Table of Contents

List of Figures

List of Tables

AQUATIC CONTROL

INTRODUCTION

A survey of the fish community and other physical, biological, and chemical factors directly affecting the fish community was completed at Hidden Valley Lake on October 18, 2010. The major objectives of this survey and report are:

1. To provide a current status report on the fish community of the lake
2. To compare the current characteristics of the fish community with established indices and averages for Indiana lakes and past surveys
3. To provide recommendations for management strategies to enhance or sustain the sport fish community

The data collected are adequate for the intended uses; however, there will be unanswered questions regarding aspects of the fish population and other related factors of the biological community in the lake. All fish numbers used in the report are based on the samples collected and should not be interpreted to be absolute or estimated numbers of fish in the lake. General information regarding water chemistry, fish communities, and methods are described in Appendix A. A detailed fish collection table is presented in Appendix B.

RESULTS AND DISCUSSION

WATER CHEMISTRY

The results of selected physio-chemical parameters from Hidden Valley Lake are presented in Table 1. Temperature and dissolved oxygen levels were taken to 50.0 feet, as this is the maximum length of the cable on our D.O. meter. Water temperatures ranged from 63.4 degrees (F) at the surface to 42.2 degrees (F) at 50.0 feet. Dissolved oxygen ranged from 9.86 parts per-million (ppm) at the surface to 0.22 ppm (Figure 1). A desirable oxygen level for maintenance of healthy stress free fish was present to a depth of 21.0 feet. These numbers indicate Hidden Valley Lake was stratified at the time of the survey. Hidden Valley Lake is classified as a biogenic meromictic lake. In some years there may be a complete mixing of the lake while other years substances build up due to a lack of circulation (See Appendix A for further details on lake stratification). The alkalinity level was 119.7 ppm at the surface and 205.2 ppm at the bottom. This has increased significantly since the survey in 2006. The hardness level was 171 at the surface and 188.1 ppm at the bottom. This parameter has remained constant. The pH was 8.5 at the surface and 8.0 on the bottom. The pH has also remained stable but is likely to drop if alkalinity levels drop again. The Secchi disk depth measurement was 6.0 feet, compared to 7.0 feet in 2006. Nitrate-nitrogen levels were 0.1 ppm at the surface and 0.6 ppm on the bottom. Nitrate levels have decreased slightly since the 2006 survey. Ortho-phosphate levels were 0.02 ppm on the surface and 1.60 ppm at the bottom. Total phosphorus levels were 0.20 ppm on the surface and 1.94 ppm at the bottom. The phosphorus levels have declined since the last survey. A slight microscopic blue-green algae bloom was noticed on the lake at the time of the survey. Algae blooms seem to appear when the lake is in a state of turnover. When turnover occurs, nutrients from deep water are brought to the surface and promote blue-green blooms. Hidden Valley Lake appears to have water quality, which is capable of supporting a healthy fish population. However due to the high potential for blue-green algae blooms, oxygen depletion and fish kills could be of major concern if heavy blooms die off suddenly.

Table 1. Selected water quality parameters measured on Hidden Valley Lake, October 18, 2010.

Sample Depth (ft.)	Temp. (°F)	Dissolved Oxygen (ppm)	pH (standard units)	Total Alkalinity (ppm)	Total Hardness (ppm)	Nitrate/ Nitrogen (ppm)	Ortho phosphate (ppm)	Total phosphorus (ppm)
Surface	63.40	9.86	8.5	119.7	171	0.10	0.02	0.20
3	63.40	9.86	-	-	-	-	-	-
6	63.10	9.49	-	-	-	-	-	-
9	63.00	9.30	-	-	-	-	-	-
12	62.80	8.65	-	-	-	-	-	-
15	62.50	7.89	-	-	-	-	-	-
18	62.30	7.18	-	-	-	-	-	-
21	61.80	5.16	-	-	-	-	-	-
24	61.60	0.93	-	-	-	-	-	-
27	52.20	0.34	-	-	-	-	-	-
30	49.70	0.24	-	-	-	-	-	-
33	47.30	0.22	-	-	-	-	-	-
36	45.30	0.21	-	-	-	-	-	-
39	44.20	0.21	-	-	-	-	-	-
42	43.30	0.21	-	-	-	-	-	-
45	42.90	0.21	-	-	-	-	-	-
48	42.40	0.21	-	-	-	-	-	-
50	42.20	0.22	8.0	205.2	188.1	0.60	1.60	1.94

*Dashes indicate no sample was taken at selected depth for given parameter.

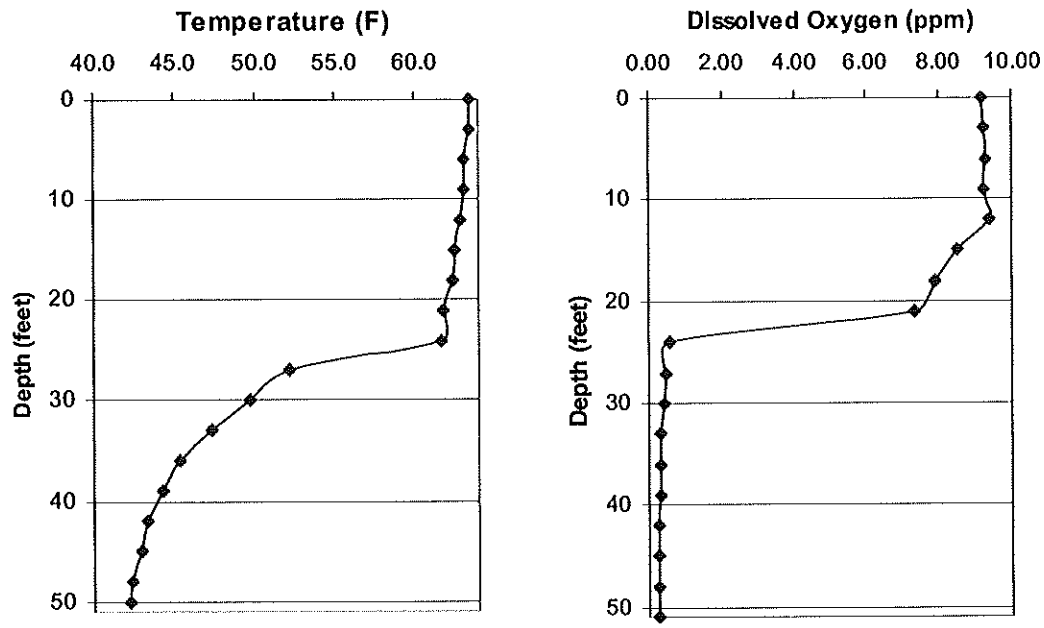


Figure 1. Dissolved oxygen and temperature profiles for Hidden Valley Lake, October 18, 2010.

FISH COLLECTION

A total of 869 fish weighing 287.35 pounds and representing six species was collected from Hidden Valley Lake (Table 2 and Figure 2). Bluegill *Lepomis macrochirus* was the most abundant species comprising 46.03% of the fish collected. Largemouth bass *Micropterus salmoides* was the second most abundant species (44.65%), followed by green sunfish *Lepomis cyanellus* (6.10%), redear sunfish *Lepomis microlophus* (2.30%), black crappie *Pomoxis nigromaculatus* (0.81%), and warmouth *Lepomis gulosus* (0.12%). All of these species are desirable in a lake of this size with the exception of green sunfish and warmouth. White bass, white crappie, brown bullhead and channel catfish have been collected on past surveys but were not collected this time. These species don't sample well with electrofishing equipment. It is likely these species remain in the lake in small populations.

Table 2. Species collected from Hidden Valley Lake, November 9, 2006.

Species	N	% N	Size Range (in)	Total Weight (lbs.)	% Wt	N/hr.
Bluegill	400	46.03	<3-9	15.69	5.46	267
Largemouth bass	388	44.65	4.5-18.0	258.65	90.01	259
Green sunfish	53	6.10	<3-8.5	5.33	1.85	35
Redear sunfish	20	2.30	<3-11.0	4.55	1.58	13
Black crappie	7	0.81	4-12.5	2.80	0.97	5
Warmouth	1	0.12	7.5	0.33	0.11	1
Total	869	100.00		287.35	100.00	

N = number of individuals
%N = percent number of a species as compared to the total number of fish collected
%Wt = percent weight of a species as compared to the total weight of all fish collected
N/hr. = catch rate of species (number of fish of a species collected per hour of electrofishing effort)

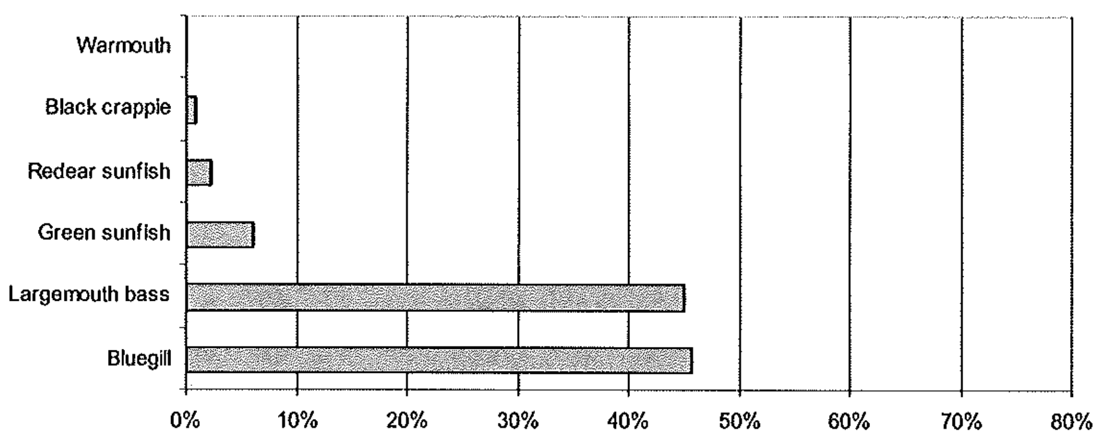


Figure 2. Relative abundance of species collected from Hidden Valley Lake, October 18, 2010.

Bluegill

Bluegill was the most abundant species collected (46.03%) and ranked second by weight (5.46%). A total of 400 bluegill ranging in size from less than 3.0 to 9.0 inches was collected (Figure 4). Nearly 89% were 3.0 inches or less indicating successful reproduction occurred in 2010. There was a significant decrease in the number of quality bluegill collected from the 2006 survey. This could be an indication that fishing pressure and harvest of bluegill has increased or there has been an increase in predation by largemouth bass. The proportional stock density for bluegill (proportion of quality fish within a population) was 53, which is well above the desired range of 20-40 for bluegill, compared to a PSD of 27 in 2006. Condition factors (measurement of overall plumpness) were good for most size ranges (Appendix B) and average weights of bluegill were normal compared to standard weights for most size ranges (Figure 5).

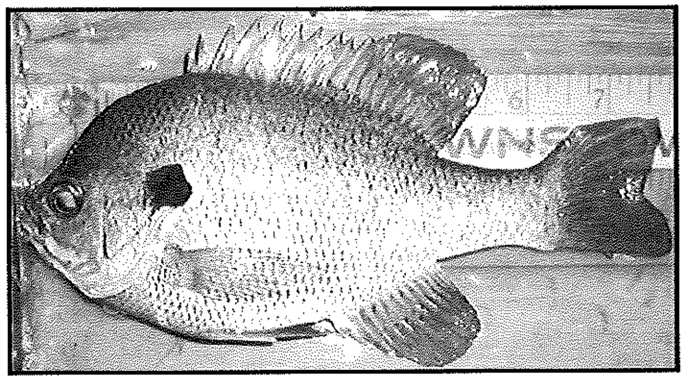


Figure 3. Photograph of bluegill, *Lepomis macrochirus*.

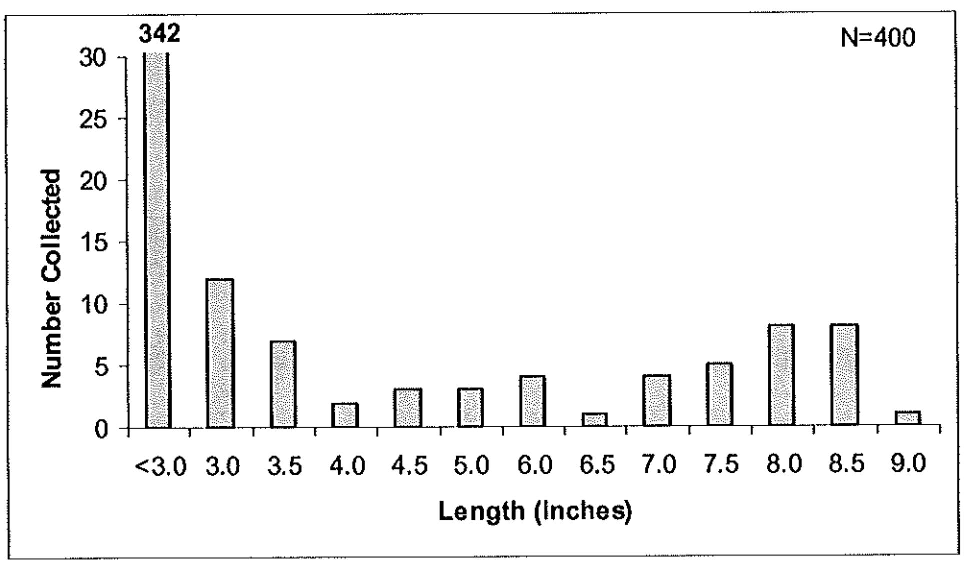


Figure 4. Length frequency distribution of bluegill collected from Hidden Valley Lake, October 18, 2010.

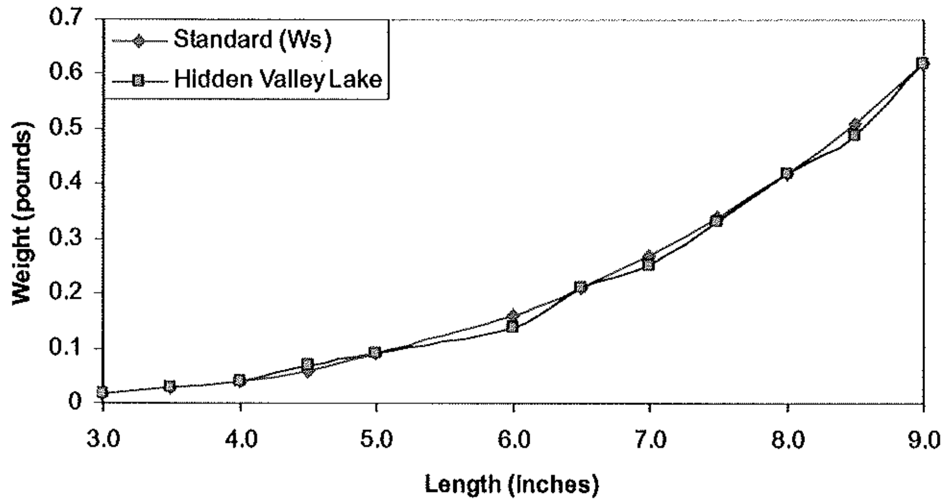


Figure 5. Comparison of Hidden Valley Lake bluegill weights to standard bluegill weights.

Largemouth Bass

Largemouth bass was the second most abundant species collected (44.65%) and ranked first by weight (90.01%). A total of 388 largemouth bass ranging in size from 4.5 to 18.0 inches was collected (Figure 7). Nearly 22% of largemouth bass collected were less than 8.5 inches. This is an indicator that spawning / recruitment has improved slightly since the last survey when 14% collected were in this range. The majority of bass collected were within the 8.5 to 15.0 inch range. This led to a PSD of 54 for largemouth bass, which within the desired PSD range of 40-60 (for more information of PSD see appendix). The PSD has increased from 41 in the last survey (Figure 9). Condition factors were below average for most length ranges (Appendix B). Largemouth bass weights were average in smaller fish and below average in larger fish compared to standard weights (Figure 8).

Figure 6. Photograph of largemouth bass, *Micropterus salmoides*.

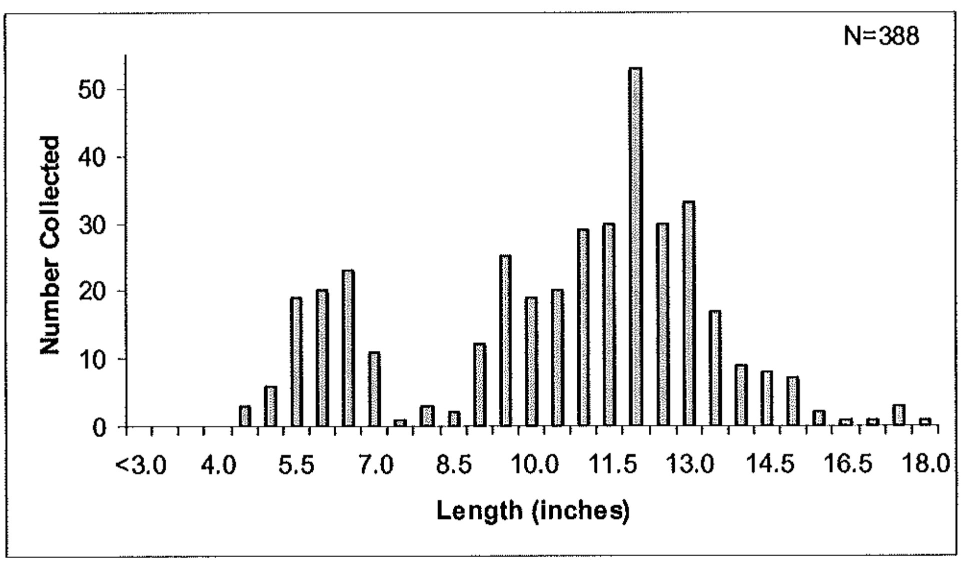


Figure 7. Length frequency distribution of largemouth bass collected from Hidden Valley Lake, October 18, 2010.

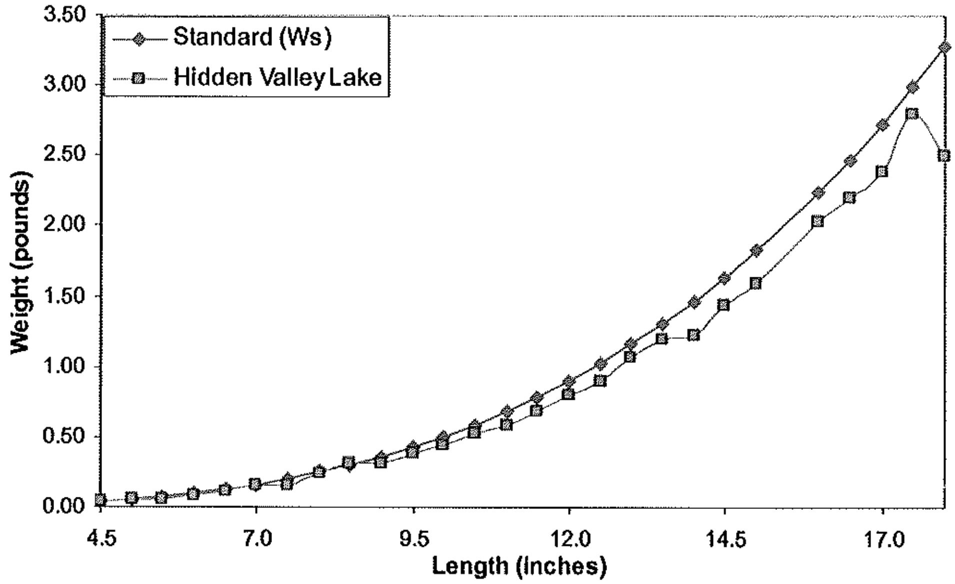


Figure 8. Comparison of Hidden Valley Lake largemouth bass weights to standard largemouth bass weights.

Green sunfish

Green sunfish was the third most abundant species collected (6.10%) and ranked third by weight (1.85%). A total of 53 green sunfish ranging in size from less than 3.0 to 8.5 inches was collected. The green sunfish population has shown a slight increase since the 2006 survey. However, it appears predators are still controlling this species currently. Green sunfish are undesirable due to their tendency to overpopulate and compete with the more desired bluegill and redear sunfish. As recommended in past surveys, all green sunfish should be harvested to help maintain a low population. Green sunfish look superficially like bluegill. They can easily be distinguished by their larger mouths and more rounded pectoral fins. Figure 9 illustrates the differences in appearance between bluegill and green sunfish.

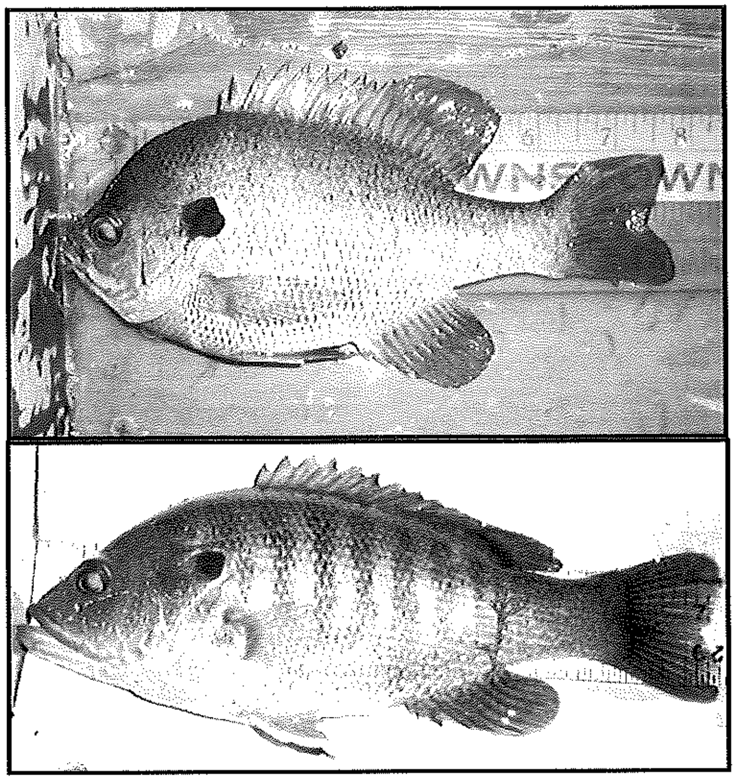


Figure 9. Photographic comparison of bluegill (top) and green sunfish (bottom), *Lepomis cyanellus.*

Redear sunfish

Redear sunfish was the fourth most abundant species collected (2.30%) and ranked fourth by weight (1.58%). A total of 20 redear sunfish ranging in size from less than 3.0 to 11.0 inches was collected (Figure 10). Redear are not prolific spawners like bluegill, so their populations will not likely become overly abundant in this lake. Compared to the last survey, the redear population has declined (Figure 11). Redear sunfish inhabit deeper water than bluegill and feed primarily on insects and snails. They also tend to grow faster than bluegill. This species should provide additional angling opportunity in Hidden Valley Lake. Due to their slower reproductive potential and small population, this species should be protected with more restrictive bag limits.

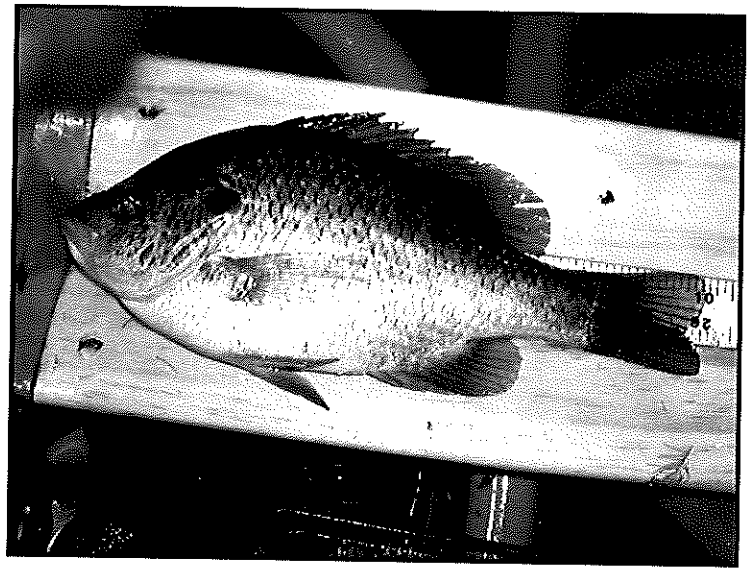


Figure 10. Photograph of redear sunfish, *Lepomis microlophus.*

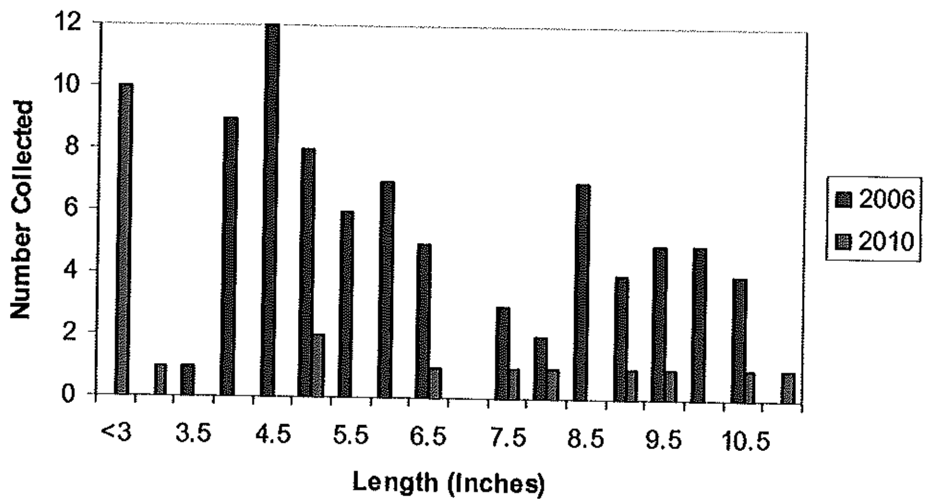


Figure 11. Length frequency distribution of redear sunfish over the past two surveys.

Black crappie

Black crappie was the fifth most abundant species collected (0.81%) and ranked fifth by weight (0.97%). A total of 7 crappie ranging in size from less than 4.0 to 12.5 inches was collected (Figure 12). There was a significant decrease in the number of crappie collected compared to the last survey. In the 2006 survey, 111 crappie were collected. Crappie populations tend to be cyclic in nature and the population is likely larger than indicated. Crappie inhabit deeper water and are usually not well represented in electrofishing surveys.

Figure 12. Photograph of black crappie, *Pomoxis nigromaculatus*.

Warmouth

A single warmouth was collected during electrofishing (Figure 13). It was 7.5 inches long and weighed 0.33 pounds. Similar to green sunfish, warmouth are undesirable due to their tendency to reach smaller sizes and compete for food resources with the more desired species. All warmouth should be harvested to help maintain a low population.

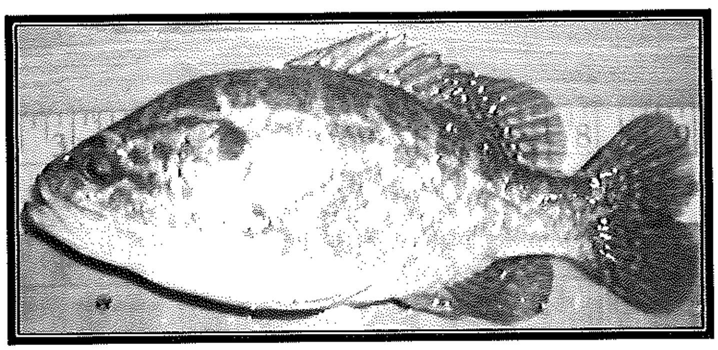


Figure 13. Photograph of warmouth, *Lepomis gulosus*.

SUMMARY AND RECOMMENDATION

Overall, the Hidden Valley Lake fishery is in relatively good shape with good numbers of quality sport fish and a lack of problematic species. However, there continues to be a slight imbalance within the bluegill/largemouth bass fishery (see appendix for discussion of balance). The overall bluegill population appears to have decreased since the last survey and fewer quality fish were collected. This is likely due to a slightly over abundant largemouth bass population. Largemouth bass appear to be growing slower than normal due to an overabundance of smaller individuals and lack of forage. Harvest of smaller bass will reduce competition and increase growth rates. Additional angling opportunities exist for redear and crappie fishing as well. Residents should continue to be encouraged to use phosphorus free fertilizers on their lawns and develop buffer strips to trap nutrients and sediment before it enters the lake.

The following recommendations, **listed in order of importance**, will help protect and enhance the fishery in Hidden Valley Lake:

1. Maintain the 13.0 to 16.0 inch slot limit on largemouth bass. Under this limit bass less than 13.0 inches should be harvested and those between 13.0 and 16.0 inches should be released. One bass over the slot could be kept, but catch and release of the larger fish should be encouraged. This limit will only be effective if smaller bass are harvested.
2. Limit bluegill harvest to 25 fish per day.
3. Limit redear sunfish harvest to 10 individuals per day.
4. Install additional structure in the lake to provide cover for young fish. Christmas trees offer a cheap and effective solution and can be deployed with cinder blocks and rope during ice-over periods. Trees can often be picked up from residential areas at-no-cost just after the Christmas holiday. Drag bundles of 3-4 trees tied together to 2 cinder blocks to a desired location on the ice. Once the ice begins to melt the blocks will pull the trees to the lake bottom.
5. No harvest restrictions are necessary on crappie at this time.
6. Remove all green sunfish and warmouth when caught.
7. Conduct a follow-up Standard survey in 2013 in order to monitor the effects of the above recommendations and assess needs for further management activities.
8. Continue to encourage residents to fill out the sample Creel Survey Form provided in Appendix-C.
9. Continue to encourage residents to use ecologically sound practices when working in the watershed. This includes limiting fertilizer use, using phosphorus free fertilizers, develop buffer strips around shorelines, disposing of yard waste in designated areas away from the lake, and obeying boating laws.

Prepared by: Aquatic Control Inc.
Jimmy Ferguson & Adam Charlton, Aquatic Biologists

APPENDIX A

GENERAL INFORMATION

In order to help understand our analysis and recommendations, basic principles of water chemistry and the physical attributes of water must be understood. Sources of dissolved oxygen (D.O.) in water include uptake from the atmosphere and photosynthesis. Decreases in D.O. are mostly attributed to the respiration of plants, animals, and aerobic bacteria that occur in a lake or pond. Large quantities of plants may produce oxygen depletion during the nighttime hours as plants stop photosynthesis and utilize oxygen for respiration. Dissolved oxygen levels below 5.0 are considered undesirable in ponds and lakes (Boyd, 1991). Lower levels of D.O. may stress fish and decrease the rate of decomposition of organic matter entering or produced within a lake or pond. If oxygen depletion is determined to be a problem in a lake or pond, solutions exist to help improve conditions. Vegetation control to reduce overly abundant vegetation may improve conditions. Aeration systems may also be used to increase oxygen levels and promote the breakdown of organic matter.

Water temperature of a lake or pond affects the activity of "cold-blooded" animals such as fish and invertebrates as well as the amount of D.O. that water is capable of holding. Deeper ponds and lakes may thermally stratify in the summer months and result in deeper waters becoming depleted of oxygen. Lake stratification is a result of the peculiar property of water density changes with temperature. The density of all liquid changes with changes in temperature, however, water behaves in a special way. As most liquids are cooled the density, or relative weight, of the liquid increases due to the compaction of the molecules in the liquid, and conversely, as liquids are heated the density decreases. Water, because of its unique characteristics, is at its maximum density at 4 degrees Centigrade, or approximately 39.2 degrees Fahrenheit. When water is either heated above this temperature or cooled below this temperature its density decreases. This is why ice floats, or forms on the surface of lakes and ponds. A normal cycle of stratification in lakes in our region of the country, in early spring after ice out is as follows: the lake water will all be nearly the same temperature shortly after ice out and wind action on the lake surface will induce circulation of the entire volume of water. As spring advances and the increased sunlight energy warms the surface waters, these become lighter and tend to separate from the deeper waters and essentially float on top of the cooler water. This continues until there is a very stable "layering" or stratification of water in the lake. There are three distinct layers of water in stratified lakes, as described by limnologists:

1. Epilimnion (upper warm layer) - this is, generally speaking, confined to the top 10 ft. to 15 ft. of the lake volume. This is a warm region, mixed thoroughly by wind to a more or less uniform temperature. It is also the zone of most photosynthetic production and is usually high in dissolved oxygen.
2. Thermocline or Metalimnion (middle layer of rapidly changing temperature) - this layer is the area in the lake where temperature decreases rapidly, usually about 1 degree centigrade or more per meter (or approximately 3 ft.). Oxygen depletion generally begins in this layer.

3. Hypolimnion (deep, cold layer) - this layer is relatively unaffected by wind mixing or motor boat activity, and is often devoid of oxygen. Oxygen is depleted by the decomposition of dead organic matter falling from the upper waters as well as external sources such as leaves and grass clippings that sink to the bottom of the lake.

Once this stratification is established (usually by early to mid-June, in our area) it is very stable and stays intact until the fall turnover, which is caused by decreasing surface water temperatures (causing increased density), and the mixing of the lake waters by the wind. The lake then circulates completely for a period of time, usually until ice cover forms, sealing off the surface of the lake from the atmosphere. A reverse stratification then sets in where the water just under the ice is just above 32 degrees Fahrenheit with increasing temperature with depth to a temperature of 39.2 degrees Fahrenheit. Decomposition continues in the bottom throughout the winter, resulting in oxygen depletion in the bottom waters. This progresses towards the surface throughout ice cover and can cause an oxygen depletion fish kill under the ice during severe winters. After the ice melts, the lake begins to circulate again, and the cycle has completed itself. This phenomenon has a profound affect on the biological and chemical components of the lake ecosystem.

Alkalinity is the ability of water to buffer against pH changes upon the addition of an acid or base. The alkalinity of a lake or pond is generally determined by the characteristics of the watershed or local geology. As a general guideline a well-buffered system has an alkalinity of 50 parts per million (ppm) or greater. Well buffered systems have potential for moderate to high productivity. Alkalinity is important in determining algaecide dosages, particularly copper sulfate. The maximum safe dosage for fish of copper sulfate if total alkalinity is less than 50 ppm is 0.25 ppm or .68 pounds / acre-foot, 1.00 ppm or 2.7 pounds / acre-foot for a total alkalinity range of 50 to 200 ppm, and 1.5 ppm or 4.0 pounds / acre- foot for a total alkalinity greater than 200 ppm.

Hardness is a measure of the calcium and magnesium (and some other ions) concentrations in water. The concept of hardness comes from the field of domestic water supply. It is a measure of soap requirements for adequate lather formation and is an indicator of the rate of scale formation in hot water heaters. Hardness and alkalinity are sometimes used interchangeably; however, these parameters sometimes have very different values. Waters containing a hardness measure of greater than 75 ppm may be considered hard and are often clearer and weedier then soft waters (Walker et al., 1985).

Nitrogen can exist in several forms within a body of water, including: ammonia, nitrite, nitrate, and organic nitrogen (amino acids and proteins). Ammonia results from the biological decomposition of organic matter by bacteria. During the process of nitrification, nitrate (which is directly available for plant uptake) is formed from the complete biological oxidation of ammonia in which nitrite is an intermediate product. Nitrate is a major plant nutrient. The most important forms of nitrogen for the growth of algae include ammonia and nitrate. Total nitrogen levels above 1.9 ppm are generally indicative of nutrient enrichment or eutrophic conditions (Wetzel, 1983). Inorganic nitrogen (nitrite, nitrate, ammonia, and ammonium) levels greater than 0.30 ppm are indicative of eutrophic lakes and ponds (Sawyer, 1948). Nitrogen in surface waters cannot be controlled by any economical method. Blue-green algae can fix nitrogen directly from the atmosphere unlike other forms of plants.

Phosphorus is a major plant nutrient and is most often the limiting factor for algae and macrophyte (vascular plants) growth within an aquatic system. Total phosphorus levels in excess of 0.03 ppm indicate eutrophic conditions (Vollenwieder, 1968). Waters with excessive plant growth high nutrients and degraded water quality are typical of eutrophic lakes and ponds. Ortho-phosphorus is a measure of the dissolved inorganic phosphorus available for immediate plant uptake. Concentrations of ortho-phosphate above 0.045 ppm may be considered critical concentrations above which nuisance algae blooms could be expected (Sawyer, 1948). The remainder of the total phosphorus is most likely bound onto particulate material and although not immediately available for uptake, could become available through biochemical degradation. Dissolved phosphorus is absorbed from the water column primarily by phytoplankton. Phosphorus supply to aquatic macrophytes is primarily from the sediment rather than from the water column. Phosphorus is released from sediment under anaerobic conditions but is precipitated to the sediment under aerobic conditions. Phosphorus can be precipitated from the water column by use of alum (aluminum sulfate). Sediment phosphorus can be inactivated and made unavailable to macrophytes by heavy applications of alum to the sediment surface.

EQUIPMENT AND METHODS

Water quality analysis equipment used in this survey included an Otterbine oxygen-temperature meter with 25 ft. remote sensing probe, a Hach field test kit, and a Wildco Alpha Water bottle sampler. The following water quality parameters were measured and recorded: dissolved oxygen, temperature, pH, total hardness, total alkalinity, nitrate-nitrogen, and orthophosphate. The parameters selected are the major water quality factors influencing the lakes productivity and fish health. Water quality testing to determine nutrient levels was completed in the lab using a Hach DR/2010 photospectometer.

Fish sampling was done with the use of an electrofishing boat. Electrofishing is simply the use of electricity to capture fish for the evaluation of population status. Various types of equipment are in use today, however, most fisheries biologists agree that pulsed DC current is more efficient and less harmful to the fish collected than AC current. Electrofishing with an experienced crew using proven equipment is probably the least selective method of sampling warm water fish species in the temperate waters of our area. Evaluation of electrofishing efficiencies have shown that night electrofishing is a reliable method for sampling populations of largemouth bass, bluegill, and redear sunfish, and generally detects the presence of green sunfish and other scaled fish species. The method is less efficient for sampling populations of channel catfish, bullheads, and crappie (Reynolds and Simpson, 1976). The largest bias in electrofishing is generally that of collecting more large fish of a given species than smaller individuals. This is due to the differential effect of the electric current on fish of different sizes, interference with collection from dense weed beds, if present, as well as the potential bias of the person dipping stunned fish (Nielsen & Johnson, 1983). Many years of experience by our personnel has reduced this bias to an acceptable level.

Electrofishing equipment used in this survey consisted of a 16 foot workboat equipped with a Smith-Root Type VI electrofisher powered by a 4000 watt portable generator and a boom mounted electrosphere designed by Coffelt Manufacturing. The electrosphere allows the use of higher voltages at lower amperage. This has proven to improve the efficiency of the electrofishing technique with lower damage to captured fish. The electrofisher was operated in the pulsed DC mode using an output level of 400 to 750 volts. The increased effectiveness of this electrofishing system makes fish of all species, including channel catfish, more vulnerable to capture. This results in a better sampling of all fish species with a higher capture rate of the more vulnerable species (bass, bluegill, redear, and green sunfish) in the samples taken. All fish collected were placed in water filled containers aboard the sampling boat for processing. A sub-sample of up to five specimens from each species was taken in each one-half inch group. The individual fish in these sub samples were weighed to the nearest hundredth pound for average weight determinations. Additional specimens were recorded by length group.

Field data was summarized and is presented in table and graph form. Condition factors and relative weight calculations (standard measurements of the relative plumpness) were calculated for important species using standard formulas (Anderson and Gutreuter, Carlander 1977, Hillman 1982, Wege and Anderson 1978). Relative weight is a comparison of fish weights at certain sizes to standard calculated weights at those sizes. Relative weights of 100 or greater are considered good. An important procedure used in our evaluation of the bass – bluegill populations, and other species to a lesser extent, is the Proportional Stock Density Index. This population index was developed by intensive research into dynamics of fish population structure, primarily in largemouth bass - bluegill dominated populations (Anderson 1976), and subsequent field testing by numerous fisheries research and management biologists in mid-western states. Bluegill samples are divided into three major groups: those less than 3.0 inches in length, those 3.0 inches and larger, and those 6.0 inches and larger. The group 3.0 inches and larger are called the "stock". The 6.0-inch and larger individuals are considered to be "quality" or harvestable size. Bluegill PSD is the percentage of bluegill "stock" that is in the harvestable size. Largemouth bass samples are separated into "stock size" (8.0 inches plus) and quality size (12.0 inches plus), for PSD calculations. Largemouth bass PSD is the percentage of bass "stock" that are of a "quality" or harvestable size.

This study, and subsequent studies and application of the techniques developed in those studies, have shown that fish populations that are producing, or are capable of producing, a sustained annual harvest of "quality" largemouth bass and bluegill have certain characteristics. These include the following:

1. Reasonably high numbers of bluegill smaller than 2.5 inches (young-of-the-year)
2. Proportional Stock Density index of 20 - 40 for bluegill.

3.Bluegill growth which results in a length of 6.0 inches by age III or IV, with low numbers of age V or older fish.

4. Proportional Stock Density index of 40 - 60 for largemouth bass.
5. A minimum of 20 adult bass per acre.
6. A maximum of 50% annual mortality (harvest) of bass in age II - V.
7. Growth rate that results in 8 inch bass reaching quality size (12 inch plus) in approximately 1 year.
8. No missing year classes in ages 0 - V.
9. A maximum of 10% of the lake bottom covered by dense weed beds.

These parameters, and other factors, are used in the evaluation and development of recommendations from Aquatic Control surveys.

LITERATURE CITED AND REFERENCE LIST

Anderson, R. 1973. Applications of theory and research to management of warmwater fish populations. Trans. Am. Fish. Soc. 102(1)164-171.

Anderson, R. 1976. Management of small warmwater impoundments. Fisheries 1(6): 5-7, 26-28.

Anderson, R., and S.J. Gutreuter. 1983. Length, weight, and associated structural indices Pages 283-300 in L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Arnold, D.E. 1971. Ingestion, assimilation, survival, and reproduction by *Daphnia pulex* fed seven species of blue-green algae. Limnology and Oceanography. 16: 906-920.

Bennett, C. W. 1971. Management of lakes and ponds. Van Nostrand Reinhold. G. New York 375 pp.

Boyd, C.E. 1990. Water quality in ponds for Aquaculture. Auburn Univ. Ag. Exp. Sta. Auburn, Al. 252 pp.

Calhoun, A. (editor) 1966. Inland Fisheries Management. State of California. Dept. of Fish & Game, 546 pp.

Carlander, K. D. 1969 & 1977. Handbook of freshwater fishery biology. Vols. 1 & 2. Iowa State University Press, Ames, Iowa, Vol 1. 752 pp, Vol 2, 409 pp.

Cole, Gerald, A. 1983. Textbook of Limnology. 3 ed. Dept. of Zoology, Arizona State Univ. Tempe, AZ. The C.V. Mosby Co. St. Louis.

D'ltri, F. (editor) 1985. Artificial reefs Marine and Freshwater applications, Lewis Publishers, Inc. Chelsea, MI 589 pp.

Funk, J. L. (editor) 1974. Symposium on overharvest and management of largemouth bass in small impoundments. North Central Div. Am.Fish. Soc. Sp. Publ. No. 3 116 pp.

Hayes, J. W., and T. E. Wissing. 1996. Effects of stem density of artificial vegetation on abundance and growth of age-0 bluegills and predation by largemouth bass. Transactions of the American Fisheries Society 125:422-433

Hillman, W.P. 1982. Structure and dynamics of unique bluegill populations. Master's Thesis. University of Missouri, Columbia.

Indiana Dept of Nat. Res. 1966, 1985, 1988, Guidelines for the evaluation of sport fish populations in Indiana. Unpublished data.

Johnson, D.L. & Stein, R.A. 1979. (editors) Response of fish to habitat structure in standing water. North Cen. Am. Fish Soc. Sp. Publ. No. 6. 77pp.

Kornman, L.E. 1990. Evaluation of a 15-inch minimum size limit on Black Bass at Grayson Lake, Bull. #90. State of KY Dept. of Fish & Wildlife Res. 71pp.

Kwak, T. J., M. G. Henry. 1995. Largemouth bass mortality and related causal factors During live release fishing tournaments on a large Minnesota lake. North American Journal of Fisheries Management 15: 621-630.

Lawrence, J.M. 1958. Estimated size of various forage fishes largemouth bass can swallow. Proc. of 11th Annual Conf. S.E. Assoc. Fish & Game Comm. 220-225.

McComas, S. 1993. Lake Smarts The First Lake Maintenance Handbook. Terrene Institute, Washington, D.C. 215pp.

Mittelbach, G. G. 1981. Foraging efficiency and body size: a study of optimal diet and Habitat use by bluegills. Ecology 65:1370-1386

National Academy of Sci. 1969. Eutrophication, causes, consequences, correctives. Washington D.C. 658pp.

Nielsen, L.A. and Johnson,D.L. (editors) 1983. Fisheries Techniques. Am. Fish. Soc. Southern Printing Co., Inc. Blacksburg, VA. 468 pp.

Novinger, G.D. & Dillard, J. 1978. New approaches to the management of small impoundments. North Cen. Div. Am. Fish. Soc. Sp. Publ. No. 5. 132 pp.

Pereira, D.L., S.A. Pothaven, and B. Vondracek. 1999. Effects of Vegetation Removal on Bluegill and Largemouth Bass in Two Minnesota Lakes. North American Journal of Fisheries Management 19: 748-756.

Pflieger, W. L. 1975. The Fishes of Missouri. Missouri Department of Conservation. 343pp.

Prather, K.W. 1990. Evaluation of a 12-16 Inch Slot limit on largemouth bass at Elmer Davis Lake. State of KY. Dept. of Fish & Wildlife Res. Bull. #89. 18pp

Reynolds & Simpson. 1976. Evaluation of fish sampling methods and rotenone census. pages in: Novinger & Dillard. 1978. New approaches to the management of small impoundments. N.C. Div. Am. Fish. Soc. Sp. Publ. No. 5 132 pp.

Ruttner, Franz. 1953. Fundamentals of limnology. 3rd edition. Univ. of Toronto Press. Toronto. 261pp.

Sawyer, C. N. 1948. Fertilization of Lakes by Agricultural and Urban Drainage. Journal of the New England Water Works Association, 61 109-127.

Savino, J.F., and R.A. Stein. 1982 Predator-prey interactions between largemouth bass and bluegills as influenced by simulated, submerged vegetation. Transactions of the American Fisheries Society 111: 255-256 Sport Fishing Inst. 1975. Black Bass Biology & Management. Washington. D.C. 534pp.

Strange, R. J., C. R. Berry, and C. B. Schreck. 1975. Aquatic Plant control and reservoir fisheries. Pages 513-521 in R. H. Stroud, editor. Predator-prey systems in fisheries management. Sport Fishing Institute, Washington D.C.

Taras, M. J., A. E. Greenberg, R. D. Hoak, and M. C. Rand eds. 1971. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington D.C. 874pp.

U S E.P.A. 1976. Quality Criteria for Water. U.S. Govt. Printing Office. 256 pp.

Vollenweider, R. A. 1968. Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters, with Particular Reference to Nitrogen and Phosphorous as Factors in Eutrophication. OECD Report No. DAS/CSI/68.27, Paris.

Wege & Anderson. 1978. Relative Weight(Wr): A new Index of condition for largemouth bass. pages in: Novinger & Dillard. 1978. New approaches to the management of small impoundments. N.C. Div. Am. Fish Soc. Sp. Publ. No. 5. 132pp.

Werner, E.E., and D.J. Hall. 1988. Ontogenetic niche shifts in bluegill: the foraging rate predation risk trade-off. Ecology 69:1352-1366

Wiley, M. J. W. Gorden, 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.

Appendix B
Fish Collection Table

SIZE GROUP (IN)	NUMBER	PERCENTAGE	AVERAGE WEIGHT (lbs)	TOTAL WEIGHT	CONDITION FACTOR	WS	RELATIVE WEIGHT
BLUEGILL							
<3.0	342	85.50%	0.01	3.42	-	-	-
3.0	12	3.00%	0.02	0.22	6.67	0.02	111
3.5	7	1.75%	0.03	0.20	6.53	0.03	103
4.0	2	0.50%	0.04	0.07	5.47	0.04	83
4.5	3	0.75%	0.07	0.22	8.01	0.06	117
5.0	3	0.75%	0.09	0.26	6.88	0.09	97
6.0	4	1.00%	0.14	0.57	6.60	0.16	88
6.5	1	0.25%	0.21	0.21	7.65	0.21	99
7.0	4	1.00%	0.25	1.00	7.29	0.27	93
7.5	5	1.25%	0.33	1.65	7.82	0.34	97
8.0	8	2.00%	0.42	3.36	8.20	0.42	100
8.5	8	2.00%	0.49	3.90	7.95	0.51	95
9.0	1	0.25%	0.62	0.62	8.50	0.62	100
TOTAL	400			15.69			
LARGEMOUTH BASS							
<3.0	0	0.00%	0.01	-	-	-	-
3.0	0	0.00%	0.00	0.00	0.00	0.01	-
3.5	0	0.00%	0.00	0.00	0.00	0.02	-
4.0	0	0.00%	0.00	0.00	0.00	0.03	-
4.5	3	0.77%	0.04	0.12	4.39	0.04	-
5.0	6	1.55%	0.06	0.36	4.80	0.06	-
5.5	19	4.90%	0.06	1.14	3.61	0.07	-
6.0	20	5.15%	0.08	1.56	3.61	0.10	-
6.5	23	5.93%	0.12	2.76	4.37	0.13	-
7.0	11	2.84%	0.15	1.65	4.37	0.16	-
7.5	1	0.26%	0.16	0.16	3.79	0.20	80
8.0	3	0.77%	0.24	0.72	4.69	0.25	97
8.5	2	0.52%	0.31	0.62	5.05	0.30	104
9.0	12	3.09%	0.32	3.84	4.39	0.36	89
9.5	25	6.44%	0.38	9.50	4.43	0.43	89
10.0	19	4.90%	0.44	8.36	4.40	0.50	88
10.5	20	5.15%	0.52	10.40	4.49	0.59	89
11.0	29	7.47%	0.58	16.82	4.36	0.68	85

11.5	30	7.73%	0.68	20.40	4.47	0.78	87
12.0	53	13.66%	0.80	42.40	4.63	0.90	89
12.5	30	7.73%	0.90	27.00	4.61	1.02	88
13.0	33	8.51%	1.07	35.31	4.87	1.16	92
13.5	17	4.38%	1.20	20.40	4.88	1.31	92
14.0	9	2.32%	1.23	11.03	4.47	1.47	83
14.5	8	2.06%	1.44	11.49	4.71	1.64	87
15.0	7	1.80%	1.59	11.14	4.72	1.83	87
16.0	2	0.52%	2.03	4.06	4.96	2.25	90
16.5	1	0.26%	2.21	2.21	4.92	2.48	89
17.0	1	0.26%	2.39	2.39	4.86	2.73	88
17.5	3	0.77%	2.80	8.40	5.22	3.00	93
18.0	1	0.26%	2.50	2.50	4.29	3.28	76
TOTAL	388			256.75			

GREEN SUNFISH

<3.0	6	11.11%	0.01	0.06
3.0	2	3.70%	0.02	0.04
3.5	7	12.96%	0.04	0.28
4.0	8	14.81%	0.05	0.40
4.5	4	7.41%	0.08	0.32
5.0	10	18.52%	0.09	0.90
5.5	5	9.26%	0.11	0.54
6.0	3	5.56%	0.14	0.42
6.5	5	9.26%	0.20	0.98
7.5	2	3.70%	0.28	0.55
8.0	1	1.85%	0.38	0.38
8.5	1	1.85%	0.46	0.46
TOTAL	54			5.33

REDEAR SUNFISH

<3	10	50.00%	0.01	0.10
3.0	1	5.00%	0.02	0.02
5.0	2	10.00%	0.10	0.19
6.5	1	5.00%	0.19	0.19
7.5	1	5.00%	0.27	0.27
8.0	1	5.00%	0.41	0.41
9.0	1	5.00%	0.63	0.63
9.5	1	5.00%	0.66	0.66
10.5	1	5.00%	1.02	1.02
11.0	1	5.00%	1.06	1.06
TOTAL	20			4.55

BLACK CRAPPIE

4.0	2	28.57%	0.05	0.09
4.5	1	14.29%	0.05	0.05
5.0	1	14.29%	0.05	0.05
6.0	1	14.29%	0.11	0.11
12.5	2	28.57%	1.25	2.50
TOTAL	7			2.80

WARMOUTH

7.5	1	100.00%	0.33	0.33
TOTAL	1			0.33

Appendix C
Creel Survey Form

Date:

Time you began fishing______
Time you finished fishing______

Fishing From: Bank__ Boat___

Location: Open Water__ Weeds__ Woody Structure___
Man-made structure___ Rock____ Other____

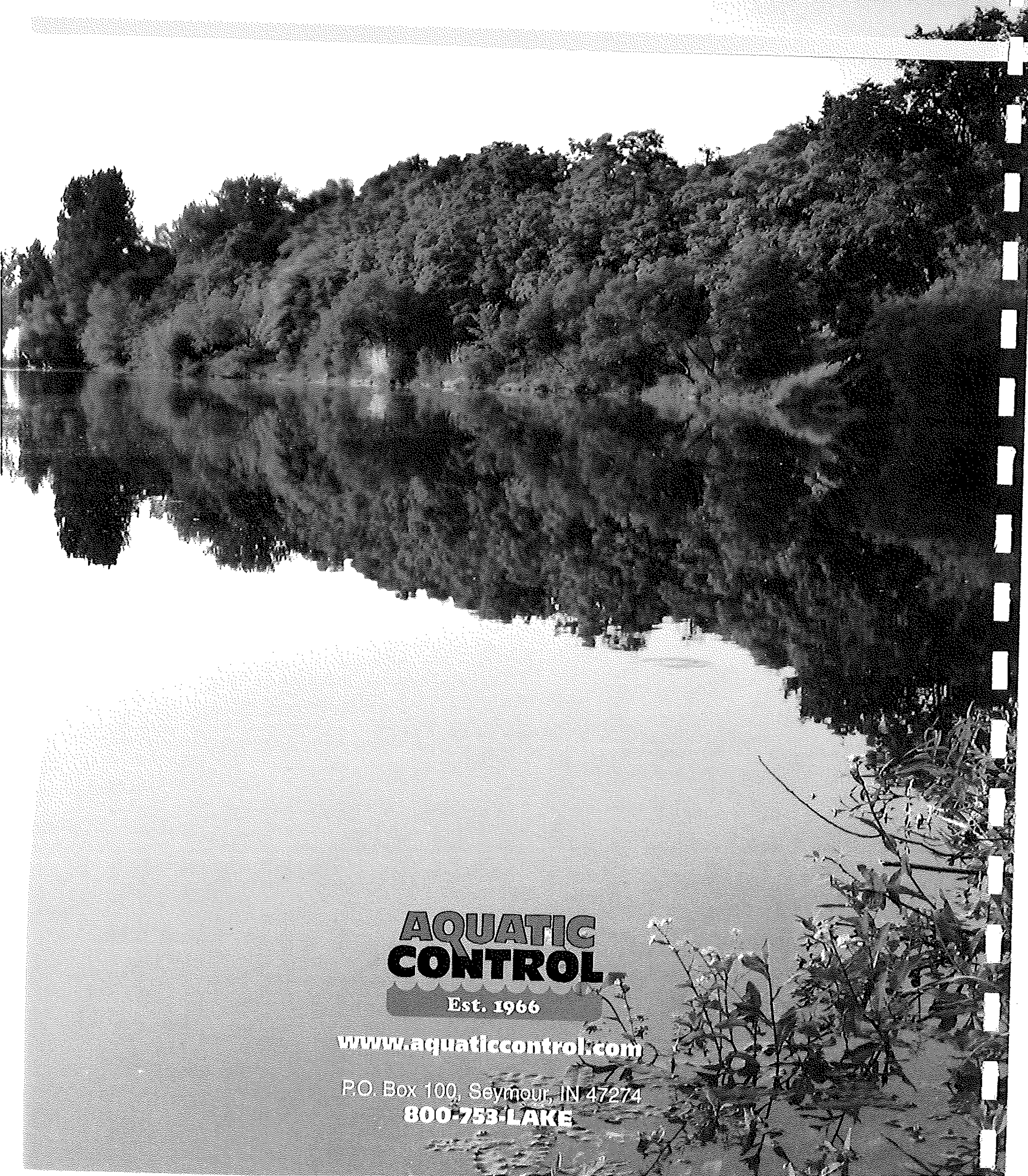
What species are you fishing for?___________________________

How many have you caught and released?____________________________.

How would you rate your fishing success today? Poor___ Fair____ Good____ Excellent____
Write down number and sizes of fish you have harvested

Species Harvested	**Length__number__**	**Length__number__**	**Length__number__**
Bluegill	_____ ______	_____ ______	_____ ______
Largemouth Bass	_____ ______	_____ ______	_____ ______
Redear Sunfish	_____ ______	_____ ______	_____ ______
Black crappie	_____ ______	_____ ______	_____ ______
Green sunfish	_____ ______	_____ ______	_____ ______
Other____________	_____ ______	_____ ______	_____ ______

Comments:



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