# THE CURRENT TROPHIC STATUS AND PRIMARY SPORT FISH POPULATIONS IN TWO CENTRAL FLORIDA LAKES THIRTEEN YEARS AFTER THE INTRODUCTION OF GRASS CARP (*Ctenopharyngodon idella*)

BY

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Abstract of Thesis Presented to the Graduate School of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Master of Science

# THE CURRENT TROPHIC STATUS AND PRIMARY SPORT FISH POPULATIONS IN TWO CENTRAL FLORIDA LAKES THIRTEEN YEARS AFTER THE INTRODUCTION OF GRASS CARP (*Ctenopharyngodon idella*)

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Clear Lake and Lake Wales are eutrophic central Florida lakes which were infested with the submersed macrophyte hydrilla (*Hydrilla verticillata*) in the 1970s. In 1974, grass carp (*Ctenopharyngodon idella*) were introduced into both lakes in an attempt to control the aquatic vegetation. Submersed macrophytes were eliminated from Clear Lake in 1976 and from Lake Wales in 1981. In 1987-88, both lakes had total phosphorus (TP) and total nitrogen (TN) concentrations averaging more than 25 and 750 $mg/m^3$, respectively. These values are similar to values reported during the 1970s when hydrilla covered approximately 33% of Clear Lake and as much as 95% of Lake Wales. Submersed macrophytes have not become re-established

in either lake. Thus, grass carp have provided long term, cost-effective control of aquatic macrophytes with little long-term effect on TN or TP concentrations.

In Lake Wales, submersed macrophytes, which covered as much as 95% of the lake, appear to have had an inhibiting effect on algal concentrations. Secchi transparencies in the 1970s were generally 2 to 3 m, but now average 0.7 m. The algal concentrations in Clear Lake were not as a affected by the elimination of hydrilla. This is probably due to the fact that a much smaller percentage, approximately 33%, of Clear Lake was initially infested with submersed macrophytes.

Largemouth bass, bluegill and redear sunfish populations in Clear Lake and Lake Wales have been able to successfully spawn and recruit juvenile fish into harvestable size on a yearly basis. In Clear Lake and Lake Wales, the largemouth bass population consisted mainly of fish less than age IV. These lakes also had bluegill and redear sunfish ranging from young of the year (YOY) to age V and VI+. Therefore, successful sport fish populations can continue to exist in lakes following the removal of submersed macrophytes.

# INTRODUCTION

Aquatic macrophytes can be an important component of lake ecosystems (Frohne 1938; Wetzel and Hough 1973). Macrophytes, especially submersed macrophytes, can influence lake water quality (Hasler and Jones 1949; Carpenter 1980; Landers 1982; Canfield et al. 1983) as well as the fishery (Colle and Shireman 1980; Durocher et al. 1984; Colle et al. 1987). Although dense submersed aquatic plant communities such as hydrilla (*Hydrilla verticillata*) can provide habitat for large populations of juvenile sport fish as well as small forage fish (Barnett and Schneider 1974; Haller et al. 1980), and they can help reduce algal levels (Canfield et al. 1984), excessive growths of aquatic macrophytes can seriously interfere with many water-use activities. Thus, when aquatic plants reach nuisance levels, some form of aquatic plant management program is often implemented (Milon et al. 1986).

Florida's warm climate and long growing season contribute to excessive plant growth within the state. Currently, mechanical, chemical and biological organisms are most often used to control aquatic macrophyte problems in Florida (Sutton and Vandiver 1986). Mechanical control is labor intensive and can be very expensive. In 1985, the mechanical plant control cost for Orange Lake, Florida was approximately $1,888/ha (Thayer and Ramey 1986). Like mechanical control, chemical control can also be expensive. Shireman et al. (1986) stated that herbicide cost for various treatment levels in ponds ranged from $417/ha to $1,339/ha over a four year period.

Grass carp (<u>Ctenopharyngodon</u> <u>idella</u>) have been used efficiently as biological controls to eliminate aquatic weed problems (Bailey 1978; Leslie et al. 1983). Grass carp are cost effective (Sutton and Vandiver 1986) and can control aquatic weeds for as long as 15 years (Leslie et al. 1987). However, grass carp can eliminate nearly all aquatic macrophytes within a lake (Shireman et al. 1985; Klussmann et al. 1988) and there has been opposition to their use for fears this removal may have an adverse environmental impact (Shireman and Hoyer 1985).

For this investigation, water quality as well as the largemouth bass (<u>Micropterus</u> <u>salmoides</u> <u>floridanus</u>), bluegill (<u>Lepomis</u> <u>macrochirus</u>) and redear sunfish (<u>L.</u> <u>microlophus</u>) populations in Clear Lake and Lake Wales were evaluated. These two central Florida lakes were stocked with grass carp in 1974 and have been void of submersed macrophytes a minimum of 7 years. My specific objectives were to (1) assess the current trophic status of Clear Lake and Lake Wales; (2) determine whether the primary sport fish have been able to successfully spawn and experience yearly recruitment in these lakes since submersed vegetation was removed; and (3) determine the abundance and standing crop of largemouth bass, bluegill, and redear sunfish populations in Clear Lake and Lake Wales.

## MATERIALS AND METHODS

Surface water (0.5 m) was collected from Clear Lake in February 1987 then monthly from April through August and from October through February 1988. Surface water was collected from Lake Wales in March and April 1987, then monthly from June through September and from November through January 1988. Three open water stations were sampled throughout the entire study in each lake. In Clear Lake, a near shore station was added in June 1987 and in Lake Wales a fourth station located near a culvert pipe was added in July (Figures 1 and 2).

All samples were collected in acid-washed, triple-rinsed, 1-liter Nalgene bottles and placed on ice before being analyzed. Water column temperature and dissolved oxygen were measured at station 2 using a Yellow Springs Instrument Model 51A temperature and oxygen meter. Temperature and dissolved oxygen were measured every meter, starting from the surface and a 20 cm Secchi disc was also used at station 2 to measure water transparency.

Using unfiltered water, pH was measured with an Orion Model 601A pH meter calibrated against buffers at pH 4.0 and 7.0. Total alkalinity (mg/L as $CaCO_3$) was determine by titration to a pH of 4.5 using 0.02 N sulfuric acid (APHA

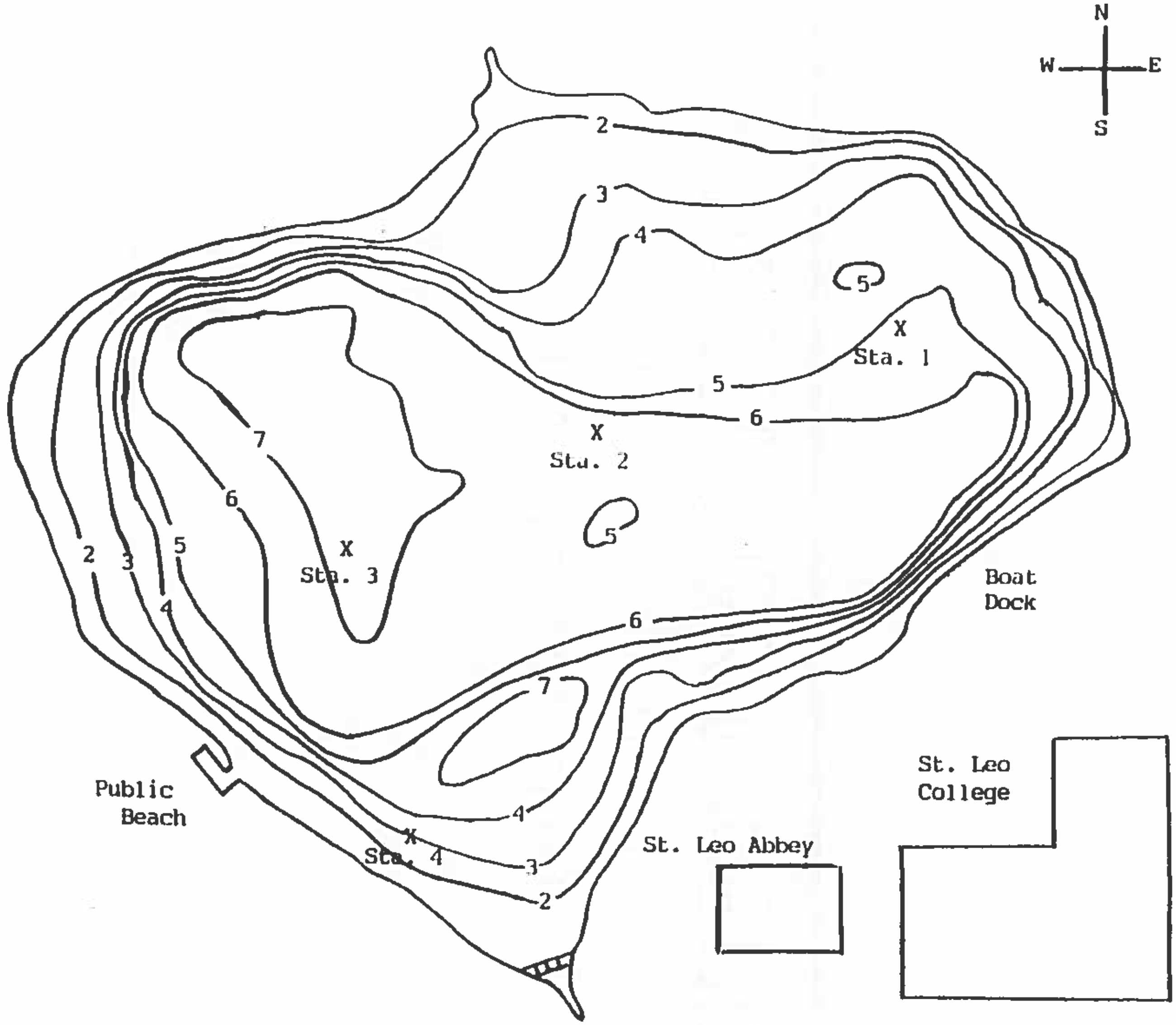


Figure 1. Bathymetric map of Clear Lake, Florida with depth in meters. Sample stations are indicated by X.

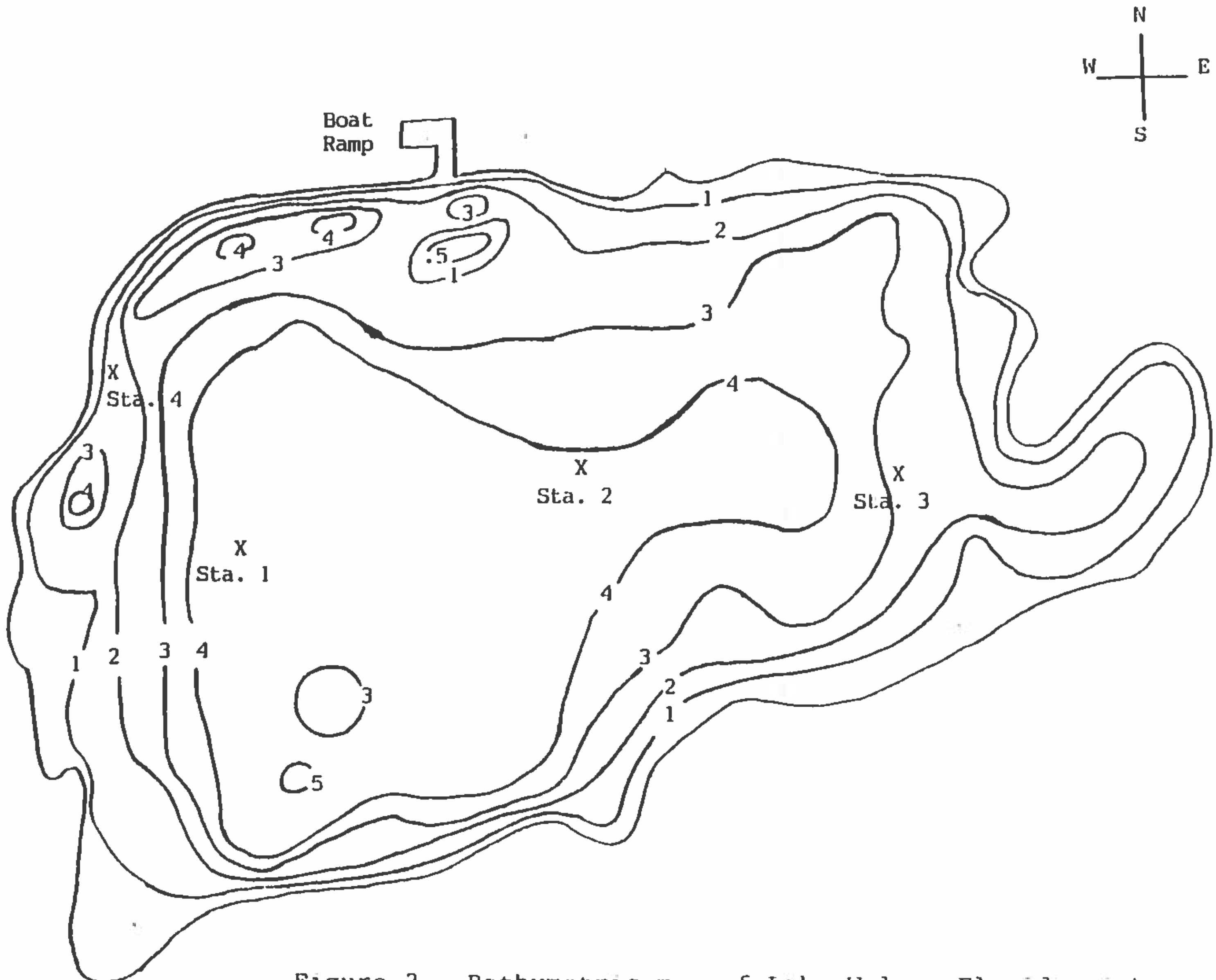


Figure 2. Bathymetric map of Lake Wales, Florida with depth in meters. Sample stations are indicated by X.

1980). Specific conductance (uS/cm at 25 C) was measured using a Yellow Springs Instrument Model 31 conductivity bridge. Total phosphorus concentrations ($mg/m^3$) were determined using the procedures of Murphy and Riley (1962) following a persulfate digestion (Menzel and Corwin 1965). Total nitrogen concentrations ($mg/m^3$) were determined using a modified Kjeldahl technique (Nelson and Summers 1975). Chloride levels were measured by titration using 0.0141 N mercuric nitrate with diphenlycarbazone as the endpoint determination (APHA 1980).

Water samples filtered through a Gelman Type A-E glass fiber filter were used to determine color, sodium, calcium, magnesium and potassium concentrations. Color (Pt-Co units) was determined by the platinum cobalt method with Nessler tubes (APHA 1980). Sodium, calcium, magnesium and potassium concentrations were measured using a Perkin-Elmer model 703 atomic absorption spectrophotometer (APHA 1980).

Submersed macrophyte coverage was monitored twice during the summer and estimated according to Shireman and Maceina (1981) using a Raytheon model DE-719 fathometer. Emergent macrophyte coverage was also estimated. Where vegetation was present, the length and width of the vegetation plot was determined using a range finder and the area was recorded. The percent of the lake surface containing aquatic macrophytes was then determined.

Phytoplankton abundance was estimated by measuring chlorophyll a concentrations. A measured volume of lake water was filtered through a Gelman Type A-E glass fiber filter. The filters were stored in desiccant and frozen until analyzed. Chlorophyll a concentrations ($mg/m^3$) were determined using the methods of Richards with Thompson (1952) and Yentsch and Menzel (1963). Chlorophyll a values were calculated using the equations of Parsons and Strickland (1963). Corrections for phaeophyton were not made.

In September 1986, three near shore 0.08-ha blocknets were used to sample the fish population in Clear Lake and Lake Wales. Blocknet areas were treated with the fish toxin rotenone and dead fish inside the nets were collected for three days. Fish were identified to species and separated into 40 mm total length (TL) size groups, counted and weighed (unpublished data from Daniel E. Canfield Jr., University of Florida).

In 1987, a Peterson single census mark-recapture study was conducted to estimate the largemouth bass, bluegill and redear sunfish populations in Clear Lake and Lake Wales. These primary sport fish were collected using an electro-fishing boat equipped with a Coffelt variable voltage pulsator electroshocking unit model VVP-15. Fish were generally collected near shore during both night and day sampling. In Clear Lake, largemouth bass and bluegill collected from February 24, 1987 to July 3, 1987 and redear sunfish collected from February 24, 1987 to June 26, 1987 were used to estimate both abundance (number/ha) and standing crop (kg/ha). In Lake Wales, largemouth bass, bluegill and redear sunfish collected from February 17, 1987 to July 10, 1987 were used for the population and standing crop estimates. Upon capture, fish were measured to the nearest mm (TL) and weighed to the nearest gram. Largemouth bass greater than 254 mm TL were given a left pelvic fin clip during the marking period. In addition, some largemouth bass greater than 150 mm TL were also given a Floy anchor tag which contained an individual identification number so growth rates could be calculated upon that fish's recapture. Harvestable ($\geq$ 150 mm TL) bluegill and redear sunfish were only given a left pelvic fin clip during the marking period then released.

During June and July 1987, electrofishing equipment was used to collect largemouth bass, bluegill and redear sunfish according to 40 mm TL size classes. The fish were then subsampled and sacrificed. The sagittae otoliths were removed and viewed in order to determine the number of annuli. Back calculated lengths at a given age were determined according to Bagenal (1978). Initially, whole otoliths were viewed and the annuli were counted and measured from the nucleus to the outer edge. A portion of the collected otoliths were then sectioned according to

Coleman et al. (1984) and the annuli counted. Whole view and sectioned readings were then compared.

Length frequency histograms were also used to evaluate age and year class strength for harvestable bass, bluegill and redear sunfish in Clear Lake and Lake Wales. In addition, subharvestable largemouth bass (100-253 mm TL) length frequencies were determined for both study lakes.

Harvestable largemouth bass were considered to be $\geq$ 254 mm TL and harvestable bluegill and redear sunfish were $\geq$ 150 mm TL. These sport fish continued to grow throughout the marking period, therefore calculated instantaneous growth rates were used to correct for any recruitment of subharvestable sport fish into harvestable size that may have occurred during the sampling period. Growth rates were calculated using both otolith data and Floy tag data for largemouth bass, and otolith data for bluegill and redear sunfish.

The standing crop (kg/ha) of harvestable sport fish was estimated by calculating the mean weight for all harvestable fish of a given species and multiplying that number by the estimated population abundance obtained from the mark-recapture study. This value was then divided by the number of lake surface hectares to give a biomass (kg/ha) estimate for each sport fish species sampled.

## RESULTS AND DISCUSSION

Clear Lake is a 64 ha solution lake located in the Brooksville Hills physiographic region (Brooks 1981) of Pasco County, Florida. Lakes in this area are found in a region dominated by the Suwannee Limestone Formation. Canfield (1981) chemically described these lakes as alkaline soft-water lakes and concluded that lakes in this region could best be classified as naturally meso-eutrophic, especially where rich phosphatic deposits of the Hawthorn Formation occur. Clear Lake has a watershed of approximately 233 ha (Leslie et al. 1983), an average depth of 4.5 m and a maximum depth of 8.3 m (Miley et al. 1979). St. Leo College is located on the south side of the lake and a small drainage canal which remained inactive throughout the present study is located on the north end of the lake.

Lake Wales is a 132 ha landlocked solution lake located within the Lake Wales Ridge physiographic region (Brooks 1981) of Polk County, Florida. The Lake Wales Ridge is dominated by sandy calcareous deposits of the Fort Preston Formation (Puri and Vernon 1964), the topography is karstic and there are numerous lakes within the region. Canfield (1981) chemically described these lakes as alkaline, soft water lakes and concluded that lakes in the Lake Wales Ridge could generally be classified as naturally meso-eutrophic. Lake Wales has a 627 ha watershed (Shireman et al. 1977), an average depth of 2.9 m and a maximum depth of 5 m. The lake is located within the City of Lake Wales and receives stormwater runoff from several drains which discharge into the lake.

Clear Lake was described by the earliest settlers in the 1880s as an "exceptionally clear lake" (Dayton 1979). In the 1940s Clear Lake was infested with water hyacinth (Eichhornia crassipes) and both mechanical and chemical controls were used to remove the plants (personal communication, Eddie Herrmann, resident of San Antonio, Florida). In 1974, hydrilla covered approximately 33% of Clear Lake (Leslie et al. 1983) and 80% of Lake Wales (Hardin and Atterson 1980). Grass carp were stocked in October of 1974 and hydrilla was eliminated from Clear Lake in 1976 and from Lake Wales in 1981.

Currently both lakes contain less than 1% aquatic vegetation and the only macrophytes found were located along the shoreline. The macrophytes currently found along Clear Lakes shoreline include elephant-ear (Colocasia esculenta), water pennywart (Hydrocotyle umbellata), pickeral weed (Pontederia cordata), spatterdock (Nuphar luteum), lizzard's tail (Saururus cernuus), sawgrass (Cladium jamaicense), and torpedograss (Panicum repens). The aquatic macrophytes found along the shoreline in Lake Wales include Umbrellagrass (Fuirena squarrosa), water pennywart, pickeral weed, cat-tail (Typha sp.), water primrose (Ludwigia octovalis), and bulrush (Scirpus sp.).

Submersed marcrophtes have not become re-established in either lake. Grass carp have therefore effectively controlled aquatic macrophytes, for at least 12 years in Clear Lake and 7 years in Lake Wales.

## Water Quality

In 1987-88, the monthly average pH ranged from 7.7 to 9.9 and had a yearly average of 8.9 in Clear Lake and ranged from 7.2 to 9.1 with a yearly average of 8.5 in Lake Wales (Figures 3 and 4). The total alkalinity in Clear Lake averaged 45 mg/L as $CaCO_3$ and ranged from 44 to 47 mg/L (Figure 5). In Lake Wales, the average total alkalinity was 27 mg/L and the total alkalinity ranged from 23 to 32 mg/L as $CaCO_3$ (Figure 6).

Specific conductance averaged 199 uS/cm at 25 C in Clear Lake and 118 uS/cm at 25 C in Lake Wales (Figures 5 and 6). In Clear Lake and Lake Wales, respectively, the concentrations of sodium averaged 9.8 and 6.5 mg/L, calcium averaged 16 and 9.0 mg/L, magnesium averaged 6.3 and 3.9 mg/L, potassium averaged 4.6 and 2.9 mg/L, chloride averaged 24 and 13 mg/L and sulfate averaged 11 and 10 mg/L (Figures 5,6,7 and 8). The largest recorded differences between minimum and maximum values was 19%. This difference was

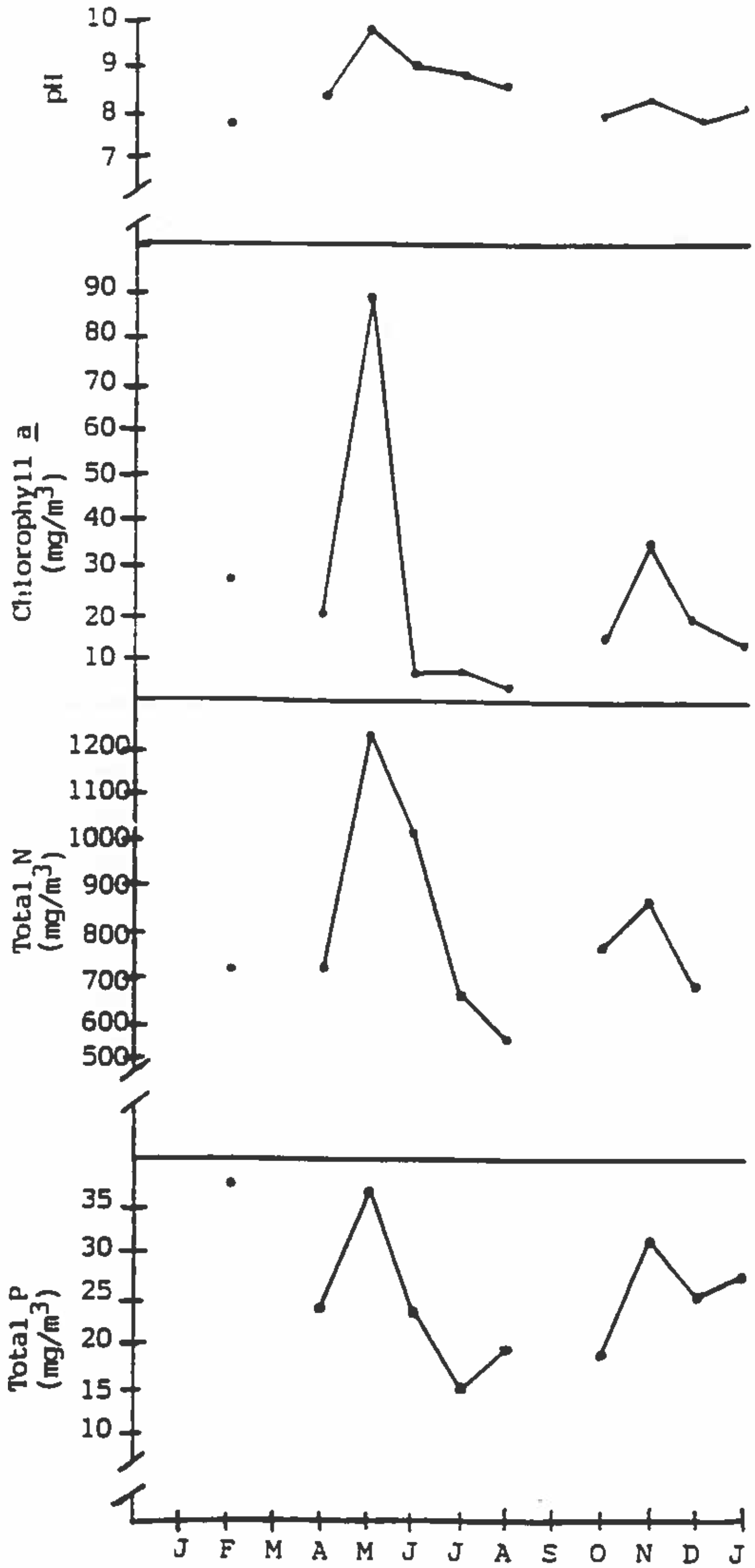


Figure 3. Monthly fluctuation in measured water quality parameters in Clear Lake, Florida 1987-88.

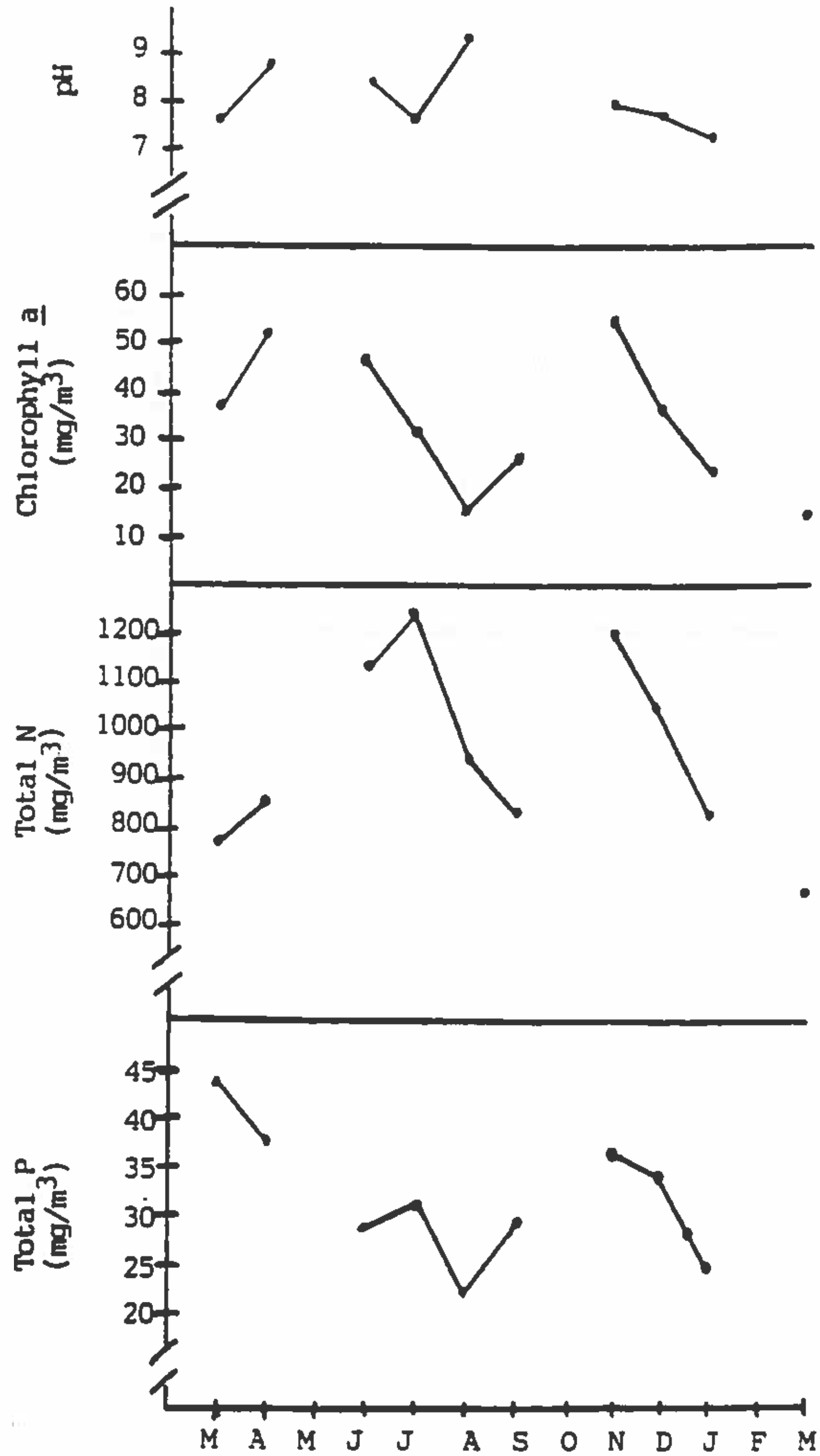


Figure 4. Monthly fluctuation in measured water quality parameters in Lake Wales, Florida 1987-88.

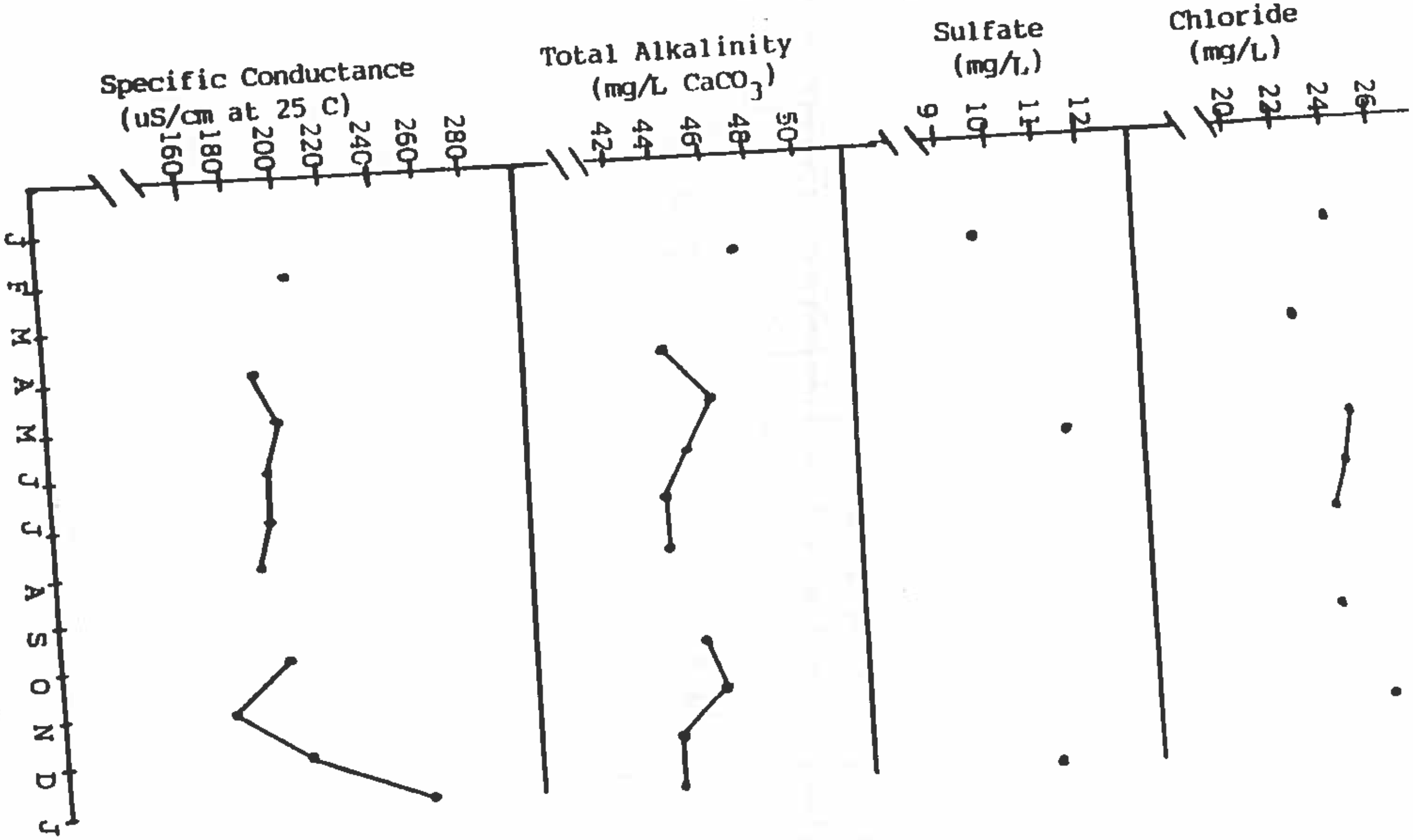


Figure 5. Monthly fluctuation in measured water quality parameters in Clear Lake, Florida 1987-88.

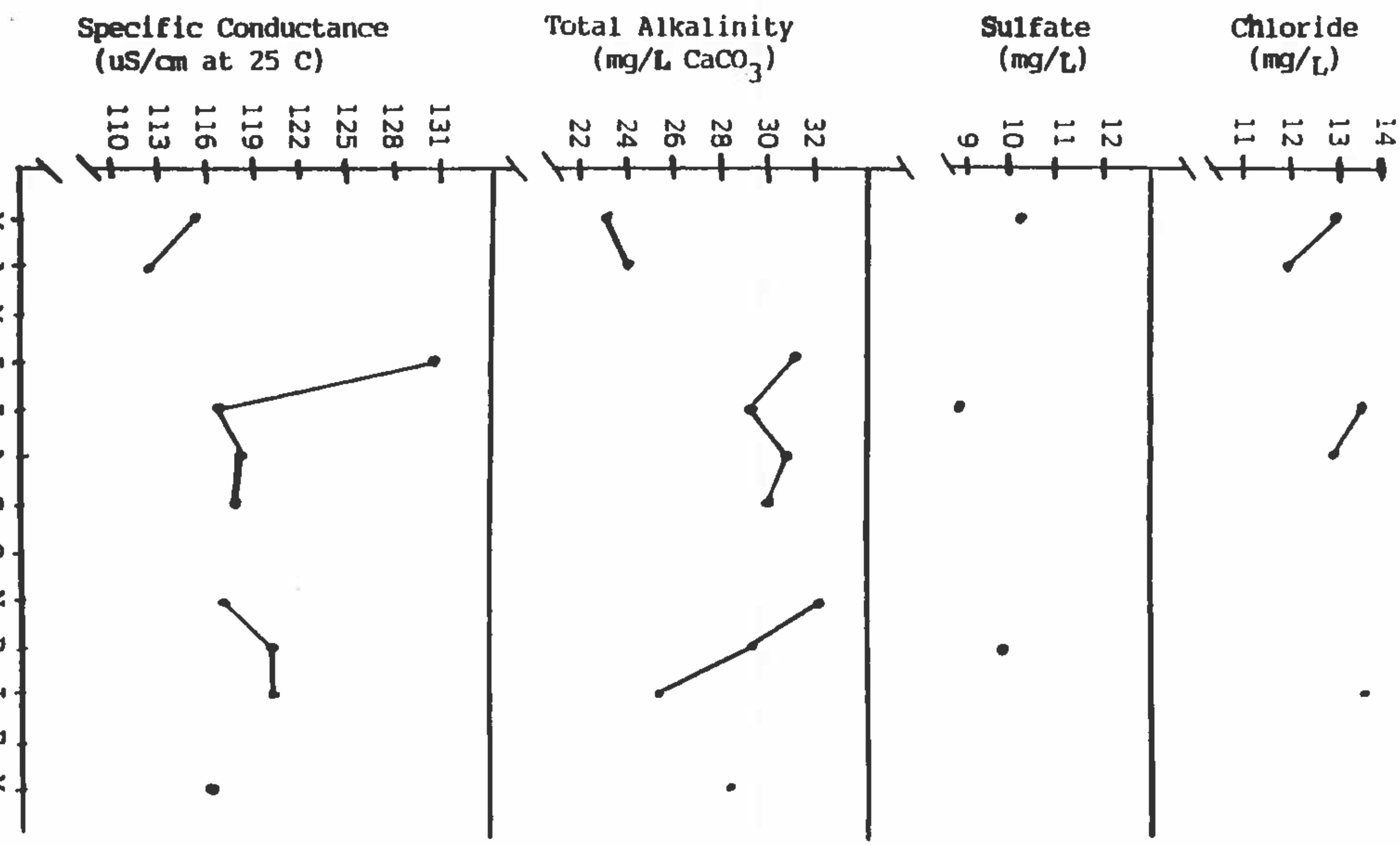


Figure 6. Monthly fluctuation in measured water quality parameters in Lake Wales, Florida 1987-88.

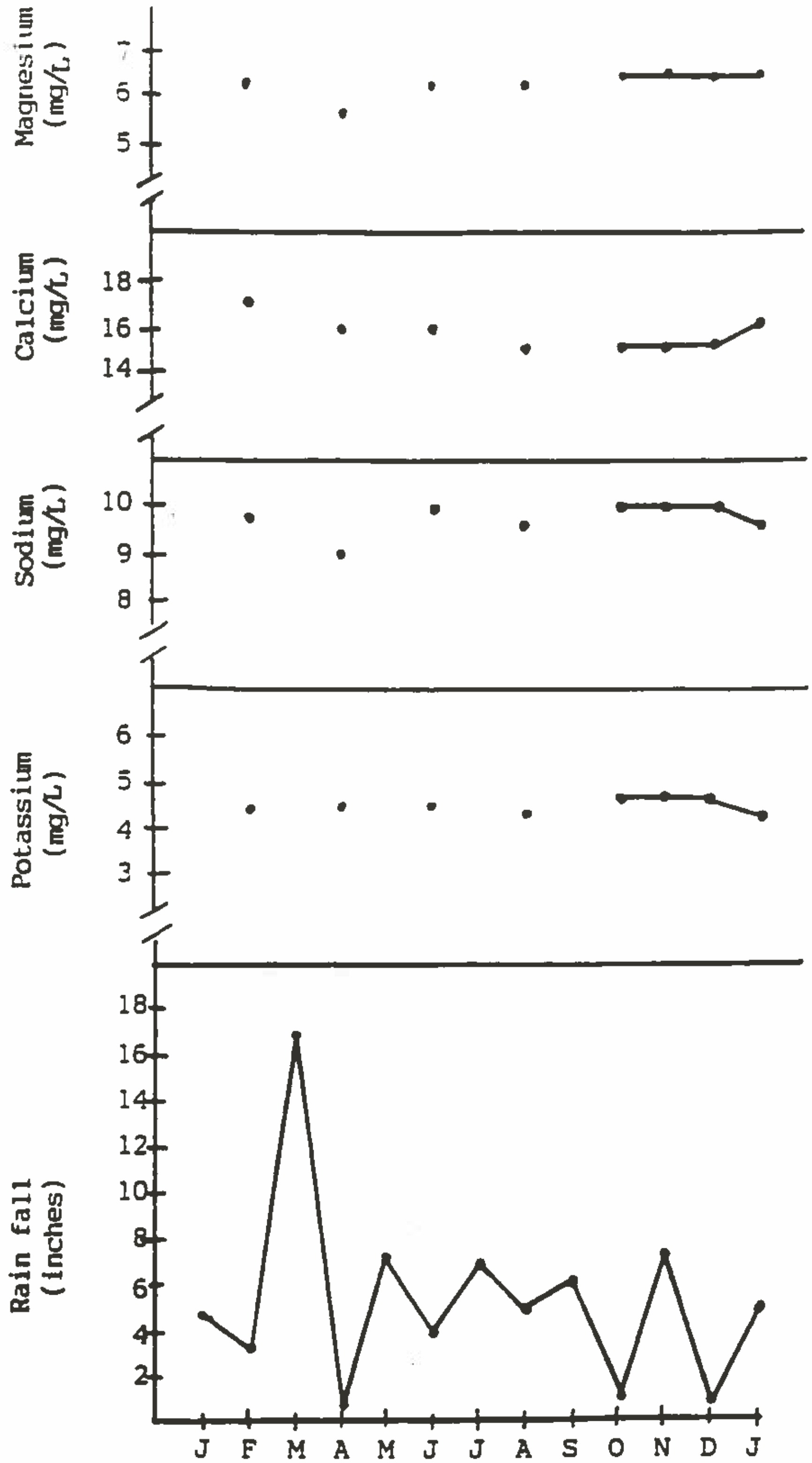


Figure 7. Monthly fluctuation in rain fall and four measured cations in Clear Lake, Florida 1987-88.

Table 2. Proposed trophic state based on total-N, total-P, chlorophyll *a* and transparency expressed as summer average values. From Forsberg and Ryding (1980).

| Trophic state | Total-N (mg/m3) | Total-P (mg/m3) | Chlorophyll *a* (mg/m3) | Transparency (m) |
|---|---|---|---|---|
| Oligotrophic | < 400 | < 15 | < 3 | > 4.0 |
| Mesotrophic | 400-600 | 15-25 | 3-7 | 2.5-4.0 |
| Eutrophic | 600-1500 | 25-100 | 7-40 | 1.0-2.5 |
| Hypereutrophic | > 1500 | > 100 | > 40 | < 1.0 |

not have a significant long-term effect on the trophic status of either lake. Based on Forsberg and Ryding's (1980) proposed trophic state index (Table 2), both lakes are eutrophic when indexed to phosphorus and nitrogen concentrations.

Clear Lake had an average TN:TP ratio of 33 with a range of 20-44. The average TN:TP ratio in Lake Wales was 32 with a range of 18-44. Sakamoto (1966) suggested that when the TN to TP ratio is greater than 17, phosphorus is the limiting element. Thus, it seems that both lakes are phosphorus limited with respect to algal growth. Chlorophyll a values ranged from 5 $mg/m^3$ to 89 $mg/m^3$ and had an average value of 20 $mg/m^3$ in Clear Lake. In Lake Wales, the chlorophyll a concentration ranged from 15 to 56 $mg/m^3$ and averaged 34 $mg/m^3$. Chlorophyll a was positively correlated ($p < 0.1$) with total nitrogen ($r=0.73$) and total phosphorus ($r=0.74$) in Clear Lake and with the total phosphorus concentration ($r=0.67$) in Lake Wales (Table 3). Chlorophyll a concentrations in Clear Lake reached a high of 89 $mg/m^3$ while the total phosphorus concentration was at its maximum value recorded, 36 $mg/m^3$ (Figure 3). In Lake Wales, the largest mean chlorophyll a concentration of 56 $mg/m^3$ occurred in November 1987 while the total phosphorus concentration was at the highest fall value recorded, 37 $mg/m^3$ (Figure 4).

Table 13. Mean coefficients of condition K(TL) for bluegill sunfish with sample size in parentheses for Clear Lake and Lake Wales, Florida 1987-88.

| Lake | Size Class (mm TL) | Season | K(TL) | Mean Length Within Size Class (mm TL) |
|---|---|---|---|---|
| Clear (1987) | 75-149 | summer | 1.72(117) a | 124 |
| | | winter | 1.73(67) a | 129 |
| | ≥ 150 | summer | 2.05(127) a | 225 |
| | | winter | 1.75(61) b | 183 |
| Wales (1987) | 75-149 | summer | 1.66(59) a | 123 |
| | | winter | 1.72(181) b | 113 |
| | ≥ 150 | summer | 1.91(126) a | 197 |
| | | winter | 1.96(83) a | 189 |
| *Wales(1975) | ≥ 150 | summer | 1.47(30) a | . |
| (1976) | | summer | 1.58(34) a | . |
| (1977) | | summer | 1.73(48) a | . |
| (1978) | | summer | 1.65(43) a | . |
| (1975) | ≥ 150 | winter | 1.47(77) a | . |
| (1976) | | winter | 1.62(58) a | . |
| (1977) | | winter | 1.76(68) a | . |
| (1978) | | winter | 1.79(102) b | . |

For each lake, values followed by the same letter within the same year and size class are not significantly different ($p > .05$).

*Colle and Shireman (1980).

Table 14. Mean coefficients of condition K(TL) with sample size in parentheses for redear sunfish in Clear Lake and Lake Wales, Florida.

| Lake | Size Class (mmTL) | Season | K(TL) | | Mean Length Within Class |
|---|---|---|---|---|---|
| Clear (1987) | 75-149 | summer | 1.65(85) | a | 120 |
| | | winter | 1.58(34) | a | 132 |
| | ≥ 150 | summer | 1.93(53) | a | 224 |
| | | winter | 2.02(86) | a | 218 |
| Wales (1987) | 75-149 | summer | 1.54(23) | a | 118 |
| | | winter | 1.56(46) | a | 114 |
| | ≥ 150 | summer | 1.93(83) | a | 206 |
| | | winter | 2.07(97) | b | 215 |
| *Wales(1975) | ≥ 150 | summer | 1.60(7) | a | . |
| (1976) | | summer | 1.60(23) | a | . |
| (1977) | | summer | 1.68(51) | a | . |
| (1978) | | summer | 1.71(45) | a | . |
| (1975) | ≥ 150 | winter | 1.42(24) | a | . |
| (1976) | | winter | 1.53(29) | a | . |
| (1977) | | winter | 1.72(42) | a | . |
| (1978) | | winter | 1.95(75) | b | . |

For each lake group, values followed by the same letter within the same year and size class are not significantly different ($p > .05$).

*Colle and Shireman (1980).

redear sunfish in Lake Wales also tended to have larger coefficients of condition when compared to values reported by Colle and Shireman (1980). The present summer value of 1.93 was significantly larger than values reported between 1975-1978 and the present winter average of 2.07 was significantly greater than values reported between 1975 and 1977 by Colle and Shireman (1980). From these data, it seems that the current average coefficients of condition for both bluegill and redear sunfish in Lake Wales are consistently greater now when compared to 1970s data. Therefore, the removal of submersed macrophytes did not have a negative impact on the condition of these fish.

In an attempt to evaluate year class strength and document spawning activity as well as recruitment, length-frequency data and otolith data from the three sport fish species were used.

Length-frequency histograms of the largemouth bass population along with known growth rates for Florida largemouth bass (Porak et al. 1987) revealed a number of year classes in both lakes (Figures 9 and 10). Coleman et al. (1984) found 65 to 90% of the largemouth bass population in seven Florida lakes and 1 river were comprised of the first three year classes. Porak et al. (1987) also found largemouth bass populations were typically comprised of the first three year classes in eleven Florida lakes and 1 river. In this investigation similar results were found,

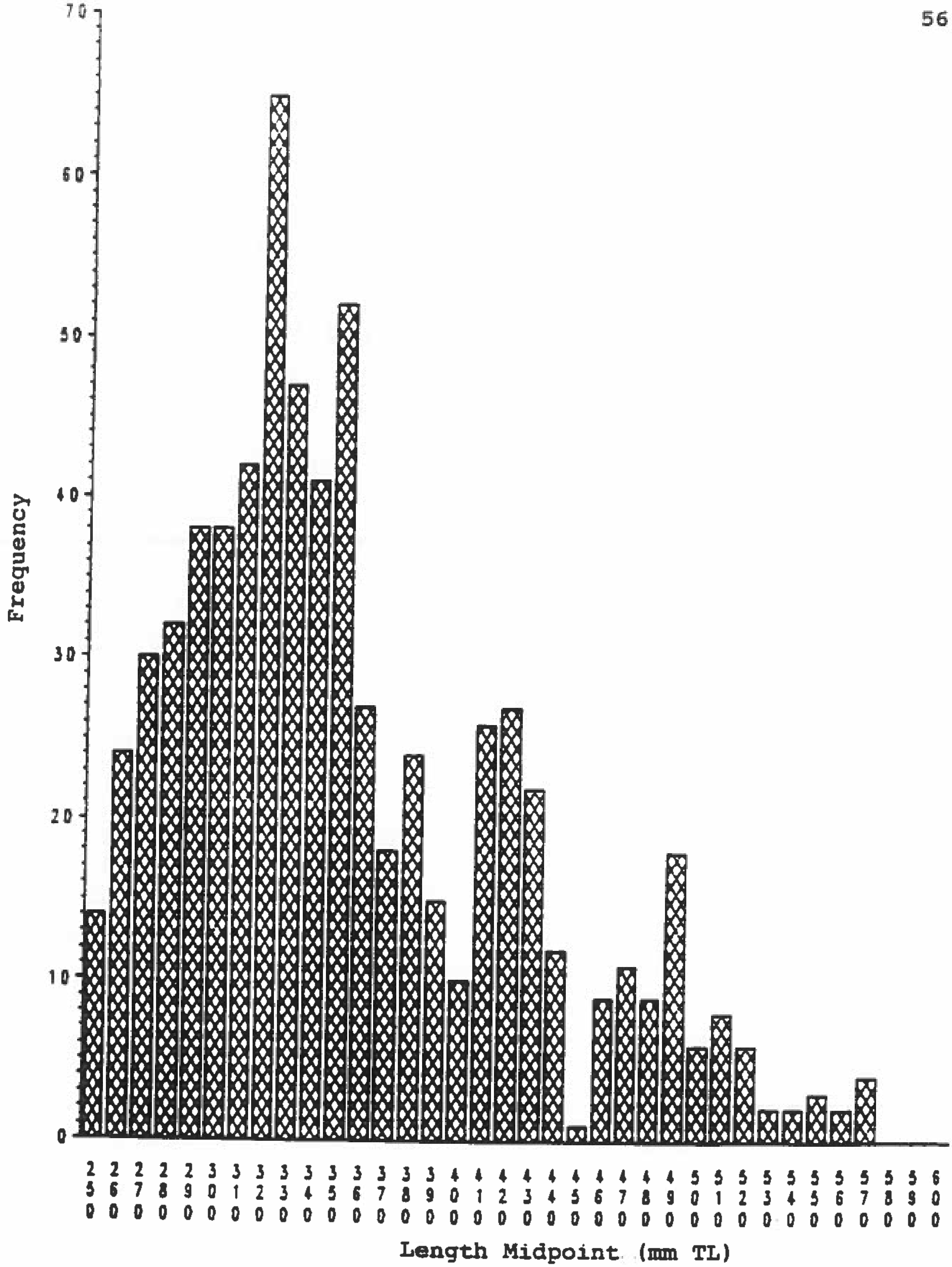


Figure .9. Length frequency histogram for harvestable largemouth bass in Clear Lake, Florida (Winter 1987).

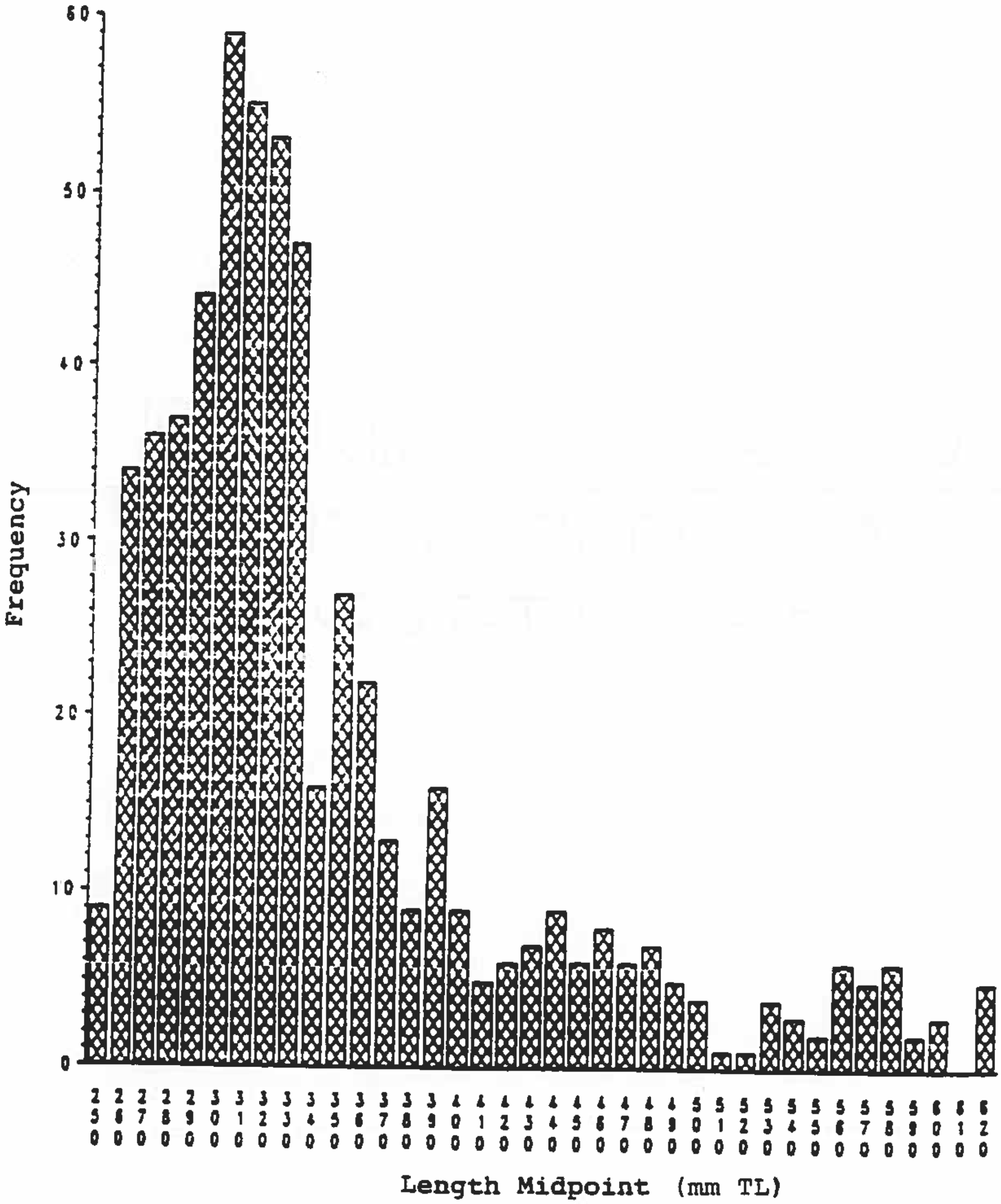


Figure 10. Length frequency histogram for harvestable largemouth bass in Lake Wales, Florida (Winter 1987).

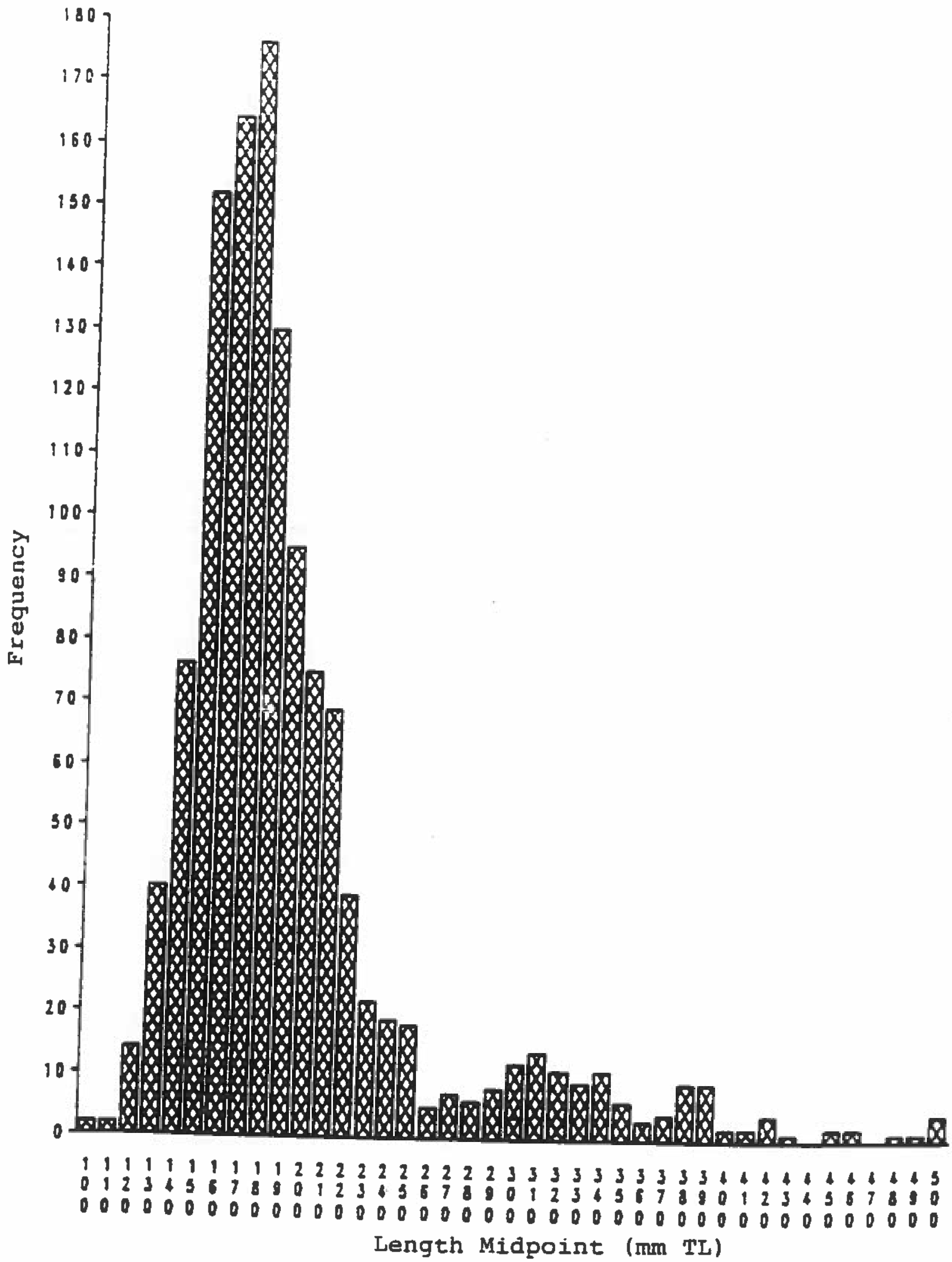


Figure 11. Length frequency histogram for largemouth bass in Clear Lake, Florida (Winter 1988).

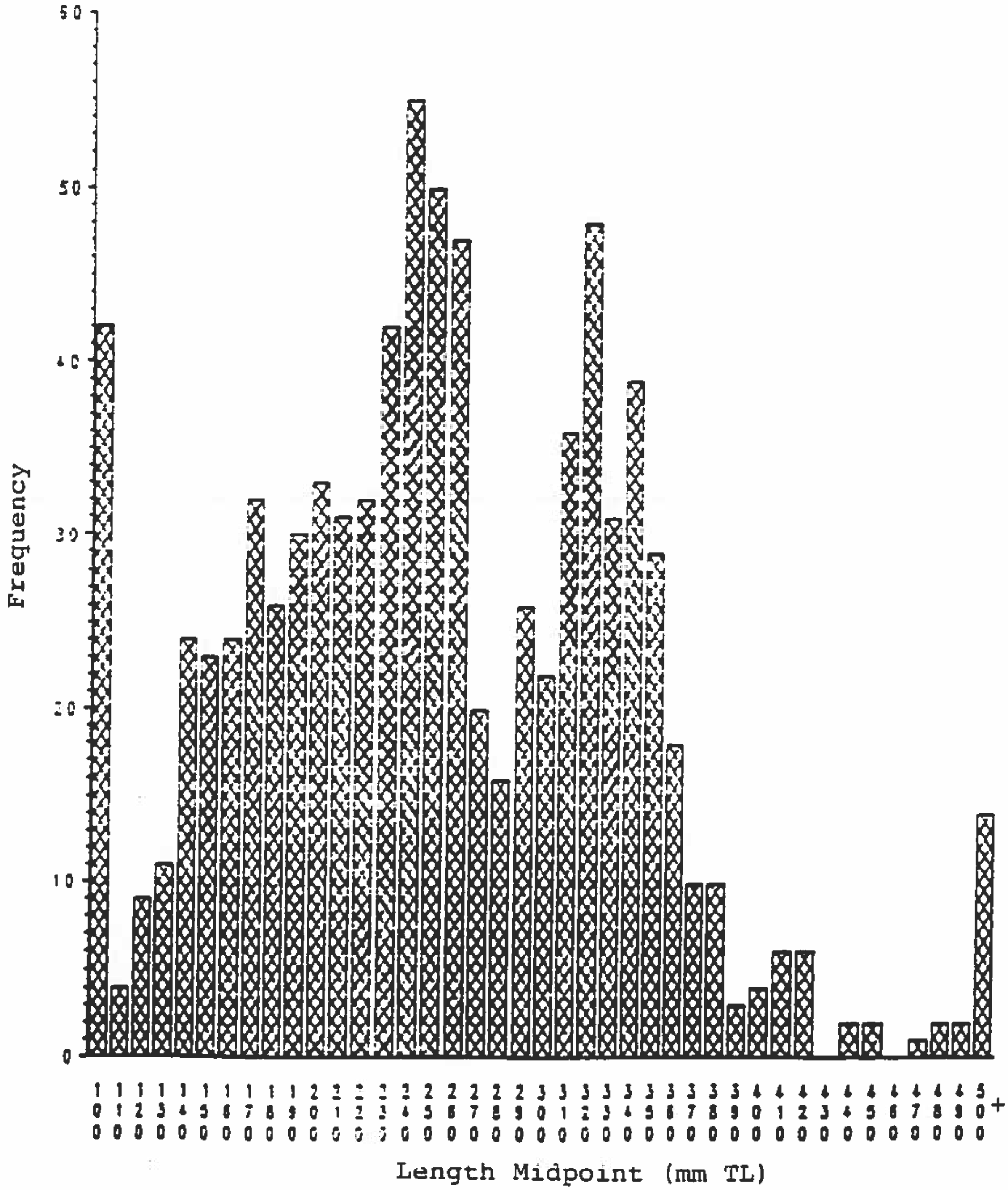


Figure 12. Length frequency histogram for largemouth bass in Lake Wales, Florida (Winter 1988).

both Clear Lake and Lake Wales had the majority of their largemouth bass population consisting of fish < 300 mm TL (Figures 11 and 12). Based on my otolith data and data from the recapture of tagged fish, largemouth bass < 300 mm TL in Clear Lake and Lake Wales generally consist of fish age III and younger. From these data, it is obvious that the largemouth bass populations in Clear Lake and Lake Wales are and have been successfully spawning and recruiting subharvestable fish into harvestable size classes in the absence of submersed macrophytes.

A potential problem exists when using otolith data to age and back-calculate bluegill and redear sunfish lengths in Florida. It has not been demonstrated that these fish only form one annuli per year. In an attempt to determine the number of otolith annuli central Florida bluegill form each year, blocknet data collected in Clear Lake in September 1986 were used to construct a length frequency histogram for young of the year (YOY) bluegill. The back calculated instantaneous growth rate (0.26 mm/day) for bluegill was used to estimate the potential 1987 summer lengths for the 1986 bluegill year class. The 1986 population (N=7638) had a length frequency peak in the 40 mm size class (0-40 mm TL). Approximately 284 growing days transpired between September 1986 and June-July 1987, the period in which otoliths were collected. During this time an estimated 74 mm TL of growth occurred. The back

Table 15. Back calculated growth rates, from otolith data, for bluegill in Clear Lake and Lake Wales, Florida, 1987-88.

| Lake | Age | N | Minimum (mm TL) | Maximum (mm TL) | Mean | Std.Dev. |
|---|---|---|---|---|---|---|
| Clear | I | 133 | 54 | 143 | 94 | 17.8 |
| | II | 104 | 112 | 207 | 147 | 22.3 |
| | III | 51 | 142 | 247 | 209 | 25.2 |
| | IV | 39 | 216 | 256 | 238 | 9.5 |
| | V | 6 | 229 | 259 | 244 | 11.1 |
| | VI | 2 | 241 | 251 | 246 | 6.8 |
| Wales | I | 143 | 43 | 147 | 86 | 19.9 |
| | II | 116 | 53 | 193 | 136 | 22.5 |
| | III | 67 | 109 | 211 | 178 | 21.0 |
| | IV | 32 | 162 | 224 | 195 | 13.6 |
| | V | 14 | 208 | 236 | 217 | 7.7 |

Table 16. Back calculated growth rates, from otolith data, for redear sunfish in Clear Lake and Lake Wales, Florida, 1987-88.

| Lake | Age | N | Minimum (mm TL) | Maximum (mm TL) | Mean (mm TL) | Std.Dev. |
|---|---|---|---|---|---|---|
| Clear | I | 101 | 57 | 145 | 110 | 16.3 |
| | II | 40 | 101 | 218 | 171 | 23.4 |
| | III | 24 | 185 | 273 | 239 | 23.2 |
| | IV | 5 | 215 | 282 | 263 | 27.2 |
| | V | 5 | 274 | 300 | 290 | 9.6 |
| | VI | 1 | 280 | 280 | 280 | . |
| Wales | I | 37 | 66 | 162 | 102 | 22.6 |
| | II | 29 | 129 | 202 | 172 | 18.7 |
| | III | 19 | 193 | 233 | 210 | 11.4 |
| | IV | 3 | 226 | 232 | 228 | 3.3 |

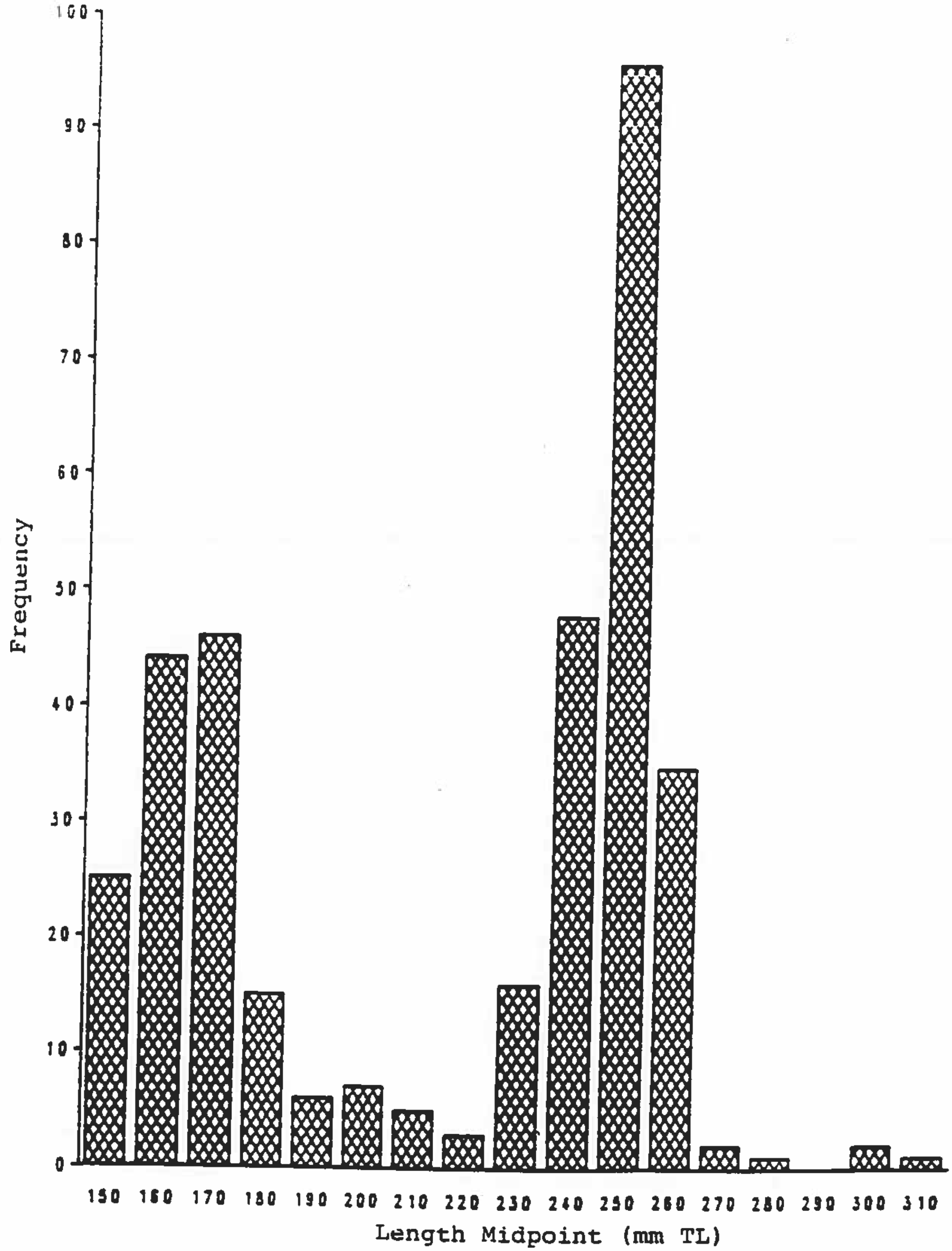


Figure 13. Length frequency histogram for harvestable bluegill in Clear Lake, Florida (Summer 1987).

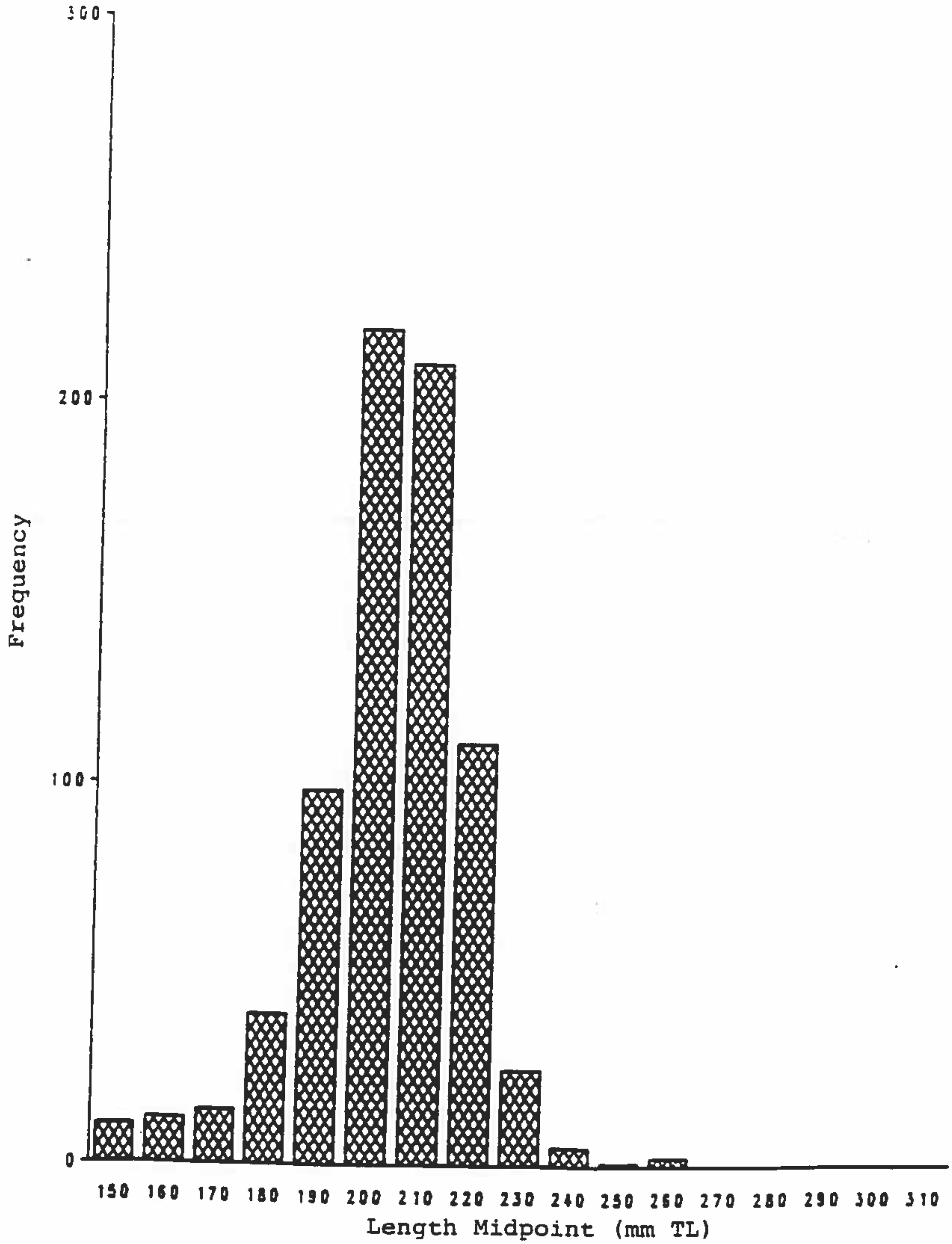


Figure 14. Length frequency histogram for harvestable bluegill in Lake Wales, Florida (Summer 1987).

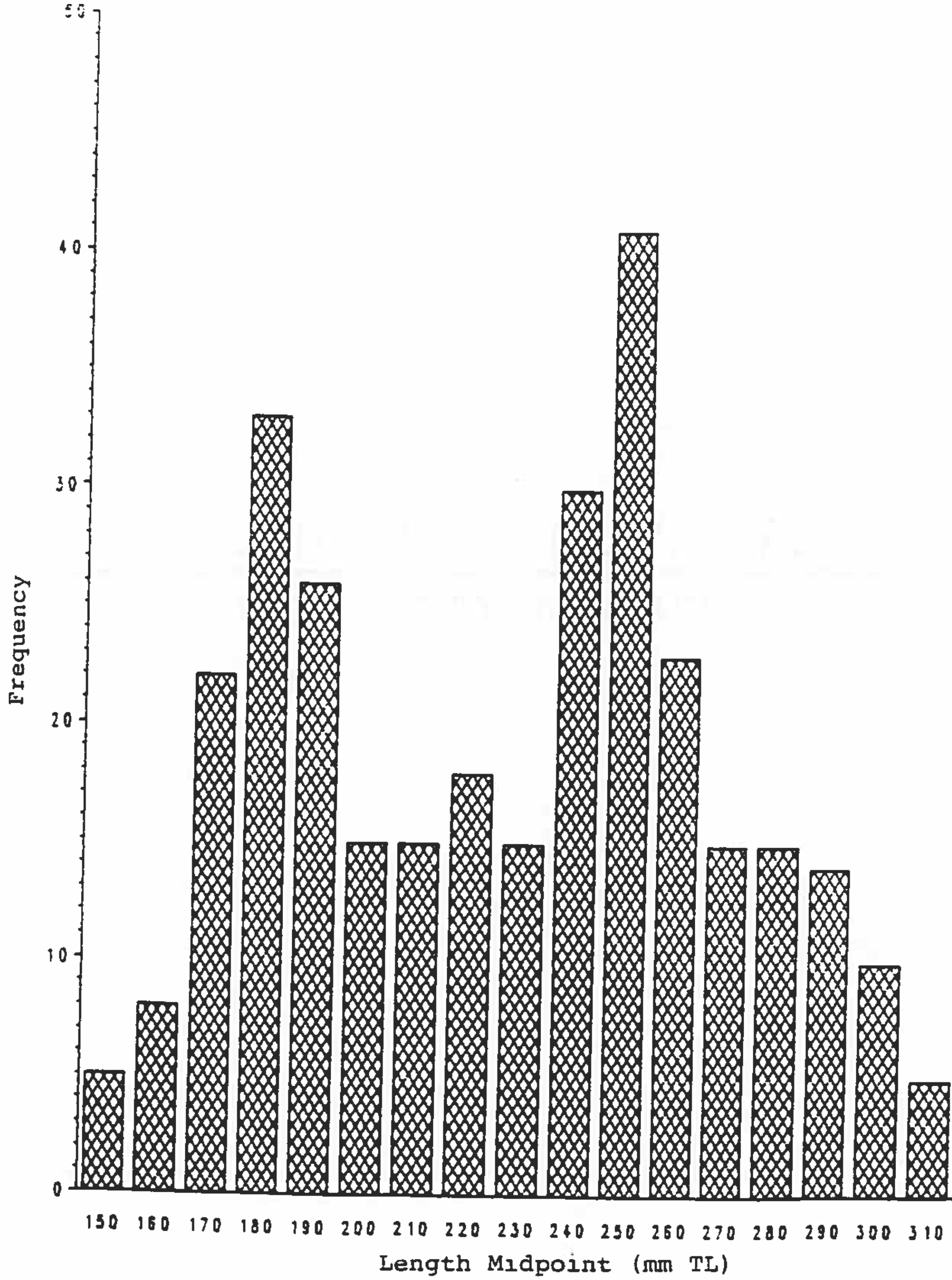


Figure 15. Length frequency histogram for harvestable redear sunfish in Clear Lake, Florida (Summer 1987).

calculated mean length for age I (only one annuli) bluegill in 1987 was 94 mm (Table 15). When 74 mm are added to the 40 mm size class bluegill sampled in 1986, their predicted 1987 summer length ranges from 74 to 114 mm TL. The back-calculated estimate of 94 mm TL falls within this range, thus it seems likely that only one annuli is formed during the first year of bluegill growth.

A number of bluegill and redear sunfish year classes were found in both Clear Lake and Lake Wales (Tables 15 and 16, Figures 13,14,15 and 16). In Clear Lake, at least 6 separate year classes of bluegill and redear sunfish were collected. In Lake Wales, bluegills age V+ and redears age IV+ were sampled. It is evident that bluegill and redear sunfish have successfully been reproducing and recruitment has occurred in both lakes in the absence of submersed macrophytes.

## CONCLUSIONS

Grass carp were stocked in Clear Lake and Lake Wales in 1974. Individuals > 800 mm TL are still present in both systems which have been void of submersed macrophytes a minimum of seven years. It is therefore obvious, that grass carp are cost-effective and have yielded long-term control of submersed macrophytes in both study lakes.

The elimination of submersed macrophytes did not change the trophic status of either lake as indicated by the total phosphorus concentration which tended to be greater than 25 $mg/m^3$ and the total nitrogen concentration which tended to be greater than 600 $mg/m^3$, both before and after macrophytes were removed. Canfield et al. (1983) found that algal biomass decreased and water clarity increased significantly in Lake Baldwin after hydrilla exceeded 40% aerial coverage. Algal biomass, as indexed by chlorophyll a concentrations, does not appear significantly different in Clear Lake when compared to 1970s data. However, in Lake Wales algal biomass has increased and Secchi transparency have decreased since submersed macrophytes were removed. This is probably due to the fact that a much larger percentage of Lake Wales was covered by submersed macrophytes, as much as 95%, when compared to Clear Lake which only experienced submersed macrophyte coverage of approximately 33%.

Fishery data from the 1970s were only available for Lake Wales. Statistical differences were not reported for the 1970s data and therefore, it could not be determine whether the present largemouth bass population in Lake Wales is significantly different from the largemouth bass population reported between 1974 and 1979. Since largemouth bass year class strengths often vary from year to year and seem to be related to local conditions such as water level and predation (Coleman et al. 1984; Porak et al. 1987) it is possible that differences between years were a result of natural fluctuations. Water levels were higher and the littoral zone increased in 1977 and 1978. It seems stronger year classes were produced during these high water years and may account for at least part of any differences in population numbers over time.

Other factors such as a rotenone treatment in Lake Wales which killed an estimated 97% of the largemouth bass population in 1979, and fish such as black crappie which often compete with largemouth bass could have had a negative influence on the largemouth bass population. Therefore, it is impossible to determine how important submersed macrophytes were for the largemouth bass population and whether the removal of the submersed macrophytes caused a reduction in the largemouth bass population.

Based on blocknet data, the total bluegill and redear sunfish populations in Lake Wales seem smaller now than they were when hydrilla was present during the 1970s. However, the harvestable populations do not seem to have been as effected, and most of the reduction in the total population occurred in the juvenile size classes. This reduction is probably the result of decreased cover which has exposed these smaller size fish to greater predation pressure.

Forage fish were abundant in both Clear Lake and Lake Wales with AP:P ratios as high as 67 in Clear Lake and 11.7 in Lake Wales. If available prey to predator fish biomass estimates, which were calculated from highly variable blocknet-rotenone data, are accurate there seems to be a sufficient forage base for predator fish in these systems which are void of submersed macrophytes. However, growth rates for harvestable largemouth bass as well as coefficients of condition (K(TL) and K(SL)) and relative weight (Wr) values for these fish suggest that there is an inadequate forage base.

First year growth rates for the largemouth bass in Clear Lake and Lake Wales were within the range reported by Coleman et al. (1984) and Porak et al. (1987) for Florida lakes. Age II largemouth bass in Clear Lake and Lake Wales tended to have a slower growth rate when compared to a number of other Florida lakes. Slow growth has been associated with poor condition and an inadequate available food supply. Average coefficients of condition, K(SL), for harvestable largemouth bass in Clear Lake and Lake Wales were less than the mean of means value calculated from Porak et al. (1987) for other Florida lakes. Harvestable largemouth bass in Lake Wales tended to have coefficient of condition values similar to values reported by Colle and Shireman (1980) during the years of hydrilla infestation. Hydrilla coverage in excess of 30% can cause a reduction in harvestable largemouth bass coefficients of condition (Colle and Shireman 1980). Therefore, in Lake Wales, coefficients of condition for largemouth bass have been negatively affected by the complete elimination of submersed macrophytes as well as excessive macrophyte coverage.

Harvestable bluegill and redear sunfish in Clear Lake and Lake Wales approached or exceeded Carlander's (1977) central 50% K(TL) range reported for bluegill throughout North America. With a decrease in the total bluegill and redear sunfish population, seen mainly by a reduction in the juvenile population, the harvestable fish tend to have significantly larger coefficients of condition when compared to Lake Wales values reported by Colle and Shireman (1980) during the 1970s. Therefore, the elimination of submersed vegetation does not appear to have had a negative impact on the condition of harvestable bluegill and redear sunfish.

A number of grass carp $\geq$ 800 mm TL were collected in Clear Lake and Lake Wales, but no evidence of their reproduction was found. Reproduction and recruitment of largemouth bass, bluegill and redear sunfish were documented in both Clear Lake and Lake Wales. Length frequency data for largemouth bass in both lakes showed a significant subharvestable year class approaching harvestable size. Otolith data were used to determine that a number of bluegill and redear sunfish year classes were present in both lakes. It is obvious that successful spawning and recruitment of subharvestable sport fish into harvestable size classes have been occurring in the absence of submersed macrophytes in Clear Lake and Lake Wales.

Before grass carp are used to eliminate aquatic macrophytes and problems associated with them, it is important to establish desired management objectives. When grass carp are used, the potential for eliminating nearly all plants as well as increasing algal concentrations exists. Although these conditions may be considered undesirable by some groups or individuals, it was determined that largemouth bass, bluegill and redear sunfish can successfully reproduce and experience yearly recruitment into harvestable size classes in lakes which have been void of submersed macrophytes for as long as 13 years.

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May, 1989

Director, Forest Resources and Conservation

Dean, Graduate School

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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