A COMPREHENSIVE POND MANAGEMENT STUDY AT THE MAX McGRAW WILDLIFE FOUNDATION

by
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ABSTRACT

Fish populations composed of various centrarchids, percids, catostomids, and cyprinids were studied in artificial ponds in northeastern Illinois. Population estimates were performed utilizing the Schumaker-Schnable method. Total length, weight, and sexual maturity were recorded for each fish captured and released. Scale samples were collected from all species. On the basis of length versus year class, data indicated varying degrees of stunting in all ponds.

A survey of plant species was performed and the plant standing-crop was determined for each pond. There was excessive rooted aquatic plant growth in all ponds.

Fintrol-5, a commercially prepared fish toxicant, was applied to a 1.2 acre, isolated portion of a pond during August, 1968 and resulted in the complete eradication of all fish in the study area. Complete detoxification was accomplished by application of potassium permanganate crystals twenty-one hours after application of the toxicant. Dissolved oxygen values decreased initially but returned to normal within twenty-four hours. Turbidity increased immediately after treatment but returned to normal within seven days.

One hundred and ninety-six pounds of adult carp (Cyprinus carpio) were stocked in a one acre pond to assess their efficacy in controlling rooted aquatic plants. The stocked fish depleted the standing-crop of rooted acquatic plants. The presence of young of the year and first year class carp indicated that continuous spawning had occurred during the period of the experiment.

Simazine 80W (80% wettable powder) was broadcasted beneath the surface of a 2.4 acre pond during June, 1969. A partial kill of Myriophyllum heterophyllum occurred during the next thirty to forty days. Simazine 4G (granular) was broadcasted by seedspreader over the mucky bottom of a previously drained 1.0 acre pond. Applied as a pre-emergent, the herbicide succeeded in limiting new growth to a few plants of Potamogeton pectinatus. These few plants were observed ca. fifty days following treatment and refilling of the pond. Potamogeton pectinatus and Chara sp. had been the dominant species in the pond.

Active redds of various species of sunfishes (Centrarchidae) were treated with Fintrol-5 in an attempt to eliminate an entire year class of fish. Initial dosages of 5 grams/redd resulted in fish mortality. Subsequent dosages of 2-3 grams/redd caused no fish deaths. Examination of eggs removed from redds twenty-four hours after treatments indicated 100% effectiveness of the toxicant.

Routine physical and chemical water analyses were performed throughout the study.

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INTRODUCTION

This study was initiated by the McGraw Wildlife Foundation to remedy the problems of fish overpopulation and excessive rooted aquatic plant growth. Initial observations indicated that an overpopulation of stunted fish prevailed and provided little inducement to fishermen. Dense stands of rooted aquatic vegetation contributed in part, to the problem of fish overpopulation by affording protective cover for fish and by inhibiting fishing pressure.

Thus, the main objectives of this study deal with the maintenance of a fishable population of desirable fish and the control of rooted aquatic vegetation to provide fishable waters.

The ponds used in this study are located on the grounds of the Max McGraw Wildlife Foundation, Dundee, Illinois.

Purchased by Mr. Max McGraw in the late 1930's, the land had been used to raise domestic ducks. Vegetative cover, originally consisting of deciduous wood lots and pasture land grasses, was augmented with plantings of evergreens and other cover types to render a natural appearing landscape. The hilly land is composed of calcareous soil. A small stream, flowing from an artesian well and emptying into the Fox River to the north, formed the nucleus upon which a system of artificial ponds was built. A total of twenty-eight have been built; thirteen of which have been designated for fishing, twelve for research, and three for research and/or experimental fish rearing (Figure 1). In addition, a trout stream was constructed immediately below the artesian well.

Ponds #9, #10, #14, #15, and #16 were used in this study (Figures 2 - 7). Study areas were isolated in ponds #15 and #16 and, except for two experiments, all work was confined to these areas. Although the values for average depth, maximum depth, and shoreline length varied considerably between pond #14 and study areas #15 and #16, the volume of each was closely similar to the volumes of the others (Table 1).

Pond #14 and study areas #15 and #16 were initially employed in the study of fish populations. Later, ponds #14 and #15 were used for experiments in fish population control and aquatic vegetation control. These three ponds are part of the interconnected system of ponds served by a common water source, the artesian well. Water flows from the well at ca. 1300 liters per minute, into and through the trout streams and empties into pond #13. The water flows from pond #13 into pond #14 through an open, submersed, twenty-four inch diameter pipe (Figure 2). Water drains from pond #14 into pond #15 through a ten inch diameter pipe with a slotted trough. There is a drop in water level of ca. 1.1 meters from pond #14 to pond #15. Flow from pond #15 into pond #16 is through a half-submerged, eighteen inch diameter pipe (Figure 2). Pond #16 is the terminal pond in the system and water is either pumped back up to higher ponds or allowed to drain into the Fox River. The rate of flow decreases slightly from the well to pond #16 due to evaporation and seepage.

Water levels in all ponds remain normal throughout the year except during periods of heavy rainfall when excessive run-off causes rapid rises in water levels.

Ponds #9 and #10 were used to determine the effect of *Cyprinus carpio* forage activities on aquatic flora. Later, pond #10 was used to test the efficacy of a herbicide in controlling rooted aquatic vegetation. Both ponds must be filled by pumping water from a pond in the flow system.

Decomposed organic sediments overlie the clay liner in all ponds and bottom particle size is ca. clay size.

The field work involved in this study was performed during the summers of 1968 and 1969. Surveillance work was performed during the first summer. Meteorological data was collected and recorded daily and routine physical and chemical water analyses were performed. A survey of aquatic plants was made and plant standing-crops were determined for each pond and study area. Fish populations were estimated and scale samples were collected to determine age, growth, and structure of the populations. An experiment to determine the foraging effects of Cyprinus carpio on aquatic plants was begun. A field trial of Fintrol-5[R] was performed to test the efficacy of the toxicant in eradicating fish under the prevailing water conditions.

Examination of the data collected during the summer of 1968 indicated two major problems: fish overpopulation and small growth increments, especially among Centrarchidae, and excessive rooted aquatic plant infestations.

The elimination of one year class of all species of Centrarchidae was attempted with the use of Fintrol-5 which was applied to active redds. Two experiments were carried out using the herbicide, Simazine[R] (2-chloro-4,6, bis (ethyl-amine) -s-triazine), to control rooted aquatic vegetation. Routine water analyses were performed throughout each experiment.

[R]Registered Trademark - Ayerst Laboratories Inc., N.Y., N.Y.

[R]Registered Trademark - Geigy Chemical Corp., Ardsley, N.Y.

LITERATURE REVIEW

WATER CHEMISTRY

The dissolved oxygen requirements of three species of fish were studied by Moss and Scott (1961). Critical levels of dissolved oxygen (ppm), as determined in shock and acclimation tests, ranged from 0.70 ppm at 25°C to 1.23 ppm at 35°C for Lepomis macrochirus and from 0.83 ppm at 25°C to 1.40 ppm at 35°C for Micropterus salmoides.

Buck (1956) studied the effects of turbidity on fish and fishing in ponds and reservoirs in Oklahoma. Turbidity had a marked influence on production of fish. Clear ponds yielded not only a much greater weight of fish but also greater numbers of large fish. Reproduction and growth in Lepomis macrochirus and L. microlophus was greatest in clear ponds (less than 25 ppm). Micropterus salmoides was most affected by turbidity both in growth and reproduction. In addition, carp (Cyprinus carpio) reduced the growth of largemouth bass and bluegills.

Carlander (1955) found a significant increase in the standing crop of fish with an increase in carbonate content in warm water lakes and midwestern reservoirs.

Ball (1952) recognized that hard waters favor abundant growth of aquatic plants and high production of crustaceans and aquatic insects.

POPULATION ESTIMATION

After performing population estimates in Iowa ponds using the marking and recovery technique, Fredin (1950) poisoned selected ponds and found that his estimates were not as accurate as desired. He attributed this to two general sources of error: (1) sampling techniques, and (2) characteristics of fish populations, such as varying numbers and sizes of fish, accessibility to the prime fish coverts, susceptibility of fish to capture, net avoidance, etc.

In a study of the effectiveness of four types of fish traps (hoop net, slat basket, 1/4 and 1 inch mesh wire traps) in capturing bluegills (Lepomis macrochirus), Cobb (1954) found that hoop nets ranked third in effectiveness, behind the 1 inch and 1/4 inch mesh wire traps. Hoop nets accounted for only 12.6% of the weight and 9.3% of the number of total fish captured. However, he assumed that fish had a hard time finding their way into the hoop nets even though they could see the bait within. No such problem was encountered with the wire traps as the bait was very near the entrance. Baited traps are effective in removing large numbers of bluegills from ponds in relatively short periods of time.

Using seine nets under laboratory conditions, Hunter and Wisby (1964) studied the net avoidance behavior of various fishes. Carp (Cyprinus carpio) showed the greatest ability to avoid nets and utilized every avenue of escape available to them. Largemouth bass (Micropterus salmoides) were only slightly less adept at net avoidance and escape than carp. Lepomis macrochirus and L. gibbosus were very susceptible to capture and sometimes even returned through an escape opening to rejoin other fish of the species still trapped in the net. Esox lucius and Catostomus commersoni were the most easily captured species. Both allowed the net to touch them and were, at times, dragged along by the net. Water temperatures affected all species, with lower temperatures decreasing fish activity.

Carlander (1955), Eschmeyer (1938), Cooper and Lagler (1956), Ricker (1968), Morgan (1958), Moyle (1949), and Swingle & Smith (1941) have contributed to our understanding of fish population estimates, growth, production, and management techniques.

MANAGEMENT

A five year study of the largemouth bass (Micropterus salmoides) - bluegill (Lepomis macrochirus) combination in New York farm ponds was completed by Regier (1963). The combination was probably not self-regulatory and must be kept in balance by management. Without management, bluegills became dominant. The main cause for crowding among bluegills was attributed to their greater reproductive capacity. However, the density of bluegill populations did not markedly affect their reproductive success or the reproductive success of bass. The danger of crowding among bass was less, due to their cannibalistic feeding habits and their less prolific reproductive capacity. Predation of 0+ bass on 0+ bluegills was found to be insignificant. Only yearling and older bass can prevent crowding. If such bass are not present in sufficient numbers, bluegill crowding may be quite certain to occur. Bluegills must be prevented from attaining their full reproductive potential by nest destruction or through the removal of small fish. Aquatic weeds are probably detrimental to the bass-bluegill combination by providing too much cover, but almost total absence of cover is no guarantee that overcrowding of one or both species cannot occur.

Ball (1952) found that with the many aquatic plants and large production of crayfish and other organisms which serve as buffer foods, it was apparent that predation pressure on bluegills was not adequate to reduce their numbers sufficiently to prevent overpopulation by bluegills.

Clark (1964) found that increased stocking of predatory fish coupled with partial poisoning (shoreline) with rotenone kept bluegill populations in check in Ohio ponds.

Potter and Rief (1952) and Rieske & Zaugg (1962) have illucidated the chemical structure and mode of action of antimycin-a.

Derse and Strong (1963) were the first investigators to report on the toxicity of antimycin-a to fish. They recognized in antimycin-a two characteristics essential to a good toxicant: efficiency at low concentrations and rapid degradation.

Walker, et.al. (1964) tested antimycin-a dissolved in acetone on twenty-four species of fish from nine families. Tests were conducted under laboratory conditions and in medium hard water at temperatures of 12'C, 17'C, and 22'C. The effect of the toxicant on fish was dependent on time of exposure and concentration of the toxicant. Members of the family Ictaluridae were most resistant. Degradation of the substance was influenced by pH, temperature, and light; an increase in any or all of these factors increased degradation. Degradation products were completely inactive on fish and other forms of aquatic life.

In other tests, Berger, et.al. (unpublished) exposed forty-eight hour old goldfish eggs to 2.5 ppm antimycin-a for four days at 17'C. At this concentration 96.1% mortality was obtained. Decreased concentrations resulted in decreased mortality. Similar tests were performed with carp eggs and similar results were obtained.

Berger (1956) conducted numerous field trials with antimycin-a dissolved in acetone and the sand based antimycin-a formulation, Fintrol-5. Complete fish mortality was obtained at all concentrations (5.0, 7.5, & 10.0 ppm) except for members of the family Ictaluridae. Natural degradation was observed within seven days.

Herr, et.al. (1967) investigated the toxicity of antimycin-a to laboratory animals and wildlife. There was a moderate irritation potential when the compound was applied repeatedly in high concentrations to the skin and eye of rabbits. However, antimycin-a had a relatively low toxicity for mammals compared to the toxicity for fish. Degradation products were devoid of toxicity. In view of the toxicant's high specificity for fish, its rapid degradation, and the safety of its degradation products, the authors concluded that antimycin-a appeared to have marked advantages over fish eradicants now in use.

Residues in the tissues of fish killed by antimycin-a were studied by Ritter and Strong (1966). The highest level of residue in an edible portion of fish was 23ug of antimycin-a or 0.33 ug/kg for a 70 kg man.

The feeding habits of Cyprinus carpio have been investigated by Moen (1953a, 1953b). Although green plant material was taken by large carp, animal material was the principle food item in the carp's diet.

Though the species is not a true herbivore, the fish has been reported to control weeds by Black (1946), Hogan (1946), Robel (1961), and Mathis (1965).

Robel (1961) found that a close negative correlation existed between the amounts of vegetation present and carp population levels. The predominant aquatic plant in the study ponds was Potamogeton pectinatus. No significant reduction in vegetation productivity occurred when carp populations were below 200 lbs./acre. In contrast, carp populations in excess of 200 Lbs./ acre greatly reduced the amount of vegetation present.

Jessen & Kuehn (1960), Tryon (1954), and Threinen & helms (1954) considered weed control by carp to be due to increased turbidity and mechanical damage caused by the feeding habits of the fish.

Avault, et. al. (1968) experimenting with carp in bass-bluegill ponds noted that the fish controlled filamentous algae (Pithospora sp. & Rhizoclonium sp.) and Eleocharis acicularis when stocked at 124 fish per hectare. Carp were not detrimental to fish populations when stocked at this rate. The authors attributed the control achieved to both weed feeding and to silting of weeds caused by feeding activities. No test ponds became muddy.

When only carp were present in ponds submerged aquatics were eliminated, ponds were muddied, and spawning of carp took place. Food preferences noted were filamentous algae and Chara sp., although Chara sp. and higher plants were eaten only when nothing else was available.

Carp stocked in densities of 2500 to 3000 per hectare and above 250 grams average weight were observed to eradicate Ceratophyllum sp. and Myriophyllum sp. by grazing over the bottom (Pruginin, 1968).

Use of the species to control filamentous algae has been reported by Swingle (1957), Grizzell & Neely (1962), and Shell (1962).

DeVaney (1967) lists the following points for Simazine: (1) it is practically insoluble in water; (2) it has practically no contact action through foliage thus eliminating the drift hazard; (3) it is absorbed through the roots; (4) it is ineffective until water carries it to the root zone; (5) its action is slow; (6) it is not approved for aquatic vegetation control; and, (7) it is not hazardous to fish and wildlife.

Grigsby (1958) found that Simazine applied at a concentration of 5 ppm showed relatively high algicidal effects on Chlamydomonas growing on water saturated pearlite.

An area containing Potamogeton americanus, P. foliosus, Chara sp., and Typha latifolia was treated with a pelleted formulation of Simazine, containing 10% active ingredient, at a rate of 100 lbs./acre by Walker (1959). The herbicide affected the submerged forms but not the Typha latifolia. Following the death of the submerged plants, phytoplankton developed in the treated area.

Simazine was found to be effective in the control of Hydrodicton reticulatum and Zygnema sp. in bass rearing and spawning ponds by Snow (1963). Phytoplankton was eliminated within twenty-four hours after application.

H. reticulatum became brown within seventy-two hours and decomposed in from seven to fourteen days. Higher concentrations (2.0 ppm vs. 1.0 or 0.5 ppm) gave more rapid kill and faster decomposition. Algae growth was inhibited for 85 days. The herbicide was not believed to be toxic to zooplankton and other animal life composing the food supply of the bass. Adult bass spawned normally.

In further tests, Snow (1964) found that Simazine inhibited growth of Pithospora sp. and Najas sp. and that certain forms of phytoplankton, including Anabaena, were suppressed. Fingerling fish yields in the hatchery test ponds were not appreciably reduced.

Otto & Bartley (1966) tested Simazine for algicidal activity on Oedogonium and Rhizoclonium spp. in 1964. Concentrations of 0.05 to 0.5 ppm resulted in only slight injury to the plants. Moderate injury resulted from 1.0 ppm concentrations. Heavy injury did not result until concentrations reached 5.0 ppm.

Pierce, et. al. (1964) performed field trials of Simazine. The herbicide effectively inhibited the development of filamentous algae when applied as a pre-emergent at concentrations of 0.5 and 1.0 ppm. However, phytoplankton blooms were adversely affected for several weeks. Pithospora, Oedogonium, Zygnema, Rhizoclonium, and Ulothrix spp. were kept at 0% infestation for 10, 30, and 60 days by Simazine concentratins of 0.5 and 1.0 ppm. Simazine was found to be an effective post-emergent algicide at concentrations of 0.75 to 1.0 ppm, but effects were not noticable for two weeks following treatment. At the concentrations tested, the herbicide did not maintain toxic levels in water. When applied as a post-emergent to rooted aquatics, Simzaine attained 100% control of Hydrolea, Myriophyllum heterophyllum, and Potamogeton diversifolius within thirty days when a concentration of 1.0 ppm were used. Hydrochloa carolinensis was controlled 100% after sixty days by a concentration of 1.0 ppm and no regrowth of the species was observed the following year. Hydrocotyle was not affected by 1.0 ppm, nor was Eleocharis acicularis affected by 1.5 ppm.

Ramachandran & Ramaprabhu (1968) found that Simazine, at a concentration of five kg. per hectare and sprayed as an aqueous emulsion, was able to kill and clear water hyacinth (Eickhornia crossipes) infestations.

Pre-emergent applications of Simazine at 1.0 to 2.0 ppm controlled Potamogeton, Najas, Ceratophyllum, Heteranthera, and Zannichella spp. Higher rates were required for filamentous algae and Chara sp. (Walker, 1964a). Early post-emergent applications of wettable powder to submersed aquatics and filamentous algae were often effective, but the granular formulation was more consistent in achieving control of rooted submersed aquatics while wettable powder was a more satisfactory inhibitor of algae. Simazine had a relatively high margin of safety with respect to actue toxicity to fish (Walker, 1964b). Granular formulations were found to be less toxic to fish than wettable powder or emulsifiable concentrates.

Lawrence (1968) determined that Simazine in wettable powder form was safe to bass at concentrations up to 40 ppm and safe to bluegills at concentrations up to 10 ppm. Test applications ranged from 2 to 11 kg/hectare. At the higher rate the herbicide controlled all submersed and emersed weeds plus filamentous and planktonic algae. Residual Simazine was detected in water and soil for eighteen months following treatment. Growth of planktonic and filamentous algae was severely inhibited for two summers, but for a much shorter period at lower rates of application.

METHODS AND MATERIALS

METEOROLOGICAL, PHYSICAL AND CHEMICAL WATER ANALYSIS DATA

Air temperature, percent of cloud cover, wind velocity and direction were checked and recorded daily. Temperature was checked with a Centigrade thermometer, while the other data was estimated.

Routine physical and chemical water analyses were performed twice weekly for all ponds and study areas and included checks of water temperature, turbidity, pH, free CO_2, dissolved oxygen, and total alkalinity.

Water temperature was checked with a Centigrade thermometer extended to a depth (from bulb to the surface) of 1/2 meter.

Turbidity was estimated to be the maximum depth of the pond or study area.

pH was measured colorimetrically and free CO_2 and alkalinity were determined titrimetrically.

Dissolved oxygen was determined with the modified Winkler Method (Welch, 1948).

SURVEY OF PLANT SPECIES AND PLANT STANDING-CROPS

Plant specimens were collected, pressed, and identified to species when possible. Only plants found growing wholly or partially in the water of each pond or study area were included.

The plant standing-crop was determined for each pond or study area. A sampling box, measuring sixty cm. deep and twenty-five cm. by twenty-five cm., was fabricated from sheet metal. The sampler was forced vertically into the bottom sediments and all plants enclosed by the sampler were removed by hand and placed in plastic bags.

In ponds #9 and #10, where extremely accurate determinations were desired, a grid was established and samples were collected at each intersect. This

Population sampling was carried out for twenty days in study areas #15 and #16 and for eighteen days in pond #14.

Scale samples were removed from all species. Scales were removed from the region immediately below the anterior portion of the dorsal fin on all Centrarchidae and Percidae and from the region directly below the lateral line and anterior to the pelvic fins on all Catostomidae and Cyprinidae. No more than ten scales were removed from any fish.

Scales were dried and impressions were made on acetate slides with a roller press. The scale impressions were examined and measured with a binocular microscope fitted with an ocular micrometer.

CONTROL OF ROOTED AQUATIC VEGETATION BY *CYPRINUS CARPIO*

Pond #10 was stocked with 155 carp weighing a total of 196 pounds and averaging 1.27 pounds per fish. Stocking was performed following determination of plant standing-crop. Twenty-four carp were obtained from the Illinois Conservation Department. Twenty-two carp were collected from the Fox River and one hundred and nine were collected from pond #16 (outside the study area) by using a shocking unit.

Pond #9 was used as a control for the experiment and was not stocked. This experiment was allowed to continue until the summer of 1969.

ERADICATION OF FISH WITH FINTROL-5

Following population estimations, complete eradication of all fish in study area #16 was attempted during August, 1968 to test the efficacy of the toxicant under prevailing water conditions.

Prior to toxification of the study area, the flow pipe carrying water into the pond was sealed to eliminate a possible safety zone of fresh water and to prevent the toxicant from being carried by currents throughout the rest of the pond.

Fintrol-5, a sand-based formulation contains 0.1% Antimycin-A as active ingredient. Antimycin-A at 5 ug/l was applied with a seed spreader to the surface of the water.

Twenty-one hours following the application, the area was detoxified with 1 mg/l $KMnO_4$ by towing a burlap sack filled with $KMnO_4$ crystals behind a boat.

Dead fish were collected, counted, weighed, and identified to species.

METEOROLOGICAL, PHYSICAL AND CHEMICAL WATER ANALYSIS DATA (Summer - 1969)

Weather data recorded was similar to 1968, however, records were kept only while the experiments were in progress.

Water temperature, free CO_2, total alkalinity, dissolved oxygen, and pH were checked only while an experiment was in progress and only in ponds where the experimentation was being carried out. A small Hach Kit[R] was used for most of these analyses.

CONTROL OF ROOTED AQUATIC VEGETATION WITH THE USE OF SIMAZINE 80W

Pond #15 which has a surface acreage of 2.4 acres and a volume of 11.3 acre feet was used.

Prior to application of the Simazine 80W (80% active ingredient - wettable powder) on June 26th, the pond was isolated from other ponds in the system by plugging both the inlet and outlet flow pipes. Isolation was maintained for 56 hours.

The air temperature prior to application was 30.0°C and cloud cover was

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[R]Registered Trademark- Hach Chemical Co., Ames, Iowa.

estimated to be 50%. Wind velocity and direction was 15 mph out of the west-southwest. The day following application the air temperature was 27.0°C; the cloud cover was 75% and the wind was out of the west-southwest at 3 to 5 mph.

Simazine 80W was applied at a concentration of 1 mg/l (Active ingredient) as a slurry. The slurry was dispensed below the water surface. Especially heavy infestations of Myriophyllum heterophyllum were administered heavier dosages by subjecting these areas to repeated passes.

CONTROL OF ROOTED AQUATIC VEGETATION WITH THE USE OF SIMAZINE 4G

Pond #10 had been used to study the effects of Cyprinus carpio forage. Following drainage and carp removal, no rooted aquatics remained and filamentous algae covered ca. 5% of the total bottom area.

On June 27th, two days following drainage, Simazine 4G (4% active ingredient - granular) was broadcasted by seedspreader over the mucky bottom to give a concentration of 0.5 mg/l when the pond was refilled to its 3.0 acre foot volume.

Prior to application of the herbicide, the air temperature was 29.0°C. The wind was out of the west-southwest at 20 mph and there was no cloud cover. The air temperature was 27°C the day following application. Percent of cloud cover was 75 and the wind was out of the west-southwest at 3-5 mph.

The pond was allowed to stand empty for ten days and then was refilled to its original volume.

FISH POPULATION CONTROL BY THE ELIMINATION OF AN ENTIRE YEAR CLASS WITH FINTROL-5

Ponds #14 and #15 were utilized in this experiment designed to eliminate a year class (young of the year) of all species of Centrarchidae except

Micropterus salmoides.

Antimycin-A was applied to the water surface above active redds and settled onto the eggs. Redds were initially treated with 5 mg of the active ingredient. The amount was gradually decreased to ca. 2 mg in subsequent applications.

Eggs and/or fry were pipetted from the redds 24 hours following application and examined under a binocular microscope to determine the efficacy of the toxicant.

RESULTS

METEOROLOGICAL, PHYSICAL AND CHEMICAL WATER ANALYSIS DATA

Air temperatures averages 25.5°C for the summer and ranged from a high of 31.0°C on August 7th to a low of 12.5°C on June 27th (Table 2). A cold spell extending from June 25th to July 3rd was reflected in low water temperatures in all ponds, the lowest recorded throughout the study (Table 3).

Water temperatures were indicative of standing water ponds (#9 & #10) and flowing water ponds (#14, #15, & #16) and of the position of the flowing water ponds in relation to proximity to the water source (Table 3).

Turbidity, estimated to be maximum depth of a pond or study area, remained fairly constant throughout the summer except during periods of heavy rainfall. In addition, slight variations between ponds #14, #15, and #16 were observed that the author believed to be somewhat indicative of the absence or presence and relative density of species of Catostomidae and Cyprinidae. The premises was given some credence when turbidity in pond #10 increased following introduction of Cyprinus carpio. Mid-summer aquatic plant mortality was accompanied by slightly increased turbidity.

pH averaged between 8.5 and 8.8 for all ponds throughout the summer.

No free Co_2 was present in any of the ponds.

The average total alkalinity was above 205 mg/l in all ponds. (Table 4).

Dissolved oxygen values for ponds #14, #15, and #16 fluctuated throughout the summer, but never fell below the 5mg/l minimum required by fish. A decrease in dissolved oxygen was observed to run concurrently with the mortality of aquatic plants that began in mid-July and continued until early August (Table 5, Figures 8 & 9).

SURVEY OF PLANT SPECIES AND PLANT STANDING-CROPS

The plant survey included all areas of ponds #9, #10, and #14, but was conducted only in the study areas of ponds #15 and #16. Later observations in all areas of ponds #15 and #16 indicated small amounts of other species, notably of the genus *Potamogeton* (Table 6).

Only submerged and semi-emergent aquatics were included in the determination of standing-crop; littoral zone species were omitted. *Myriophyllum heterophyllum* was totally absent from ponds #9 and #10. Likewise, *Potamogeton pectinatus* was absent from pond #14 and study areas #15 and #16. *Chara sp.* was not found in any samples taken from the study areas in ponds #15 and #16. Filamentous algae, known to be present in all ponds, was not found in the samples taken from #10, #14, #15, and #16 and it was assumed that the amount present in these ponds was negligible (Table 7). The values recorded were computed for only the study areas of #15 and #16 and not for the entire pond areas.

DETERMINATION OF POPULATION, AGE, GROWTH, AND STRUCTURE

The total population in study area #16 was estimated at 4519 fish. The estimate was based on 834 initial captures and 81 recaptures. *Lepomis macrochirus* was the predominant species and *Lepomis cyanellus* and *Cyprinus carpio* were the immediate sub-dominants.

A total population of 1180 fish, based on 273 initial captures and 31 recaptures, was estimated for study area #15. *Lepomis machochirus* and *L. microlophus* were the co-dominant species.

The low number of initial captures (94) and recaptures (2) were the determining factors which resulted in ending the sampling in pond #14 after only eighteen days. The total population was estimated at 2088 fish. *Lepomis* cyanellus was the dominant species and L. gibbosus was the immediate subdominant.

Only four species were present in pond #14. Pond #15 contained the same four species found in pond #14 and six additional species. Erimyzon succetta was not found while sampling was being undertaken in study area #16. However, the species might be present in the remainder of the pond due to the ease of fish migration through the pipe connecting the two ponds (Table 8).

The average lengths plotted against year class for Lepomis macrochirus (Figure 10) compare favorably with approximations of length for each successive year of life as listed by Lagler (1956). This is especially true for data on study areas #15 and #16 where lengths of 65 and 62 fish respectively were recorded. Only five fish (one from each year class) provided data from pond #14 and the disparity between the three graphs might be attributed to the total number of fish measured per pond. Twenty-six of the sixty-five fish from pond #15 were in the year class five; twenty-four of the sixty-two fish from pond #16 were in year class three. Though length-frequency was not plotted, data indicated a preponderance of second, third, and fourth year class fish in pond #16. Similarly, data from pond #15 indicated a preponderance of fourth, fifth, and sixth year class fish. However, in the latter instance sampling was performed when fish were spawning in beds adjacent to the nets and it was assumed that this resulted in the capture of a larger numbers of older, sexually mature fish.

Plots for Lepomis gibbosus (Figure 11) were based on data collected on twenty-three fish from pond #14, three fish from pond #15, and nine fish from pond #16. Fourth year class fish were most frequent in pond #14 (14 fish). Frequency was about equally distributed in data from pond #16. Two of the fish from pond #15 were in the five year class.

The inconsistencies in the average lengths plotted for Lepomis cyanellus in pond #14 (Figure 12) could not be explained on the basis of available data. However, data indicated an excellent length-frequency distribution for this species in pond #14. Data from pond #15 was based on only seven fish and was insufficient to afford much information. Fish sampled from pond #16 indicated a majority of second year class fish.

The fact that Micropterus salmoides is one species that will seldom enter frame nets, whether the mesh is large or small (Parker), afforded an explanation for the small number of specimens collected during the sampling even though more fish and some larger fish were in evidence in all three ponds. Plots (figure 13) for ponds #14, #15, and #16 are based on nine, four, and six fish respectively. Eight of the nine fish from pond #14 were in the second year class. Only five of the six fish from pond #16 were collected in frame nets; the large specimen was obtained after the study area had been poisoned with antimycin-A. Frequency was evenly distributed in study areas #15 and #16.

Conditions of capture of specimens of Lepomis microlophus were the same as those of L. macrochirus in pond #15 with the result that large numbers of sexually mature fish were represented in the collection data (Figure 14). Twenty fish were in the four year class and twenty-five were in the five year class. In study area #16, the fourth year class was most frequent (6 of 10 fish).

Only one specimen of Perca flavescens was collected from study area #15. Two were collected from study area #16 (Figure 15).

Information on Pomoxis annularis in pond #15 was limited as only six fish were captured. The fact that certain species are attracted to frame nets (Parker) was in part substantiated when the largest white crappie (38.3 cm.) was recaptured four times. Ten of the twelve specimens of P. annularis captured in pond #16 were of the third year class (Figure 16).

Eight carp (Cyprinus carpio) were collected from pond #15. Seven fish were from the fourth year class and average 28.53 cm. in total length. The other fish was from the third year class and measured 22.7 cm. Four different year classes were represented by carp collected from study area #16. Third year class fish were most frequent (36 fish). Nine fish were in the two year class and four were in the four year class. Only two carp were five years old; both were collected following the antimycin-A experiment. (Figure 17).

CONTROL OF ROOTED AQUATIC VEGETATION BY CYPRINUS CARPIO

Pond #10 was drained during the summer of 1969 and the carp were collected, weighed, and discarded. A total of 138 large carp were recovered that weighed a total of 285 lbs. 3 ozs., an average of 2 lbs. 1 oz. per fish. This compares with the stocking record of 155 fish weighing a total of 196 lbs. and averaging 1.27 lbs. per fish. The average weight increment per fish amounted to ca. 0.8 lbs. Seventeen fish could not be accounted for and were assumed to have died. In addition, many fry and first year class fish were collected. Individual weights of these ranged from 3.4 grams to 26.25 grams. It was estimated that approximately 1000 small carp were recovered which weighed approximately 25 lbs. Therefore, the total recovered weight of carp was approximately 310 pounds.

All rooted aquatic vegetation had been removed by the carp and only filamentous algae, covering no more than 5% of the total bottom area, remained. The total weight of the algae, based on the 5% estimate, was computed to be 2.13 kg. This compares with a total standing-crop weight of all vegetation of 371.6 kg. computed prior to the introduction of carp (Table 7).

Vegetation samples were removed from pond #9, the control for the experiment, dried, weighed, and the total standing-crop weight was computed to be 309.38 kg. Of this total, 247.13 kg (88.61%) was Chara sp. and 35.27 kg. (11.39%) was Potamogeton pectinatus. This compares with a total standing-crop weight of 268.7 kg. computed the previous summer (Table 7).

ERADICATION OF FISH WITH FINTROL-5

Application of Fintrol-5 resulted in the complete eradication of all fish in the pond #16 study area within four days. Fish demonstrated slight degrees of stress within one hour after application. Larger fish of all species succumbed within the first twenty-four hours. Dead fish were collected over a period of four days. Water analysis values were similar before and after the test except for a depressed dissolved oxygen value due to the chemical action of the Fintrol-5 and increased turbidity which returned to normal after a week. Dissolved oxygen returned to normal within twenty-four hours following detoxification. Repeated, daily inspection of the area revealed no surviving fish. Collection data is tabulated in Table 9.

METEOROLOGICAL, PHYSICAL AND CHEMICAL WATER ANALYSIS DATA (Summer - 1969)

Meteorological data, when considered significant, has been included in the results of the particular experiment.

Water analysis data was recorded only while an experiment was in progress. Data on pond #10 was collected before drainage and after the pond had been completely refilled. No significant changes in water quality were noted. (Table 10).

The only significant changes in water chemistry in ponds #14 and #15 occurred following the application of Fintrol-5 to Centrarchidae redds and during the decomposition of dead plant material. In both instances dissolved oxygen decreased. (Tables 11 & 12).

CONTROL OF ROOTED AQUATIC VEGETATION THROUGH THE USE OF SIMAZINE 80W

Pond #15 did not show any immediate effects of the Simazine; rather, the herbicide seemed to take a long time to take effect. This may have been due in part to the excessive stands of Myriophyllum heterophyllum already present or to the fact that water was flowing through the pond within sixty hours following application. However, though the kill was gradual, the effect on the milfoil was satisfactory. Parts of the plants died and floated to the surface throughout the summer. By August 5th, forty days following treatment, the stands of Myriophyllum heterophyllum were reduced to such a degree that they were covered by three to four feet of weed free water where formerly the plants had been emergent or but scant inches below the surface. The herbicide seemed to have worked at the nodes of the plant stems rather than through the roots as it is intended. This action may, again, be due to the excessively dense stands of the plant (Table 13).

CONTROL OF ROOTED AQUATIC VEGETATION THROUGH THE USE OF SIMAZINE 4G

Approximately fifty days following treatment, pond #10 was almost plant free except for some single plants of Potamogeton pectinatus located in the shallowest end of the pond. The exceptions might be attributed to uneven distribution of the herbicide, as the single plants were well separated and no stands could be found (Table 13)

FISH POPULATION CONTROL BY THE ELIMINATION OF AN ENTIRE YEAR CLASS WITH FINTROL-5

Sixty-one redds were treated in pond #14 throughout the summer. Initially, 35 redds were treated with 5 grams of Fintrol-5 (5ug - antimycin-A). Sixteen additional redds were treated with the same dosage three days later. Seventeen days later, ten new redds were treated with 2 - 3 grams of the toxicant. Very few dead fish resulted from these treatments. Examination of eggs taken from treated nests 24 hours following treatment indicated 100% effectiveness of the toxicant.

Initial treatment of 136 redds in pond #15 with 5 ug of antimycin-A per redd resulted in the death of 126 fish, 85 *Lepomis macrochirus*, 20 *Cyprinus carpio*, 2 *Catostomus commersoni*, and 19 unidentified small fish. A subsequent treatment of 68 new redds with 2 - 3 ug/redd of the toxicant resulted in the death of 78 various specimens of Centrarchidae, 1 *Cyprinus carpio*, and 1 *Erimyzon succetta*. A later treatment of nine redds with the same dosage resulted in no deaths.

Examination of eggs indicated 100% effectiveness of the toxicant.

Spawning activity occurred approximately every 15 to 18 days and attempts decreased from June to August. The number of active redds was highest in June at the beginning of the experiment and decreased to nine in pond #15, and none in pond #14 by the 5th of August. No redds were found after August 5th.

DISCUSSION

At no time throughout the entire study was water quality found to be detrimental to fish. Water temperatures remained well below levels described by Bennett (1962) as being lethal to centrarchids. Neither the reproductive capacity nor the physiological well-being of the fish were affected by the small degree of turbidity in the ponds. The 8.5 average pH was well within the tolerance range of fish. Dissolved oxygen values never dopped below the minimum requirement for game fish species, even subsequent to the application of Fintrol-5. The high total alkalinity (200+ ppm) contributed to the high productivity of fish and plants.

The production of Chara sp. in pond #14 was excessive and by mid-summer, it became emergent, died, and collected in windrows. Myriophyllum heterophyllum, comprising 41.5% of the plant standing-crop by weight in pond #14, grew in dense stands along the shoreline and in the shallower areas of the pond.

Pond #15 was choked with M. heterophyllum throughout its entire area. Similarly, study area #16 was crowded with dense stands of Myriophyllum heterophyllum.

The lack of measurable turbidity was undoubtedly conducive to plant growth in all ponds. The excessive plant growth provided protection for small fishes. In addition, the dense stands of vegetation constituted a major deterrent to fishing, resulting in underfishing of the ponds. Bennett (1948) illustrated the relationship of reduced yield of fish associated with the spread of dense stands of rooted pondweeds.

A comparison of the population estimate (4519 fish) for study area #16 and the number of fish (1245) collected following the application of Fintrol-5 indicated that the population estimate was not accurate. The other two population estimates were also suspected to be inaccurate.

Varying degrees of overpopulation were found in all ponds. Fish of useful size (greater than 15 cm.) were found to comprise but a small percentage of the total population of any species in any pond.

Pond #16 was considered to be the most overpopulated of the three ponds. Excessively large numbers of small Centrarchidae, especially of the species, Lepomis macrochirus and L. cyanellus, were present. Lesser numbers of the species Lepomis gibbosus and L. microlophus were in evidence. It was assumed that the larger bluegills and green sunfish took possession of the suitable nesting sites and that reproduction in the other two species was reduced. No pumpkinseed or redear sunfish males were observed over redds. Several large schools of Micropterus salmoides fry were noted, but survival rate was questionable on the basis of sampling date. Increments of length of ca. two cm. for each year of life for the first five years, followed by little or no increase in length suggests possible intraspecific competition, at least among the two dominant Centrarchidae. Specimens of Micropterus salmoides exhibited excellent growth per year, based on available data. In addition, the presence of Catostomus commersoni and Cyprinus carpio affected the carrying capacity of the pond in terms of desirable fish.

A lesser degree of overpopulation was evident in pond #15 and that in pond #16. Lepomis macrochirus and L. microlophus were considered to be co-dominants on the basis of sampling data. A disproportionately large number of sexually mature fish of both species were collected due to the occurrence of spawning in the immediate area of the frame net sites at the time of sampling. Average increments in length from year class to year class were 1.8 cm. for bluegills and 0.3 cm. for redear sunfish. Bluegills gained in length beyond the five year class and did not show the limited growth or cessation of growth indicated for the species in pond #16. Redear sunfish increased in increment growth from the fifth to the sixth year class. Maximum average lengths of sample species were 13.25 cm. (10 fish) for redear sunfish, and 16.8 cm. (2 fish) for bluegills. Though a few more fish of useful size were found during the sampling, the predominant size was less than 15 cm., considered to be the minimum useful size.

Competition between Lepomis machrochirus and L. microlophus for nesting sites was observed. Observations were made of spawning activities and in a few instances, it appeared that male bluegills were spawning with female redear sunfish. What appeared to be bluegill/redear sunfish hybrids were captured.

Little data on Lepomis gibbosus and L. cyanellus was collected. Spawning in these species was not observed.

Growth increments of Micropterus salmoides for each year class were good, but reproductive success for the species is unknown.

The carrying capacity of the pond in terms of game fish was reduced by presence of Cyprinus carpio, Catostomus commersoni, and Erimyzon succetta.

Overpopulation of sunfish species in pond #14 was not considered to be as severe as in pond #15. Data on the dominant species, Lepomis cyanellus, indicated a well structured population with a somewhat even distribution of length-frequencies was present. The mean length of the fifth year class was 12.37 cm., but 27.7% of the fish were 16.0 cm. or longer. Growth increments for each year class varied considerably but averaged 1.4 cm. Two fish in the ninth year class exhibited a total length of 18.6 cm. each.

Other species of Centrarchidae showed greater degress of stunting, probably due to competition with the green sunfish for the limited spawning sites. Neither Lepomis macrochirus nor L. gibbosus reached useful size (greater than 15.0 cm. total length) in seven years.

Increments in length per year class for Micropterus salmoides indicated good growth. Examination of bass stomach contents during the summer revealed that crayfishes were their principle food item. This indicated that bass probably had little effect in controlling sunfish populations, at least during the summer when small sunfishes were most susceptible to predation.

Fintrol-5 was applied to study area #16, after population estimates had been completed, to test the efficacy of the toxicant under prevailing water conditions.

An increase in turbidity was noted immediately after treatment but decreased to normal within a week following treatment. A decrease in dissolved oxygen occurred subsequent to treatment. This may have been due to the chemical oxidation of the antimycin-A. Dissolved oxygen values returned to normal within twenty-four hours.

No pattern of fish mortality was evident when the average total lengths were plotted against time (Table 10). Fish of all sizes were collected at both the twenty and forty hour intervals after treatment.

Daily, repeated inspection of the study area for ten days after treatment revealed no surviving fish. Two weeks after eradication, carp were observed in the study area. These fish may have entered the area from the other part of pond #16, since small carp had been observed leaping the wall net.

Pond #10 was stocked with 196 lbs. of adult carp (Cyprinus carpio) to assess their efficacy in controlling rooted aquatic vegetation. Turbidity increased markedly following the introduction of the carp. Robel (1961) reported that no relationship existed between carp stocking rates and turbidity.

The average weight gain for all stocked carp was 0.8 lbs./fish. The presence of young carp of various ages, including first year class fish, indicated that continuous spawning had occurred throughout the summers of 1968 and 1969. There was a total combined (adult & young fish) weight increase of approximately 114 pounds. A greater increase in total weight might have been possible if the fish had not depleted their food supply. Prior to drainage of the pond, carp were observed burrowing into the shoreline in search of food. The stocked fish depleted the rooted aquatic plant standing-crop during the study period. The same results might be obtained with smaller numbers of stocked carp.

Two days following the drainage of pond #10 and the subsequent removal of the carp, Simazine 4G was applied by seed spreader to the mucky, plant-free bottom. The pond was allowed to stand as treated for ten days and then was refilled.

Results with the Simazine 4G treatment were considered excellent. This was undoubtedly due to the fact that the herbicide was applied in the manner for which it was intended, as a pre-emergent. No Chara sp. was found approximately fifty days following treatment and only minimal amounts of Potamogeton pectinatus were in evidence, probably due to uneven dissemination of the herbicide.

The duration of Simazine's herbicidal activity is in the general range of 80 to 120 days (Snow - 1964).

Simazine is practically insoluble in water. It is absorbed through the roots and is ineffective until water carries it to the root zone. The herbicide is slow in action. It has not been approved for aquatic vegetation control. Simazine is not hazardous to fish and wildlife when used as recommended (DeVaney - 1967).

Simazine was also used to treat Myriophyllum heterophyllum in pond #15.

The 80% wettable powder formulation was used in this case and was applied beneath the surface of the water. Although the herbicide was disseminated from a rowboat, better distribution might be obtained from an outboard motor powered craft.

Significant results were not observed until approximately thirty days after the treatment. It was initially assumed that the density of the infestation of Myriophyllum heterophyllum and the presence of continuously flowing water served to delay results. Eipper et. al. (1959) noted that heavy growths of plants and stream flow had detrimental effects on herbicide treatments. However, the slow action of Simazine in terms of elapsed time from application to control was reported by Pierce et. al. (1964). Simazine, at a concentration of 1.0 ppm., was used to control M. heterophyllum. Thirty days elapsed before 100% control of the species was achieved.

The results obtained with Simazine in pond #15 was considered satisfactory, but better results might have been obtained if a concentration of 2.0 ppm. had been used.

The only water quality change evident during and after this experiment was a depressed dissolved oxygen value. It was assumed that this was due in part to the decomposition of dead plant material. However, the use of Fintrol-5 to eliminate a whole year class of sunfishes was being made at the same time and this chemical undoubtedly contributed to the maintenance of low dissolved oxygen values for a few days at a time.

A dosage of 2 - 3ug/redd of antimycin-A has been shown to be 100% effective in killing eggs and fry when applied to sunfish redds. Mortality of adult fish was low when this dosage was used, an advantage over former management techniques which employed toxicants, such as rotenone, to treat shoreline areas or sections of ponds which resulted in non-selective fish kills.

Compared to mechanical destruction of redds, Fintrol-5 treatment is easier, less time consuming and surer.

In terms of effort expended, the technique required little more than the time to locate active redds and pour a 2 - 3 ug dose of the toxicant on the surface of the water over each redd. Actual application time took no more than ten seconds per redd. Locating active redds presented no problems. Under very turbid conditions, redds might be more difficult to locate, but where extremely turbid conditions are encountered sunfish reproduction is minimal.

Rapid degradation and lack of toxicity of the degradation products to fish, fish food items, and aquatic plants allow repeated application to active spawning sites.

Constant surveillance of redds followed by prompt treatment with Fintrol-5 can, with time, be as effective in population adjustment as any technique now in use.

SUMMARY AND CONCLUSIONS

1. During the summer of 1968, fish populations were estimated for three artificial ponds using the Schumaker-Schnable method. Scale samples were removed from all species to determine the age, growth, and structure of each population.

2. Overpopulation, especially of sunfish species (Centrarchidae), was common to all three ponds.

3. Fish of desirable size, considered to be 15 cm. or longer in total length, comprised but a small percentage of the total population in any pond and offered little inducement to fishermen, resulting in reduced fishing pressure.

4. Excessive rooted aquatic plant growth, especially of *Myriophyllum heterophyllum*, contributed to the problem of overpopulation by affording small fish protection from predation. In addition, the excessive stands of vegetation acted as a deterrent to fishermen, further reducing fishing pressure.

5. Predation by *Micropterus salmoides* was inadequate in controlling sunfish populations. Examination of largemouth bass stomach contents revealed that during the summer crayfishes were their principle food item even though young sunfish were available.

6. The presence of *Cyprinus carpio* and *Catostomus commersoni* reduced the carrying capacity of pond 16 in terms of desirable game fish. *Erimyzon succetta*, *Cyprinus carpio*, and *Catostomus commersoni* likewise reduced the carrying capacity of pond 15.

7. Water analysis data indicated conditions conducive to excellent fish and plant production. High total alkalinity and lack of measurable

turbidity contributed to the excessive aquatic plant growth in all ponds.

8. Fintrol-5 (antimycin-a) proved its efficacy under prevailing water conditions by totally eradicating all fish in study area 16. No permanent changes in water quality resulted, although dissolved oxygen was decreased for twenty-four hours after treatment and turbidity increased, but returned to normal within a week. Collection data on dead fish indicated that the population estimated for the study area was inaccurate and, as a result, the accuracy of the other two population estimates was suspect.

9. In July, 1968, pond 10 was stocked with 196 pounds (155 fish) of adult carp (Cyprinus carpio) to assess their efficacy in controlling rooted aquatic vegetation. Turbidity increased markedly with the introduction of the carp. The pond was drained during June, 1969. The presence of young-of-the-year and first year class fish indicated that spawning had taken place during both 1968 and 1969. The fish had completely eliminated all rooted aquatic plants. Control of rooted aquatic vegetation could have undoubtedly been achieved with lesser numbers and/or pounds of stocked carp.

10. Simazine 80W effecively controlled Myriophyllum heterophyllum in pond 15 when applied at 1.0 mg/l as a slurry beneath surface of the water. The herbicide reduced the standing crop of the plant species by about one half. Similar results were obtained in pond 14 on the same species. Density of the stands of Myriophyllum heterophyllum at the time of application coupled with the continuous water flow through the ponds was assumed to effect the action of the herbicide adversely. It was believed that application of the herbicide earlier in the year, before growth had become excessive, might have resulted in even more effective control.

11. Simazine 4G was effective in controlling Chara sp. and Potamogeton pectinatus in pond 10 when applied as a pre-emergent. However, six months

after treatment Myriophyllum heterophyllum was found to be growing in the pond. No explanation can be given for this, since M. heterophyllum was not found in the pond either in 1968 or 1969.

12. Examination of fish eggs taken from redds treated with two to three grams of Fintrol-5 (2-3 ug of antimycin-a) indicated 100% mortality. The dosage resulted in very few fish deaths. On the basis of egg mortality data, it was assumed that an entire year class of all species of sunfishes had been eliminated from ponds 14 and 15.

APPENDIX

TABLE 1. Physical dimensions of study ponds, McGraw Wildlife Foundation, Dundee, Illinois

Pond #	Year Completed	Average Depth (meters)	Maximum Depth (meters)	Length of Shoreline (meters)	Area (acres)	Volume (acre feet)
9	1957	1.27	1.90	259.30	1.00	4.17
10	1957	0.92	1.60	252.85	1.00	3.01
14	1945	1.30	1.90	221.40	0.70	2.50
15	1940's	1.50	1.90	192.50*	0.58	2.85
16	1945	0.70	1.30	347.95*	1.10	2.53

*Only portions of ponds #15 and #16 were used in the determination of plant standing crops and population estimations. Isolation was accomplished by extending a wall net (200 ft long x 10 ft. deep) across the width of each pond. Length of shoreline in these two ponds refers to shoreline and net combined.

TABLE 2. Air temperature, percent of cloud cover, wind velocity and direction during the summer of 1968. McGraw Wildlife Foundation, Dundee, Ill.

Date	Air Temperature (Centigrade)	Percent of Cloud Cover	Wind Velocity (mph)	Wind Direction
6/4	24.00	---	5	SW
6/5	28.00	---	2-4	SW
6/6	26.00	90	5-8	W-SW
6/7	27.00	75	8	S-SW
6/8	28.00	---	---	---
6/9	29.00	15	3-4	SW
6/10	27.00	50	---	---
6/11	27.00	95	15-20	SW
6/12	19.00	80	3-5	S
6/13	23.50	10	2	SW
6/14	25.00	95	7-10	W

TABLE 2. Continued

Date	Air Temperature (Centigrade)	Percent of Cloud Cover	Wind Velocity (mph)	Wind Direction
6/15	23.00	60	1-3	SW
6/16	21.00	10	1-3	SW
6/17	21.00	75	1-3	NW
6/18	18.75	100	15-20	S
6/19	24.00	20	3-5	SW
6/20	23.25	85	---	---
6/21	26.00	100	3 5	S
6/22	24.00	40	1-3	SW
6/23	32.00	25	10-12	S
6/24	29.00	45	1-3	SW
6/25	16.50	100	5	SW
6/26	18.25	100	10-15	SW
6/27	12.50	100	5-10	SW
6/28	23.00	25	5	NE
6/29	22.00	100	5	W
6/30	22.50	50	15	SW
7/1	26.50	10	18	SW
7/2	18.75	90	5-8	W
7/3	18.50	50	5	SW
7/8	23.00	100	5-8	SW
7/9	24.75	100	---	---
7/10	20.00	---	3-5	N
7/11	25.00	70	---	---

TABLE 2. Continued

Date	Air Temperature (Centigrade)	Percent of Cloud Cover	Wind Velocity (mph)	Wind Direction
7/12	25.50	50	5	W
7/13	28.00	10	5	SW
7/14	31.50	50	3	SW
7/15	29.5	45	7-10	SW
7/16	30.50	50	1-3	SW
7/17	28.50	40	5-8	SW
7/18	26.00	90	10-15	SW
7/19	27.50	30	---	---
7/20	27.00	50	---	---
7/21	29.50	---	5 10	SW
7/22	25.00	50	3-5	SW
7/23	23.00	100	---	---
7/24	26.50	75	3-5	SW
7/25	25.50	100	---	---
7/26	20.50	40	3	SW
7/27	24.00	100	1-3	SW
7/28	24.00	100	1-3	SW
7/29	23.00	30	3	SW
7/30	24.00	10	15-20	S
7/31	24.00	60	5-10	SW
8/1	22.00	50	1-3	SW
8/2	24.00	30	3	SW
8/3	27.00	65	1-3	SW

TABLE 2. Continued

Date	Air Temperature (Centigrade)	Percent of Cloud Cover	Wind Velocity (mph)	Wind Direction
8/4	28.00	80	----	----
8/5	26.50	90	5-10	S
8/6	32.00	10	10-15	SW
8/7	31.00	75	----	----
8/9	29.00	75	1-3	SW
8/10	28.50	100	5-10	SW
8/12	24.00	30	8	SW
8/13	25.50	20	15-20	SW
8/14	25.00	----	1-3	SW
8/15	27.50	75	5-8	S

TABLE 3. Water temperatures in degrees Centigrade for all study ponds during the summer of 1968. McGraw Wildlife Foundation, Dundee, Illinois

Date	Pond #9	Pond #10	Pond #14	Pond #15	Pond #16
6/9	----	----	27.00	27.00	27.00
6/12	26.50	25.00	24.00	25.00	24.00
6/26	23.00	23.00	21.00	22.00	23.00
6/29	23.00	22.00	21.00	22.00	21.50
7/3	23.00	22.50	20.50	21.00	21.50
7/8	27.00	26.00	23.50	24.00	23.00
7/11	26.50	27.00	23.50	24.00	24.00
7/15	29.50	30.00	27.00	27.00	27.50
7/18	29.50	29.00	27.00	27.00	27.50
7/22	30.00	30.00	27.00	28.00	28.00
7/25	28.00	27.00	26.00	26.00	26.00
7/29	28.50	29.00	29.00	26.00	26.50
8/1	24.00	24.50	21.50	23.00	23.00
8/5	27.50	28.00	24.50	26.50	26.50
8/7	30.50	30.00	28.50	29.00	29.50
8/12	28.00	28.50	29.00	25.00	25.50
8/15	27.00	27.00	23.00	24.00	25.00

TABLE 4. Total alkalinity in mg/l for all study ponds during the summer of 1968. McGraw Wildlife Foundation, Dundee Illinois

Date	Pond #9	Pond #10	Pond #14	Pond #15	Pond #16
6/9	----	----	240.00	244.00	248.00
6/12	204.00	218.00	242.00	241.00	233.00
6/26	191.00	197.00	257.00	250.00	234.00
6/29	189.00	198.00	263.00	242.00	246.00
7/3	219.50	206.00	252.00	245.00	242.00
7/8	213.00	226.50	249.00	232.50	237.10
7/11	203.00	222.00	256.00	249.00	249.00
7/15	208.00	224.00	254.00	243.00	236.00
7/18	203.00	208.00	234.00	223.00	235.00
7/22	210.00	211.00	242.00	235.00	240.00
7/25	200.00	210.00	246.00	229.00	233.00
7/29	201.00	206.00	246.00	233.50	239.00
8/1	191.00	213.00	246.00	250.00	248.00
8/5	200.00	236.00	270.00	237.00	242.00
8/7	227.00	257.00	273.00	246.00	255.00
8/12	222.50	264.00	257.00	246.00	254.00
8/15	222.00	265.00	287.00	257.00	261.00

TABLE 5. Dissolved oxygen in mg/l for all study ponds during the summer of 1968. McGraw Wildlife Foundation, Dundee, Illinois

Date	Pond #9	Pond #10	Pond #14	Pond #15	Pond #16
6/26	10.0	9.9	8.8	10.2	9.1
6/29	9.5	9.8	12.7	9.7	7.7
7/3	11.0	13.6	14.5	11.7	12.4
7/8	11.4	13.0	14.8	13.6	12.4
7/11	10.0	10.25	15.8	12.6	11.5
7/15	10.8	10.1	13.8	14.6	13.6
7/18*	8.7	5.9	9.5	10.1	9.7
7/22	8.1	7.5	7.5	10.2	12.5
7/25	6.5	6.4	9.2	10.7	8.5
7/29	6.7	5.1	13.6	13.9	11.4
8/1	5.8	5.4	10.6	9.0	8.3
8/5	9.1	7.2	10.7	11.4	9.8
8/7	10.5	7.7	12.1	14.0	13.4
8/12	7.2	10.9	11.3	13.4	12.1
8/15	7.7	5.7	11.0	13.5	9.9

*Figures from this date on reflect the effect that a massive plant mortality had on the dissolved oxygen content of pond water. Dissolved oxygen values decreased most in ponds #9 and #10 (standing water ponds) where the decomposition of plant material had the most effect. Less plant mortality was noticed in the other ponds and dissolved oxygen values were not depressed as much, probably due to the continuous flow of water through these ponds.

TABLE 6. A list of plant species present in each study pond. McGraw Wildlife Foundation, Dundee, Illinois

Species	Pond #9	Pond #10	Pond#14	Pond #15	Pond #16
Myriophyllum heterophyllum			X	X	X
Potamogeton pectinatus	X	X			
Potamogeton crispus	X				
Eleocharis obtusa	X	X	X	X	X
Polygonum sp.	X				
Salix sp.	X	X		X	X
Typha latifolia			X	X	X
Chara sp.	X	X	X		
Filamentous algae	X	X	X	X	X

An X signifies that the plant is present in the pond.

TABLE 7. The plant standing-crop by total weight, species weight and percent composition for each pond and study area. (Computed - summer 1968) McGraw Wildlife Foundation, Dundee, Illinois

Pond #	Total Weight	Myriophyllum heterophyllum Weight	Chara sp. Weight	Potamogeton pectinatus Weight	Filamentous Algae Weight
9	268.7 kg	-----	177.98 kg (66.24%)	71.98 kg (26.79%)	18.8 kg (6.76%)
10	371.6 kg	-----	91.15 kg (24.52%)	280.45 kg (75.47%)	-----
14	495.4 kg	207.80 kg (41.50%)	287.45 kg (58.50%)	-----	-----
15*	409.5 kg	409.50 kg (100.0%)	-----	-----	-----
16*	305.2 kg	305.20 kg (100.0%)	-----	-----	-----

* Standing-crop determined for study areas only, not the entire pond area.

TABLE 8. A list of fish species present in each pond. McGraw Wildlife Foundation, Dundee, Illinois

Species	Pond #14	Pond #15	Pond #16
Lepomis macrochirus	X	X	X
Lepomis gibbosus	X	X	X
Lepomis cyanellus	X	X	X
Micropterus salmoides	X	X	X
Lepomis microlophus		X	X
Perca flavescens		X	X
Pomoxis annularis		X	X
Cyprinus carpio		X	X
Catostomus commersoni		X	X
Erimyzon succetta		X	

An X signifies that the fish is present in the pond.

TABLE 9. Data on fish collected following application of Fintrol-5 on August 6th, 1968. McGraw Wildlife Foundation, Dundee, Illinois

Species	Hours after Application	Number of Fish	Mean Length (cm.)	Mean Wt. (gms.)	Total Wt. (gms.)
Lepomis macro-	20	378	9.6	13.70	5178.6
chirus	40	560	8.1	10.87	6087.2
Lepomis micro-	20	4	13.5	33.75	135.0
lophus	40	16	10.0	20.25	202.5
Lepomis cyanel-	20	12	11.5	35.91	420.9
lus	40	38	8.0	14.85	564.3
Micropterus	20	4	34.8	607.50	2430.0
salmoides	40	5	28.9	216.00	1080.0
Pomoxis	20	4	17.0	81.00	324.0
annularis	40	1	20.8	108.00	108.0
Perca	20	1	10.7	27.00	27.0
flavescens	64	1	6.5	14.00	14.0
Cyprinus carpio	20	72	24.2	183.60	13219.0
	40	67	20.8	102.33	6856.1
	64	37	22.5	116.64	4315.7
	88	1	21.0	108.00	108.0
Catostomus commersoni	20	47	24.6	132.10	6208.7
	40	20	23.8	126.90	2538.0
	64	2	22.0	108.00	216.0

TABLE 10. Water analysis data, pond 10, summer, 1969. Max McGraw Wildlife Foundation, Dundee, Illinois

DATE	WATER TEMPERATURE (°C)	DISSOLVED OXYGEN (mg/l)	FREE CO_2 (mg/l)	TOTAL ALKALINITY (mg/l)	pH
6/17	22.5	10.0	0.0	190.0	---
6/18	22.5	9.8	0.0	187.0	---
6/19	26.0	9.0	0.0	189.0	---
6/20	Pond drained				
7/13	Pond refilled to normal level				
7/14	27.0	8.0	0.0	196.0	8.5
7/16	28.0	9.0	0.0	187.0	9.0
7/18	26.0	9.0	0.0	186.0	9.0
7/20	27.0	9.0	0.0	186.0	9.0

TABLE 11. Water analysis data, pond 14, summer, 1969. Max McGraw Wildlife Foundation, Dundee, Illinois

DATE	WATER TEMPERATURE (°C)	DISSOLVED OXYGEN (mg/l)	FREE CO_2 (mg/l)	TOTAL ALKALINITY (mg/l)	pH
6/17	21.0	14.0	0.0	264.0	---
6/18	21.0	13.3	0.0	244.0	---
6/19	24.0	12.8	0.0	250.0	---
6/27	26.0	12.8	0.0	229.0	---
6/28	25.5	14.0	0.0	245.0	---
6/29	23.5	13.2	0.0	250.0	---
6/30	24.0	9.0*	0.0	222.0	9.0
7/1	22.0	8.0*	0.0	261.0	9.0
7/14	26.0	13.0	0.0	261.0	9.0
7/16	27.0	11.0	0.0	242.0	9.0
7/18	24.5	7.0*	0.0	257.0	9.0
7/20	26.0	10.0	0.0	259.0	9.0

*Low dissolved oxygen values due to the oxidation of antimycin-a (applied for fish population control).

TABLE 12. Water analysis data, pond 15, summer, 1969. Max McGraw Wildlife Foundation, Dundee, Illinois

DATE	WATER TEMPERATURE (°C)	DISSOLVED OXYGEN (mg/l)	FREE CO_2 (mg/l)	TOTAL ALKALINITY (mg/l)	pH
6/26*	24.5	12.5	0.0	248.0	---
6/27	26.0	8.5	0.0	261.0	---
6/28	26.0	8.3	0.0	255.0	---
6/29	23.0	8.8	0.0	252.0	---
6/30	24.5	8.0	0.0	261.0	9.0
7/1	23.0	6.0**	0.0	275.0	8.5
7/14	26.0	11.0	0.0	256.0	9.0
7/16	27.0	12.0	0.0	256.0	9.0
7/18	24.5	6.0**	0.0	241.0	9.0
7/20	26.0	9.0	0.0	250.0	9.0

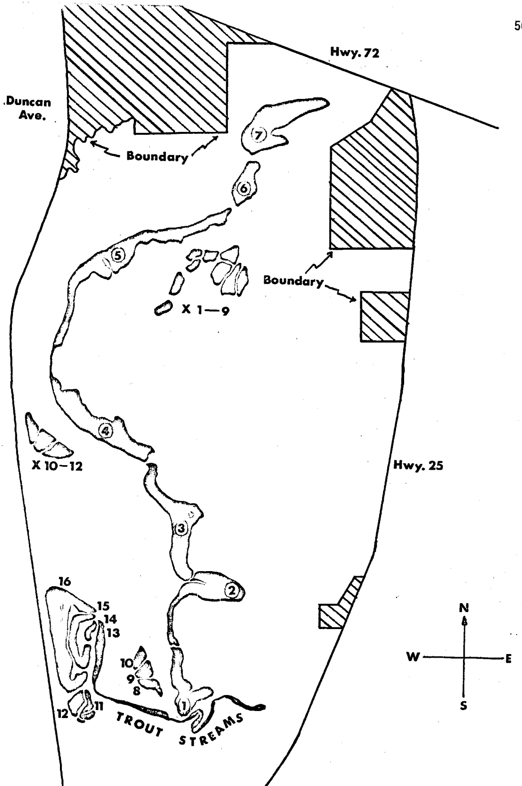
*Simazine 80W was applied to the pond on June 26th and 27th and decreased dissolved oxygen values accompanied plant decomposition.

**Low dissolved oxygen values due to the oxidation of antimycin-a (applied for fish population control).

TABLE 13. Plant standing-crops before and after treatment with Simazine 80W and 4G. McGraw Wildlife Foundation, Dundee, Illinois

	Summer - 1968				Summer - 1969
Pond #	Species	Species Weight	% of Total Weight	Total Combined Wt.	Total Weight
15	*Myriophyllum heterophyllum*	1638.0 kg	100.0	1638.0 kg.	819.0 kg
10	*Chara sp.*	91.15 kg	24.52	371.6 kg	00.0 kg
	Potamogeton pectinatus	280.45 kg	75.48		

Figure 1. Map of the McGraw Wildlife Foundation grounds, showing location, boundaries, and ponds, Max McGraw Wildlife Foundation, Dundee, Illinois.



Hwy. 72
Duncan Ave.
Boundary
7
6
5
X 1—9
Boundary
4
X 10—12
Hwy. 25
3
2
16
15
14
13
10
9
8
1
12
11
TROUT STREAMS
N
W
E
S
Interstate 90

Figure 2. Map of ponds 13, 14, 15, and 16, showing proportionate sizes, water flow, and connecting flow pipes, Max McGraw Wildlife Foundation, Dundee, Illinois.

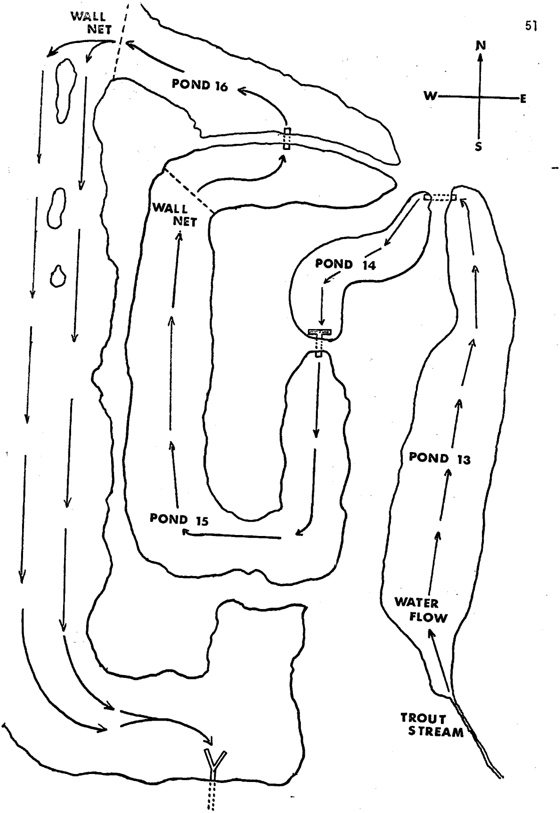
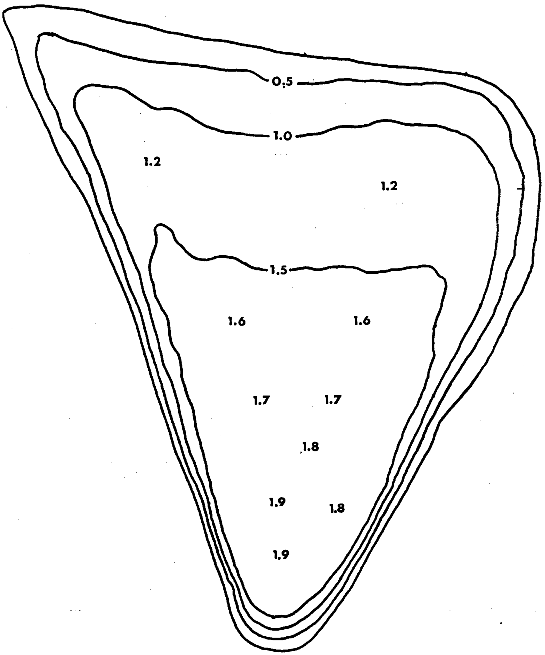

WALL NET
POND 16
N
W
E
S
WALL NET
POND 14
POND 13
POND 15
WATER FLOW
TROUT STREAM

Figure 3. Map of pond 9, showing depth contours, Max McGraw Wildlife Foundation, Dundee, Illinois.



CONTOUR INTERVAL — 0.5 meters

Figure 4. Map of pond 10, showing depth contours, Max McGraw Wildlife Foundation, Dundee, Illinois.

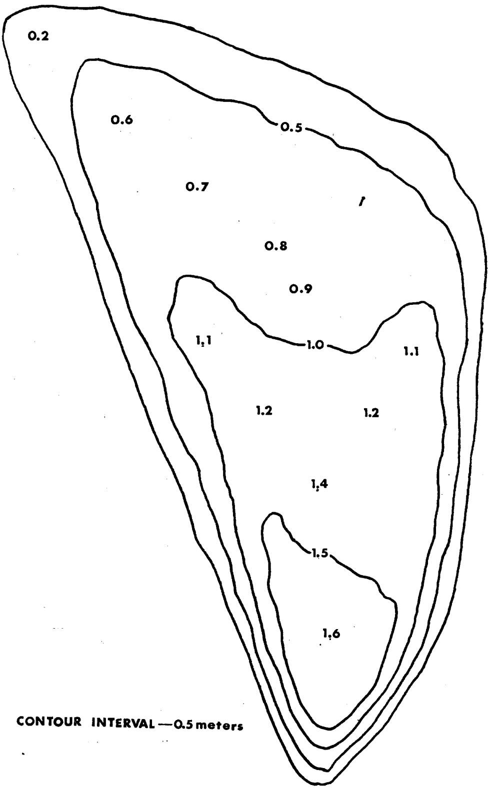
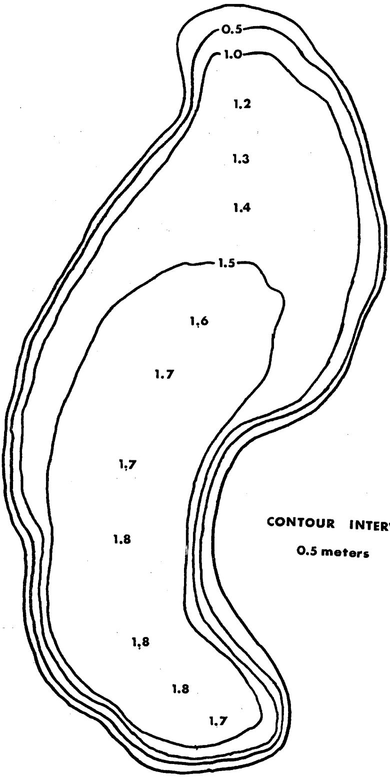

0.2
0.6
0.5
0.7
0.8
0.9
1.1
1.0
1.1
1.2
1.2
1.4
1.5
1.6
CONTOUR INTERVAL — 0.5 meters

Figure 5. Map of pond 14, showing depth contours, Max McGraw Wildlife Foundation, Dundee, Illinois.



CONTOUR INTERVAL

0.5 meters

Figure 6. Map of study area 15, showing depth contours, Max McGraw Wildlife Foundation, Dundee, Illinois.

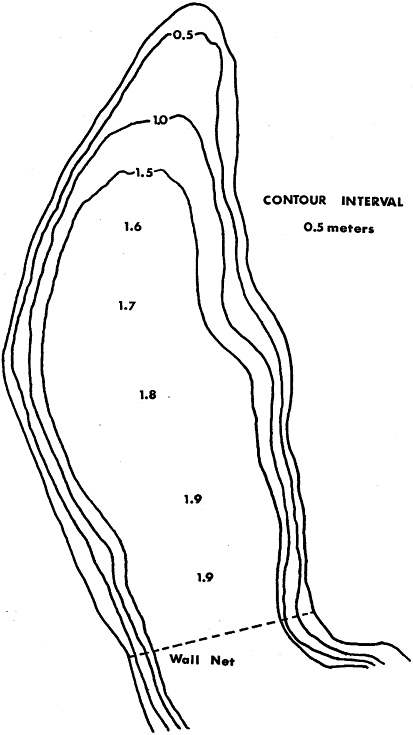

0.5
1.0
1.5
CONTOUR INTERVAL
0.5 meters
1.6
1.7
1.8
1.9
1.9
Wall Net

Figure 7. Map of study area 16, showing depth contours, Max McGraw Wildlife Foundation, Dundee, Illinois.

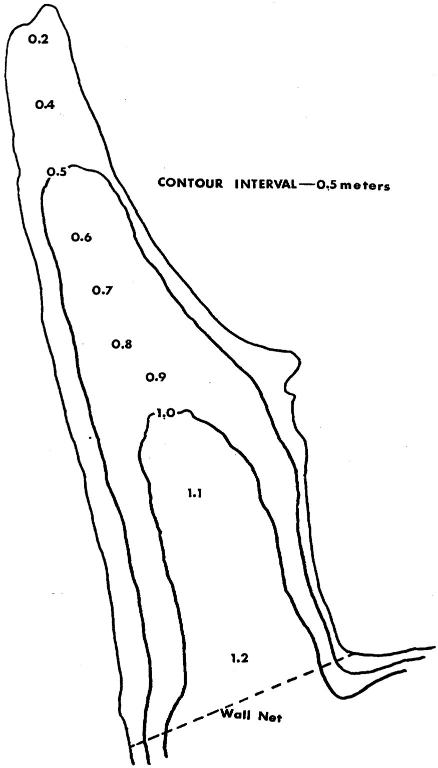

0.2
0.4
0.5
CONTOUR INTERVAL—0.5 meters
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Wall Net

Figure 8. Dissolved oxygen values in mg/l for ponds 9 and 10, summer, 1968, Max McGraw Wildlife Foundation, Dundee, Illinois.

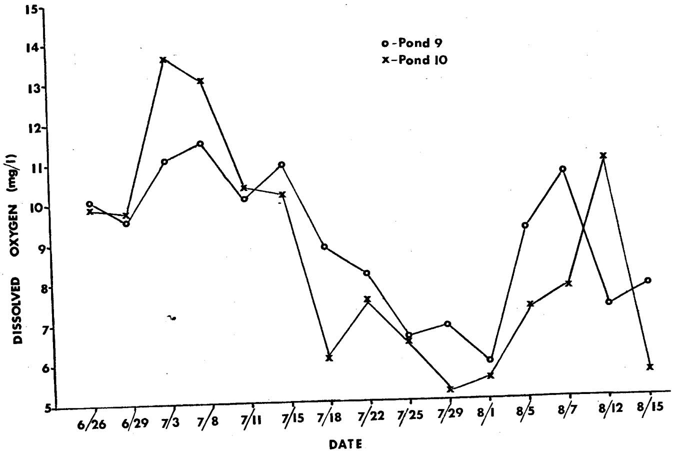

o - Pond 9
x - Pond 10
DISSOLVED OXYGEN (mg/l)
5
6
7
8
9
10
11
12
13
14
15
6/26
6/29
7/3
7/8
7/11
7/15
7/18
7/22
7/25
7/29
8/1
8/5
8/7
8/12
8/15
DATE

Figure 9. Dissolved oxygen values in mg/l for ponds 14, 15, and 16, summer, 1968, Max McGraw Wildlife Foundation, Dundee, Illinois.

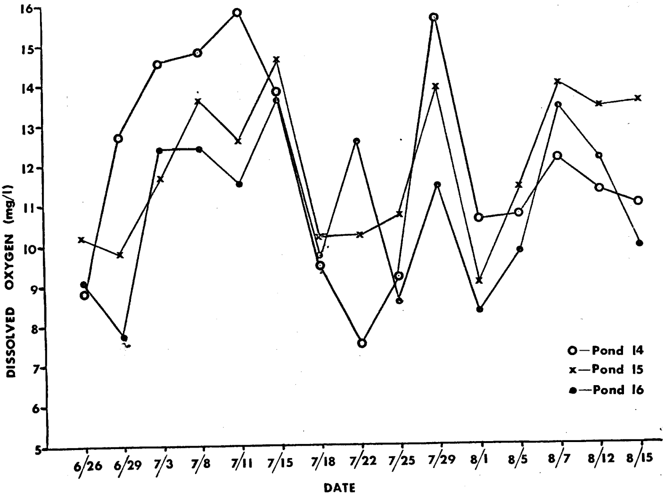
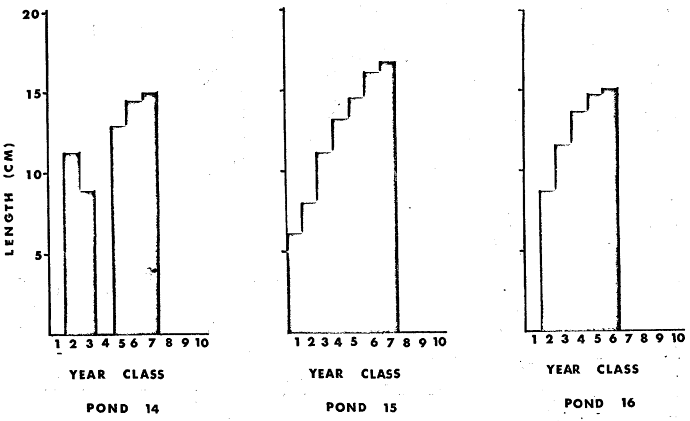
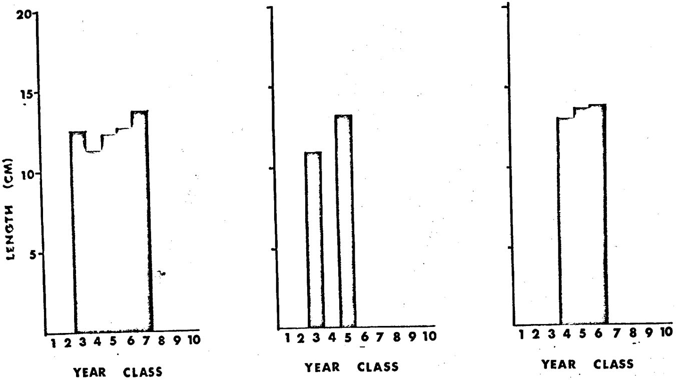

16
15
14
13
12
11
10
9
8
7
6
5
DISSOLVED OXYGEN (mg/l)
6/26
6/29
7/3
7/8
7/11
7/15
7/18
7/22
7/25
7/29
8/1
8/5
8/7
8/12
8/15
DATE
O—Pond 14
x—Pond 15
●—Pond 16

Figure 10. Average length for each year class of *Lepomis macrochirus* in ponds 14, 15, and 16, summer, 1968, Max McGraw Wildlife Foundation, Dundee, Illinois.



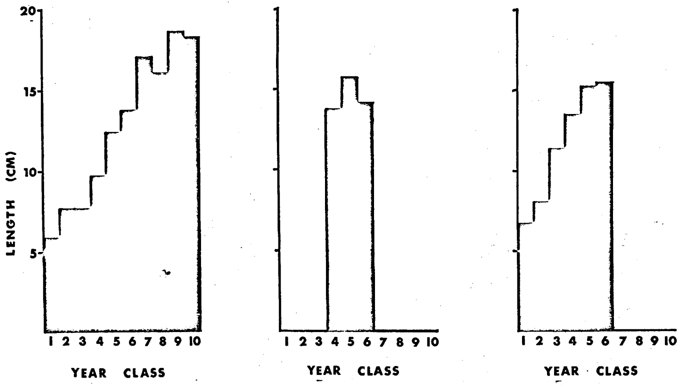
20
15
10
5
LENGTH (CM)
1 2 3 4 5 6 7 8 9 10
YEAR CLASS
POND 14
1 2 3 4 5 6 7 8 9 10
YEAR CLASS
POND 15
1 2 3 4 5 6 7 8 9 10
YEAR CLASS
POND 16

Figure 11. Average length for each year class of <u>Lepomis gibbosus</u> in ponds 14, 15, and 16, summer, 1968, Max McGraw Wildlife Foundation, Dundee, Illinois.



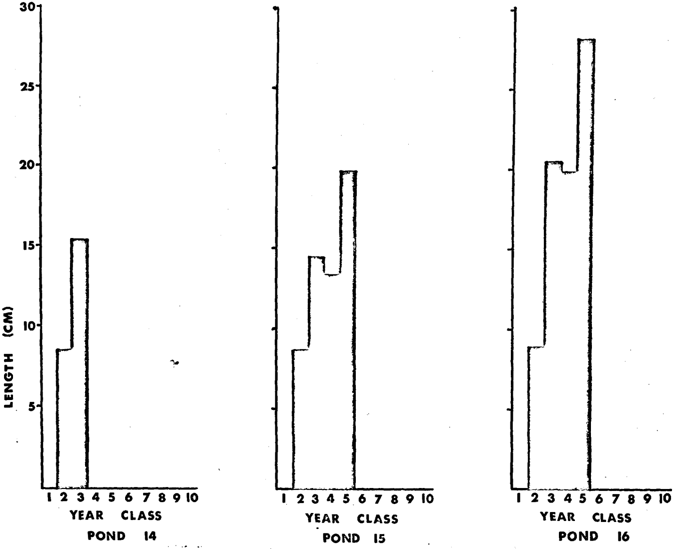
POND 14 POND 15 POND 16

Figure 12. Average length for each year class of Lepomis cyanellus in ponds 14, 15, and 16, summer, 1968, Max McGraw Wildlife Foundation, Dundee, Illinois.



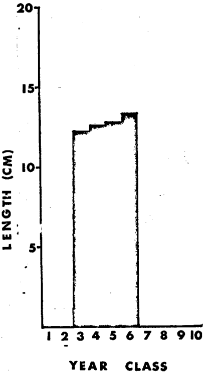
POND 14   POND 15   POND 16

Figure 13. Average length for each year class of *Micropterus salmoides* in ponds 14, 15, and 16, summer, 1968, Max McGraw Wildlife Foundation, Dundee, Illinois.

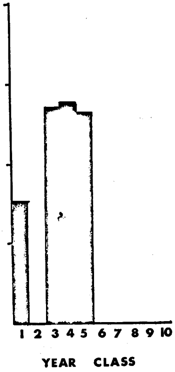


30
25
20
15
10
5
LENGTH (CM)
1 2 3 4 5 6 7 8 9 10
YEAR CLASS
POND 14
1 2 3 4 5 6 7 8 9 10
YEAR CLASS
POND 15
1 2 3 4 5 6 7 8 9 10
YEAR CLASS
POND 16

Figure 14. Average length for each year class of *Lepomis microlophus* in ponds 15 and 16, summer, 1968, Max McGraw Wildlife Foundation, Dundee, Illinois.



POND 15



POND 16

Figure 15. Average length for each year class of *Perca flavescens* in ponds 15 and 16, summer, 1968, Max McGraw Wildlife Foundation, Dundee, Illinois.

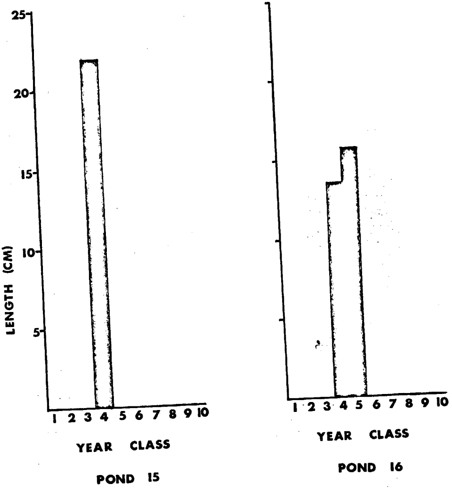
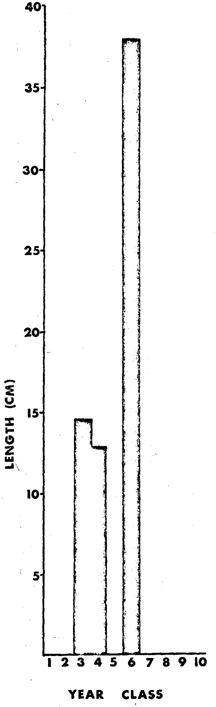
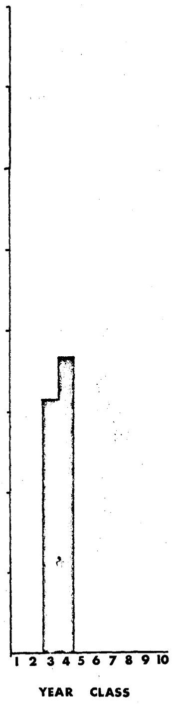

25
20
15
10
5
LENGTH (CM)
1 2 3 4 5 6 7 8 9 10
YEAR CLASS
POND 15
1 2 3 4 5 6 7 8 9 10
YEAR CLASS
POND 16

Figure 16. Average length for each year class of *Pomoxis annularis* in 15 and 16, summer, 1968, Max McGraw Wildlife Foundation, Dundee, Illinois.

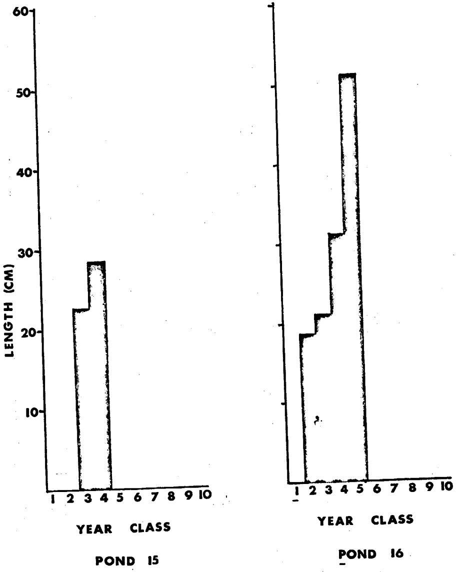


POND 15



POND 16

Figure 17. Average length for each year class of _Cyprinus carpio_ in ponds 15 and 16, summer, 1968, Max McGraw Wildlife Foundation, Dundee, Illinois.


60
50
40
30
20
10
LENGTH (CM)
1 2 3 4 5 6 7 8 9 10
YEAR CLASS
POND 15
1 2 3 4 5 6 7 8 9 10
YEAR CLASS
POND 16

LITERATURE CITED

Avault, J.W. Jr., R.O. Smitherman, and E.W.Shell. 1968. Evaluation of eight species of fish for aquatic weed control. FAO Fisheries Reports. 5(44): 106-119.

Ball, R. C. 1952. Farmpond management in Michigan. Trans. of the 17th N. Am. Wildlife Conf.

Bennett, G. W. 1948. Ill. Nat. Hist. Surv. Bull. 24(3): 377-412.

_____ 1962. Management of artificial lakes and ponds. Reinhold Publishing Co. New York, New York.

Berger, B.L. 1965. Antimycin (Fintrol) as a fish toxicant. Proceedings of the 19th Annual Meeting of the Southeastern Assoc. of Fish & Game Comm.

Berger, B.L., R.E. Lennon, and P. Gilderhaus. (in preparation) Fish Control Laboratory. U.S.Fish and Wildlife Service. La Crosse, Wis. 54 601

Black, J.D. 1946. Nature's own weed killer, the German carp. Wis. Conserv. Bull. 11(4):3-7.

Buck, D. H. 1956. Effects of turbidity on fish and fishing. Trans. of the 21st N. Am. Wildlife Conf. 249-261.

Carlander, K. D. 1955. Handbook of freshwater fishery biology. Wm. C. Brown Co. Dubuque, Iowa.

Clark, C. F. 1964. Bluegill control experiments in Hamler Lake, Ohio. Ohio Dept. of Nat. Resources. Division of Wildlife.

Cobb, E. S. 1954. The use of fish traps in the management of farm ponds. Journal of the Tenn. Acad. of Sci. 29 (1).

Cooper, G.P. and K. F. Lagler. 1956. The measurement of population size. Trans. of the 21st N. Am. Wildlife Conf.

Derse, P. H. and F. M. Strong. 1963. Toxicity of antimycin-a to fish. Nature 200: 600-601.

DeVaney, T. E. 1967. Chemical vegetation control manual for fish and wildlife management programs. U.S. Dept. of Interior. Fish and Wildlife Service. Bureau of Sport Fisheries and Wildlife. Washington, D. C.

Eipper, A. W. and H. B. Brumsted. 1959. How to control weeds and algae in farm ponds. N.Y. State College of Agri. Cornell Exten. Bull. 1014: 1-32.

Eschmeyer, R. W. 1938. The significance of fish population studies in lake management. Trans. of the 3rd N. Am. Wildlife Conf. 458-468.

Fredin, R. A. 1950. Fish population estimates in small ponds using the marking and recovery technique. Iowa State College Journal of Sci. 24(4): 363-384.

Grigsby, B. H. 1958. Response of certain unicellular green algae to several herbicides. Proceedings of the 15th Annual Meeting of the N. Central Weed Control Conf.

Grizzell, R.A. Jr. and W. W. Neely. 1962. Biological controls for water-weeds. Trans. N. Am. Wildlife Conf. 27:107-113.

Herr, F., E. Greselin, and C. Chappel. 1967. Toxicology studies of antimycin-a, a fish eradicant. Trans. Am. Fisheries Soc. 96(3): 320-326.

Hogan, J. 1946. The control of aquatic plants with fertilizers in rearing ponds at the Lonoke hatchery, Arkansas. Trans. Am. Fisheries Soc. 76:183-189.

Hunter, J.R. and W. J. Wisby. 1964. Net avoidance behavior of carp and other species of fish. Journal of the Fisheries Research Board of Canada 21(3): 613-633.

Jessen, R. L. and J. H. Kuehn. 1960. A preliminary report on the effect of the elimination of carp on submerged vegetation. Minn. Fish and Game Investigations. FS(2): 1-13.

Lagler, K. F. 1956. Freshwater Fishery Biology. Wm. C. Brown Co. Dubuque, Iowa.

Lawrence, J. M. 1968. Aquatic weed control in fish ponds. FAO Fisheries Reports. 5(44): 76-91.

Mathis, W. P. 1965. Observations on control of vegetation in Lake Catherine using Israeli carp and a fall and winter drawdown. Proceedings of the 18th Annual Meeting of the Southern Weed Control Conf.

Moen, T. 1953a. Food habits of carp in north west Iowa lakes. Proc. Iowa Acad. Sci. 60:665-686.

____ 1953b. Carp are not vegetarians. Iowa Conservationist. 12(5):129-134.

Morgan, G. D. 1958. A study of six different pond stocking ratios of largemouth bass (micropterus salmoides) and bluegill (Lepomis macrochirus); and the relation of the chemical, physical and biological data to pond balance and productivity. Journal of Sci. Labs., Denison University. 44(11):193-203.

Moss, D. D. and D.C.Scott. 1961. Dissolved oxygen requirements of three species of fish. Trans. Am. Fisheries Soc. 90(4):377-393.

Moyle, J. B. 1949. Fish population concepts and management of Minnesota Lakes. Trans. of the 14th N. Am. Wildlife Conf.

Otto, N. E. and T. R. Bartley. 1966. Aquatic weed control studies. A Water resources technical publication. Research Report No. 2. U.S.Dept. of Interior. Bureau of Reclamation.

Parker, R. A. 1958. Ecology. 39:304-317.

Pierce, P. C., J. E. Frey, and H. M. Yawn. 1964. Field evaluations of newer aquatic herbicides. Proceedings of the 18th Annual Conf. Southeastern Assoc. of Game and Fish Comm. 448-473.

Potter, V. R. and A. E. Rief. 1952. Inhibition of an electron transport component by antimycin-a. Journal Biol. Chem. 194:287-297.

Pruginin, Y. 1968. Weed control in fish ponds in the Near East. FAO Fisheries Reports. 5 (44):18-25.

Ramachandran, V. and T. Ramaprabhu. 1968. Investigation on aquatic weed control with special reference to use of chemicals. FAO Fisheries Reports. 5(44):92 -108.

Regier, H. A. 1963. Ecology and management of largemouth bass and bluegills in farm ponds in New York. Journal of N.Y. Fish and Game. 10(1):1-86.

Ricker, W. E. 1968. Methods for assessment of fish production in fresh waters. IBP Handbook No. 3. Blackwell Scientific Publications. Oxford & Edinburgh.

Rieske, J.S. and W.S.Zaugg. 1962. The inhibition by antimycin-a of the cleavage of one of the complexes of the respiratory chain. Biochem. Biophys. Res. Commun. 8:421-426.

Ritter, P. O. and F. M. Strong. 1966. Residues in tissues of fish killed by antimycin-a. Journal Agri. Food Chem. 14:403-407.

Robel, R. J. 1961. The effects of carp population on the production of water-fowl food plants on a western waterfowl marsh. Trans. of the 26th N. Am. Wildlife Conf.

Snow, J. R. 1963. Simazine as an algicide for bass ponds. Progressive Fish Culturist. 25 (1):34-36.

_____1964. Simazine as a pre-flooding treatment for weed control in hatchery ponds. Proceedings of the 18th Annual Conf. Southeastern Assoc. of Game and Fish Comm. 441-447.

Shell, E. W. 1962. Herbivorous fish to control _Pithospora sp._ and other aquatic weeds in ponds. Weeds. 10:326-327.

Swingle, H. S. 1957. Control of pond weeds by the use of herbivous fishes. Proceedings of the 10th Annual Meeting of the Southern Weed Control Conf. 10:11-17.

Swingle, H. S. and E. V. Smith. 1941. The management of ponds for the production of game and pan fish. In a symposium on hydro-biology. Univ. of Wis. Press. 218-226.

Threinen, C. W. and W. T. Helms. 1954. Experiments and observations designed to show carp destruction of aquatic vegetation. Journal of Wildlife Management. 18:247-251.

Tryon, C.A. Jr. 1954. The effect of carp enclosures on growth of submerged aquatic vegetation in Pymatuming Lake, Pennsylvania. Journal of Wildlife Management. 18:251-254.

Walker, C. R. 1959. Control of certain aquatic weeds in Missouri farm ponds. Weeds. 7(3):310-316.

______ 1964a. Simazine and other s-triazine compounds as aquatic herbicides in fish habitats. Weeds. 12(2):134-139.

______ 1964b. Toxicological effects of herbicides on the fish environment. Parts I and II. Water and Sewage Works. 3(3).

Walker, C. R., R. E. Lennon, and B. L. Berger. 1964. Investigations in fish control. 2. Preliminary observations on the toxicity of antimycin-a to fish and other aquatic animals. U. S. Circular No. 186. Bureau of Sport Fisheries and Wildlife.

Welch, P. S. 1948. Limnological Methods. Blakiston Pub. Co., Philadelphia, Pennsylvania.