1998 Lake Hummel Survey: The Largemouth Bass-Bluegill Community of a Eutrophic, Island Lake

by

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Introduction and Background

Lake Hummel is a small (surface area = 15 ha), shallow (maximum depth = 3 meters), productive, lowland lake (elevation = 30 meters) located on Lopez Island (San Juan County). Sedimentary and metamorphic materials characterize basin geology and the drainage area of the lake is small (less than two square kilometers). Two ephemeral, poorly channeled outlet drain the lake intermittently to the north and to the southeast, and one small intermittent stream enters the lake on the west side (Figure 1).

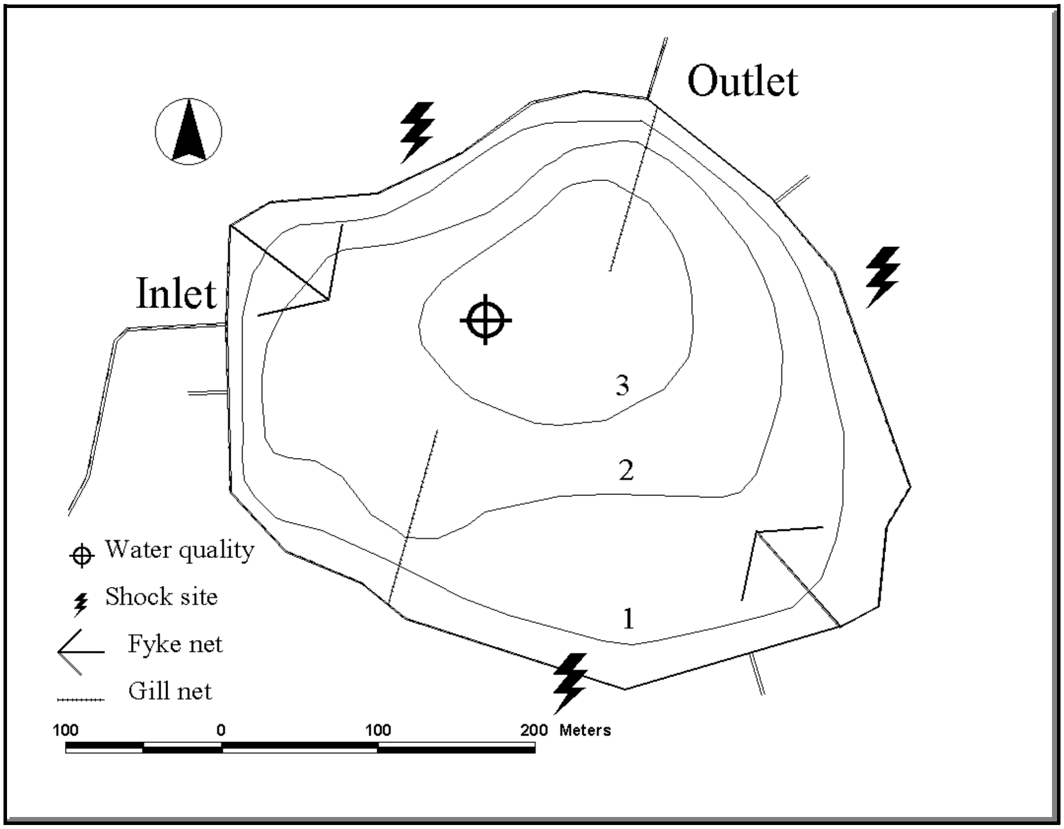

Figure 1. Hydrology, bathymetry at 2 meter intervals, and 1998 sampling sites on Lake Hummel (San Juan County).

A dense, extensive aquatic plant community suggests these waters are highly productive. The littoral zone is dominated by coontail (*Ceratophyllum demersum*), extending to 2 meters deep and choking much of the lake in summer months. Most of the shore is lined with common cat-tail (*Typha latifolia*) and bulrush (*Scirpus sp.*). Yellow water lily (*Nuphar sp.*) occurs extensively along the south side of the lake, and semi-terrestrial reed canary grass (*Phalaris arundinacia*) and nightshade (*Solanum sp.*) encroach along much of the lake margin (Jenifer Parsons, Washington Department of Ecology, unpublished data). Frequent blooms of green and blue-green algae, occurring regularly in Lake Hummel since the 1960’s, provide further evidence of high primary productivity and possible system enrichment. Attempts to control algae with copper sulfate treatments have had only short-term effects on standing crops and biologists have concluded that the only long term solution to overproduction is to identify and reduce nutrient inputs into the lake [Washington Department of Fish and Wildlife (WDFW) Files, unpublished data).

Water quality data for Lake Hummel with regard to phosphorus, clorophyll *a*, and dissolved oxygen is currently limited or unavailable. However, the lake's small size, shallow depth, restricted drainage area, and sedimentary geology predispose it to eutrophication (Hern et al. 1981, Wetzel 1983). Agricultural land use and septic systems are likely to contribute additional nutrients resulting in high productivity by aquatic macrophytes and algae. Eutrophication impacts the fish community of Lake Hummel directly since plant and algae production and subsequent decomposition result in summer and fall oxygen depletion. Low dissolved oxygen concentrations have been identified in Lake Hummel as a major stressor to trout populations and a possible cause of winter fish kills occurring in the lake (WDFW, Lake Hummel Files, unpublished data).

Washington Department of Fish and Wildlife files suggest that there were no native sportfish in the lake prior to the first introductions of rainbow trout (*Oncorhynchus mykiss*) in the 1930's. As part of a standard trout management program, Lake Hummel was rehabilitated with the piscicide, rotenone, in 1936, 1948, 1962, 1972, and 1979. During these rehabilitations common carp (*Cyprinus carpio*), black crappie (*Pomoxis nigromaculatus*), largemouth bass (*Micropterus salmoides*), and brown bullhead (*Ameiurus nebulosus*) were routinely removed from the lake to enhance trout stocking and subsequent production. Interest in managing Lake Hummel for warmwater species began to develop in the 1970's due to the ability of these species to tolerate environmental conditions in the lake and due to the intensive management required to maintain quality trout populations under conditions they were poorly adapted to. In the early 1980's the WDFW, then acting as the Washington Department of Game (WDG) stocked bluegill (*Lepomis macrochirus*) and largemouth bass into the lake, and began stocking channel catfish (*Ictalarus punctatus*) on a regular schedule. Preliminary follow up surveys in 1981 and 1982 indicated that intermediate sized bluegill had become too numerous and that growth rates of both largemouth bass and bluegill were slow. However, biologists believed the fish community would achieve balance when enough largemouth bass became large enough to begin cropping the bluegill population, thus relieving competition at lower trophic levels. Due to local interest in establishing suitable fisheries in Lake Hummel, and the predisposition of lake conditions to warmwater species, the Department of Fish and Wildlife (WDFW) Warmwater Enhancement Program conducted a stock assessment in early fall of 1998. We assessed the growth, condition, and balance of the largemouth bass-bluegill community in Lake Hummel.

Materials and Methods

Two WDFW biologists and one scientific technician surveyed Lake Hummel on 5 and 6 October 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 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. 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 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 water less than three meters deep, perpendicular to the shoreline with wings extended at 70° 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.

All fish captured were identified to species. 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 a simple 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 on 5 October 1998 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 Hummel (San Juan County) collected at mid-day on 5 October 1998. Secchi depth = 0.9 m.

	Parameter				
Depth (m)	**Temp (°C)**	**DO (mg/L)**	**pH**	**Conductance (uS/cm)**	**TDS (g/L)**
0	14.91	4.98	8.36	156.4	0.1002
1	14.89	4.77	8.36	156.6	0.1002
2	14.88	4.52	7.65	157.6	0.1007
3	14.87	4.46	7.55	158.9	0.1008

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 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 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 size fish and larger were used to determine CPUE. Stock length, which varies by species (see Table 2 and discussion below), refers to the minimum size of fish having recreational value. Since 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.

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.

The proportional stock density (PSD) of each warmwater fish species was determined following procedures outlined in Anderson and Neumann (1996). PSD, which was calculated as the number of fish ≥ quality length/number of fish ≥ stock length×100, is a numerical descriptor of length frequency data that provides useful information about 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 2). 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 ≥ specified length/number of fish ≥ stock length×100. For example, RSD P was the percentage of stock length fish that also were longer than preferred length, RSD M, the percentage of stock length fish that also were longer than memorable length, and so on. Eighty-percent confidence intervals for PSD and RSD were selected from tables in Gustafson (1988).

Table 2. Length categories for warmwater fish species by Gabelhouse (1984) used to calculate stock density indices (PSD,RSD) for fish captured at Lake Hummel (San Juan County) during early fall 1998. Measurements are minimum total lengths (mm) for each category (Willis et al. 1993; Bister et al. unpublished data).

	Size				
Species	**Stock**	**Quality**	**Preferred**	**Memorable**	**Trophy**
Largemouth bass	200	300	380	510	630
Bluegill	80	150	200	250	300
Brown bullhead	130	200	280	360	430

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

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 3).

Table 3. 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
Trophy bass	50 – 80	30 – 60	10 – 25	10 – 50	0 – 10

Age and growth of warmwater fishes in Lake Hummel 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 Lake Hummel 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 or food (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.

Results and Discussion

Species Composition

During early fall 1998, our sample from the fish community of Lake Hummel was dominated by warmwater species, primarily largemouth bass by biomass and bluegill by number (Table 4). Together, largemouth bass and bluegill accounted for more than 90% of the number and more than 85% of the biomass of fish captured. Largemouth bass made up 57% of our sample by biomass but only 39% by number. Brown bullhead accounted for only 3% of the species composition by biomass and 2% by number. Rainbow trout also made up 3% by biomass and 2% by number.

Table 4. Species composition by weight (kg) and number of fish captured at Lake Hummel (San Juan County) during early fall 1998.

	Species composition				
	by weight		**by number**		
Species	**(kg)**	**(%) weight**	**(#)**	**(%) n**	**Size range (mm TL)**
Largemouth Bass (*Micropterus salmoides*)	33.540	56.6	213	39.2	63-497
Bluegill (*Lepomis macrochirus*)	19.732	33.3	311	57.2	23-196
Brown Bullhead (*Ameiurus nebulosus*)	4.078	6.9	11	2.0	250-310
Rainbow Trout (*Oncorhynchus mykiss*)	1.921	3.2	9	1.7	293-325
Total	59.271		544		

CPUE

While electrofishing, catch rates were highest for stock-length bluegill (Table 5). Catch rates for stock-length largemouth bass were also high while electrofishing but low for both species while gill netting. Fyke nets sampled only bluegill effectively. Catch rates for stock-length brown bullhead and rainbow trout were similarly low for all gear types.

Table 5. 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 Lake Hummel (San Juan County) while electrofishing, gill netting, and fyke netting during early fall 1998.

Species	**Electrofishing (fish/hr)**	**n (sites)**	**Gillnetting (fish/hr)**	**n (net nights)**	**Fyke netting (fish/hr)**	**n (net nights)**
Largemouth Bass	174.83 ± 86.34	3	2.5 ± 0.64	2	0	2
Bluegill	295.45 ± 129.6	3	2.5 ± 0.64	2	25 [a]	2
Brown Bullhead	5.98 ± 4.42	3	2 ± 1.28	2	2 ± 1.28	2
Rainbow Trout	11.95 ± 7.66	3	1.5 [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

Proportional stock density indices (PSD) and relative stock density indices (RSD) for largemouth bass (Table 6) were below those reported in other Western Washington lakes (Mueller and Downen 1999, Downen and Mueller 1999), below western Washington State averages compiled by the WDFW Inland Fisheries Research Division (PSD = 29, RSD-P = 13), and below values generally accepted for balanced largemouth bass-bluegill communities (Willis et al. 1993). Conversely, PSD for bluegill were higher than values generally accepted for balanced lakes but RSD values for bluegill were low.

Table 6. Traditional stock density indices, including 80% confidence intervals, for warmwater fishes collected from Lake Hummel (San Juan 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	88	14 ± 5	13 ± 5	0	0
	GN	5	40 [a]	20 [a]	0	0
	FN	0	0	0	0	0
Bluegill	EB	149	83 ± 4	0	0	0
	GN	5	20 [a]	0	0	0
	FN	50	74 ± 8	0	0	0
Brown Bullhead	EB	3	100	0	0	0
	GN	4	100	25 [a]	0	0
	FN	4	100	0	0	0
Rainbow Trout	EB	6	0	0	0	0
	GN	3	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

Largemouth bass ranged from 63 to 497 mm (age 0+ to 12+) (Table 7, Figure 2). Age 1+, 2+ and 3+ fish were relatively abundant. Fish older than age 3+ were less abundant but age classes beyond three were well represented. Growth of largemouth bass collected from Lake Hummel was consistent with the western Washington State average. Relative weights were consistent with western Washington State averages for small size classes with lower W_r values occurring with larger size classes (Figure 3). The Spearman coefficient (Rho) for largemouth bass length and relative weight was –0.287 ($p < 0.01$).

Table 7. Age and growth of largemouth bass captured at Lake Hummel (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	6	7	8	9	10	11	12
1997	12	63.2											
		75.1											
1996	15	66.1	141.4										
		79.6	147.8										
1995	17	72.2	128.6	170.7									
		86.1	137.8	176.4									
1994	8	61.1	128.8	167.8	180.2								
		76.1	138.4	174.3	183.4								
1993	1	108.3	212.1	239.2	315.9	347.5							
		122.3	220.3	245.9	318.4	348.2							
1992	2	97.5	153.8	220.4	266.9	308.1	351.3						
		112.3	165.5	228.6	272.6	311.6	352.5						
1991	2	77.1	146.7	223.8	284.7	330.0	360.1	379.3					
		93.4	159.6	232.9	290.9	333.9	362.6	380.8					
1990	3	76.1	138.2	193.6	242.6	282.6	318.7	360.6	391.8				
		92.3	151.4	204.0	250.6	288.6	322.9	362.8	392.4				
1989	2	54.8	137.5	201.7	237.5	294.2	356.1	342.0	369.8	397.5			
		72.2	150.9	212.0	246.0	300.0	358.9	345.6	372.0	398.3			
1988	3	92.9	162.1	210.2	258.0	294.8	325.7	364.4	398.0	427.8	440.5		
		108.9	175.0	220.9	266.6	301.8	331.5	368.5	400.5	429.0	441.2		
1987	0												
1986	1	79.5	131.2	188.9	256.5	314.1	347.9	383.7	399.6	427.4	445.3	461.2	481.1
		96.3	145.9	201.3	266.1	321.5	353.9	388.2	403.5	430.2	447.4	462.7	481.7
Overall mean		77.2	148.0	201.8	255.3	310.2	343.3	366.0	389.8	417.6	442.9	461.2	481.1
Weighted mean		84.0	147.5	191.4	237.4	309.4	343.5	366.8	391.8	419.0	442.7	462.7	481.7
State Average		60.4	145.5	222.2	261.1	289.3	319	367.8	396	439.9	484.6	471.7	495.6

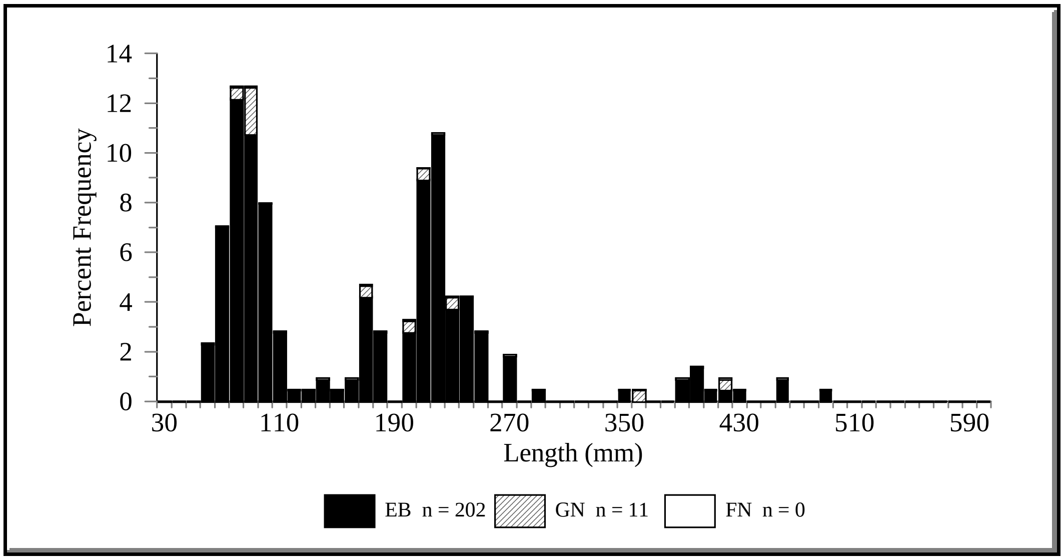

Figure 2. Length frequency histogram of largemouth bass sampled from Lake Hummel in early fall 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

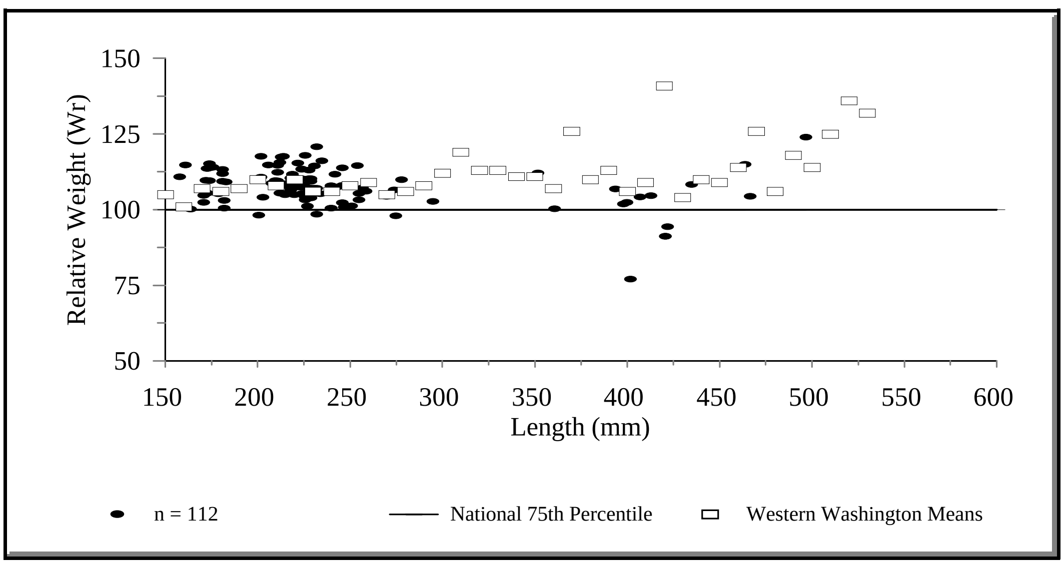

Figure 3. Relationship between total length and relative weight (W_r) of largemouth bass from Lake Hummel, (San Juan County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Bluegill

Bluegill ranged from 23 to 196 mm (TL) (age 1+ to 7+) (Table 8, Figure 4). Growth rates for bluegill in Lake Hummel were consistent with the Washington State average. Relative weight values were also consistent with the Washington State average (Figure 5). The spear man coefficient (Rho) for bluegill length and relative weight was 0.464 ($p < 0.01$).

Table 8. Age and growth of bluegill captured at Lake Hummel (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	6
1997	4	51.8					
		62.1					
1996	6	53.4	87.9				
		65.4	94.8				
1995	9	56.0	100.0	127.1			
		68.8	107.0	130.6			
1994	11	51.5	92.8	123.3	144.7		
		65.3	101.7	128.6	147.5		
1993	8	54.4	93.3	131.4	153.0	173.4	
		68.5	103.2	137.2	156.5	174.7	
1992	1	72.8	116.0	139.5	156.7	175.3	193.8
		85.3	124.1	145.2	160.7	177.3	193.9
Overall mean		56.6	98.0	130.3	151.5	174.3	193.8
Weighted mean		67.0	102.9	132.2	151.7	175.0	193.9
State Average		37.3	96.8	132.1	148.3	169.9	200.9

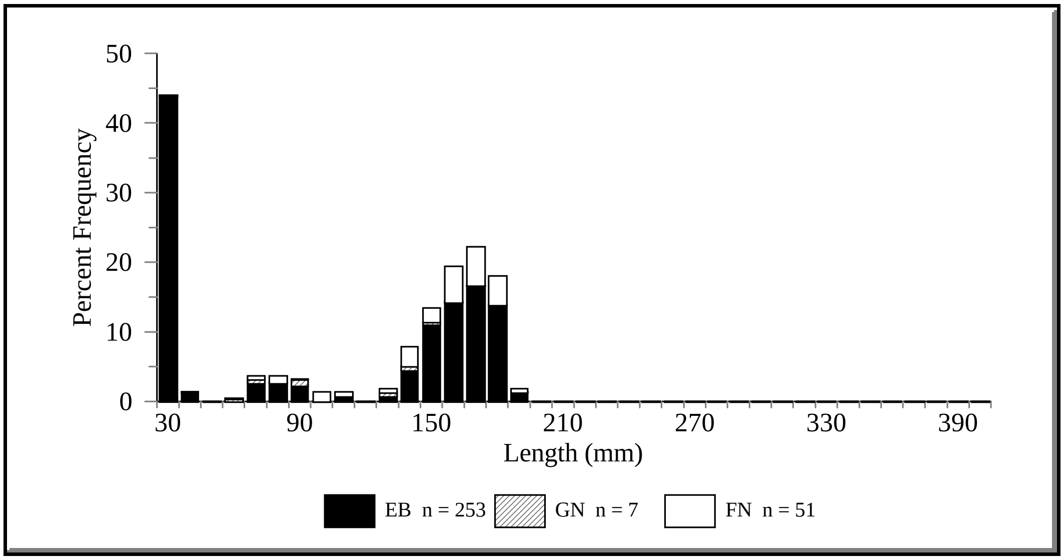

Figure 4. Length frequency histogram of bluegill sampled from Lake Hummel in early fall 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

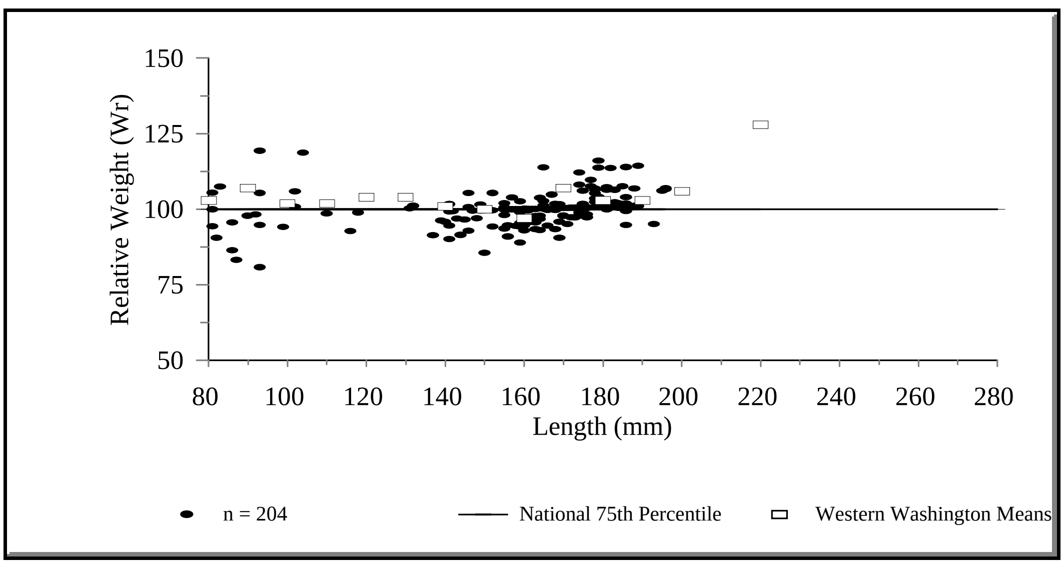

Figure 5. Relationship between total length and relative weight (W_r) of bluegill from Lake Hummel, (San Juan County) compared with means from up to 25 western Washington lakes and the national 75th percentile.

Members of the Family *Ictaluridae*

Eleven brown bullhead were captured in Lake Hummel ranging from 250 to 310 mm TL (Figure 6). The relative weights of individuals captured were generally above the national 75th percentile (Figure 7). Although channel catfish have been stocked in Lake Hummel, none were collected during our stock assessment.

Members of the Family *Salmonidae*

Nine rainbow trout were captured in Lake Hummel ranging from 293 to 325 mm FL (Figure 8). Relative weights were consistent with the western Washington trend of falling below the national 75th percentile (Figure 9) but fell far below those reported for other rainbow trout populations in western Washington waters (Mueller and Downen 1999).

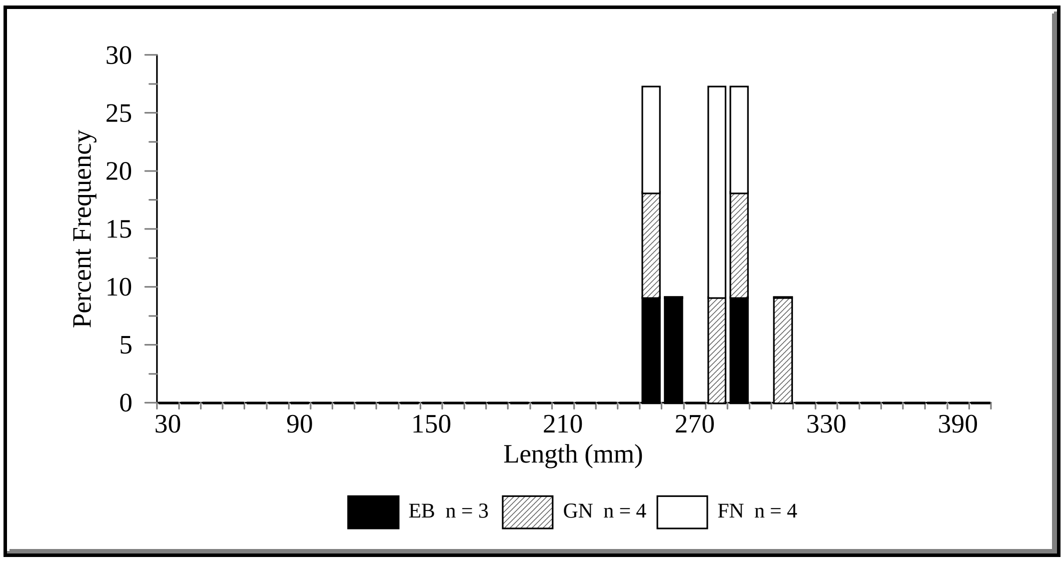

Figure 6. Length frequency histogram of brown bullhead sampled from Lake Hummel in late fall 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

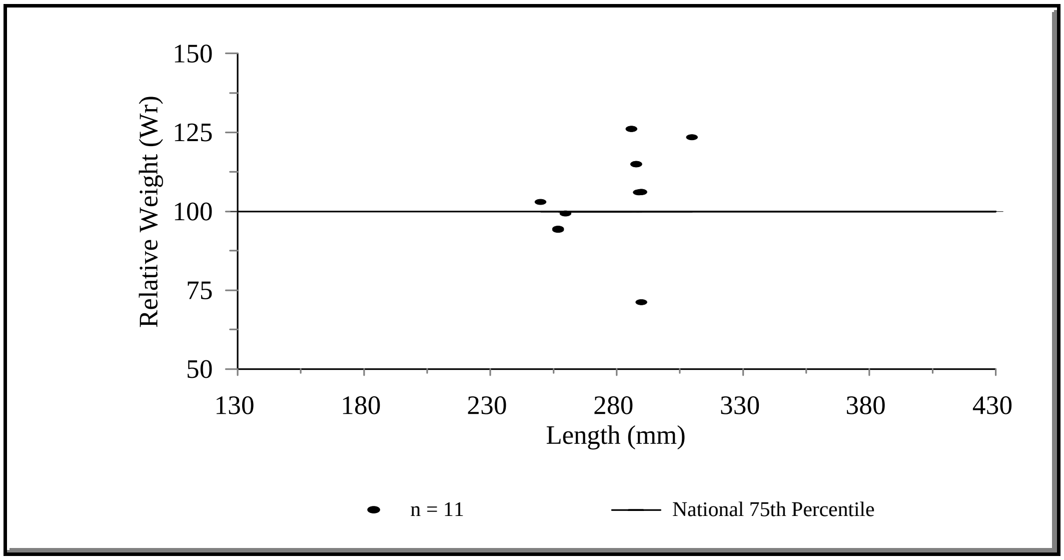

Figure 7. Relationship between total length and relative weight (Wr) of brown bullhead from Lake Hummel (San Juan County) compared to the national 75th percentile.

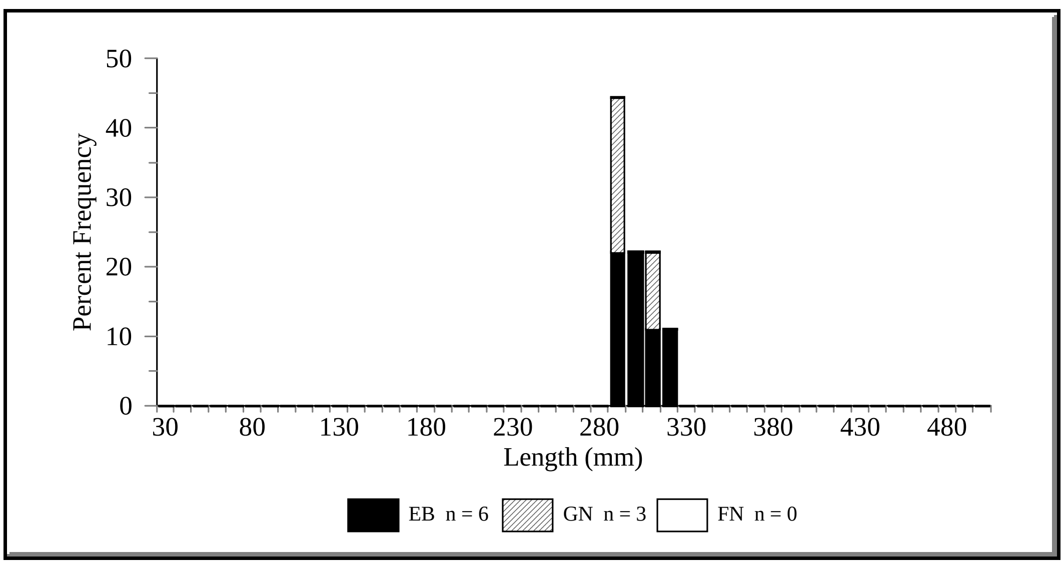

Figure 8. Length frequency histogram of rainbow trout sampled from Lake Hummel in early fall 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

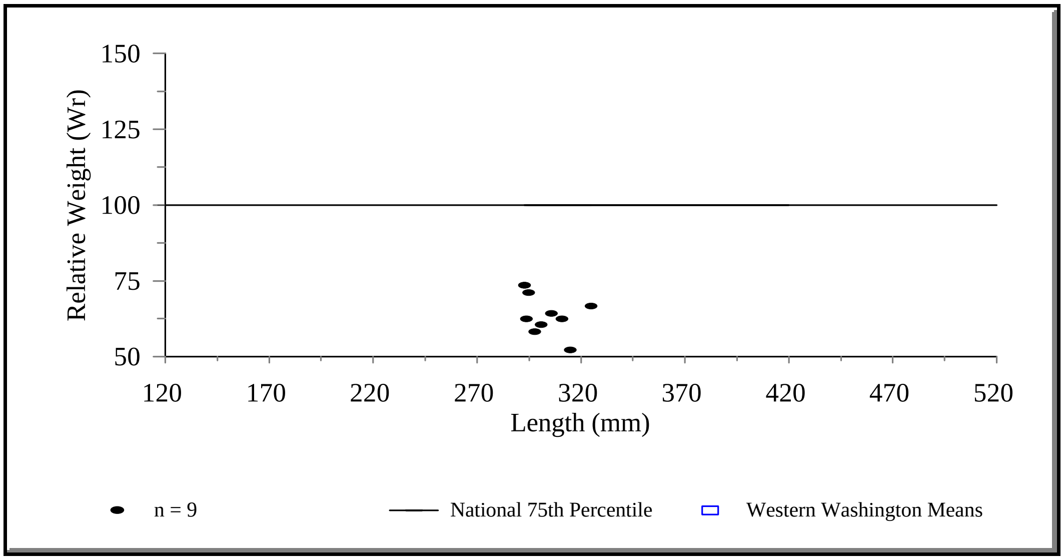

Figure 9. Relationship between total length and relative weight (Wr) of rainbow trout from Lake Hummel, (San Juan County) compared the national 75th percentile.

Warmwater Enhancement Options

Growth rates for both largemouth bass and bluegill in Lake Hummel were consistent with the western Washington State averages, suggesting some degree of balance exists between these closely co-evolved species. However, proportional stock density indices indicate lake productivity is not currently maximizing the production of quality largemouth bass. Currently PSD values for largemouth bass and bluegill favor management of Lake Hummel as a panfish fishery. High bluegill PSD and low largemouth bass PSD suggest production of prey fish is high but not being effectively transferred to higher trophic levels (Willis et al. 1993). Moreover, corresponding low RSD for bluegill suggests a large proportion of forage fish are limited in size. The bluegill population of Lake Hummel resembles populations in heavily vegetated Midwestern lakes where decreased foraging efficiency of predators leads to large numbers of bluegill <200 mm (Schneider 1999).

Trends in relative weights for bluegill and largemouth bass support the hypothesis that productivity is not being transferred effectively to higher trophic levels. While relative weights for bluegill increase significantly with increasing total length, those for largemouth bass decline with increasing total length. Decreasing relative weight with increasing length are commonly interpreted as evidence for competition (Willis 1997) but in the presence of a large forage base may in fact be the result of decreased foraging efficiency. High aquatic macrophyte densities and low dissolved oxygen concentrations may be responsible for this. Based upon this premise, warmwater enhancement options for Lake Hummel might include, but are not limited to, the following:

Aquatic Vegetation Control

Aquatic plant cover is an important habitat constituent for most warmwater fishes, which are more likely to be found around plant cover than away from it (Killgore et al. 1989). Submerged aquatic vegetation provides important foraging, refuge and spawning habitat (see review by Willis et al. 1997), improving survival and recruitment to harvestable sizes (Durocher et al. 1984). Changes in the standing crop of aquatic plants can alter fish production (Willis et al. 1997) and the structure of the fish community itself (Bettoli et al. 1993). However, dense vegetation reduces foraging efficiency of many predatory warmwater fish species. Fish communities tend to maximize their numbers under conditions of intermediate plant density (Wiley et al. 1984). Balancing the contribution of aquatic macrophytes to habitat structure with their potential to reduce foraging efficiency should be an important aspect of aquatic plant control.

Much of the littoral zone (75 to 90 %) of Lake Hummel is densely vegetated with submerged, floating, and emergent plants (Jenifer Parsons, Washington Department of Ecology, unpublished data). Dense plant communities of coontail (*Ceratophyllum demersum*) and yellow water lily

(*Nuphar polysepalum*) occurring in Lake Hummel probably inhibit foraging by largemouth bass while providing too great a refugia for bluegill (Wiley et al.1984).

Several options are available to reduce the density of aquatic vegetation in Lake Hummel. Grass carp (*Ctenopharyngodon idella*) would provide an economical biological control. Since the mid-1980's, grass carp have proven to be a cost-effective aquatic plant management tool in the Pacific Northwest (Pauly et al. 1994). In Washington State the public has generally approved of grass carp as a means of controlling nuisance vegetation growth in lakes (Bonar et al. 1996). Stocking low densities of grass carp may improve foraging efficiency of largemouth bass in Lake Hummel. However, grass carp will not remove nutrients from the system. Instead, they will convert plant biomass into fish biomass and excretions. Excretions will raise nutrient levels and subsequently, the potential for algal blooms in the water column (KCM 1995). Selective application of a pelletted aquatic herbicide may reduce vegetation density without eliminating it, thus increasing foraging efficiency of predators without eliminating the beneficial contributions of the vegetation to fish habitat. Mechanical removal might be a final option if fish introduction or herbicide prove impractical. However, mechanical removal methods might not be as selective as previously mentioned methods or as cost-effective.

Destratify Lake with Aerator

Poor growth and condition as well as fish die-offs of fish have been attributed to poor water quality in a number of lakes (Fletcher 1981, Mueller and Downen 1999). Low dissolved oxygen concentrations cause chronic and lethal stress in fish that may lead to reduced reproduction, growth, and condition or fish kills in extreme cases. Elevated temperatures exacerbate these situations. Trout and other salmonids are particularly sensitive to dissolved oxygen concentrations and generally require 9 to 12 mg/L at 100% saturation. Chronic values of 5 mg/L arrest growth and induce mortality in most salmonid species (Wallace 1993). Many warmwater species can survive values as low as 2 mg/L but growth for these species also declines at low concentrations (Stuber et al. 1982). The WDFW routinely aerates a number of lakes throughout the state to improve or maintain dissolved oxygen levels during summer months. In the early 1980's an aerator was installed in Anderson Lake in Jefferson County. Prior to the installation of the aerator, fish die-offs occurred periodically due to low oxygen levels when the lake stratified. Currently the aerator runs continuously during summer months and fish die-offs have not occurred since its installation.

Low dissolved oxygen concentrations occur in Lake Hummel during late summer and fall. We measured dissolved oxygen concentrations below 5 gm/L throughout the water column. Lake Hummel has experienced fish kills in past decades that have been attributed by WDG biologists to low dissolved oxygen. Aerating Lake Hummel would reduce the likelihood of fish kills by increasing the volume of habitable water (water with DO concentrations above 5 mg/L). Elevated dissolved oxygen would reduce fish densities in the epilimnion during periods of stratification and enhance the entire aquatic food web, improving growth and possibly numbers of fish.

Coordinate Water Quality Monitoring Efforts

Regular water quality monitoring would support the success of the previously mentioned options. Useful water quality data does not currently exist for Lake Hummel. Assessments of lake productivity and overall environmental conditions experienced by fish are, therefore, currently anecdotal. However, excessive vegetation and algae growth, seasonally low dissolved oxygen concentrations, and restricted fish populations are related phenomena, often caused by or exacerbated by high nutrient levels (Sterner 1990, Wetzel 1983, Fletcher 1981). Inputs of nutrients, particularly phosphorus and nitrogen, can dramatically increase plant and algae growth. Subsequent senescence and decomposition of plant and algal biomass by bacteria can deplete dissolved oxygen to levels lethal to fish (Wetzel 1983). Lake Hummel's small size, shallow basin, sedimentary geology, and small watershed make it particularly sensitive to these processes of eutrophication and to nutrient inputs from human activity such as agriculture and septic drainage (Hern et al. 1981, Sterner 1990). Problems involving excessive plant growth, algae blooms, and fish kills in Lake Hummel may not be adequately addressed unless the nutrients dynamics driving productivity in the lake are better understood.

The WDFW should coordinate water quality monitoring efforts with local agencies and interested parties and help develop a pratical monitoring plan. Phosphorus, chlorophyll *a*, and Secchi depth are routinely used to identify trophic status because of their relationships to productivity (Carlson 1979) and should be measured monthly to determine the overall trophic status of Lake Hummel. If resources preclude routine monitoring, these parameters should be measured in the summer (France et al. 1995). Parameters related to fish survival such as temperature and dissolved oxygen concentrations should be monitored throughout the water column during summer months.

Change Existing Fishing Rules to Prevent Overharvest of Largemouth Bass

Currently, Lake Hummel is opened year round with a five fish per day limit on largemouth bass. The small size of Lake Hummel makes it susceptible to overharvest of larger largemouth bass as fishing pressure on these fish increases. Many lakes in western Washington with slow growing or crowded populations of largemouth bass have a 305 – 381 mm (12 – 15 inch) slot limit that makes it illegal to retain largemouth bass between 305 and 381 mm. 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 improve size structure of largemouth bass and protect fish required for a balance within the lake. However, low abundance of large largemouth bass and paucity of size classes within the slot observed during 1997 and 1998 surveys of other lakes suggests the rule is not working as intended (Mueller and Downen 1999b, Downen and Mueller 1999).

Widening the slot limit to 254 – 457 mm TL (10 – 18 inches) while reducing the creel limit from three to one fish above the slot (still maintaining the daily limit of five fish), might allow more largemouth bass to realize their full growth potential. It may also preserve enough larger fish to check the abundance of smaller forage fish. 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 alike (McHugh 1990).

A simpler alternative would be to implement catch-and-release fishing for largemouth bass on the lake. Under this rule, all largemouth bass captured must be released back into Lake Hummel. Since the rule is indisputable it would be simpler to enforce. Moreover, increased numbers of larger fish would act as a control on numbers of smaller fish and forage fish of all species.

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). Rules and their purpose should be posted at Lake Hummel inform and encourage anglers in the active management of their resource. The presence of WDFW enforcement personnel during peak harvest periods would also lessen illegal harvest.

Coordinate a Creel Survey

We currently know very little about the fishing pressure on Lake Hummel. Data on angler interest and harvest would provide useful information for assessing rule changes. This information would also be valuable to local groups and agencies that are trying to assess the recreational usage of the lake. The WDFW should consider implementing a self-registration survey at the bulletin board where rules are posted. Local groups may be able to assist in a more extensive survey and if this is the case, then department personnel should be available to help develop a sampling plan.

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