# 1998 Lake Cassidy Survey: A Warmwater Fish Community Competing under Conditions of Hypolimnetic Anoxia and Dense Aquatic Macrophytes

by
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# Introduction and Background

Lake Cassidy is a small (surface area = 48 hectares), shallow (maximum depth = 6 meters), seasonally eutrophic body of water located directly east of Marysville in Snohomish County (Figure 1). The lake lies in the Catherine Creek watershed and forms the headwater of Catherine Creek.

Water quality is characterized by thermal stratification and anoxia in the hypolimnion during the late summer (Figures 2 and 3) (Drainage Improvement District #8 1998). Based upon Carlson's Trophic Status Index (TSI) which uses total phosphorus and chlorophyll *a* data to rate a lake's trophic status, Lake Cassidy is an upper mesotrophic body of water (Carlson 1977).

Although algal production appears to contribute significantly to microbial respiration and subsequent anoxia in the hypolimnion, much of the productivity of Lake Cassidy and hypolimnetic anoxia probably result from littoral macrophyte growth and decomposition. Over 65 percent of the shoreline to the two meter bathymetric contour is densely vegetated with yellow water lily (*Nuphar polysepalum*), coontail (*Ceratophyllum demersum*), and bullrush (*Scirpus sp.*). The remaining shoreline is moderately vegetated with these and other aquatic plant species (Jenifer Parsons, Department of Ecology, unpublished data).

Lake Cassidy's shallow basin, low altitude and relief, and largely undeveloped shoreline should provide good habitat for warmwater fish species which have formed the basis for a popular sport fishery there. Habitat suitability and popularity of this warmwater fishery led to a 1982 survey of the warmwater community by the Washington Department of Game (WDG) which found slow growth and poor condition in populations of largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), and pumpkinseed sunfish (*Lepomis gibbosus*). In 1984, a slot limit was imposed on largemouth bass to increase recruitment to larger size classes, and cursory sampling indicated that growth rates for largemouth bass began improving throughout the 1980s. Meanwhile, the popularity of the warmwater sport fishery has continued to develop. A 1993 angler survey of 354 anglers found that largemouth bass and black crappie were the dominant target species with 32.7 and 20.4 trips/acre, respectively. Anglers seeking to catch any species made up 36.7 trips/acre and trout anglers made up 4.4 trips/acre (Curt Kraemer, WDFW, unpublished data).

Due to Lake Cassidy's history and popularity as a warmwater fishery, the Washington Department of Fish and Wildlife (WDFW) Warmwater Program conducted a detailed survey of the warmwater fish community in late summer 1998. Our goal was to detect changes in community structure, growth and condition of warmwater fish, assess previous management strategies, and form a basis for other management options that might increase warmwater fishing opportunities in the lake.

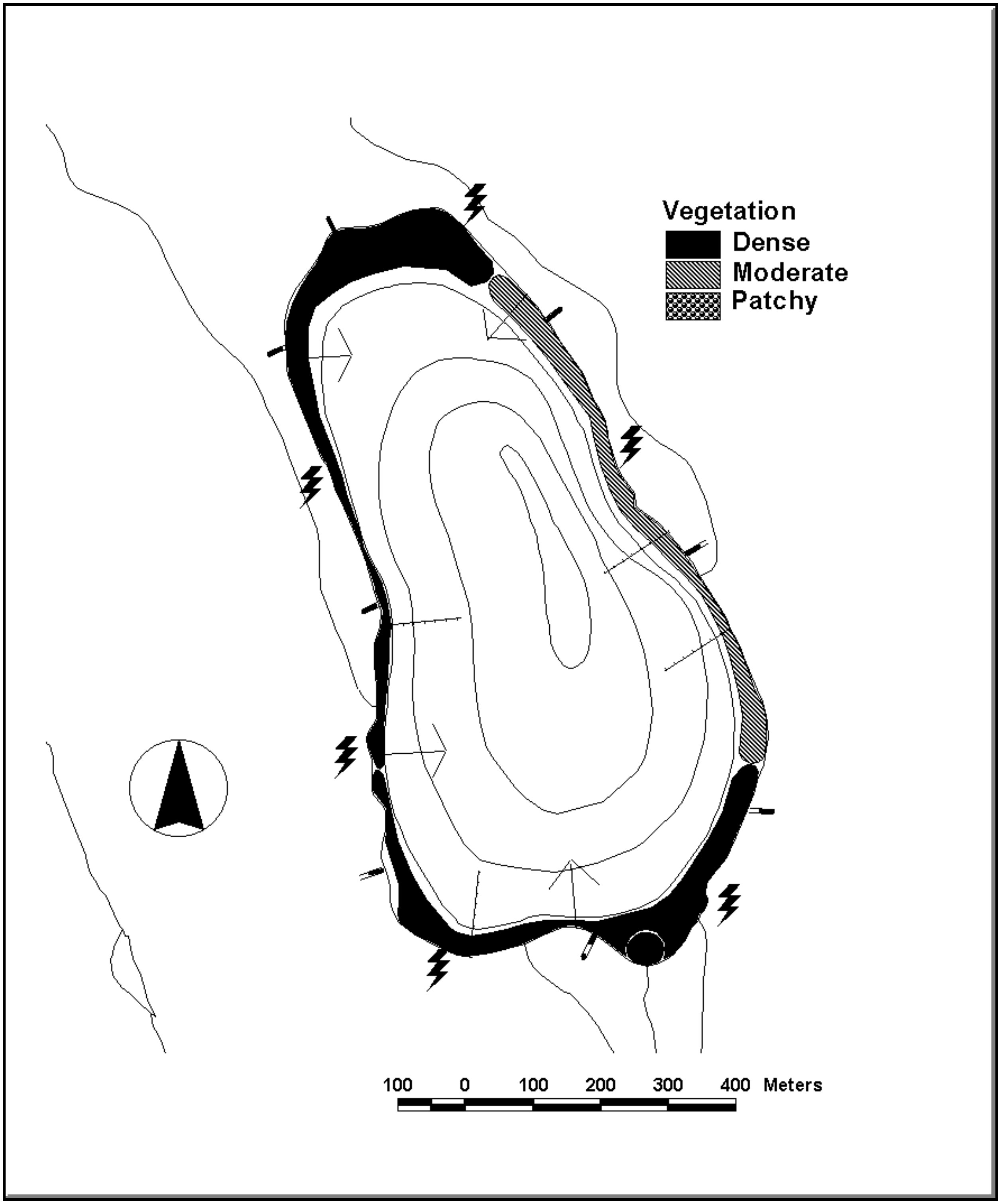


**Figure 1.** Lake Cassidy hydrology, bathymetry, aquatic vegetation, and sampling locations. Double filled lines bisecting lake shoreline denote sampling section boundaries, hatched lines denote gillnet locations, arrow symbols denote fyke net locations, and lightning bolt icons denote electrofished sections.

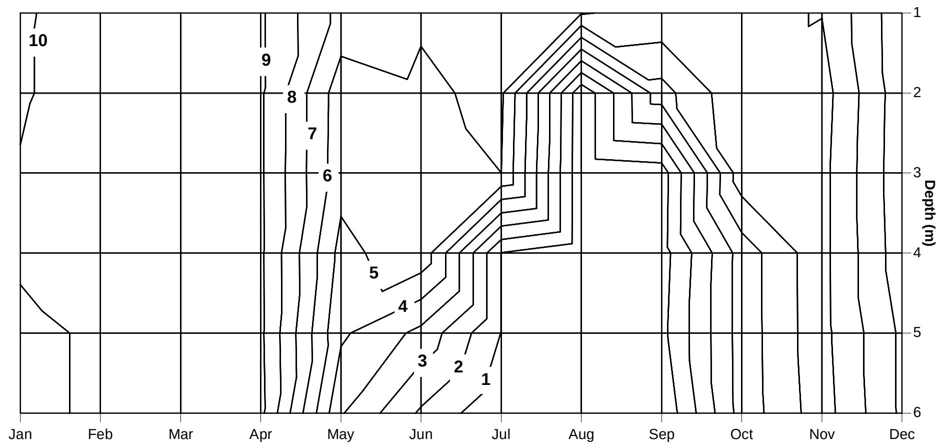


**Figure 2.** Lake Cassidy 1997 vertical dissolved oxygen profile dynamics through time. Contour lines are at one mg/L intervals. (Source: Drainage Improvement District #8 1998.)

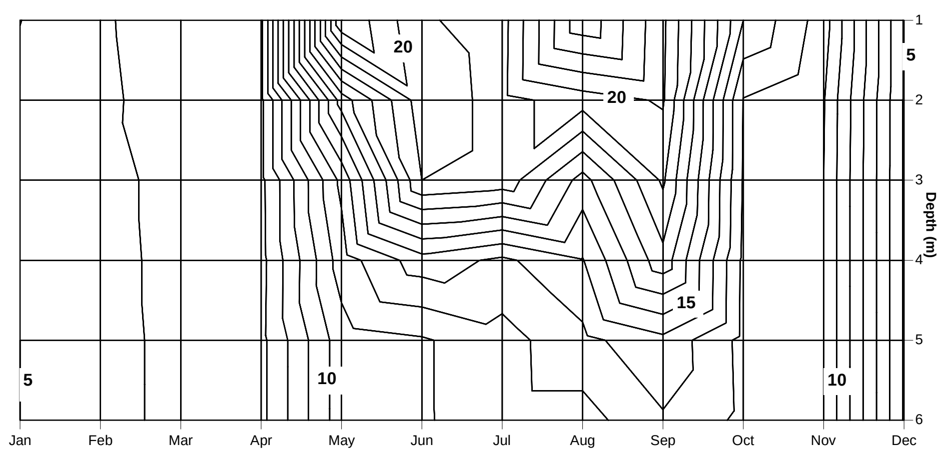


**Figure 3.** Lake Cassidy 1997 vertical temperature profile dynamics through time. Contour lines are at one degree Celsius intervals (Source: Drainage Improvement District #8 1998).

# Materials and Methods

Two WDFW biologists and one scientific technician surveyed Lake Cassidy on September 8, 9, and 10, 1998. Fish were captured using three sampling techniques: electrofishing; gill netting; and fyke netting. The electrofishing unit consisted of a 4.9 meter Smith-Root 5.0 GPP electrofishing boat set to a DC current of 120 cycles/sec at three to six 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 seven consecutively numbered sections of about 400 meters each as determined from a 1:24,000 USGS map (Figure 1). The majority of the shoreline was sampled by electrofishing six randomly selected sections. While electrofishing, the boat was maneuvered through the shallows (depth range: 0.2-1.5 m), adjacent to the shoreline, at a rate of 18.3 m/minute. Four gill nets were set perpendicular to the shoreline. The small–mesh end was attached onshore while the large–mesh end was anchored offshore. Four fyke nets were set in water less than three meters deep, perpendicular to the shoreline with wings extended at 70° angles from the lead. Sampling occurred during evening hours to maximize the type and number of fish captured. In order to reduce bias between techniques and standardize effort, the sampling time for each gear type was standardized to a ratio of 1:1:1 (Fletcher et al. 1993) as follows: total electrofishing time was one unit of 1,800 sec (actual pedal-down time), or roughly three sections of 600 sec each; total gill netting and fyke netting time was one unit of 24 h (= 2 net nights) for each net type.

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 mid–day from one site on September 8, 1998. We report the vertical profiles from the deep site. Using a Hydrolab® probe and digital recorder, we measured dissolved oxygen, redox, temperature, pH, and specific conductance. Secchi disc readings were recorded in meters (Table 1).

**Table 1.** Water quality from the deepest location on Lake Cassidy (Snohomish County) collected at mid–day on September 8, 1998. Secchi depth = 0.9 m.

| | | | Parameter | | |
|---|---|---|---|---|---|
| **Depth (m)** | **DO (mg/L)** | **Temp (°C)** | **pH** | **Conductance (uS/cm)** | **TDS (g/L)** |
| 1 | 7.84 | 21.83 | 7.62 | 43.2 | 0.0276 |
| 2 | 7.20 | 21.29 | 7.43 | 43.7 | 0.0278 |
| 3 | 0.57 | 17.50 | 6.71 | 50.4 | 0.0323 |
| 4 | 0.28 | 14.17 | 6.60 | 51.2 | 0.0332 |
| 5 | 0.23 | 13.20 | 6.56 | 53.5 | 0.0346 |
| 6 | 0.19 | 12.49 | 6.56 | 55.0 | 0.0353 |
| 7 | 0.16 | 12.04 | 6.56 | 55.1 | 0.0354 |

Anoxic conditions were present below one meter during August 1997 (Figure 2 and 3) (Drainage Improvement District #8) and below two meters during September 1998, when we collected water quality data (Table 1), suggesting the principal volume of the lake becomes anoxic during late summer. In order to characterize the trophic status of the lake we applied Carlson's Trophic Status Index (TSI) to total phosphorus and chlorophyll *a* data collected by the Drainage Improvement District #8. The TSI rates a lake's trophic status on a continuous scale from 0 to 100 based upon Secchi depth, total phosphorus concentrations, and chlorophyll abundance. Criteria derived from application of the TSI have led to classifications for oligotrophic lakes ranging between 0 and 40, mesotrophic lakes between 40 and 60, and eutrophic lakes between 60 and 100. Carlson (1977) generated regression equations for chlorophyll a and total phosphorus which are as follows:

$$TSI(Chl\ a)=9.81(\ln Chl\ a)+30.6 \text{ where Chl a is in ug/L}$$
$$TSI(TP)=14.42(\ln TP)+4.15 \text{ where TP is in ug/L}$$

We used median monthly values of chlorophyll a and total phosphorus (Figure 4) which placed Lake Cassidy in the mid to upper mesotrophic class with median TP and Chl a values of 25.9ug/L and 9.3ug/L respectively, and corresponding TSI values of 51.1 and 52.5, respectively.

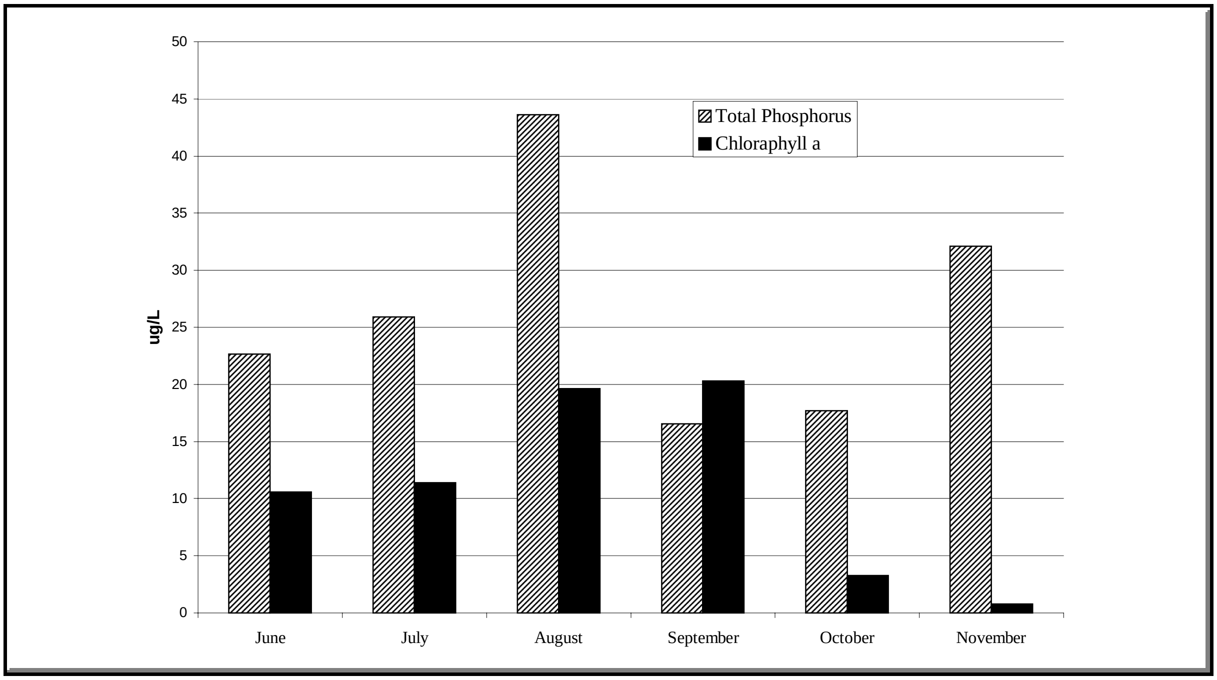


**Figure 4.** Epilimnetic total phosphorus and chlorophyll a concentrations for Lake Cassidy between June and November 1997. (Source: Drainage Improvement District #8 1998.)

## 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 fishers and an adequate forage base for piscivorous fish or predators. Predators must reproduce and grow to control overproduction of both prey and predator species, as well as provide adequate fishing. To maintain balance, predator and prey fish must be able to forage effectively. Evaluations of species composition, size structure, growth, and condition (plumpness or robustness) of fish provide useful information on 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 these evaluations (Swingle 1950; Bennett 1962).

We determined species composition by weight (kg) of fish captured using procedures adapted from Swingle (1950). The species composition by number of fish captured was determined using procedures outlined in Fletcher et al. (1993). While young–of–year or small juveniles are often not considered because large fluctuations in their numbers may distort 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, forage base for larger fish, and interspecific and intraspecific competition at lower trophic levels (Olson 1995).

Catch per unit effort (CPUE) by gear type was determined for each warmwater fish species (number of fish/hour electrofishing and number of fish/net night). Only stock size fish and larger were used to determine CPUE. Stock length, which varies by species (see Table 2 and discussion below), refers to the minimum size of fish having recreational value. Since sample locations were randomly selected, which might introduce high variability due to habitat differences within the lake, 80 percent confidence intervals (CI) were determined for each mean CPUE by species and gear type. CI was calculated as the mean ± $t_{(\alpha, N\text{-}1)} \times SE$, 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.

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

| Species | Size: Stock | Quality | Preferred | Memorable | Trophy |
|---|---|---|---|---|---|
| Yellow perch | 130 | 200 | 250 | 300 | 380 |
| Black crappie | 130 | 200 | 250 | 300 | 380 |
| Brown bullhead | 130 | 200 | 280 | 360 | 430 |
| Largemouth bass | 200 | 300 | 380 | 510 | 630 |
| Pumpkinseed | 80 | 150 | 200 | 250 | 300 |

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

The size structure of each species captured was evaluated by constructing a stacked length frequency histogram (percent frequency of fish in a given size class captured by each gear type). Although length frequencies are generally reported by gear type, we report the length frequency of our catch with combined gear types which is then broken down by the relative contribution each gear type makes to each size class. Selectivity of gear types not only biases species catch based on body form, and behavior, but also based on size classes 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$\geq$quality length/number of fish$\geq$stock length$\times$100, is a numerical descriptor of length frequency data that provides useful information about size class structure. Stock and quality lengths, which vary by species, are based on percentages of world-record lengths. Again, stock length (20-26 percent of world–record length) refers to the minimum size fish with recreational value, whereas quality length (36-41 percent of world–record length) refers to the minimum size fish most anglers like to catch.

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

Age and growth of warmwater fishes in Lake Cassidy were evaluated using the direct proportion method (Jearld 1983; Fletcher et al. 1993) and Lee's modification of the direct proportion method (Carlander 1982). Using the direct proportion method, total length at annulus formation was back–calculated as $L_n = (A \times TL)/S$, where $A$ is the radius of the fish scale at age $n$, $TL$ is the total length of the fish captured, and $S$ is the total radius of the scale at capture. Using Lee's modification, $L_n$ was back–calculated as $L_n = a + A\times(TL - a)/S$, where $a$ is the species–specific standard intercept from a scale radius–fish length regression. Mean back–calculated lengths at age $n$ for each species were presented in tabular form for easy comparison of growth between year classes, as well as between Lake Cassidy 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 ($75^{th}$ percentile) for that species. Furthermore, $W_r$ is useful for comparing the condition of different size groups within a single population to determine if all sizes are finding adequate forage or food (ODFW 1997). Following Murphy et al. (1991), the index was calculated as $W_r = W/W_s \times 100$, where $W$ is the weight (g) of an individual fish and $W_s$ is the standard weight of a fish of the same total length (mm). $W_s$ is calculated from a standard $\log_{10}$weight-$\log_{10}$length relationship defined for the species of interest. The parameters for the $W_s$ equations of many cold– and warmwater fish species, including the minimum length recommendations for their application, are listed in Anderson and Neumann (1996). The $W_r$ values from this study were compared to the national standard ($W_r = 100$) and where available, with mean $W_r$ values from up to 25 western Washington warmwater lakes sampled during 1997 and 1998 (Steve Caromile, WDFW, unpublished data). Trends in the dispersion of points on the relative weight graph have been used to infer ecological dynamics of fish populations (Willis 1999). For example, a decrease in relative weight with increasing total length often occurs where competition is high among larger size classes. Conversely, lower relative weights occurring with smaller fish suggests competition and crowding for these fish. We 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 late summer 1998, our sample from the fish community of Lake Cassidy was dominated by warmwater species, primarily yellow perch (Table 3). Together, largemouth bass and yellow perch accounted for more than four–fifths of the biomass and number captured. Pumpkinseed sunfish accounted for only 1 percent of the species composition by biomass and number. Brown bullhead catfish made up 7 percent by biomass and 2 percent by number, while only one cutthroat trout and one bluegill were collected (Table 3).

**Table 3.** Species composition by weight (kg) and number of fish captured at Lake Cassidy (Snohomish County) during late summer 1998.

| | **Species composition** | | | | |
|---|---|---|---|---|---|
| | **by weight** | | **by number** | | **Size range** |
| **Species** | **(kg)** | **(%) weight** | **(#)** | **(%) n** | **(mm TL)** |
| Largemouth bass (*Micropterus salmoides*) | 27.053 | 32.585 | 157 | 15.560 | 43 - 510 |
| Black crappie (*Pomoxis nigromaculatus*) | 4.063 | 4.893 | 79 | 7.830 | 41 - 262 |
| Yellow perch (*Perca flavescens*) | 44.008 | 53.008 | 733 | 72.646 | 53 - 266 |
| Pumpkinseed (*Lepomis gibbosus*) | 1.432 | 1.724 | 17 | 1.685 | 106 - 181 |
| Bluegill (*Lepomis macrochirus*) | 0.076 | 0.092 | 1 | 0.099 | 147 |
| Brown bullhead (*Ameiurus nebulosus*) | 6.311 | 7.602 | 21 | 2.081 | 187 - 348 |
| Cutthroat trout (*Oncorhynchus clarki*) | 0.080 | 0.096 | 1 | 0.099 | 211 |
| Total | 83.021 | | 1,009 | | |

## CPUE

While electrofishing, catch rates were highest for yellow perch and largemouth bass (Table 4). Catch rates for stock–size pumpkinseed were very low for all gear types. Catch rates for stock–size brown bullhead were similarly low between gear types.

**Table 4.** Mean catch per unit effort (number of fish /hour electrofishing and number of fish/net night), including 80 percent confidence intervals, for stock size warmwater fish collected from Lake Cassidy (Snohomish County) while electrofishing, gill netting, and fyke netting during late summer 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 | 68.67 ± 16.58 | 6 | 2 ± 1.38 | 4 | 0 | 4 |
| Black crappie | 2.99 ± 1.71 | 6 | 2.25 ± 0.81 | 4 | 4.75[a] | 4 |
| Yellow perch | 441.21 ± 74.61 | 6 | 37 ± 7.65 | 4 | 0.25[a] | 4 |
| Pumpkinseed | 15.92 ± 4.27 | 6 | 0.25[a] | 4 | 0 | 4 |
| Bluegill | 1[a] | 6 | 0 | 4 | 0 | 4 |
| Brown bullhead | 1.99 ± 1.61 | 6 | 0.25[a] | 4 | 4.5[a] | 4 |
| Cutthroat trout | 0 | 6 | 0 | 4 | 0.25[a] | 4 |

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

## Stock Density Indices

Although we captured one memorable largemouth bass from Lake Cassidy, quality and preferred largemouth bass were captured in low numbers (Table 5). PSD was higher for black crappie, which had comparable values for electrofishing and gill netting and a substantially higher value accompanying the larger sample size captured fyke netting. Yellow perch were captured in large numbers both electrofishing and gill netting and PSD was higher gill netting. Pumpkinseed were captured in relatively low numbers, but exhibited a relatively high PSD. PSD and RSD for pumpkinseed, black crappie and yellow perch (Table 5) were close to, or within, the stock density index objective ranges for a body of water managed for balance between predator and prey species while stock density indices for largemouth bass were low (Willis et al. 1993).

**Table 5.** Traditional stock density indices, including 80 percent confidence intervals, for warmwater fishes collected from Lake Cassidy (Snohomish County) while electrofishing, gill netting, and fyke netting during late summer 1998.

| Species | Gear Type | n | PSD | RSD-P | RSD-M | RSD-T |
|---|---|---|---|---|---|---|
| Largemouth bass | EB | 69 | 17 ± 6 | 9 ± 4 | 1[a] | 0 |
| | GN | 8 | 25[a] | 0 | 0 | 0 |
| | FN | 0 | 0 | 0 | 0 | 0 |
| Black crappie | EB | 3 | 33[a] | 33[a] | 0 | 0 |
| | GN | 9 | 33[a] | 0 | 0 | 0 |
| | FN | 19 | 53 ± 15 | 0 | 0 | 0 |
| Yellow perch | EB | 443 | 14 ± 2 | 0 | 0 | 0 |
| | GN | 148 | 3 ± 5 | 1[a] | 0 | 0 |
| | FN | 1 | 0 | 0 | 0 | 0 |
| Pumpkinseed | EB | 16 | 50 ± 16 | 0 | 0 | 0 |
| | GN | 1 | 0 | 0 | 0 | 0 |
| | FN | 0 | 0 | 0 | 0 | 0 |
| Brown bullhead | EB | 2 | 100 | 0 | 0 | 0 |
| | GN | 1 | 0 | 0 | 0 | 0 |
| | FN | 18 | 94 ± 7 | 33 ± 14 | 0 | 0 |

[a] Sample size too small or catch too variable to permit the calculation of reliable confidence intervals.
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 = gillnetting, and FN = fyke netting.

## Largemouth Bass

Largemouth bass ranged from 50 to 510 mm (age 0+ to 7+) (Table 6, Figure 5). Age 1+, age 2+, and age 3+ fish were relatively abundant. Fish older than 3+ were rare, and no fish older than 7+ were collected. Growth of largemouth bass collected from Lake Cassidy was part of an increasing trend since the Washington Department of Game survey by Fletcher (1982) and above the western Washington State average until age 7. Relative weights were generally consistent with, or below, western Washington State averages for most size classes with lower $W_r$ values occurring with larger size classes (Figure 6). Testing the statistical significance of the relationship between total length and relative weight, standard transformation failed to normalize the length data so we evaluated the correlation with the Spearman coefficient (Rho). The correlation coefficient for largemouth bass length and relative weight was –0.453 ( $p < 0.01$).

**Table 6.** Age and growth of largemouth bass captured at Lake Cassidy (Snohomish County) during late summer 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** |
| 1997 | 31 | 59.5 | | | | | | |
| | | 72.0 | | | | | | |
| 1996 | 31 | 33.3 | 116.1 | | | | | |
| | | 50.2 | 125.0 | | | | | |
| 1995 | 15 | 55.2 | 134.6 | 205.9 | | | | |
| | | 71.2 | 144.7 | 211.0 | | | | |
| 1994 | 4 | 49.2 | 143.6 | 227.2 | 285.9 | | | |
| | | 66.2 | 154.9 | 233.5 | 288.7 | | | |
| 1993 | 5 | 80.3 | 185.8 | 274.5 | 344.6 | 394.7 | | |
| | | 96.7 | 197.0 | 281.6 | 348.5 | 396.1 | | |
| 1992 | 2 | 48.4 | 147.5 | 214.5 | 284.2 | 349.1 | 397.5 | |
| | | 66.0 | 160.6 | 224.4 | 290.7 | 352.4 | 398.5 | |
| 1991 | 2 | 36.0 | 156.4 | 215.9 | 259.0 | 299.7 | 330.2 | 353.6 |
| | | 54.1 | 168.2 | 224.7 | 265.5 | 304.1 | 333.0 | 355.2 |
| | 1982 | 47.2 | 81.0 | 115.3 | 161.0 | 180.1 | 181.1 | |
| | 1988 | 36.3 | 94.7 | 151.9 | 195.1 | 241.0 | 264.4 | |
| | 1992 | 51.8 | 121.9 | 199.9 | 254.8 | 302.0 | 338.1 | |
| 1998 mean | | 51.7 | 147.3 | 227.6 | 293.4 | 347.8 | 363.9 | 353.6 |
| Weighted mean | | 64.9 | 140.8 | 228.7 | 308.4 | 366.0 | 365.8 | 355.2 |
| State Average | | 60.4 | 145.5 | 222.2 | 261.1 | 289.3 | 319 | 367.8 |

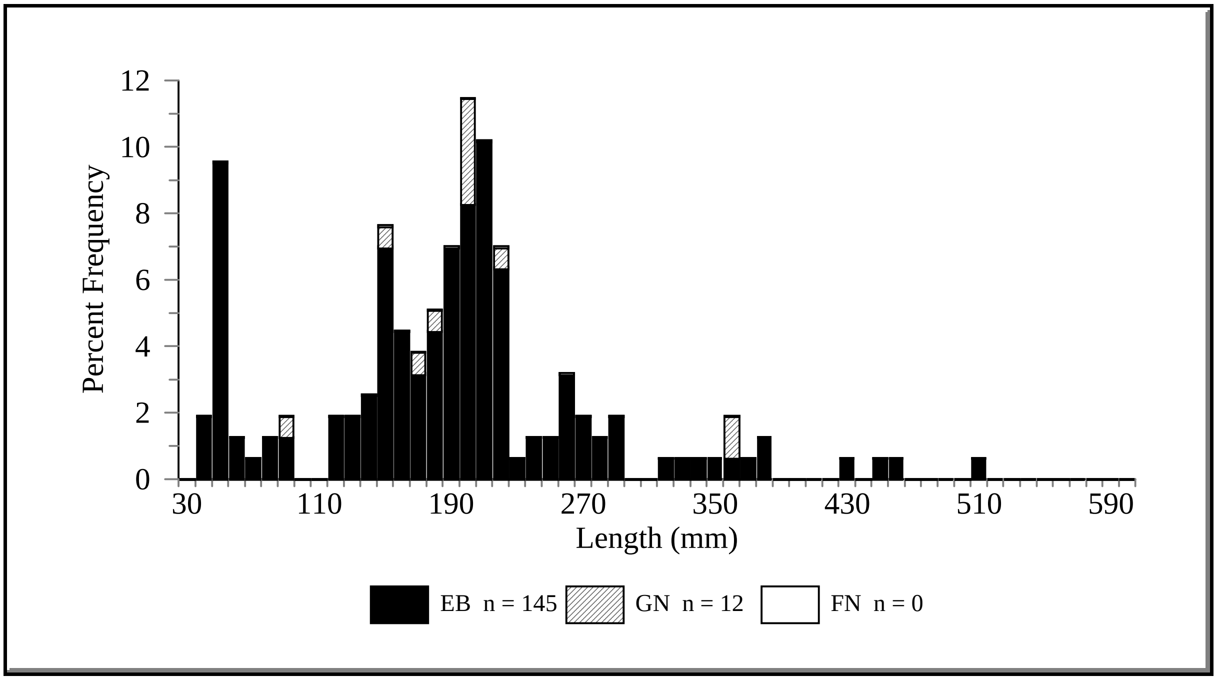


**Figure 5.** Length frequency histogram of largemouth bass sampled from Lake Cassidy in late summer 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

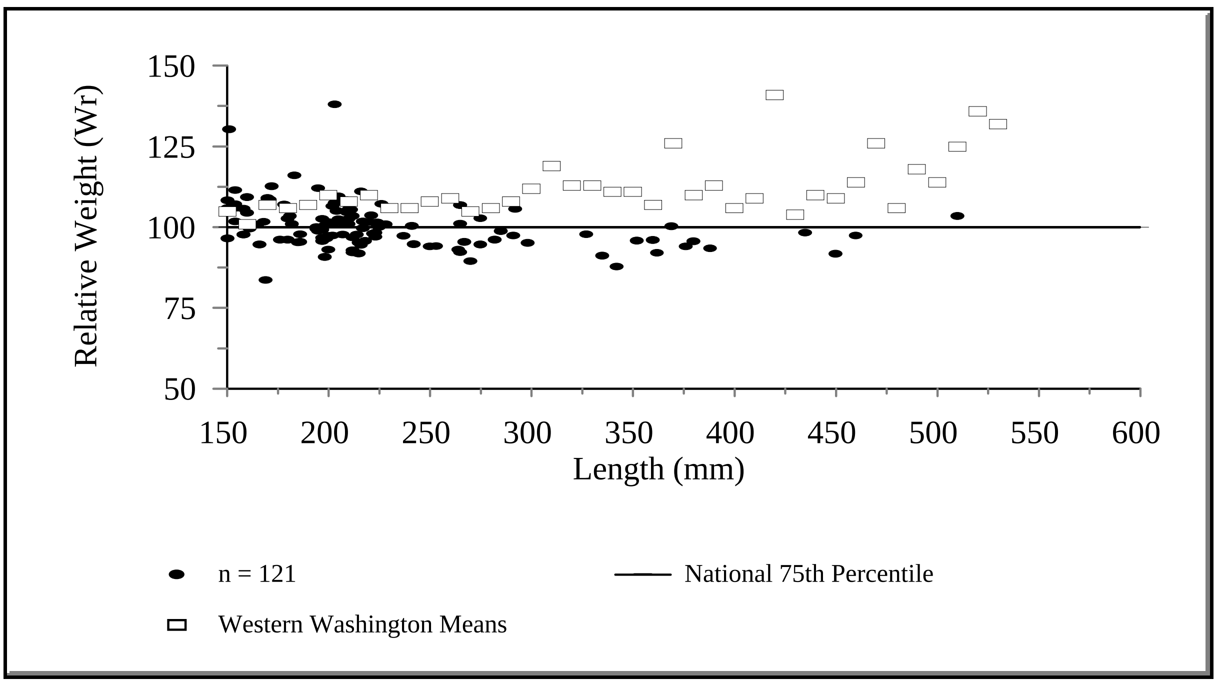


**Figure 6.** Relationship between total length and relative weight ($W_r$) of largemouth bass from Cassidy (Snohomish County), compared with means from up to 25 western Washington lakes and the national 75$^{th}$ percentile.

## Black Crappie

Black crappie ranged from 41 to 262 mm (TL) (age 1+ to 4+) (Table 7, Figure 7). Age 1+ and 2+ fish were relatively abundant and exhibited growth rates that were an improvement over those seen in 1982. However, no age 3+ fish were collected and only one age 4+ fish was collected. Growth rates for black crappie in Lake Cassidy were below the Washington State average for the first and second year of life but above the average thereafter. However, we cannot draw conclusions about growth for fish older than 2+ based upon the single individual we sampled. While $W_r$ values were consistent with the Washington State average, a similar downward trend as with largemouth bass appeared with increasing length (Figure 8). Testing the statistical significance of the relationship, standard transformation failed to normalize the length data so we evaluated the correlation with the Spearman coefficient (Rho). The correlation coefficient for black crappie length and relative weight was –0.561 ( $p < 0.01$).

**Table 7.** Age and growth of black crappie captured at Lake Cassidy (Snohomish County) during late summer 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 | 25 | 43.6 | | | | |
| | | 66.1 | | | | |
| 1996 | 19 | 23.5 | 111.3 | | | |
| | | 54.3 | 126.5 | | | |
| 1995 | 0 | | | | | |
| 1994 | 1 | 13.3 | 94.6 | 184.4 | 240.2 | |
| | | 46.6 | 117.0 | 194.7 | 243.1 | |
| Overall mean | | 26.8 | 103.0 | 184.4 | 240.2 | |
| Weighted mean | | 60.7 | 126.0 | 194.7 | 243.1 | |
| 1982 survey mean | | 41.9 | 95.8 | 154.4 | 194.3 | 207.5 |
| State average | | 46.0 | 111.2 | 156.7 | 183.4 | |

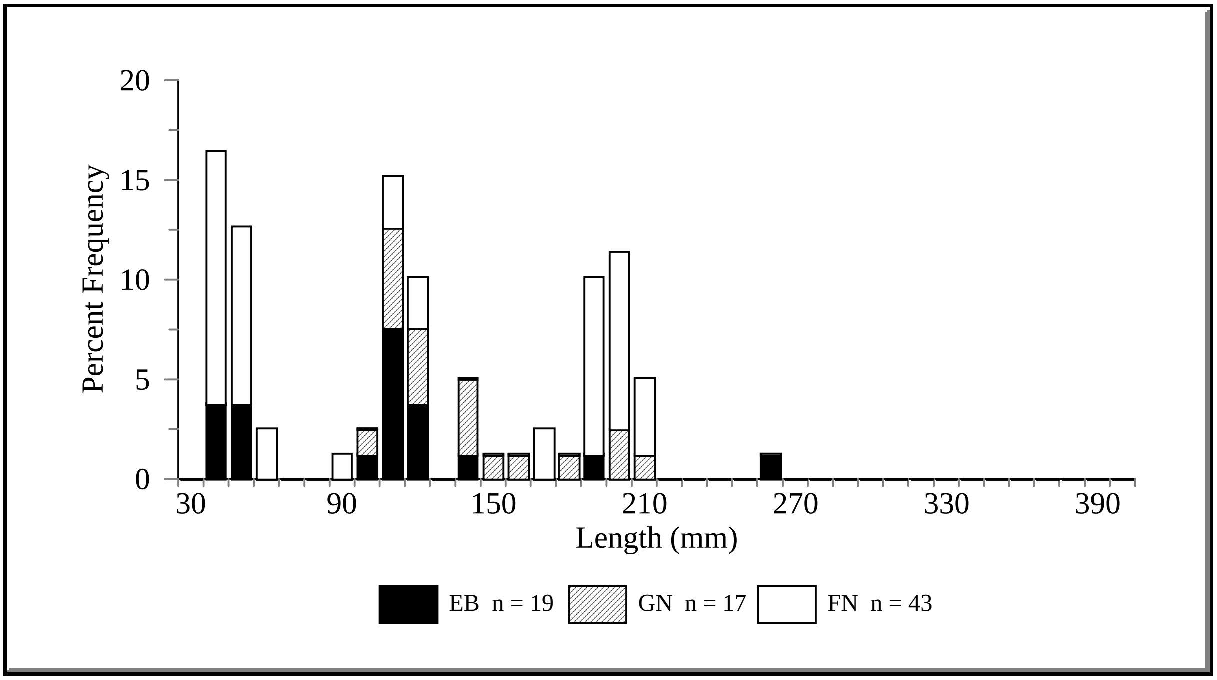


**Figure 7.** Length frequency histogram of black crappie sampled from Lake Cassidy in late summer 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

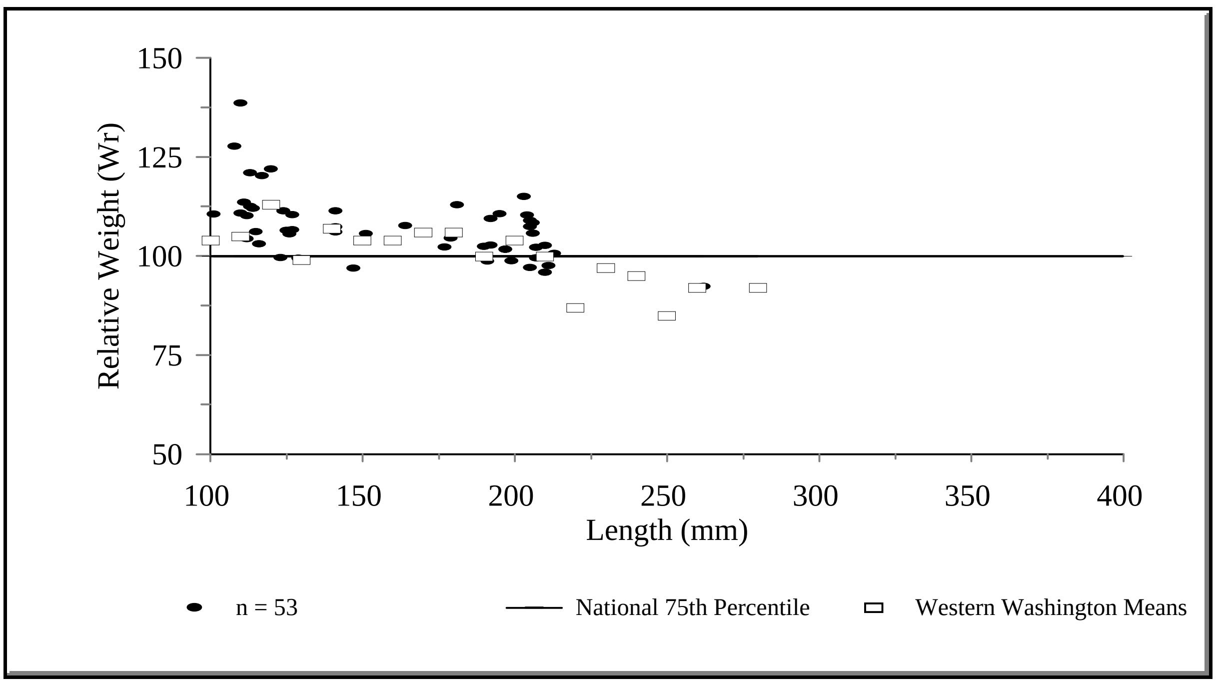


**Figure 8.** Relationship between total length and relative weight ($W_r$) of black crappie from Lake Cassidy (Snohomish County), compared with means from up to 25 western Washington lakes and the national 75th percentile.

## Yellow Perch

Yellow perch ranged from 53 to 266 mm (TL) (age 1+ to 6+) (Table 8, Figure 9). Growth rates for yellow perch in Lake Cassidy were part of an increasing trend since 1982 and consistent with or above the Washington. Despite this, $W_r$ values were still generally below the Washington State average (Figure 10).

**Table 8.** Age and growth of yellow perch captured at Lake Cassidy (Snohomish County) during late summer 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 | 23 | 55.5 | | | | | |
| | | 71.1 | | | | | |
| 1996 | 13 | 38.0 | 107.4 | | | | |
| | | 60.2 | 115.3 | | | | |
| 1995 | 43 | 52.1 | 107.8 | 160.8 | | | |
| | | 73.8 | 120.7 | 165.3 | | | |
| 1994 | 9 | 55.5 | 123.4 | 172.4 | 201.2 | | |
| | | 78.1 | 136.9 | 179.5 | 204.5 | | |
| 1993 | 4 | 54.0 | 120.9 | 164.7 | 191.1 | 213.3 | |
| | | 77.0 | 135.4 | 173.5 | 196.5 | 215.8 | |
| 1992 | 2 | 47.9 | 134.7 | 163.7 | 193.4 | 210.0 | 232.3 |
| | | 72.1 | 148.4 | 173.8 | 200.0 | 214.6 | 234.2 |
| | 1982 | 41.9 | 62.7 | 92.5 | 117.3 | 138.9 | 155.2 |
| | 1988 | 46.7 | 109.0 | 143.3 | 175.0 | 187.7 | 192.3 |
| | 1992 | 53.6 | 127.8 | 163.3 | 192.8 | 230.9 | - - |
| | 1981 mean | 50.5 | 118.9 | 165.4 | 195.2 | 211.6 | 232.3 |
| | Weighted mean | 71.8 | 123.4 | 168.4 | 201.8 | 215.4 | 234.2 |
| | State Average | 59.7 | 119.9 | 152.1 | 192.5 | 206.0 | |

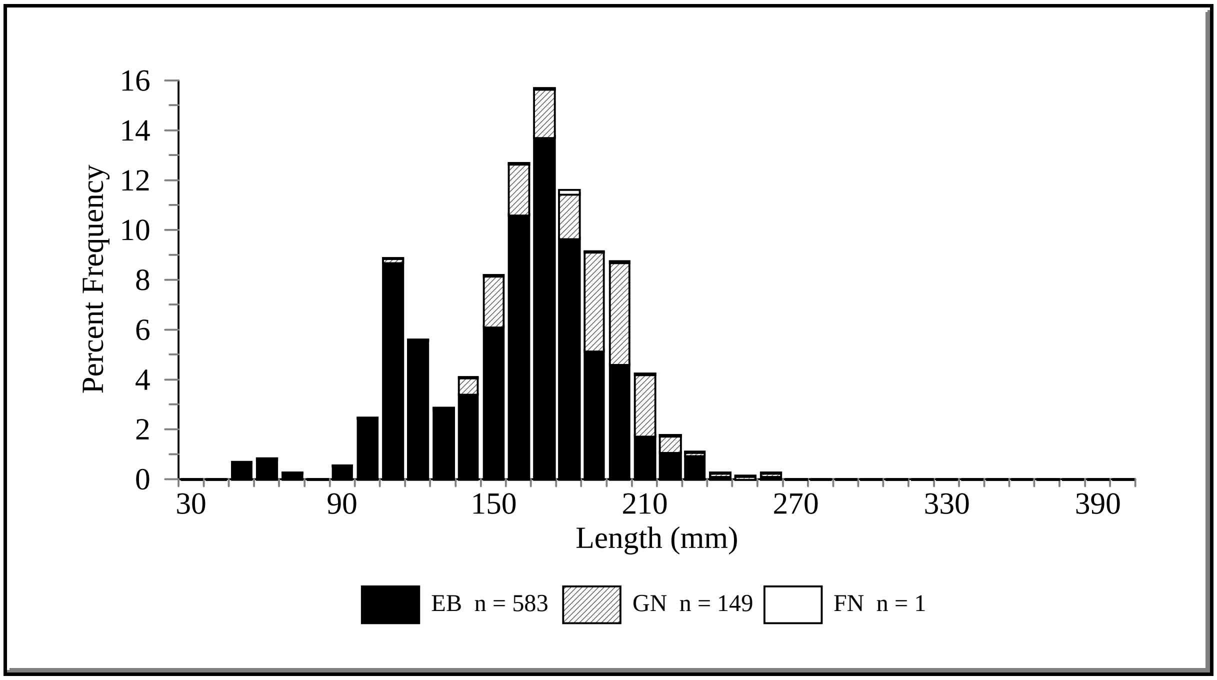


**Figure 9.** Length frequency histogram of yellow perch sampled from Lake Cassidy in late summer 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

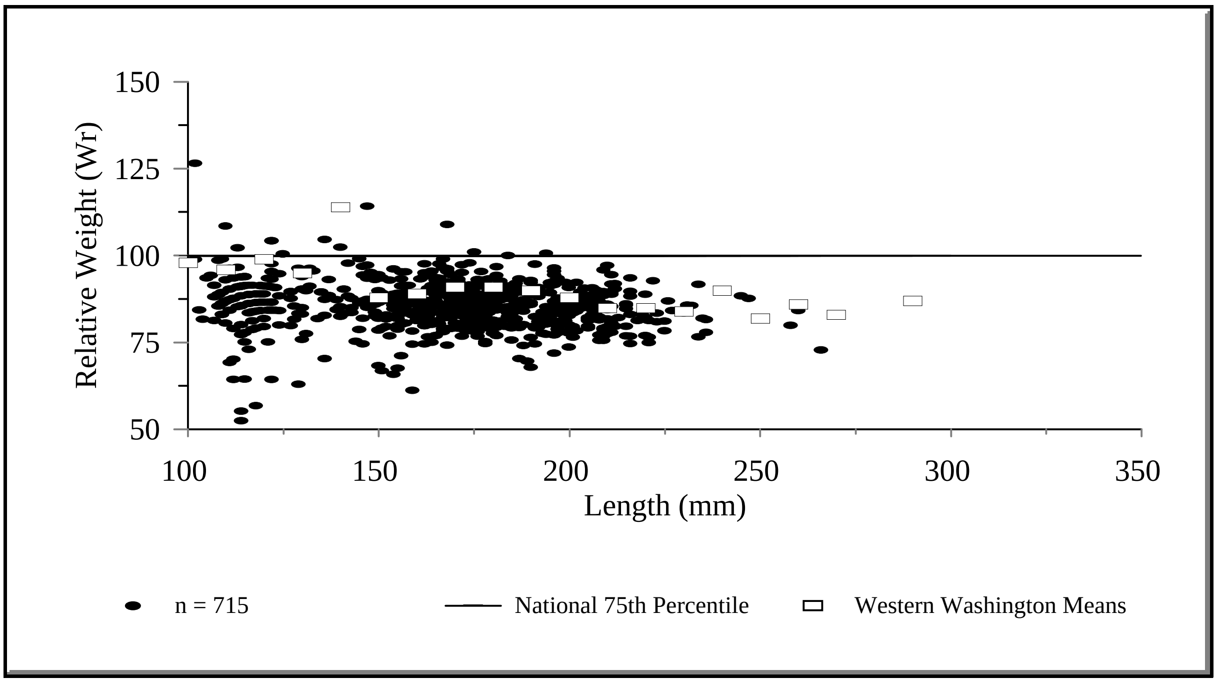


**Figure 10.** Relationship between total length and relative weight ($W_r$) of yellow perch from Lake Cassidy (Snohomish County), compared with means from up to 25 western Washington lakes and the national 75th percentile.

## Pumpkinseed

Pumpkinseed ranged from 106 to 181 mm (TL) (age 1+ to 4+) (Table 9, Figure 11). Growth rates for pumpkinseed in Lake Cassidy were above the Washington State average and much higher than Fletcher (1982) reported. Relative weight values were above the Washington State average, and while the sample size is small there may be a downward slope to these values with increasing length as well (Figure 12).

**Table 9.** Age and growth of pumpkinseed captured at Lake Cassidy (Snohomish County) during late summer 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 | 0 | | | | | | |
| 1996 | 8 | 15.0 | 81.2 | | | | |
| | | 37.3 | 91.4 | | | | |
| 1995 | 5 | 21.3 | 72.3 | 113.9 | | | |
| | | 42.5 | 84.2 | 118.4 | | | |
| 1994 | 2 | 21.4 | 80.6 | 111.5 | 145.2 | | |
| | | 43.2 | 93.7 | 120.0 | 148.8 | | |
| Overall mean | | 19.2 | 78.0 | 112.7 | 145.2 | | |
| Weighted mean | | 39.8 | 89.3 | 118.8 | 148.8 | | |
| 1982 survey mean | | 22.3 | 61.2 | 88.9 | 118.6 | 141.0 | 155.7 |
| State Average | | 23.6 | 72.1 | 101.6 | 122.7 | | |

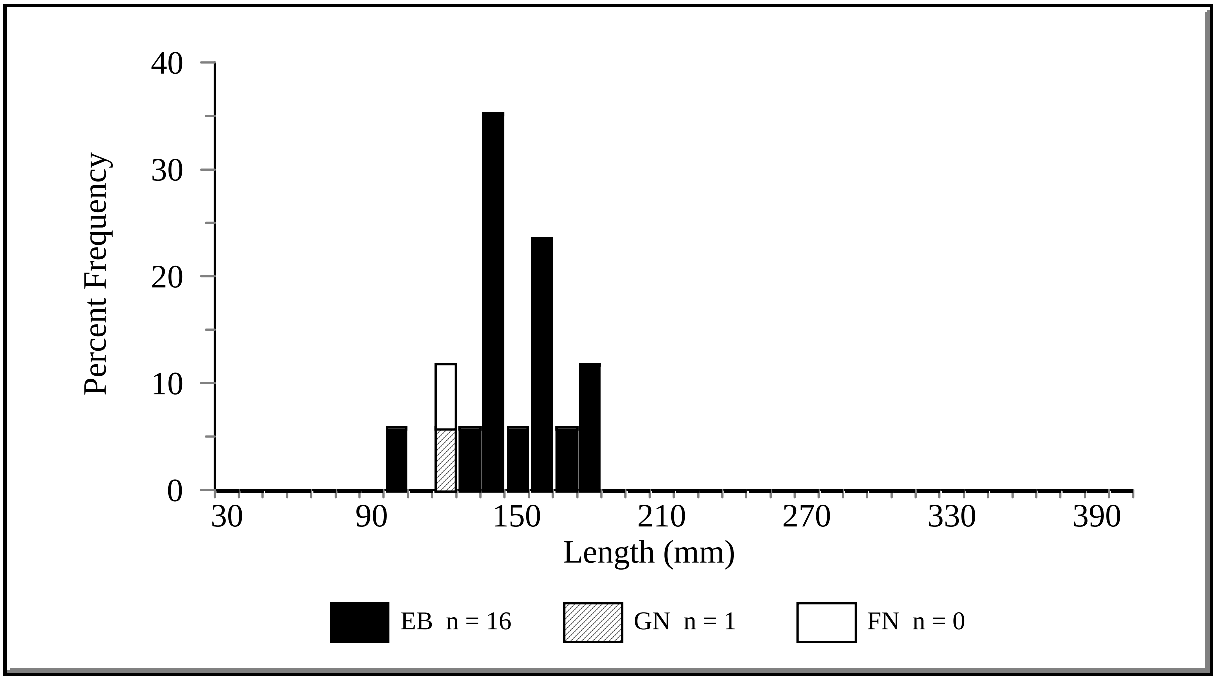


**Figure 11.** Length frequency histogram of pumpkinseed sampled from Lake Cassidy in late summer 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

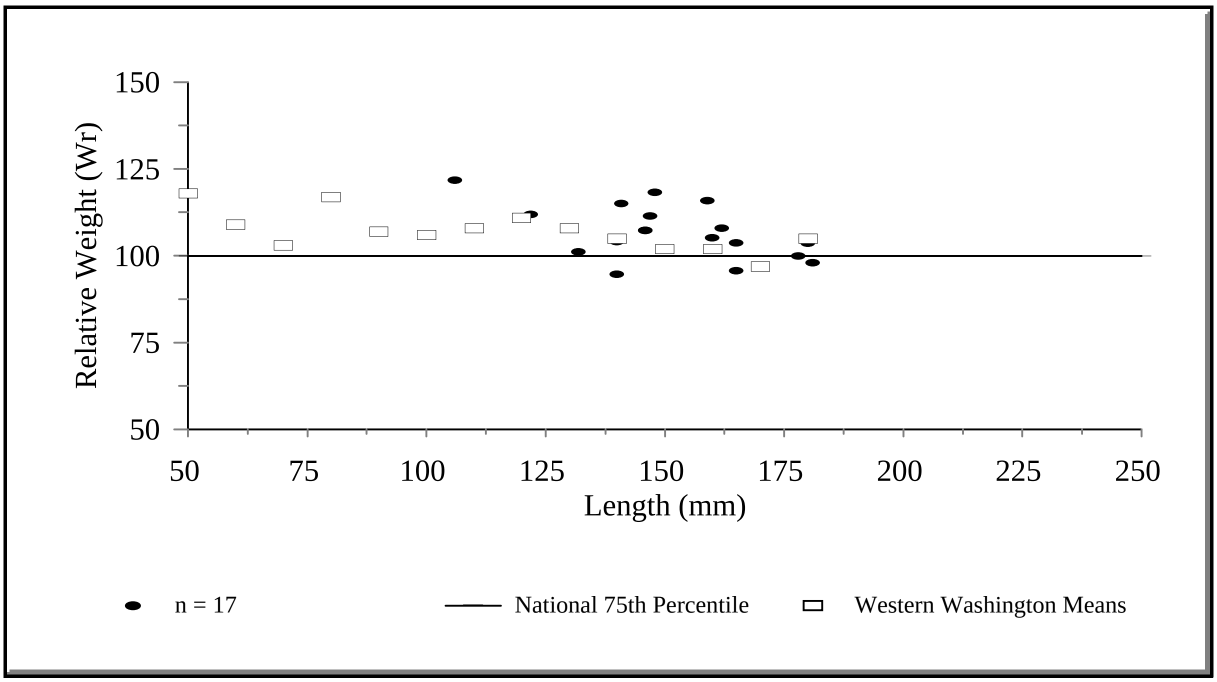


**Figure 12.** Relationship between total length and relative weight ($W_r$) of pumpkinseed from Lake Cassidy (Snohomish County), compared with means from up to 25 western Washington lakes and the national 75th percentile.

## Brown Bullhead

Brown bullhead ranged from 187 to 348 mm TL (Figure 13). Relative weight values were below the national 75th percentile (Figure 14).

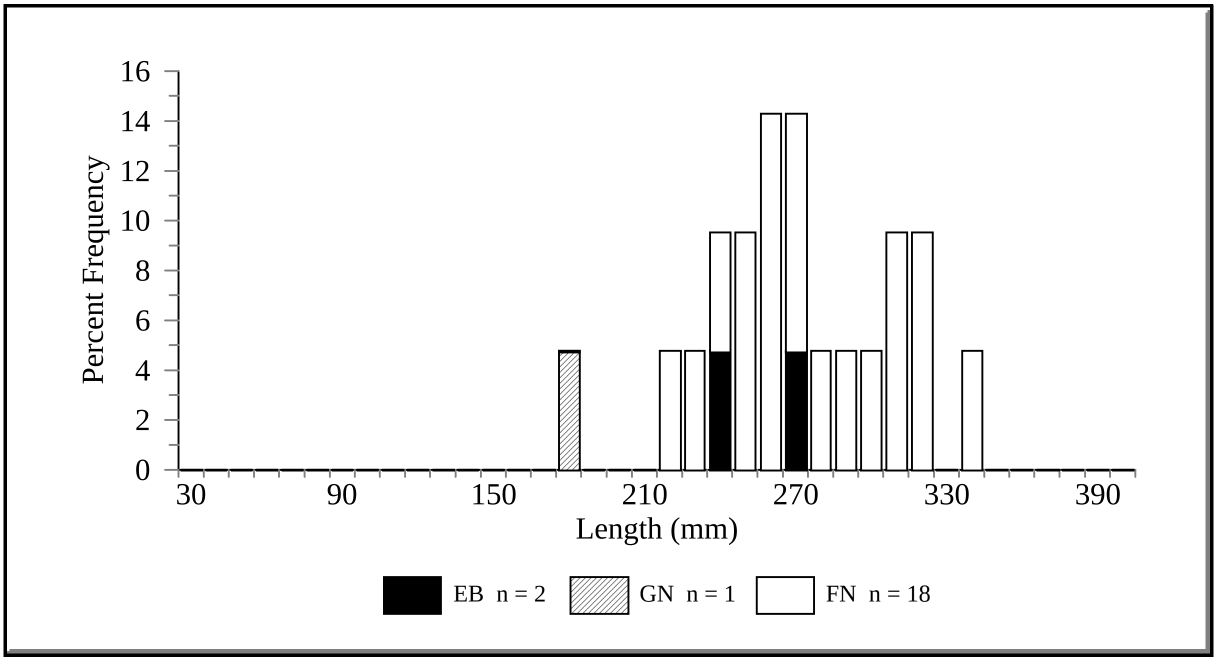


**Figure 13.** Length frequency histogram of brown bullhead sampled from Lake Cassidy in late summer 1998. Stacked bars show relative contribution of each gear type to size classes. Length frequencies can be viewed collectively or by gear type. EB = electrofishing, GN = gill netting, and FN = fyke netting.

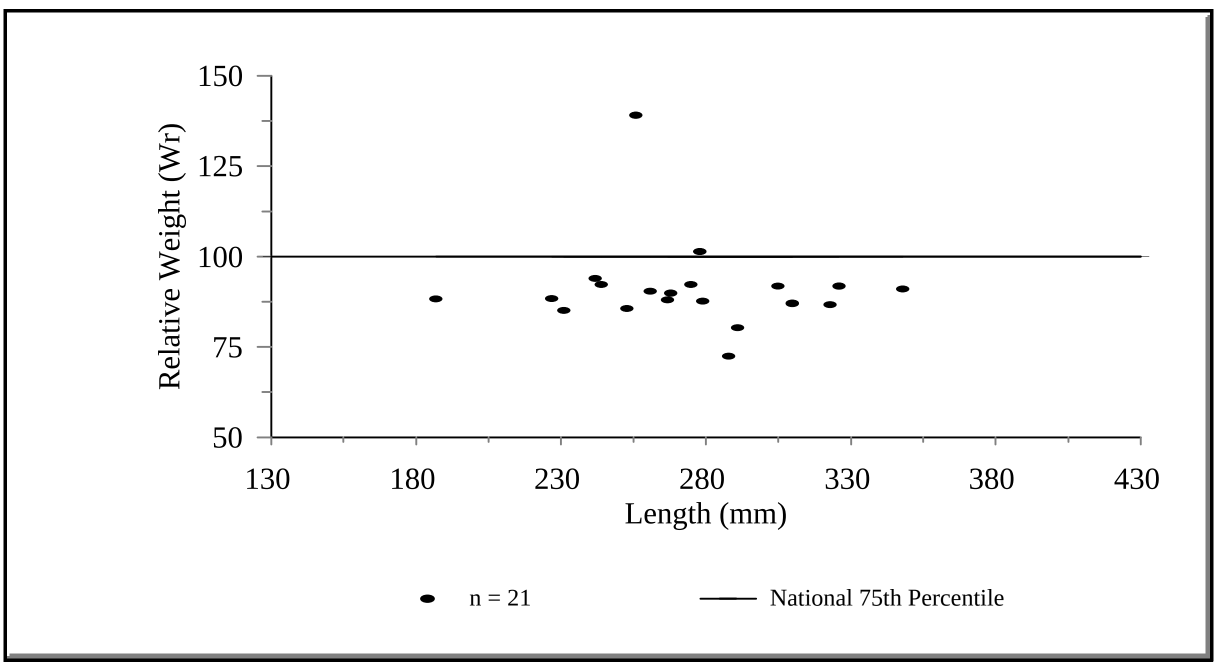


**Figure 14.** Relationship between total length and relative weight ($W_r$) of brown bullhead from Lake Cassidy (Snohomish County), compared with the national 75th percentile.

# Warmwater Enhancement Options

Largemouth bass, yellow perch, and pumpkinseed demonstrated growth rates above or consistent with the Washington State average. Moreover, these growth rates, and those of black crappie, were much higher than those reported in the 1982 WDG survey. One explanation for increased growth in largemouth bass might be the 1984 slot limit imposed on largemouth bass. A slot limit, in theory, alters the size structure of largemouth bass by allowing more individuals to recruit to larger size classes. This can increase numbers of upper level predators that crop populations of forage fish and smaller largemouth bass, ultimately reducing competition among smaller fish and increasing growth (Turman and Dennis 1998).

However, despite improved growth rates, proportional stock indices for largemouth bass were considerably lower than the values generally accepted for balanced communities or trophy waters. Low PSD values reflect the absence of larger size classes relative to numbers of stock–length fish. Low PSD values occur where fish density is high, growth is relatively low, recruitment is moderate to high, and mortality is high. Violations of these conditions, such as the rapid growth observed in Lake Cassidy largemouth bass, may signify overharvest of larger fish (Willis et al. 1993).

Relative weights for largemouth bass, black crappie, and possibly pumpkinseed sunfish decreased with increased length. These patterns often appear in populations where competition and food limitation occur (Willis 1999). However, the absence of larger fish and presence of large numbers of forage fish in Lake Cassidy is inconsistent with a predator–crowded situation suggesting some other factor is unaccounted for.

The abundance of smaller yellow perch suggests a good forage base exists for larger largemouth bass. However, few large largemouth bass were sampled, and those we did collect were in poorer condition than smaller individuals. The absence of larger largemouth bass may be the result of harvesting. The presence of an adequate food base and apparent absence of larger individuals suggests dense aquatic vegetation, low dissolved oxygen in summer, or some other environmental factor may also interfere with efficient foraging of largemouth bass in Lake Cassidy (Fletcher 1981; Wiley et al. 1984; Mueller and Downen 1999). Management options that might improve the warmwater fishery at Lake Cassidy include, but are not limited to, the following:

## Destratify Lake with Aerator

Extreme oxygen deficits occur in the hypolimnion of Lake Cassidy during late summer and fall. These deficits determine the volume of oxygenated water in the lake and the subsequent distribution of fish, causing them to become crowded at temperatures that support high metabolic rates.

Poor growth and condition of fish in a number of lakes have been attributed to poor water quality (Fletcher 1981, Mueller and Downen 1999). The WDFW routinely aerates a number of lakes throughout the state to improve or maintain dissolved oxygen levels during summer months. In the early 1980s 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.

Aerating Lake Cassidy would reduce fish crowding by increasing the volume of habitable water (water with DO concentrations above 5 mg/L). Elevated dissolved oxygen should reduce fish densities and enhance the entire aquatic food web, thus improving growth and possibly numbers of fish.

## Aquatic Vegetation Control

Much of the littoral zone (65 to 90 percent) of Lake Cassidy is densely or moderately vegetated with submerged, floating, and emergent plants (Jenifer Parsons, Washington Department of Ecology, unpublished data). Dense plant communities of yellow water lily *(Nuphar polysepalum*), common elodea (*Elodea canadensis*), common bladderwort *(Utricularia vulgaris*), thin–leaf pondweed (*Potamogeton sp*.), and coontail (*Ceratophyllum demersum*) present in Lake Cassidy may inhibit foraging by largemouth bass and black crappie while providing too great of a refugia for forage fish such as yellow perch (Wiley et al.1984).

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. 1993) and the structure of the fish community itself (Bettoli et al. 1993). Dense vegetation reduces foraging efficiency of many predatory warmwater fish species (Wiley et al. 1984). Fish communities seem to maximize their numbers under conditions of intermediate plant density. Balancing the contribution to habitat structure with the potential for reduced foraging efficiency should be an important aspect of aquatic plant control.

Several options are available to reduce the density of aquatic vegetation in Lake Cassidy. Grass carp (*Ctenopharyngodon idella*) would provide and economical biological control. However, screening the outlet of Lake Cassidy may be necessary before implementing this option. 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 were impractical. However, mechanical removal methods might not be as selective as previously mentioned methods or as cost–effective.

## Change Existing Fishing Rules to Alter Size Structure of Largemouth Bass

Currently, a 305-381 mm (12-15 inch) slot limit makes it illegal to retain largemouth bass between 305 and 381 mm from Lake Cassidy. 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. Although the slot and creel limits are intended to protect fish required for a balance within the lake, the size structure observed during late summer 1998 suggests the rule is not working as intended. The absence of largemouth bass longer than 381 mm TL suggests fish are being harvested at a rate that exceeds recruitment into older age groups.

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 (while still maintaining the daily limit of five fish), might allow more largemouth bass to realize their full growth potential. 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 Cassidy. Since the rule is indisputable, it would be simpler to enforce. Despite the possibility of predator–crowded conditions developing, catch–and–release fishing would at least ensure the likelihood that some fish would reach larger size classes. 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 Cassidy to 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.

# Literature Cited


Anderson, R.O., and R.M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447-482 *In:* Murphy, B.R., and D.W. Willis (eds.), Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, MD.

Bennett, G.W. 1962. Management of artificial lake and ponds. Reinhold Publishing Corporation, New York.

Bettoli, P.W., M.J. Maceina, R.L. Noble, and R.K. Betsill. 1993. The response of a reservoir fish community to aquatic vegetation removal. North American Journal of Fisheries Management 13: 110-124.

Carlander, K.D. 1982. Standard intercepts for calculating lengths from scale measurements for some centrarchid and percid fishes. Transactions of the American Fisheries Society 111: 332-336.

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography 22: 361-369.

Chew, R.L. 1974. Early life history of the Florida largemouth bass. Florida Game and Fish Commission, Fishery Bulletin No. 7, 76 p.

Drainage Improvement District #8. 1998. 1997 Water Quality Monitoring: Lake Stevens, Lake Cassidy, Stitch Lake, Snohomish County, Washington.

Durocher, P.P., W.C. Provine, and J.E. Kraai. 1984. Relationship between abundance of largemouth bass and submerged vegetation in Texas reservoirs. North American Journal of Fisheries Management 4: 84-88.

Fletcher, D. 1981. Warmwater Fishery Investigations in Washington State. Annual Report submitted to the US Fish and Wildlife Service under Federal Aid in Fish Restoration Program, Project No. F-71-R. Washington State Game Department, Olympia Washington.

Fletcher, D. 1982. Lake Cassidy, Snohomish County fishery survey. Report submitted to the US Fish and Wildlife Service under Federal Aid in Fish Restoration Program, Project No. F-71-R. Washington State Game Department, Olympia Washington.

Fletcher, D., S. Bonar, B. Bolding, A. Bradbury, and S. Zeylmaker. 1993. Analyzing warmwater fish populations in Washington State. Washington Department of Fish and Wildlife, Warmwater Fish Survey Manual, 137 p.

Gabelhouse, D.W., Jr. 1984. A length categorization system to assess fish stocks. North American Journal of Fisheries Management 4: 273-285.

Glass, R.D. 1984. Angler compliance with length limits on largemouth bass in an Oklahoma reservoir. North American Journal of Fisheries Management 4: 457-459.

Gustafson, K.A. 1988. Approximating confidence intervals for indices of fish population size structure. North American Journal of Fisheries Management 8: 139-141.

Jearld, A. 1983. Age determination. Pages 301-324 *In*: Nielson, L.A., and D.L. Johnson (eds.), Fisheries techniques. American Fisheries Society, Bethesda. MD.

Keast, A. 1979. Patterns of predation in generalist feeders. Pages 243-255 *in* H. Clepper, editor. Predator-Prey Systems in Fisheries Management. Sport Fishery Institute, Washington D.C.

Killgore, K.J., R.P. Morgan, II, and N.B. Rybicki. 1989. Distribution and abundance of fishes associated with submersed aquatic plants in the Potomac River. North American Journal of Fisheries Management 9: 101-111.

Kohler, C.C., and A.M. Kelly. 1991. Assessing predator-prey balance in impoundments. Pages 257-260 *In* Proceedings of the Warmwater Fisheries Symposium I, June 4-8, 1991, Scottsdale, Arizona. USDA Forest Service, General Technical Report RM-207.

McHugh, J.J. 1990. Response of bluegills and crappies to reduced abundance of largemouth bass in two Alabama impoundments. North American Journal of Fisheries Management 10: 344-351.

Mueller, K.W., and M.R. Downen. 1999. 1997 Lacamas Lake survey: the warmwater fish community of a highly eutrophic lowland lake. Washington Department of Fish and Wildlife Warmwater Program Technical Report. Washington Department of Fish Wildlife, Olympia WA.

Murphy. B.R., D.W. Willis, and T.A. Springer. 1991. The relative weight index in fisheries management: status and needs. Fisheries 16: 30-38.

ODFW (Oregon Department of Fish and Wildlife). 1997. Fishery biology 104- Body condition. Oregon Department of Fish and Wildlife, Warmwater Fish News 4(4): 3-4.

Olson, M.H., G.G. Mittelbach, and C.W. Osenburg. 1995. Competition between predator and prey: resource-based mechanisms and implications for stage-structured dynamics. Ecology 76: 1758-1771.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Board of Canada 191: 382 pp.

Swingle, H.S. 1950. Relationships and dynamics of balanced and unbalanced fish populations. Auburn University, Alabama Agricultural Experiment Station Bulletin No. 274, 74 p.

Turman, D., and C. Dennis. 1998. Review of largemouth bass minimum length and slot limits on Lake Columbia, Arkansas. American Fisheries Society, Fisheries Management Section Newsletter 17(1): 17.

WDFW (Washington Department of Fish and Wildlife). 1999. Warmwater Game Fish Enhancement Program. Washington Department of Fish and Wildlife, Publication FM96-04, 2p.

Wiley, M.J., R.W. Gordon, S.W. Waite, and T. Powless. 1984. The relationship between aquatic macrophytes and sport fish production in Illinois ponds: a simple model. North American Journal of Fisheries Management 4: 111-119.

Willis, D.W., B.R. Murphy, C.S. Guy. 1993. Stock density indices: development, use, and limitations. Reviews in Fisheries Science 1(3): 203-222.

Willis, D.W., D.O. Lucchesi, and B.G. Blackwell. 1997. Influence of Aquatic Vegetation on Natural Recruitment of Some Centrarchid, Esocid, and Percid Fishes: A Literature Review. South Dakota Department of Game, Fish, and Parks, Special Report No. 97-4, 26 p.

Willis, D.W. 1999. Fisheries Management, Instruction Manual, FIS2103. US Fish and Wildlife Service National Conservation Training Center Branch of Aquatic Resources Training, Minneapolis, MN.

Zar, J.H. 1984. Biostatistical Analysis, $2^{nd}$ edition. Prentice-Hall, Englewood Cliffs, NJ.