakes as a panfish fishery by implementing a minimum length limit on predator species and a maximum length limit on panfish. A minimum length limit would require that all fish below a given length would be released while the opposite would be true of a maximum length limit. This management strategy works best in smaller impoundments. It seeks to maintain numbers of 190 to 250 mm largemouth bass that thin the bluegill population so that competition among remaining bluegills decreases, thus increasing potential for growth (Willis 1989). A maximum length limit on bluegill and pumpkinseed would protect larger panfish where populations currently appear to suffer from overharvest.

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