EXPERIMENTAL PROPAGATION AND PRODUCTION OF BAIT FISHES IN MICHIGAN PONDS

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EXPERIMENTAL PROPAGATION AND PRODUCTION OF BAIT FISHES IN MICHIGAN PONDS

By

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A THESIS

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INTRODUCTION

Within the past few years, Michigan's second largest industry, the resort industry, has shown remarkable growth and expansion. Today Michigan's tourists number in the millions with the number increasing each year. For the most part this great throng of vacationers migrate from outstate farming and metropolition areas to Michigan wilderness expanses for outdoor recreation. A very large portion of these tourists plan some fishing on Michigan's scenic lakes and streams. This influx of sportsmen, supplemented by a large resident angling population, combine to create an annual army of fishermen reaching well over a million. Many of these anglers are bait fishermen and the magnitude of the demand for live-bait is evident.

Increasingly greater demands for live-bait resulting from expansion of the resort industry, led to zealous exploitation and scarcities of natural bait minnow supplies. Such scarcities were noted in reports by Hubbs (1933), Hubbs and Cooper (1936), Carbine (1940), and others. The commercial minnow dealers of the state attested to the existance of minnow shortages through a Michigan Institute for Fisheries Research post card survey showing that 94 per cent of those answering the questionnaire were unable to obtain an adequate supply of bait (Washburn, 1946). Complaints from fishermen about high cost of minnows or the inability to purchase the desired size gave indication of scarcity from yet another source. Thus the evidence at hand from biologist, minnow dealer, and fisherman alike, supports the contention that a scarcity of minnows and bait fishes actually does exist in many areas of Michigan during some seasons.

Michigan's minnow problem is not unique. Workers from Minnesota (Dobie, 1948), Ohio (Wascko and Clark, 1948), Illinois (Hutchins, 1946), and others, indicate minnow population depletion in regions of these states adjacent to the better fishing areas. So many similar but separate observations in varied locations seem to warrant the conclusion that the minnow is unable to compete successfully in the face of both a heavy natural predation and collection by Man for commercial purposes.

Minnows have considerable direct economic value when sold as bait fishes. A 1950 Michigan survey (Lauff, 1951 ms.) verifies this by showing minnow sales of the year to have been nearly two million dollars.

The indirect value of adequate minnow supplies is of even greater and more far reaching consequence than the direct values. These small, soft-rayed, fishes are converters of minute aquatic animal and plant forms into larger food forms useable by the major game-fish species. In many lotic environments the productive level attained by warm water, fish eating, game fish, species may be reflected by the population levels of the minnows present. Decimation of minnow populations in these streams through increasing industrial pollution and intensified commercial harvest, have probably been deleterious factors contributing to the unproductiveness of streams once known for their game fish populations. These forage fishes are an essential link in the fish food chain and their influence on the dynamics of game fish populations should not be underestimated.

The scarcity and importance of the minnow to the state's sports fishing industry warranted experimental propagation investigations toward an alleviation of shortages. The success of such a program hinges primarily on the facility with which bait fishes can be propagated and upon the production that can be achieved. The purpose of this investigation was to show by experimentation the feasibility of producing bait fishes in Michigan ponds.

REVIEW OF THE RELATED LITERATURE

The Institute for Fisheries Research of the Michigan Conservation Department has conducted several projects in an effort to obtain a realistic picture of the states minnow populations and bait fish propagation possibilities.

Cooper (1935) found that the red bellied dace (Chrosomus eos), the western golden shiner (Notemigonus crysolencas auratus), the fathead minnow (Pimephales promelas), the bluntnose minnow (Hyborhynchus notatus) were species which reproduced successfully in ponds. The horny-headed chub (Nocomis biguttatus) and the common shiner (Notropis cornutus chrysocephalus) failed completely to reproduce.

Washburn (1946 and 1947, Unpublished Institute Reports 1052 and 1084) worked principally on a method of propagating creek chub fry (Semotilus a. atromaculatus) in specially designed raceways. Some propagation work was carried on for the common sucker (Catostomus c. commersonii), golden shiner (Notemigonus chrysoleucas), northern fine scale dace (Pfrille neogaea), and the northern pearl dace (Margariscus margarita nachtriebi).

Yoder (1950, Unpublished Institute Report No.1267) worked mainly with common sucker (*Catostomus c. commersonii*) and chub (*Semotilus a. atromaculatus*) propagation. Some work was done with the fathead minnow (*Pimephales promelas*), golden shiners (*Notemigonus crysoleucas auratus*), the northern red belly dace (*Chrosomus eos*), and the northern pearl dace (*Margariscus margarita nachtrilbi*).

Bacon (1951 ms.) experimented with pituitary injections as a means of producing creek chub fry (*Semotolus a. atromaculatus*).

Surveys designed to evaluate certain aspects of the bait minnow problem were carried on by Carbine (1940, Unpublished Institute Report No. 627), Washburn (1946, Unpublished Institute Report No. 1046), and Lauff (1951, ms). Bait dealer business facilities, collecting equipement, and general practices employed were surveyed by Carbine and Lauff through personal interviews while Washburn collected the opinions of minnow dealers on various bait fish questions by means of a post card questionnaire. Questionnaires mailed to 901 dealers in the state resulted in a 37 per cent return. Bait minnows were declared to be scarce by 94 per cent of the dealers. Minnows of the 2 to 3½ inch size and 3 to 6 inch size class were reported as being scarce by many of those canvassed.

Hedges (1951 ms.) worked on methods of harvesting minnow populations from small ponds.

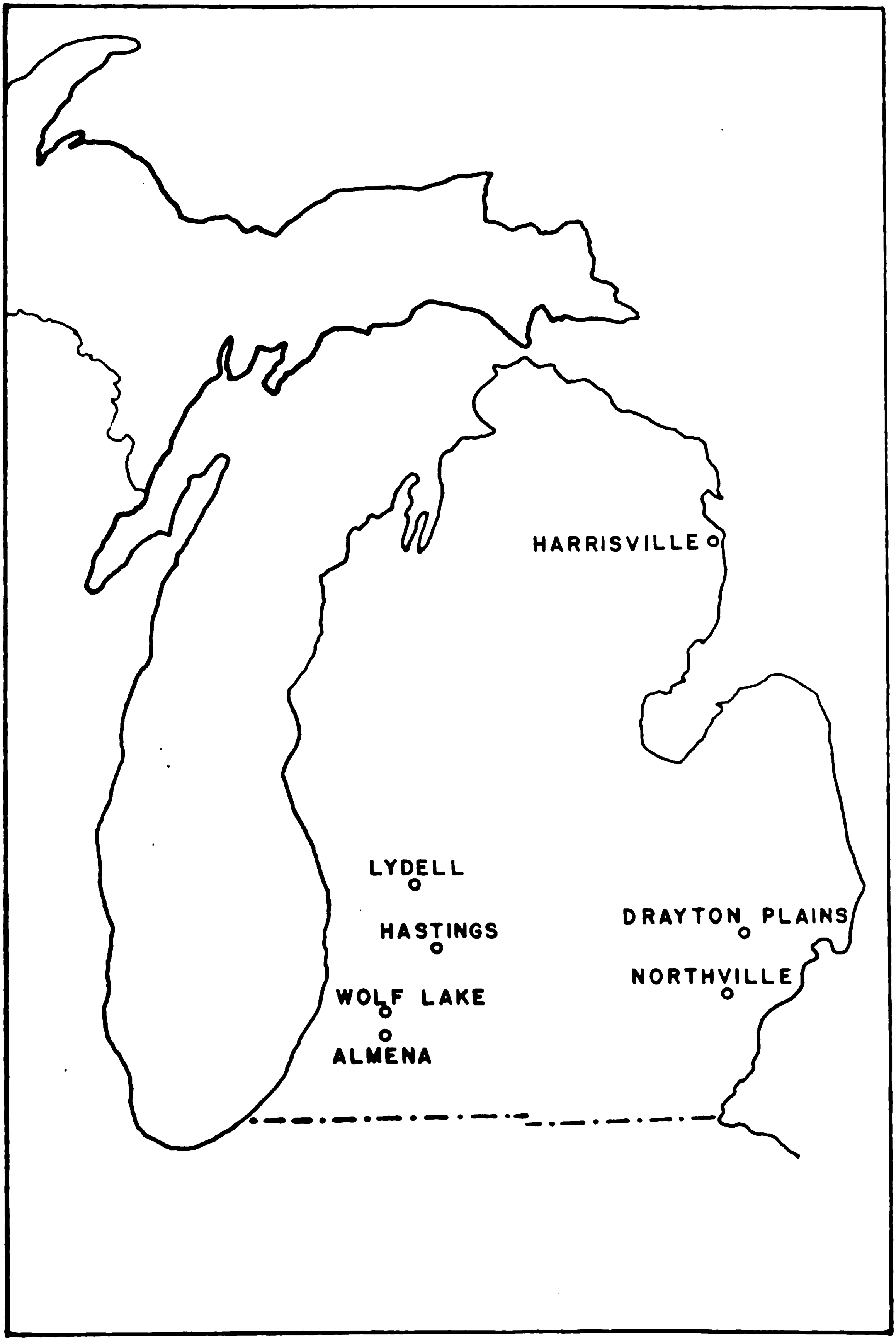
SOURCES OF DATA AND DEFINITIONS OF TERMS

Source of Data

During the course of these investigations the facilities of seven Michigan State Fish Hatcheries were used (Figure 1). Several workers besides the author conducted experiments at these hatcheries on various phases of bait minnow culture. Others working on the project were Mr. Troy Yoder, Dr. Robert Ball and graduate students of Michigan State College. This report summarizes the minnow propagation and production data from 114 experimental ponds representing a water area of 80.2 acres. The investigations were made over a five-year period.

Nine species of minnows and bait fishes were propagated. These were _Semotilus atromaculatus atromaculatus_ Mitchill (northern creek chub), _Notemigonus crysoleucos auratus_ Rafinesque (western golden shiner), _Pimephales promelas promelas_ Rafinesque (northern fathead minnow), _Hybognathus hankinsoni_ Hubbs (brassy minnow), _Chrosomus eos_ _Cope_ (northern redbelly dace), _Margariscus margarita nachtriebi_ Cox (northern pearl dace), _Catostomus commersonnii commersonnii_ Lacepede (common white sucker), _Erimyzon sucetta kennerlii_ Girard (western lake chubsucker), and _Umbra limi_ Kirtland (western mud minnow).

Figure 1: Location of the Experimental Bait minnow Ponds.


HARRISVILLE
LYDELL
HASTINGS
DRAYTON PLAINS
NORTHVILLE
WOLF LAKE
ALMENA

Definitions of Terms

Minnow.--The term minnow is construed to mean a member of the family Cyprinidae. The following characteristics taken collectively separate the Cyprinidae from other families.

1. Soft-rayed fishes (excepting the introduced carp and gold fish which have a stout serrate spine anterior in the dorsal and anal fin).
2. A single dorsal fin of less than 10 soft rays (excepting the introduced carp and gold fish which have more than 11 soft rays).
3. Well developed pharyngeal teeth in not more than two rows (excepting carp which has 3 rows).
4. A non-sucking mouth formed by toothless jaws.
5. The distance from the snout to the insertion of the anal fin is less than 2.5 times the distance from the insertion of the anal fin to the caudal base (excepting the carp and goldfish which contains the anal insertion-caudal base distance more than 2.5 times in the snout tip-anal insertion distance).
6. Head is naked (except in spawning season, breeding tubercles may be present).

Bait fish or bait minnow.--The term refers to those fishes suitable for bait purposes. Although most bait fish species are members of the family Cyprinidae, the families Umbridae (mud minnow), Catostomidae (sucker), and Cottidae (Millers Thumb), also contribute some species to this grouping of fishes.

Raceway or race.--The raceways used in these experiments were approximately 125 feet in length, with a depth of 1.5 feet at the upper end and grading to 3.5 feet at the lower end. The surface area of these ponds was .04 of an acre. The long narrow construction make it possible to maintain a continual flow of water through them.

Eyed eggs.--When the eyes or eye spots of the developing embryo are discernable to the unaided eye, the eggs are known as eyed eggs.

Sac fry.--This designation is given to those small fishes which bear a yolk sac. The term covers that stage of developement from the time of hatching to the time the yolk sac is absorbed and feeding begins.

Advanced fry.--As the yolk sac nears complete absorption, the fry are able to maintain a normal position, swim feebly and support themselves in a weak current. With absorption of the yolk sac nearly complete, the fry is ready to begin feeding and the advanced fry stage is reached.

POND MANAGEMENT PRACTICES

The pond management practices of fertilization, direct feeding, and rearing species combinations were employed in efforts to obtain greater production. Both ponds and raceways were used. The relative value of these programs as a means of increasing production were determined by comparison of the yields taken from control waters.

Fertilizing Ponds

Effects of fertilizer on fish food organisms.--The addition of organic and inorganic fertilizers to pond waters to increase fish production, is an indirect method of feeding. The nutrient materials of the fertilizer dissolve in the water, then become dispersed throughout the environment. Minute algal plants (phytoplankters) appear more numerously which in turn support a greater population of small animal forms (zooplankters). Small fish of nearly all species, and adults of several kinds, depend directly on these minute forms for food. Other aquatic fauna, including the water insects, depend on these organisms diredtly or indirectly for sustenance. The fish food-chain resulting from the natural fertility of the water is thus supplemented by the nutrients of the fertilizer and the productive capacity of the pond is increased.

Reports from biologists working with farm-pond fertilization vary greatly in detail but seem to agree generally on two major points:

(1.) Plankton and bottom fauna in fertilized ponds are usually present in larger quantities than in unfertilized controls (Van Deusen, ms. 1946), (Swingle 1947), (Ball 1949), (Patriarche and Ball 1949).

(2.) The fertilization of pond waters starts a succession of events resulting in an unpredictable growth and species composition of algal populations.

Ponds fertilized alike, with similar physical characteristics, often produce highly divergent results. Workers report variations in the effect of fertilization from immediate plankton blooms to delayed blooms or no apparent change in the waters treated. Methods developed by Swingle (1947) for ponds in Alabama generally fail to give corresponding results when applied to ponds in Michigan (Patriarche and Ball, 1949) (Ball in press). Differences in climate, soil, and water are factors influencing the results of fertilization.

Since most bait minnows are produced over a short period and delayed plankton blooms often occur, it is assumed that much of the value of fertilization may be lost before the elements are transferred through the food-chain to ultimately become salable fish. To justify fertilization on a production increase basis for short seasons, the bait fish culturist must determine if his particular ponds will produce plankton blooms early in the growing season without undue quantities of fertilizer. When the ponds in question do respond well, the fertilization method of pond management causes increased production with little labor or capital outlay and is economically sound.

No chemical tests are presently available which make it possible to calculate the amount or type of fertilizer needed to produce "blooms". Experience with pond fertilization or experimentation are the only guides to individual pond needs.

The fertilization of some pond waters produces deleterious results. Applications of fertilizer may cause a filamentous algae scum covering the most of the pond surface. This type of growth creates difficulty if the ponds are drawn down to harvest the minnow crop. Constant attention must be given the screens at the drain to prevent clogging and the fish have a tendency to become helplessly entangled in the filamentous mass.

Harvest by any method other than with glass traps is very difficult under these conditions. The culturist should also consider the greater risk of winter kill in ponds that have been heavily fertilized.

Response of fishes to fertilizers.--All bait fish species do not respond equally well to fertilizers. Those fishes feeding directly on the lower organic forms, such as phytoplankton and the smallest zooplankton, benefit most. Fertilization promotes a greater quantity of this type of food and it is available earlier in the growing season.

There appears to be some evidence that fertilized waters are beneficial to the survival of young fish. Chub and sucker fry stocked in fertilized ponds survived better than did the fry introduced to non-fertilized waters.

The data collected in these investigations reveal that increases in the production of crayfishes and tadpoles were greater than increases in fish production in fertilized ponds.

Application of fertilizer.--Various methods for applying fertilizers to ponds can be used. Organic fertilizers are most easily applied to the pond bottom after draining. Inorganic fertilizer may be applied to small ponds by casting from shore or from a moving boat on larger impoundments (Figure 2). Application of fertilizer should be made to shallow waters.

A commercial 10-6-4 fertilizer applied at the rate of 1250 pounds to the acre proved satisfactory. Production results did not indicate that weekly or biweekly applications were advantageous where the fertilization rate per acre remained constant. Applications at three week intervals were used most extensively to save labor. Blooms should be perpetuated early in the growing season to be most beneficial to the short term minnow production period.

Figure 2: Fertilization of a Bait Fish Pond.

Feeding of Bait Fishes

Several species of bait fishes were fed to obtain information on diets, production increases, and feeding methods. The largest minnow crops per unit water area produced in these investigations resulted from feeding programs. Significant increases in production were found to parallel large seasonal production costs and to require additional facilities for handling volumes of perishable food materials.

In contrast to the use of fertilizer the percentage increases in fish production under direct feeding programs were much greater than increases occurring in the crayfish and tadpole production.

Feeding in ponds and raceways.--It was difficult to feed fish efficiently in ponds of over one half acre in size, especially if heavy growths of aquatic vegetation existed. Under such circumstances where few feeding stations were employed, small populations of chubs in the immediate area feed to the exclusion of others further removed. On several occassions in heavily weeded ponds it was possible to remove a population in the feeding area to a point where further trapping proved fruitless. Movement of fish from other areas of the pond usually took from one to two days to rebuild a comparable population. The need for closely spaced feeding stations in the situation described is therefore apparent if all the fish are to be fed. The production in terms of pounds per acre coming from ponds was generally found to be less than yields obtained from raceways.

Intensified feeding programs were carried on in raceways. The narrow construction of the raceway basins allow running water to counteract the detrimental effects of crowded fish populations and the decay of rejected food materials. A comparatively high chub or sucker production per water surface area can be obtained by feeding a good diet to these fishes in raceways. The amount of labor involved to feed an acre of small raceways is much greater than that required to feed an equal surface area of ponds.

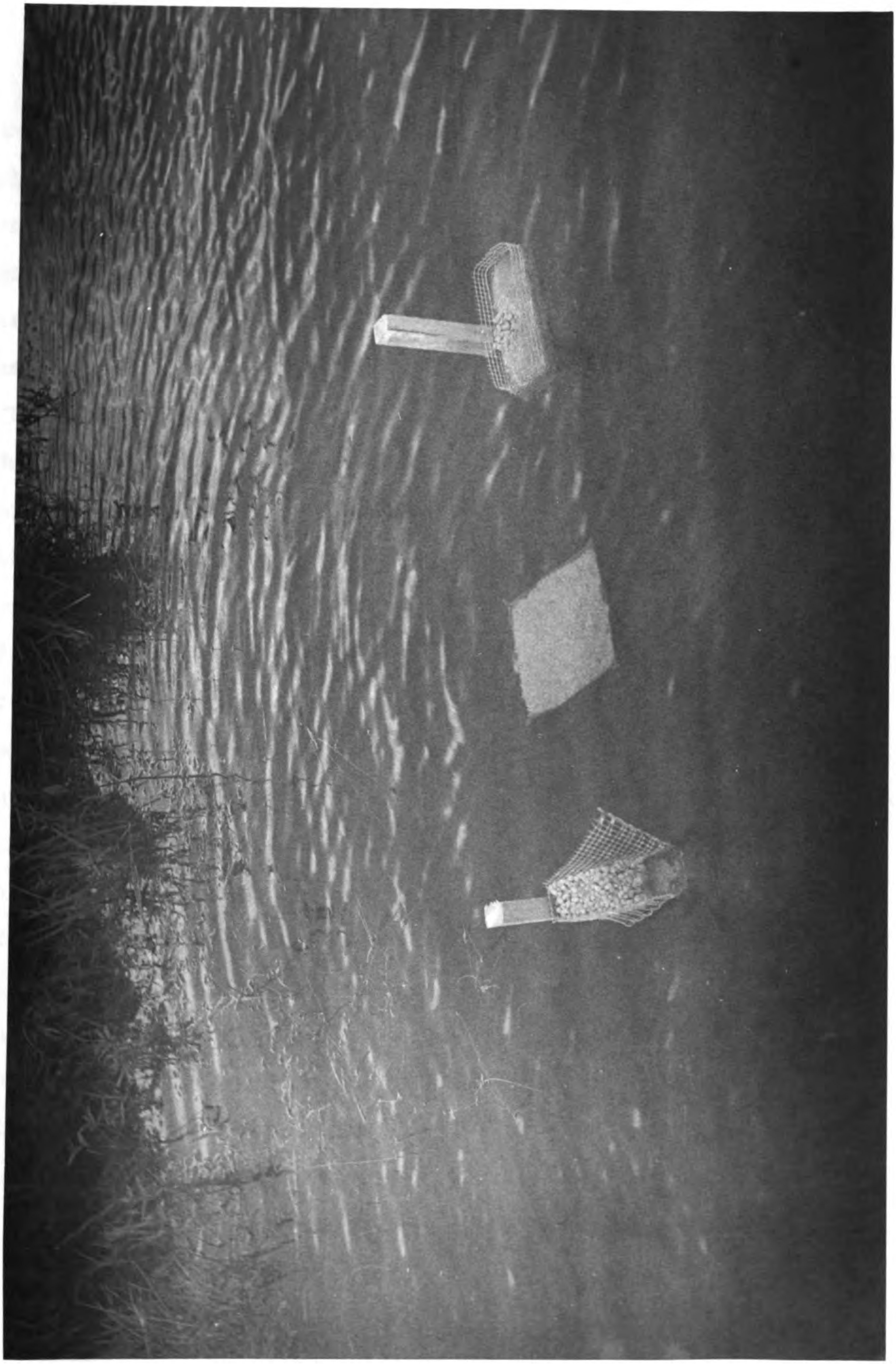
Feeding schedule.--For best results, the feeding schedule must be adjusted to the habits of the fish. As water temperatures rise to 80° F. or above, many bait fish do not feed actively and early morning or late evening feeding schedules result in a higher food consumption. In these experiments two feeding periods a day were established as soon as the fish indicated a need for the added ration.

Methods of feeding.--The usual method of feeding employed in these investigations was to establish a permanent station by cleaning the bottom area of aquatic vegetation or other debris and placing the food on the pond bottom at these locations. A ration sufficient to permit feeding over a two hour period was introduced. Daily increases in rations were based on the previous days feeding activities. This method allowed a more accurate appraisal of the amounts of food utilized by the fishes than could be determined from scattering methods of feeding. Food waste is reduced to a minimum and labor involved in feeding is considerably less, thus making it possible to manage more ponds.

The practice of hand feeding or scattering food over the surface of the water was not generally used in these feeding experiments even though this method has certain advantages. Most bait fishes measuring less than 1½ inches in length will eat sinking food particles but show disinterest for food piled on the pond bottom. Even the larger fishes which do eat from piles of food seem to eat more voraciously when hand fed.

In an effort to combine the efficiency of the feeding method used in these experiments with the advantages of the method just described several feeding devices were constructed and tested. The devices operating best were hardware cloth baskets having a weave size permitting the gradual disposition of food from the bottom and sides (Figure 3). The baskets were supported on stakes over

Figure 3: Minnow Feeding Devices.



several feet of water in an area previously cleaned of plants, silt, or debris. Where water levels fluctuate, anchored, floating baskets serve well. Wading to the baskets with food usually clouds the water with silt and for this reason a small container on the end of a long handle is the recommended tool for filling these devices. The rate at which the food is released to the fish is dependent upon the bottom area of the basket, mesh size of the hardware cloth, texture of the food, agitation of the water caused by the wind and the feeding activities of the fish. The containers on the water surface delivered food more rapidly when long sides or open ends were faced toward the wind. Devides submerged, operated independently of surface disturbances, emitting food in increasing quantities as larger numbers of minnows congregated in the area and created more subsurface disturbance. Nibbling at the food through the mesh by a few fish causes a downfall of food providing the more hesitant fish with the incentive to attack the slowly sinking particles. Food not taken while sinking, piles up at the base of the supporting stake and is utilized by those fishes inclined to feed on the bottom. The devices have the advantage of discriminating against crayfish and tadpoles. Type A (Figure 3) with a narrow bottom submerged less than one inch delivers food more rapidly and in larger food particles. Prepared livestock food in pellet form acted or served well with gentle surface disturbance. Type B was submerged in the water to the top of the basket. Considerable surface disturbance or feeding activity at the bottom of the basket causes moderate food emission. Ground food mixed with water to form a dry paste or food in pellet form can be used. Type C is supported several feet above the bottom on a post and submerged about eight inches below the surface. Feeding occurs from above and below.

Experimental diets.--Nine diets were fed to bait fishes. The availability and keeping qualities of commercially prepared livestock feeds prompted trials with chicken mash and dog foods. Cereal and liver-cereal combinations were also used.

The cereal component of all the diets was composed of 20 per cent dried milk, 35 per cent meat scrap (pork melts), 30 per cent cotton seed meal, 9 per cent low grade flour and 6 per cent salt.

Sources of fresh meat in the liver-cereal combinations were horse and condemned beef livers.

The composition of the nine diets used in these investigations may be found in Table 1.

Table 1

Diets Fed to Bait Fishes

Diet Designation	Composition
1	65 per cent liver, 35 per cent cereal.
2	54 per cent liver, 46 per cent cereal.
3	100 per cent cereal.
4	Chicken mash.
5	35 per cent liver, 65 per cent cereal.
6	29 per cent liver, 71 per cent cereal.
7	15.6 per cent horse liver, 78.1 per cent chicken mash, 3.1 per cent dried clam meal, 3.1 per cent dog ration, and .2 per cent powdered egg meal.
8	4.7 per cent horse liver, 79.4 per cent chicken mash, 2.6 per cent dried clam meal, 19 per cent powdered egg meal and 13.1 per cent dog ration.
9	36.5 per cent chicken mash, 28.5 per cent dried clam meal, 3.8 per cent powdered egg meal, 31.1 per cent dog ration.

Species Combinations

Combinations of species were reared together in an attempt to obtain a greater total production from ponds. Examination of the feeding habits of fish have shown that certain food organisms may be utilized quite extensively while other foods in the environment remain untouched or little used. Competition in many respects is keenest among crowded individuals of the same kind because they need and strive for essentially the same food, spawning places, and other life necessities. When only one species of fish is present in an environment the unused niches represent a lose to maximum fish production. Combinations of fish species having unlike habits tend to fill these unused niches by cropping off a greater number and variety of the food organisms present in the pond. A considerably greater total fish production per water area results.

In most localities fishermen prefer to buy minnows of a certain size and kind. The operator raising bait fish combinations will be forced to sort the harvest, which entails considerable labor. Significant mortalities may occur during sorting, depending on temperatures, size of fish, or amount of handling required by the sorting facilities available. In some instances the increases in production resulting from rearing mixed species did not justify the added labor and loss of fish.

Overwintering Bait Fishes

The spawning activities of most bait minnows do not occur until late spring in southern Michigan waters. The growth rate of the new fry in the experimental ponds was fast enough so that a limited amount of bait suitable for the smaller game fish species could be grown in time for late summer and fall fishing of the same year.

Under the methods and population densities employed in the investigations a minimum of one growing season was necessary to rear bait fishes to the customary three inch length used for bass and the five inch size used for pike fishing. Most fishes raised for pike bait must be held two growing seasons. As a consequence the propagator intending to supply pike fishermen or any early season fishing needs, must maintain large populations of minnows through the winter.

The overwintering results given in this report for the various species were obtained from rearing ponds of the usual type. Shallowness, aquatic vegetation, and silt deposits were common characteristics. These waters are not ideal for overwintering and it is assumed that better, more consistant results would be obtained from ponds designed specifically to overwinter fish. The European carp industry long ago found it necessary to utilize special wintering ponds in climates similar to that of southern

Michigan (Schaeperclaus 1933). Waters with a 9 foot depth or more, a constant flow of aerated water, negligible amounts of aquatic plants and organic bottom mud deposits, make good overwintering ponds. The quantity of oxygenated, inflowing water is probably the most important single factor to successful overwintering since accumulations of plants or organic muds can be removed and a large inflow compensates somewhat for less depth.

Other methods preventing oxygen depletion in shallow waters have been used. One of the most practical methods is mechanical snow removal which permits the penetration of enough sunlight for the photosynthetic action of plants.

Dobie (1948) cites some work done by John O'Donnell of the Wisconsin Conservation Department who used the heat absorbing power of soot to remove the unwanted snow cover. A pond receiving a light soot covering melted 6 inches of snow and 3 inches of ice during two cold sunny days with a subsequent jump in the dissolved oxygen from 2.4 to 7 parts per million.

European food fisheries in cold climates are protected from winterkill by the construction of a heavy plank framework just below the normal water level of the special overwintering ponds (Schaeperclaus 1933). After the ice forms around the framework the water level is lowered which forms an air space. This method is reported to prevent winterkill and provide access to the fish for winter harvesting. A subsistence diet is usually provided.

Harvesting the Minnows

Nearly all of the ponds used in these minnow investigations were equipped with drains which greatly facilitated the harvest of the fish crop. The pond water was allowed to drain slowly from the outlet pipe enabling the fish to retreat to deeper water with less tendency of becoming stranded or entangled in the pond vegetation as the waters receeded. Where the aquatic vegetation was dense a large area of the deepest water adjacent to the drain box was cleaned of vegetation and escape channels radiating from this area to the shallow regions of the pond were made (Figure 4). As much as thirty-three hours of labor per acre may be required to prepare heavily weeded pond basins for the final phases of draining.

The method used to take the minnows from the pond was dependent upon the construction of the drain. Figure 5 illustrates the method used where the pond drain pipe was long. A 30 foot minnow seine supported vertically on a pole provides an effective barrier to the drain valve within the pond basin. The fish were caught in scap nets and transferred to tubs as they collected against the seine. Ponds having short drain pipes emptying into other ponds or small streams were cropped as shown in

Figure 6. A crib framework was constructed to support a large seine horizontally just below the outlet end of the drain pipe. The seine leads when tied around the exposed end of the drain pipe form a net to receive the minnows. This latter method harvests minnows in better condition and requires less labor than any other method used.

Partial population removal can be accomplished with lift nets, seines or glass traps but the value of drainable ponds cannot be overemphasized when total populations are to be removed.

Harvest mortalities are materially reduced if cool days are selected for the pond draining operation.

Figure 4: Preparing a Heavily Weeded Pond Basin for Final Draining.

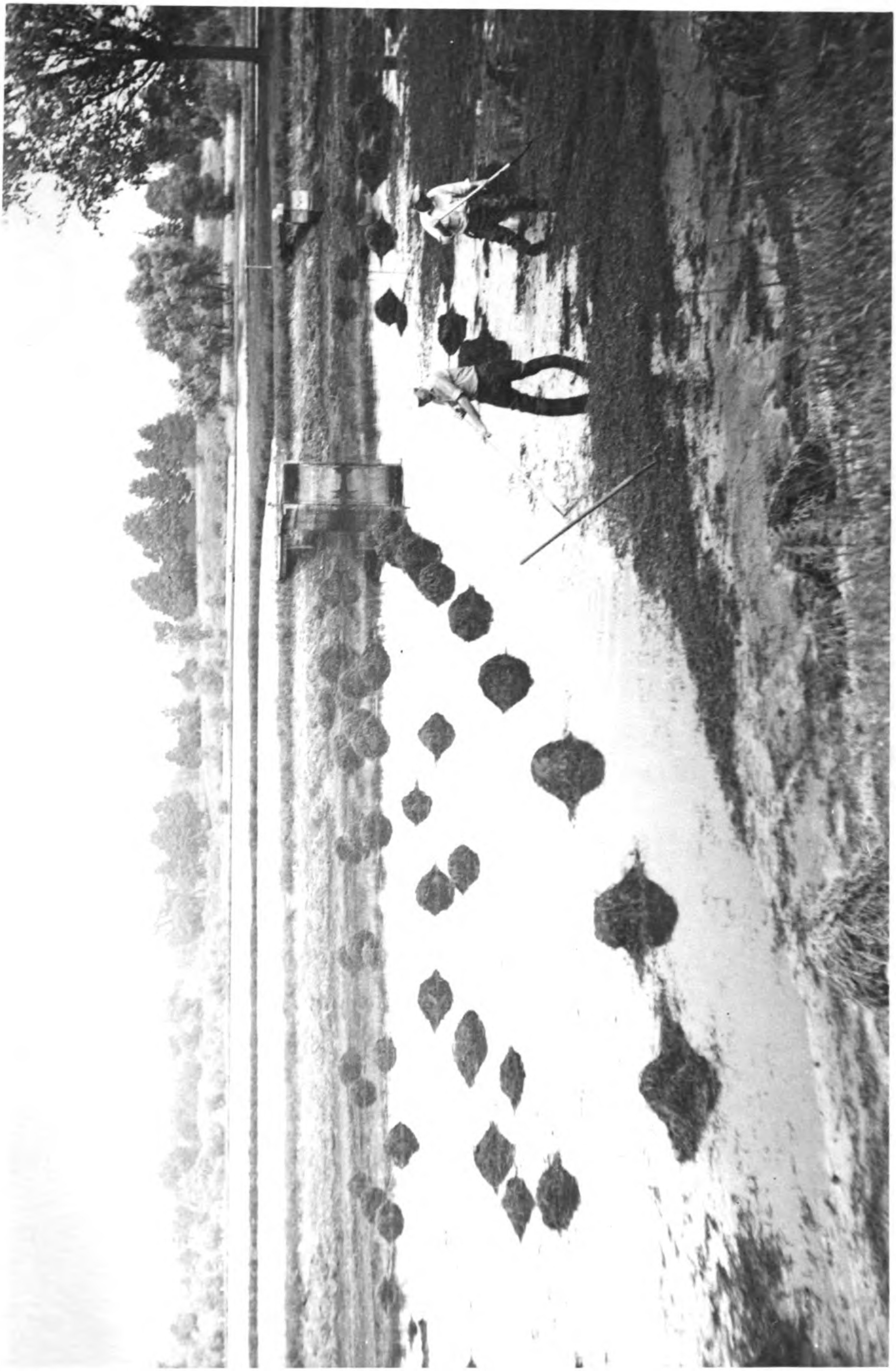


Figure 5: Harvesting the Minnow Crop Within the Pond Basin at the Drain Box.

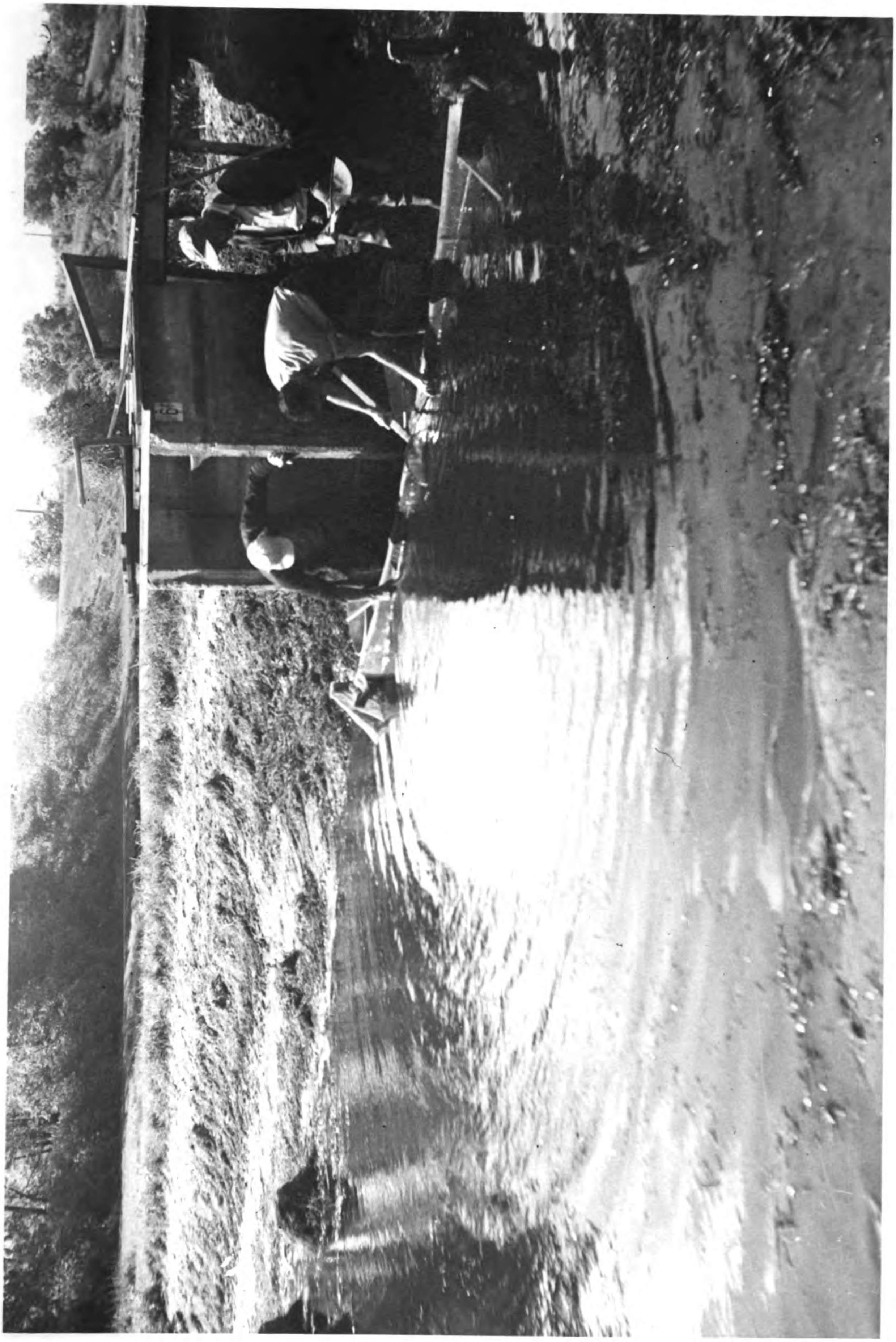


Figure 6: Harvesting the Minnow Crop
at the Drain Pipe Outlet.

LIFE HISTORIES AND PRODUCTION DATA OF THE MAJOR BAIT MINNOW SPECIES

The Northern Creek Chub

The creek chub or "horned dace" is an excellent bait minnow. It is an active swimmer, tenacious of life, and more tolerant to handling than most other bait fishes. The dusky, olive-green coloring of the back, shading to the steel blue sides and silvery bottom give this fish attractive coloring.

Life history

The natural habitat of the chub is the swift to moderately flowing creek having a rock and sandy bottom. The species shows a preference for small streams over larger streams, swift to moderate current over a slow to stagnant current, and rock and sand bottoms over mud bottoms. Populations may be found in lakes with inlets or outlets.

Reproduction of the species occurs only where breeders have access to flowing water over a gravel bottom. Spawning season begins around mid-April in southern Michigan at temperatures of about 55° F.

and may extend through the month of June in the Upper Peninsula. Spawning activities cease at temperatures below 51° F. The spawning period in any one locality usually lasts about four weeks. Preparatory to mating, the male builds a small concavity by transporting pebbles in his mouth and piling them at the upstream edge of the depression (Hubbs and Cooper 1936). The male lies in wait in this depression, fending off fishes entering the territory. A female enters the concavity below the mound and the male embraces her in the U-shaped curve of his body aided by his nuptial tubercles. Eggs and milt are emitted simultaneously. The male then covers the eggs with gravel filling the old depression and creating a new one adjacently down stream. Nests continue to grow in this fashion as the males mate with other females or the same female on a later date. Finished nests, oriented with the current, consist of gravel ridges several inches deep, a foot or so wide, and may be as long as 10 to 15 feet. Females of 5 to 6 inches in length produce 2,000 to 4,000 eggs.

The chub is one of the larger minnows occurring in Michigan, reaching a length up to 12 inches with sizes of 6 to 8 inches being much more common. In natural habitats, Greeley (1930) reports a growth of 2 to 3 inches for the first year and the attainment of a 4 to 7 inch size during the fourth year. The females and males matured in the fourth and fifth year respectively. The growth potential of the chub is considerably greater than this however since a population has shown an average growth of 4.7 inches in a 118 day growing season in ponds. Of this group approximately one third were more than 5 inches in total length and two thirds were between 4 and 5 inches. The average growth was .3 inches per week through July and September. Since the attainment of a certain size is probably more important to maturity than age, these chubs would nearly all be ready to spawn by the second year.

Records reveal a longevity of 6 to 7 years for some individuals.

Producing the chub

Methods of propagation.--Since chubs do not spawn in ponds, the fry stock must be obtained by artificial methods. Three methods for propagation have been used and brief descriptions of these methods are presented.

Propagation can be achieved by introducing adult spawners into a raceway designed to provide spawning facilities. (Clark 1940, Washburn 1948). Eggs may be left in the redds in the raceways and the resulting fry allowed to move into a rearing pond at the base of the raceway. An alternate method is to remove the eggs from the redds, placing them in hatching jars for further development and hatching. Such raceways necessitate a sizable, constant flow of water and are expensive to build. This method of propagation is laborsome, the mortality of the eggs is high, and since the adults spawn over an extended period the fry are not available for distribution at any one time.

Attempts to propagate chubs by stripping adults were unsatisfactory. Mortality or injury to the breeders resulted and very few eggs were obtained.

At the present time the most successful way to obtain chub fry on a large scale is by use of pituitary injections (Bacon, 1951 ms.). Male and female chubs in the spawning condition are given an injection in the abdominal cavity with a carp pituitary suspension. The suspension brings the adults to a ripened condition enabling nearly all of the fish to be stripped within 48 hours. The resulting eggs are impregnated, water hardened, washed and placed in jars receiving a gentle inflow of water. Incubation lasts approximately 11 days at 56° F. Sac fry are transferred to a trough where development to the advanced fry stage is reached. Several egg lots incubated as described resulted in a 76 per cent hatch.

Stocking the rearing ponds.--Chub production necessitates the introduction of chub fry to the waters of rearing ponds. The survival results from ponds stocked with sac fry or advanced fry show distinct advantage in stocking advanced fry. Approximately 60 per cent of the chubs stocked as advanced fry survived and were present at draining, whereas only 9 per cent remained from the sac fry plantings (Table 2).

The establishment of proper stocking rates is very important since there is a trend toward an inverse relationship between size and numbers of fish produced in a pond (Figure 7). Even ponds similarly constructed and having a common water source often vary in the number or weight of organisms they will produce. A particular pond usually possesses characteristics which favor some species of bait minnows more than others. Good pond management requires the consideration of these inherent pond characteristics when stocking rates are formulated.

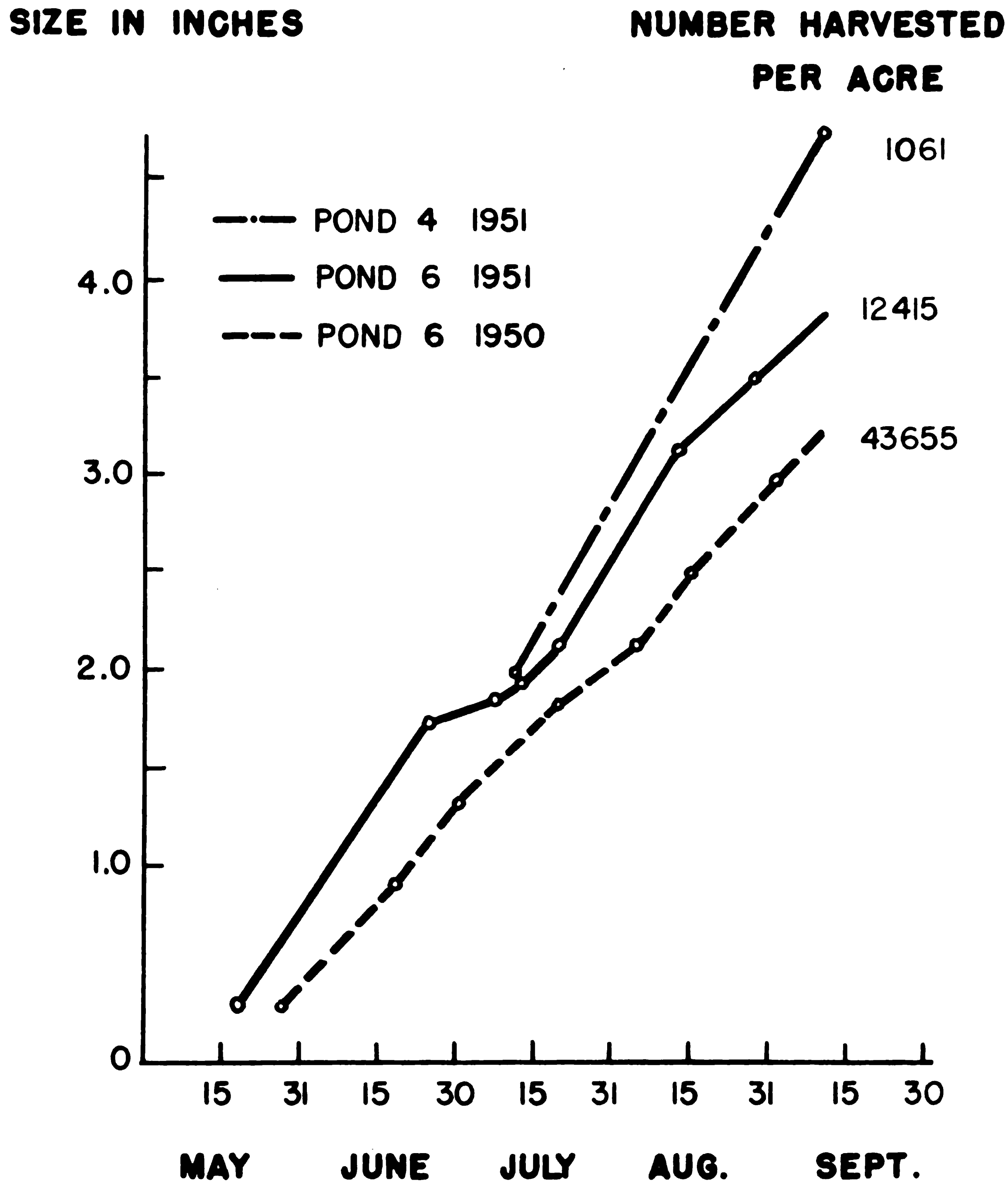
Whenever the producing capacity of pond waters is increased, either indirectly through the use of fertilizer or directly by adding food, the stocking rates can be revised upward. The phenomenon of inverse relationship between size and numbers of bait minnows produced by a pond allows further stocking rate increases when greater numbers of smaller fishes are desired. Optimum stocking rates for individual ponds can be determined through a

Table 2: Survival Rate of Chubs Stocked as Sac Fry and Advanced Fry.

Pond location	Pond number	Pond acreage	Stocking rate per acre	Harvest per acre	Fry stage introduced	Per cent survival
Drayton Plains	3	.46	38,700	19,873	Advanced	51.4
	4	.48	32,000	23,346	Advanced	72.9
Hastings	6	.40	75,000	43,655	Advanced	58.2
Wolf Lake (raceways)	2,5,8,11	.16	100,000	46,356	Advanced	46.3
Hastings*	2	1.00	50,000	10,454	Sac	20.9
	6	.40	75,000	12,415	Sac	16.5
	5	1.40	15,000	300	Sac	2.0
	12	1.50	10,000	145	Sac	1.5
	6	.40	52,500	9,625	Sac	18.3
	2	1.00	25,000	4,410	Sac	17.6
	8	.98	35,000	1,338	Sac	3.8
	10	1.00	35,000	2,880	Sac	8.2
	7	1.11	25,000	248	Sac	1.2
	11	1.25	25,000	67	Sac	.3

* Two years data from Hastings Pond 6 and 2.

Figure 7: Inverse Relationship Between Size and Numbers of Bait Minnows Produced in a Pond.


SIZE IN INCHES
NUMBER HARVESTED PER ACRE
POND 4 1951
POND 6 1951
POND 6 1950
1061
12415
43655
4.0
3.0
2.0
1.0
0
15
31
15
30
15
31
15
31
15
30
MAY
JUNE
JULY
AUG.
SEPT.

process of increasing or decreasing the recommended rates until the desired size of bait minnow is produced.

Occasionally the fry may be produced in places distant from the rearing ponds. Trials showed that fry can be transported in 10 gallon milk cans without aeration for 3 or 4 hours at temperatures of about 50° F. but not exceeding 60° F. As many as 50,000 fry may be carried in each milk can without significant loss.

The actual stocking procedure is simple but utmost care at this time will pay dividends. If wide differences in water temperatures exist between the pond water and water in the transfer can, the container should be placed in the shallow water of the pond for a period of time to allow gradual tempering of the fry and ultimate transfer to the pond water with little shock to the fishes. The fry and water may then be gently poured from the transfer can into a smaller basin, and in turn distributed to the shallow waters of the pond. When this is accomplished without wading, suffocation loses caused by stirring up bottom mud and silt do not occur (Figure 8).

With consideration for the natural spawning requirements of this fish and supporting experimental evidence, the stocking of the fry should be made over the gravel shoal areas of ponds if they are present. Greater mortalities occurring from plantings in silty, weedy ponds is believed

Figure 8: Stocking a Pond with Chub Fry.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HASTINGS
MICHIGAN

to result from suffocation of the heavy sac fry or predation by aquatic insects. Predation has been observed on several occasions in weedy ponds where greater populations of insects exist. In weedy, silt bottomed ponds, specially constructed devices or beds to receive the fry stock might help to increase the survival rate.

Chub production in fertilized and non-fertilized waters.--A series of 10 ponds was used to measure the effect of fertilization on chub production. The chub harvest from the four ponds receiving the fertilizer averaged 65.4 pounds to the acre more than the harvest taken from the non-fertilized waters.

Chub mortalities were slightly less in fertilized waters. Stocked sac fry survived 3 per cent and advanced fry 1.2 per cent better in the fertilized ponds.

Enrichment of the waters seemed to be more effective in increasing crayfish-tadpole production since the harvest of these organisms from fertilized waters was nearly five times that taken from waters not receiving fertilizer.

A summary of the chub production from fertilized and non-fertilized ponds may be seen in Table 3.

Organic (manure) and inorganic (commercial 10-6-4) fertilizers were used. Ponds fertilized with manure, received 1320 pounds per acre before the fish were stocked and 200 pounds per acre of 10-6-4 in three applications through the summer. Other ponds were fertilized exclusively

Table 3

Summary of Production in Fertilized and Non-Fertilized Chub Ponds

Organisms	Non-fertilized pond averages*	Fertilized pond averages**
Chubs		
numbers/acre	15,300	71,700
pounds/acre	80.4	145.8
total length (inches)	2.6	2.9
per cent survival		
sac fry	7.0	10.0
advanced fry	51.8	53.0
Miscellaneous (crayfish-tadpoles)		
pounds/acre	39.9	195.0
Total organisms		
pounds/acre	120.6	340.8

* 6 ponds

** 4 ponds

with 10-6-4. The greatest production of bait minnows for this series of fertilized ponds occurred where a total of 1250 pounds of 10-6-4 per acre were introduced by three applications.

The optimum advanced fry stocking rates per acre for the experimental fertilized and non-fertilized chub ponds, based on average production and survival are given in Table 4. Pond owners will need to modify these stocking rates to suit their own local conditions.

Table 4

Advanced Chub Fry Stocking Rates Based on Average Production From Fertilized and Non-Fertilized Ponds

Fertilized ponds** per acre Stocked	Fertilized ponds** per acre harvested	Approximate total length at harvest (inches)	Non-fertilized ponds* per acre stocked	Non-fertilized ponds* per acre harvested
88,000	46,600	2	50,600	25,800
30,200	16,000	3	17,400	8,800
3,300	1,700	5	1,900	960

** Average production 145.8#, 54% survival, 123 growing days

* Average production 80.7#, 51% survival, 125 growing days

Chub production by direct feeding.--Most of the chub feeding experiments were carried on in raceways. Cereal, meat-cereal combinations and a commercial chick starter were used as feed.

Diet 1 (composition 65 per cent liver and 35 per cent cereal) proved superior to the others fed in these chub experiments. A large harvest resulted and a relatively small amount of food was supplied for each pound of fish produced. An attempt was made to feed the fish in two raceways (Races 11 and 12) all they would eat within a two hour period. In comparison, chubs in another raceway (Raceway 10) were fed half as much food. The harvest from the three raceways show a decreasing efficiency with the higher feeding rates (Table 5). In this connection it should be remembered that the natural productive capacity of a pond becomes progressively less important to the harvest with increased feeding rates. Miscellaneous organisms, such as crayfish and tadpoles, composed approximately 20 per cent of the total harvest from the raceways supplied with food at the heaviest rate. This same group of organisms made up only about 9 per cent of the harvest from the raceway supplied with half as much food. On an acre basis, Raceway 11 and 12 received 400,000 fry while Raceway 10 was stocked with 200,000.

Diet 2 composed of 54 per cent liver and 46 per cent cereal, did not prove efficient. The high rate of feeding, small average size of minnows produced, and total production

Table 5: Results Obtained by Feeding Chubs in Raceways.

Raceway number	Diet used*	Chubs per acre numbers	Chubs per acre pounds	Average size	Pounds per acre fed	Pounds food supplied per pound of fish harvested
10	1	178,425	975	2.6	7,125	7.3
11	1	134,550	1,150	2.9	14,250	12.4
12	1	354,125	1,662	2.5	14,250	8.5
7	2	294,925	1,175	2.3	22,000	18.7
8	3	120,050	350	2.1	22,000	62.9
2	4	42,100	265	2.8	1,300	4.9
8	4	29,175	317	2.8	1,300	4.1
11	4	83,600	440	2.3	1,300	2.9

* Diets

1. Composed of 65 per cent liver, and 35 per cent cereal
2. 53.9 per cent liver, 46.1 per cent cereal
3. 100 per cent cereal
4. Wayne Chick Starter (Allied Mills, Inc).

are the basis for the assumption. The stocking rate was 1,000,000 fry per acre.

Diet 3 (100 per cent cereal) did not give comparable results to either of the preceeding diets. A heavy feeding schedule with this food produced an inferior crop with regards to the total weight of minnows harvested and average length attained by the fish. The stocking rate was 1,000,000 fry per acre.

Diet 4 (Wayne Chick Starter, Allied Mills, Inc.). A much lower rate of feeding, in this case, make direct comparisons with other diets difficult. The effect of this food on the production of bait minnows was compared to the harvest obtained from a raceway stocked at the same rate (100,000 fry per acre) but receiving neither feed nor fertilizer. The three Wolf Lake Raceways fed Diet 4 averaged 340 pounds of minnows to the acre with the fish attaining an average total length of approximately 2.6 inches. The raceway not supplied with food produced 235 pounds of minnows of 2.6 inch average size. The difference in these crops is presumably the result of feeding and on this basis about 12.0 pounds of food was supplied for each additional pound of minnows harvested from the raceways receiving the food. This ratio of pounds of food to pounds of fish produced compares favorably with diets containing fresh meat. Some loss in efficiency due to heavier feeding rates would probably take place.

Details and production results from feeding chubs in raceways may be found in Table 5.

Miscellaneous organisms, such as crayfish and tadpoles, composed approximately 18 per cent of the total production from artificially fed raceways. This was considerably less than was obtained from fertilized or non-fertilized waters (Table 6).

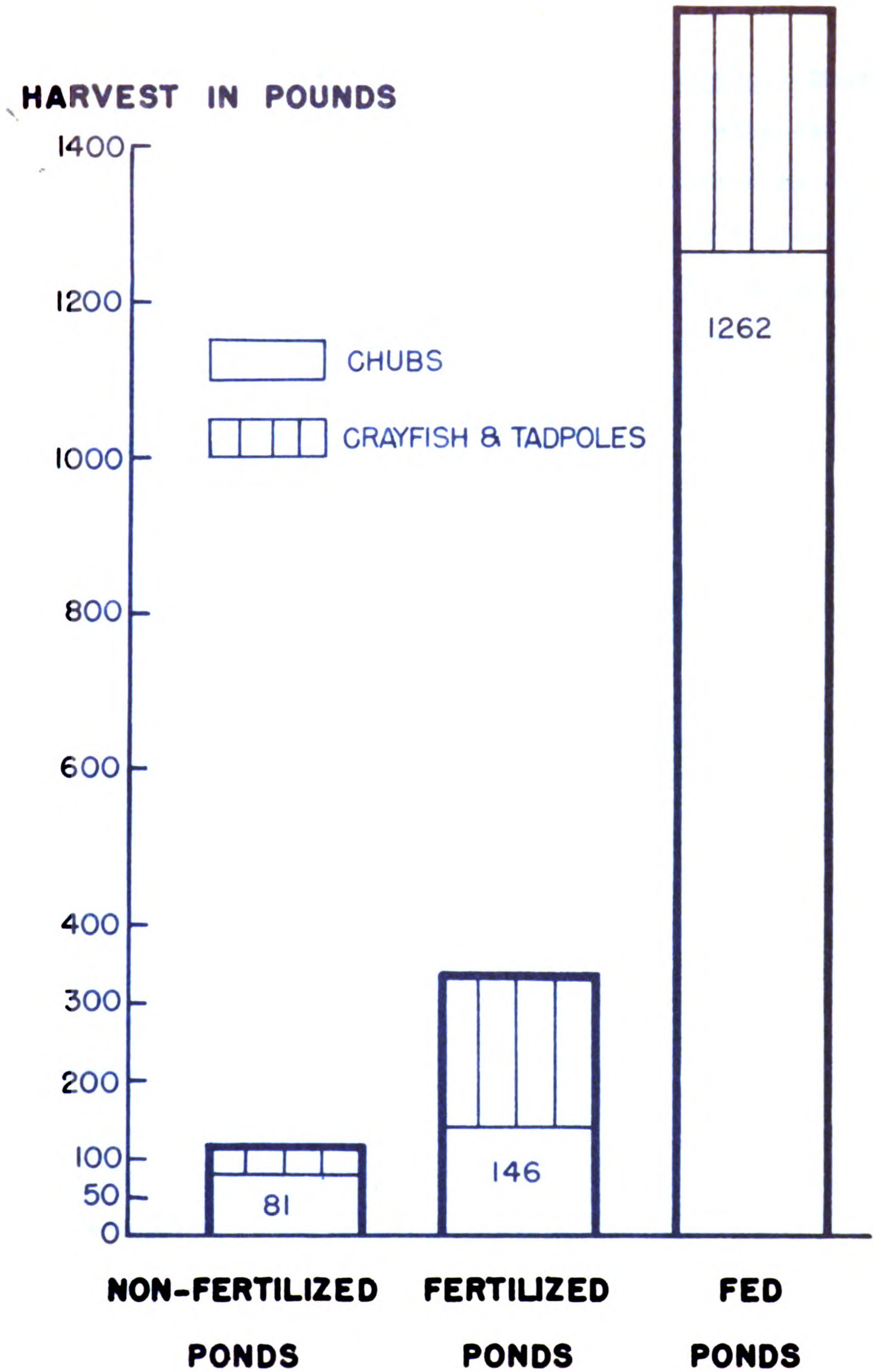
Table 6

Crayfish and Tadpole Production from Waters Non-Fertilized, Fertilized, and Fed

Pond Management	Observations	Per cent of total pond production
Non-fertilized	6	33
Fertilized	4	57
Fed	7	18

The production in pounds per acre obtained by feeding (Diet 1) as compared to the production averages from fertilized and non-fertilized ponds may be seen by reference to Figure 9.

Figure 9: Northern Creek Chub Production from Waters Non-Fertilized, Fertilized, and Supplied with Food.


HARVEST IN POUNDS
1400
1200
1000
800
600
400
300
200
100
50
0
CHUBS
CRAYFISH & TADPOLES
81
146
1262
NON-FERTILIZED PONDS
FERTILIZED PONDS
FED PONDS

Chub and fathead production reared in combination.--Chubs were reared in combinations with suckers and fatheads.

The chub-fathead combination was attempted as a method of providing food for chubs in the form of fathead fry. A one-acre pond was stocked with 50,000 chub fry and 1400 adult fathead minnows. A good crop of minnows suitable for perch and bass fishing was harvested four months later (Table 7).

Table 7

Production of Chubs and Fatheads Reared in Combination

	Chubs	Fatheads
Numbers stocked	50,000 (fry)	1400 (adult)
Numbers harvested	10,454	71,564
Pounds harvested	103.5	121.5
Average harvest size (in.)	3.2	1.7

Chub stomach samples taken in August revealed identifyable fathead rib-bones, scales, and pharyngeal arches with teeth, in 15.5 per cent of the fish examined. The chubs were often observed under fathead spawning boards containing nests and many newly hatched fathead were undoubtably utilized even though they were not found in the stomachs. Fish eating the fry had little else in their stomachs. The predilection however, was for insects since nearly all chub stomachs contained them inspite of the more abundant fathead fry. Three hundred pounds of 10-6-4 fertilizer was added to the pond during the summer.

The production resulting from the chub and sucker combination is discussed under sucker production.

Overwintering chubs.--Chub populations were overwintered in two ponds (Table 8). Of the 22,712 fish placed in the ponds during the fall, 64.8 per cent survived to be harvested the next spring.

One of the ponds contained rich deposits of organic muds and quantities of aquatic vegetation yet about 89 per cent of the fish population wintered successfully. The continual flow of fresh water through this pond was probably a factor contributing to the high survival rate.

Preliminary studies of chub mortalities occurring in the latter half of the first year growing season show a 75 per cent survival for the 9 week period (July to September) suggesting that mortalities may usually be less during the fall and winter than they are for corresponding periods during the growing season. Extreme winter weather may eliminate an entire fish population in ponds if the oxygen is exhausted or becomes too low to support fish.

Table 8

Overwinter Survival of Creek Chubs in Ponds

Introduced in Fall				Spring Recovery	
Pounds per acre	Average size (inches)	Number per acre	Pond	Per cent survival	Average growth
182.6	2.7	14,960	6	88.9	.3
152	3.7	5,500	5	40.8	.2

The Common White Sucker

The young of this species up to 8 inches in length are natural food for pike and pikeperch. Fishermen desiring a large bait fish for still fishing or an excellent decoy for winter spearing activities, depend heavily on supplies of young suckers. The sucker survives for long periods of time when hooked properly and is suited to artificial propagation. Growth is fast in warm waters where adequate food is available. The sucker has a dusky back and sides with creamy white underside.

Life history

The sucker inhabits the bottoms of lakes and streams. Sluggish currents over sand and mud bottoms are environmental conditions where suckers thrive best.

Under natural circumstances suckers usually migrate to tributary waters to spawn in the clear, swift, riffles over gravel bottoms. Shallow wind swept shoal areas of lakes are also used in many instances. Spawning begins early in April in southern Michigan. No nest is built nor parental care of the eggs or young exercised.

Suckers are prolific with females of 14 to 16 inches containing an average of 67,000 eggs per fish (Vessel, Matt and Eddy 1941).

The growth rate potential of the sucker is considerably greater than might be expected on the basis of studies of these fish in natural habitats. Populations exceeding an average length of 8 inches have been raised in ponds within 149 days while growth in natural environments for a corresponding period is usually much less. Adults reach an age of 10 years (Bean 1936), 22 inch length, and 5 pounds weight (Forbes and Richardson, 1920). Suckers of 15 to 18 inches are common to many places in Michigan.

Producing the sucker

Methods of propagation.--Suckers produced in rearing ponds must be introduced to the waters as eyed eggs or fry. Attempts to stock a rearing pond with 16 adult spawners yielded 8,511 young suckers in one instance and 13 spawners produced 6,800 young on another occassion yet other ponds stocked at the same rate produced no young. The uncertainty of adults to produce young in ponds combined with the difficulty of predicting and controlling the stocking rate per acre, made it advisable to resort to other propagation methods. At the present time sucker young are obtainable in two ways.

1. Fertilized eggs may be collected from natural spawning places. A sufficient population of suckers congregating in suitable spawning areas of small streams sometimes

make egg collection possible or eggs can often be gathered from wind swept shoal areas of lakes where suckers are spawning in large numbers. Following collection, the eggs should be screened to remove the intermingled gross debris.

2. Eggs may be obtained by stripping ripe adults netted during the spawning season. The eggs procured are impregnated, water hardened, and placed in jars. Two to three quarts of eggs may be incubated in a standard hatchery jar supplied with running water at the rate of one to two gallons per minute, depending on water temperature. A two week incubation period with temperatures in the low fifties is required to bring developement to the hatching phase. Suckers hatch in the jars and swim out through the jar lip collecting in a tank provided for that purpose. Feeding or stocking must follow within 4 days if heavy mortality is to be avoided.

The survival of many thousand eggs from several lots gathered along lake shoal areas or obtained by stripping adults ranged between 50 and 59 per cent.

Preliminary attempts in Michigan to obtain sucker eggs by the pituitary injection method have not been entirely satisfactory. However, inasmuch as some positive results have been obtained (Bacon 1951), the technique holds promise for refinement making it practical for sucker propagation.

Stocking rearing ponds.--Experimental ponds were stocked with eyed eggs or free swimming fry.

Eyed eggs were stocked principally in the early phases of these investigations. Trays on legs placed in shallow pond waters received the eyed eggs. (Eggs disturbed after water hardening up to the time the eye spot developes, are very likely to suffer heavy mortalities). The eggs were deposited on these trays just prior to hatching at rates as high as one pint (approximately 15,000 eggs) per square foot of tray bottom area. Covers help to prevent predation within the trays. The fry escape through a 14 X 18 mesh screen after hatching and consequently a smaller mesh is better to retain the fry where pond bottoms are silty. Average survival rates for ponds stocked with 420,000 eyed eggs was 9.5 per cent.

Much better survival rates were obtained when ponds were stocked with advanced sucker fry. These ponds had an average survival of 29 per cent.

Eyed eggs or fry may be transported for considerable distances with little difficulty. Ten gallon milk cans containing eggs or fry in water at temperatures from 46° F. to 56° F. maybe transported without appreciable loss. Fifty thousand sucker fry per container experience negligible loss when transported without aeration for three or four hours and at 2,000 fry per container little loss occurred for periods of 15 hours.

<u>Sucker production in fertilized and non-fertilized waters</u>.--In all, twenty eight ponds and raceways were used to raise suckers in non-fertilized and fertilized situations. A comparative study of the results from these waters indicates that suckers respond well to a fertilization management program.

In one experiment, a series of six ponds were stocked similarly but three received 10-6-4 fertilizer at the rate of 370 pounds per acre. The average production for the fertilized ponds was 68.8 per cent greater than the non-fertilized controls (Table 9).

In another experiment six raceways were used. Three of the six raceways received 10-6-4 fertilizer at the rate of 1200 pounds per acre. An attempt was made to regulate the inflow of water to equalize seepage and evaporation. The differences in production obtained from the fertilized and control ponds was 187.5 pounds per acre. The greater harvest came from the fertilized raceways and was 115.4 per cent of the average non-fertilized raceway production (Table 10).

A summary comparison of all fertilized and non-fertilized sucker waters was made. The 14 sucker ponds, of which half were fertilized, shows that the enriched waters produced a 31.4 per cent larger crop. Four fertilized raceways yielded a crop of suckers that was 72.5 per cent greater than production from the 3 non-fertilized races. Collectively

Table 9

Sucker Production in Fertilized and Non-Fertilized Ponds

Non-fertilized ponds				Fertilized ponds		
Length (inches)	Number per acre	Pounds per acre	Ponds	Length (inches)	Number per acre	Pounds per acre
7.0	292	34.1	--11 7--	6.7	1,902	205.8
3.4	5,340	102.4	--17 9--	8.2	490	100.6
3.8	5,760	96.2	-- 5 4--	3.3	8,236	86.7
3.7	3,798	77.6	Average	4.1	3,543	131.0

Table 10

Sucker Production from Fertilized and Non-Fertilized Raceways

Non-Fertilized Raceways			Raceways		Fertilized Raceways		
Length (inches)	Number per acre	Pounds per acre			Length (inches)	Number per acre	Pounds per acre
3.4	17,100	262.5	--4	1--	2.7	17,525	162.5
3.7	5,425	125.0	--5	2--	3.0	42,850	450.0
4.3	2,975	100.0	--6	3--	2.9	43,750	437.5
3.5	8,500	162.5	Average		2.9	34,375	350.0

the fertilized waters produced a crop of fishes 54 per cent greater than the non-fertilized waters. Production details for the 21 sucker waters can be found in Table 11. Seven waters producing less than 29 pounds of fish to the acre were not included in these discussions.

Apparently the fertilization of sucker waters promotes higher survival rates when eyed eggs and advanced fry are stocked (Table 12).

Table 12

Survival of Sucker Eggs and Fry

Non-Fertilized Waters		Fertilized Waters	
Per cent survival		Per cent survival	
Eyed eggs--	Advanced fry	Eyed eggs--	Advanced fry
4.8	6.9	13.1	29.6

<u>Sucker</u> <u>production</u> <u>from</u> <u>waters</u> <u>directly</u> <u>fed</u>.--Six diets were employed in sucker feeding experiments.

Diet 3 (100 per cent cereal) produced a greater minnow harvest in pounds per acre than other diets used in the raceway feeding experiments. The harvest was 1,487.5 pounds of suckers to the acre. Nearly 15 pounds of this diet were placed in the raceway for each pound of suckers removed

Table 11

Comparison of Sucker Production from Fertilized and Non-Fertilized Waters

Harvest		Non-Fertilized waters	Fertilized waters	Production increases due to fertilization (pounds)	(per cent)	Average rate of fertilization (pounds/acre)
From Ponds	lbs/acre	111.0	145.9	34.9	31.4	652.3
	no/acre	9,560	118,998			
	av. lgth.	3.1	2.6			
From Races	lbs/acre	162.5	280.3	117.8	72.5	1375.0
	no/acre	8,500	26,776			
	av. lgth.	3.6	2.9			
Ponds and Races	lbs/acre	126.5	194.8	68.3	54.0	917.0
	no/acre	9,242	17,309			
	av. lgth.	3.2	2.8			

at harvest.

Diet 5 (35 per cent beef liver and 65 per cent cereal) was a more costly feed than the all cereal diet due to the meat content and the harvest results were less compensating. Two raceways averaged 1062 pounds of fish to the acre on this diet. Nearly 25 pounds of food was supplied for each pound of fish produced. A third raceway receiving half as much food during the growing season produced 725 pounds of suckers to the acre. Less than 18 pounds of food was fed for each pound of fish harvested in this raceway showing greater efficiency when feeding rates are lower.

Diet 6 (29 per cent liver and 71 per cent cereal) produced small fish as well as a low yield at harvest. The crop of suckers taken from the raceway weighed 675 pounds to the acre and was produced at the expense of providing 32.6 pounds of feed for each pound of fish harvested.

Diet 7 (15.6 per cent horse liver, 78.1 per cent Rowena Chicken Mash, 3.1 per cent Balto Dog Ration and .2 per cent powdered egg meal) was fed to suckers in a small pond. A crop of fishes weighing 578 pounds to the acre resulted. Food was placed in the pond at the rate of 17.9 pounds for each pound of suckers removed at harvest.

Diet 8 (4.7 per cent horse liver, 79.4 per cent Rowena Chicken Mash, 2.6 per cent dried clam meal, 19 per cent powdered egg meal and 13.1 per cent Balto Dog Ration) fed to suckers gave the best results obtained in ponds. A yield of 1,152 pounds of suckers per acre resulted from a pond .41 of an acre in size. Bait minnows of the size used for bass fishing were raised and the ratio of food pounds supplied per fish pound harvested was 6.5 to 1.

Diet 9 (36.5 per cent Rowena Chicken Mash, 28.5 per cent dried clam meal, 3.8 per cent powdered egg meal, 31.1 per cent Balto Dog Ration) was supplied to suckers in two small ponds. The two ponds averaged 549 pounds production to the acre. Food was placed in the two ponds at the average rate of 4.2 pounds for each pound of suckers harvested. The feeding rates per acre were comparatively lower in these instances which may explain in part the low ratio of food supplied per pound of fish removed at harvest.

The production results obtained in these sucker feeding experiments show a parallel relationship between high liver content in the diet and poor food conversion efficiency. Whether this relationship is coincidental or obligatory can not be decided on the limited data presented. The cheaper and more easily fed cereal diets are apparently the better producers.

The miscellaneous harvest of crayfish and tadpoles from raceways and ponds where suckers were fed was 18 per cent of the total production. The results of feeding suckers in ponds and raceways are summarized in Table 13.

Table 13

Data from Feeding Suckers in Raceways and Ponds

Diet	Water area (acres)	Stocking rate per acre	Sucker harvest per acre numbers	- pounds	Average size (inches total length)	Pounds of food supplied per acre
	Raceways					
5	.04	200,000 fry	35,100	725.0	3.4	12,800
5	.04	400,000 "	66,425	1,275.0	3.4	25,600
5	.04	400,000 "	32,700	850.0	4.2	25,600
6	.04	800,000 "	93,150	675.0	2.5	22,000
3	.04	800,000 "	200,825	1,487.5	2.8	22,000
	Ponds					
7	.13	300,000 fry	24,602	578.0	3.8	10,331
8	.41	300,000 "	77,151	1,152.0	3.2	7,598
9	.13	1,385,000 eggs	30,800	461.5	3.2	2,672
9	.41	875,000 fry	91,185	637.0	2.7	1,944

Figure 10 compares sucker production from non-fertilized, fertilized, and artificially fed waters. The results graphed were obtained by averaging the fish production for the respective management programs.

Sucker and chub production reared in combination.--Suckers and chubs were fed and reared together as a means of obtaining better food utilization. Food material unavailable to chubs in the bottom muds are still often accessable to the suckers. Diet 9 was supplied to the fish in a .5 acre pond in this experiment. A good production of bass sized bait minnows resulted (Table 14) and the 6:1 ratio of food supplied per fish pound harvested is evidence to support the recommendation of this method.

Overwintering suckers.--Loses in overwintering sucker populations were calculated for three ponds. Of the 59,322 suckers stocked in the three ponds 57.4 per cent were recovered after overwintering (Table 15). The average growth in the ponds for the eight months period varied from .3 to .8 of an inch. Greatest losses occurred in a shallow pond.

Figure 10: Sucker Production in Terms of Pounds Per Acre for Waters Non-Fertilized, Fertilized, and Supplied with Food.

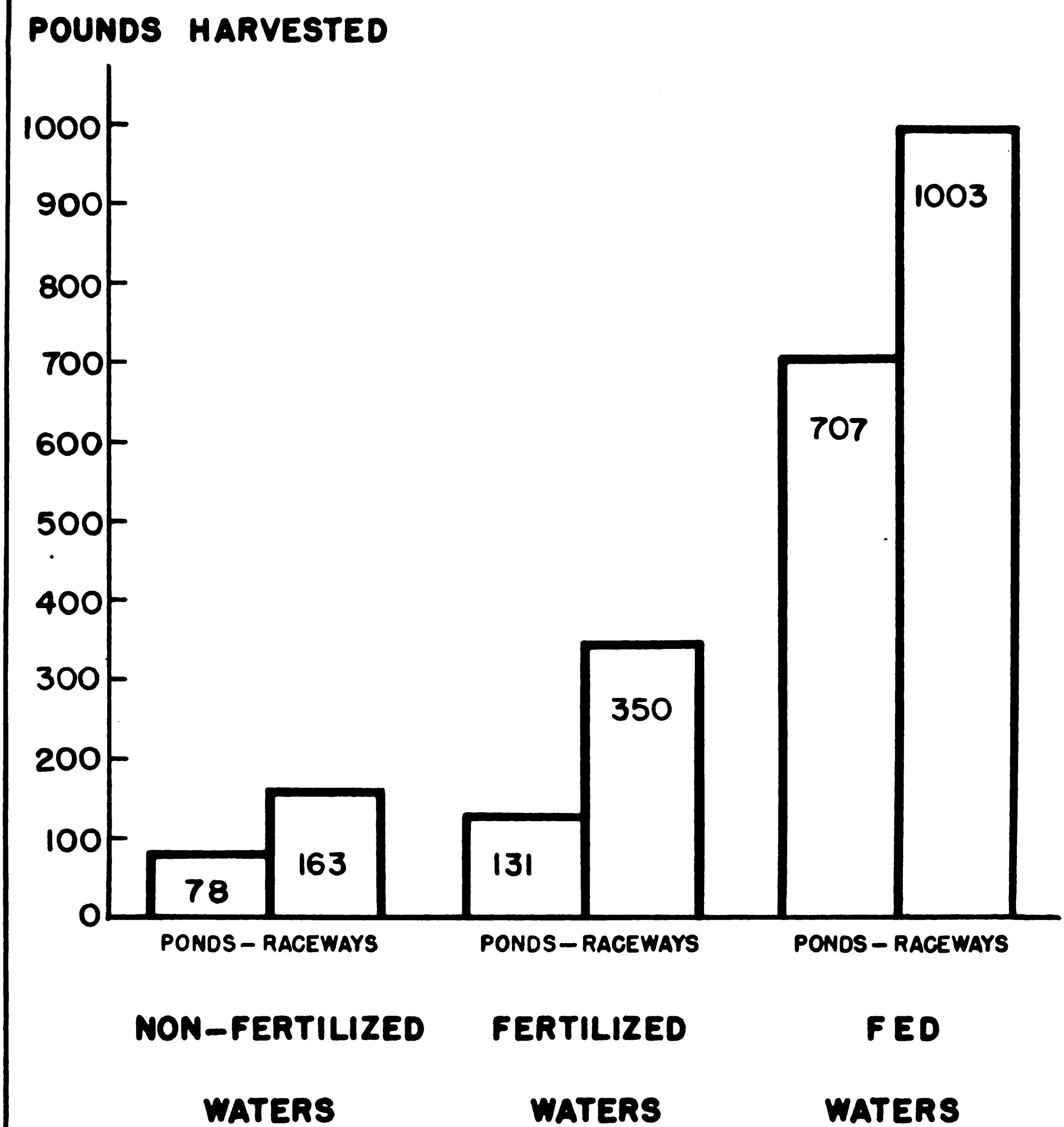

POUNDS HARVESTED
1000
900
800
700
600
500
400
300
200
100
0
78
163
131
350
707
1003
PONDS – RACEWAYS
PONDS – RACEWAYS
PONDS – RACEWAYS
NON–FERTILIZED WATERS
FERTILIZED WATERS
FED WATERS

Table 14

Production Resulting from Feeding

Chubs and Suckers Reared

in Combination

	Chubs	Suckers	Chubs and Suckers combined
Fry stocking rate/acre	33,600	300,000	333,600
Numbers/acre harvested	29,400	72,836	102,236
Pounds/acre harvested	246	570	816
Average length (inches)	2.8	3	--
Growing period (days)	112	138	--
Pounds food fed/acre*			4,955

* Diet 9

Table 15

Overwinter Survival of Suckers in Ponds

Introduced in the fall				Spring recovery	
Pounds per acre	Average size (inches)	Number per acre	Pond	Per cent survival	Average growth (in.)
206	2.0	36,897	4	76.1	.4
150	4.1	12,900	9	85.4	.8
150	4.1	9,525	17	10.6	.3

The Golden Shiner

Many fishermen prefer the "flashy" shiner bait minnows to all others. The golden shiner known also as the roach or bream, is able to withstand conditions of low oxygen better than most of the common bait minnows but is easily subject to mortalities from bruises and fungus growth. The color is an iridescent golden lustre imposed on an olive green back, silvery sides and cream white underside. The fins are yellow.

Life history

The golden shiner is found abundantly throughout most of Michigan. Shallow bays of lakes or ponds having mud bottoms which support heavy growths of aquatic vegetation comprises suitable habitats. Populations may also be found in rivers or creeks especially where currents are sluggish.

The spawning season is prolonged, extending from June to August in southern Michigan. Adhesive eggs are scattered over algae or beds of higher aquatic vegetation in shallow waters. In natural waters of the state this fish reaches a total length of 3 inches during its second summer, 4.5 inches during its fourth, and 5 inches during its fifth summer (Cooper 1936). Females were found to grow faster than males, attain a greater size and live longer. Maturity is reached when a length of 2.5 to 3.5 inches is attained or when reaching an age of 1 to 2 years. Cooper (1936) reported finding some fishes 10 inches in total length and 8 years old.

Experiments with the golden shiner show the growth potential to be considerably greater than that usually occurring in natural habitats. Experimentally, fishes averaging .9 inches when stocked averaged 3.2 inches 62 days later. The size range was from 2.8 to 3.6 inches with 96.1 per cent of the population attaining a 3 inch size or better.

Producing the golden shiner

In southern Michigan the breeders should be placed in rearing ponds by the first of May. Breeding stock should not be selected on the basis of largest size only since females grow larger than males and a preponderance of females would thus be chosen. In the spawning season males may be differentiated from females by examining the back which is somewhat more swollen at the nape. Seven hundred to 1000 breeders averaging 5 inches in total length will populate one acre ponds. Approximately 200 young for each female stocked were harvested in these investigations under favorable circumstances. Local conditions, such as predation and adequacy of the spawning area, exert a great influence on the number of young obtained from each female at harvest.

Attempts to propagate golden shiners in ponds void of higher aquatic plants or matts of filamentous algae were usually unsuccessful. Best results occurred where a dense growth of Anacharis canadensis filled the pond basin. Efforts to stock ponds lacking natural spawning areas by capturing fry from "brood ponds" and transplanting them were generally unsuccessful. The small shiner fry are exceedingly susceptible to injuries and even a short exposure to air produces mortalities. With careful handling, small fishes of .9 to 1.0 inch in length can be transferred without great loses.

Unfortunately, the experimental production data for this fish is limited due to pond drain box failures or instances where spawning was unsuccessful. In these minnow investigations a pond neither fertilized nor fed produced 73 pounds of fish to the acre. No data from fertilized ponds is presently available for comparison but fertilization should be effective as a means of increasing production since Cooper (1936) found rapid growing populations of golden shiners in waters enriched by domestic sewage near Ann Arbor, Michigan.

Two attempts were made to feed golden shiners. Diets 3 and 4 were used with little success. Production details for these ponds may be found in Table 16.

Golden shiners and fatheads were propagated together in four ponds (Table 17). Perch sized minnows were produced in each pond and the average production was 194 pounds per acre. Species sorting of fishes this size proved difficult and time consuming.

Table 16

Golden Shiner Production in Fed and Non-Fed Ponds

Pond management	Adults stocked per acre	Shiner Harvest		
		Pounds per acre	Number per acre	Average size (inches)
Non-fed	560	73	59,286	1.5
Fed				
(182 pounds Diet 4/acre)	700	120	66,066	1.9
(4022 pounds Diet 3/acre)	2,382	100	27,878	2.4

Table 17

Production of Golden Shiners and Fatheads Reared Together

Pond (combination)		Numbers/acre harvested	Pounds/acre harvested	Average length (in.)
2	fatheads	2,759	134	2.5
	golden shiners	23,124		2.2
5	fatheads	32,000	200	---
	golden shiners	37,500		---
2	fathead	129,930	284	1.3
	golden shiner	83,070		1.8
5	fathead	155,613	157	1.4
	golden shiner	9,317		2.3

Overwintering golden shiners.--Golden shiner overwintering data is available from one pond. Of the 283 adults introduced to a pond in the fall, 70.4 per cent by number were recovered the following spring.

Although experimental evidence is limited, golden shiners should winter comparatively well. On the basis of pail holding tests where several species of bait minnows were kept under crowded conditions and low oxygen tensions, the golden shiner survived better than most of the others tested. Young golden shiners lived slightly longer than adults when equal weights of fish were placed in small containers of water.

The Fathead Minnow

The fathead or black-head is one of the easiest minnows to raise in ponds. It is a suitable bait for the smaller piscivorous game fishes. Pail holding tests showed the fathead survived equally as well as did chubs under crowded conditions and low oxygen. This minnow is not highly colored being dark olive or black on the back. The entire body has a dusky appearance.

Life history

The fathead minnow is found most often in creeks and small streams where the current is moderate. Most typical bottom types forming a part of the environment are combinations of sand and rock or mud. Small ponds and lakes may also have considerable populations of fatheads, especially where the competition from other fishes is not keen.

During the breeding season, which extends from May through August in southern Michigan, the males acquire a black head and three rows of horn-like breeding tubercles across the snout. The male selects a small territory possessing a suitable place for egg disposition. Branches, stones, boards, or any object presenting a submerged underside for egg attachment may be used. Males guarding adjacent territories were observed to approach each other cautiously, then turn and back up in a manner bringing the caudal peduncles together. The two swim about with heads apart and tails adjoining forming a V of their bodies. Sculling actions of the tail are accomplished in unison. This ceremonial behavior is usually of short duration, being quickly terminated if other fishes chance to enter the territories under guard of the participating males.

When a ripe female skirts the guarded territory, the male darts out to strike her. A female ready to spawn is herded to the designated place where spawning commences. Males use their tail and pelvic fins to clasp the female and push her around in "cartwheel" fashion. The female wriggles stiffly with the body color becoming noticeably lighter. The spawning embrace may be broken for an instant while the male darts out to strike other females as invitation to the spawning act. If the male is successful in acquiring another spawning partner, he arranges himself to one side of both the females and continues the spawning behavior.

Eggs deposited on the undersides of submerged objects are guarded by males who stroke them with a special spongy dorsal pad. Territories are maintained over a considerable period resulting in nests which contain eggs in many developemental phases from several female breeders.

A few spawners within a favorable environment, are capable of producing prodigious populations of young. As many as 4,144 offspring are known to have been produced by one female that spawned 12 different times in a 68 day period (Markus 1934). Observations at Hastings showed that nesting sites covered areas of 6 to 120 square centimeters and contained up to 2400 eggs. Female egg counts were found to range from 200 to 1,000 eggs (Wascko and Clark 1948). The egg incubation period ranges from four to five days. In southern Michigan, fishes become mature during the second summer of life.

Hubbs and Cooper (1936) give the maximum length of this minnow to be 3 inches for females and 3½ inches for males. The males have the faster growth rate. This should be remembered when choosing brood stock since a preponderance of males is not desirable. The maximum growth under natural situations is usually attained during the second or third year of life. The growth potential is greater under more ideal situations as demonstrated by a population of fatheads stocked at .8 inches and harvested 63 days later at 2.5 inches in length.

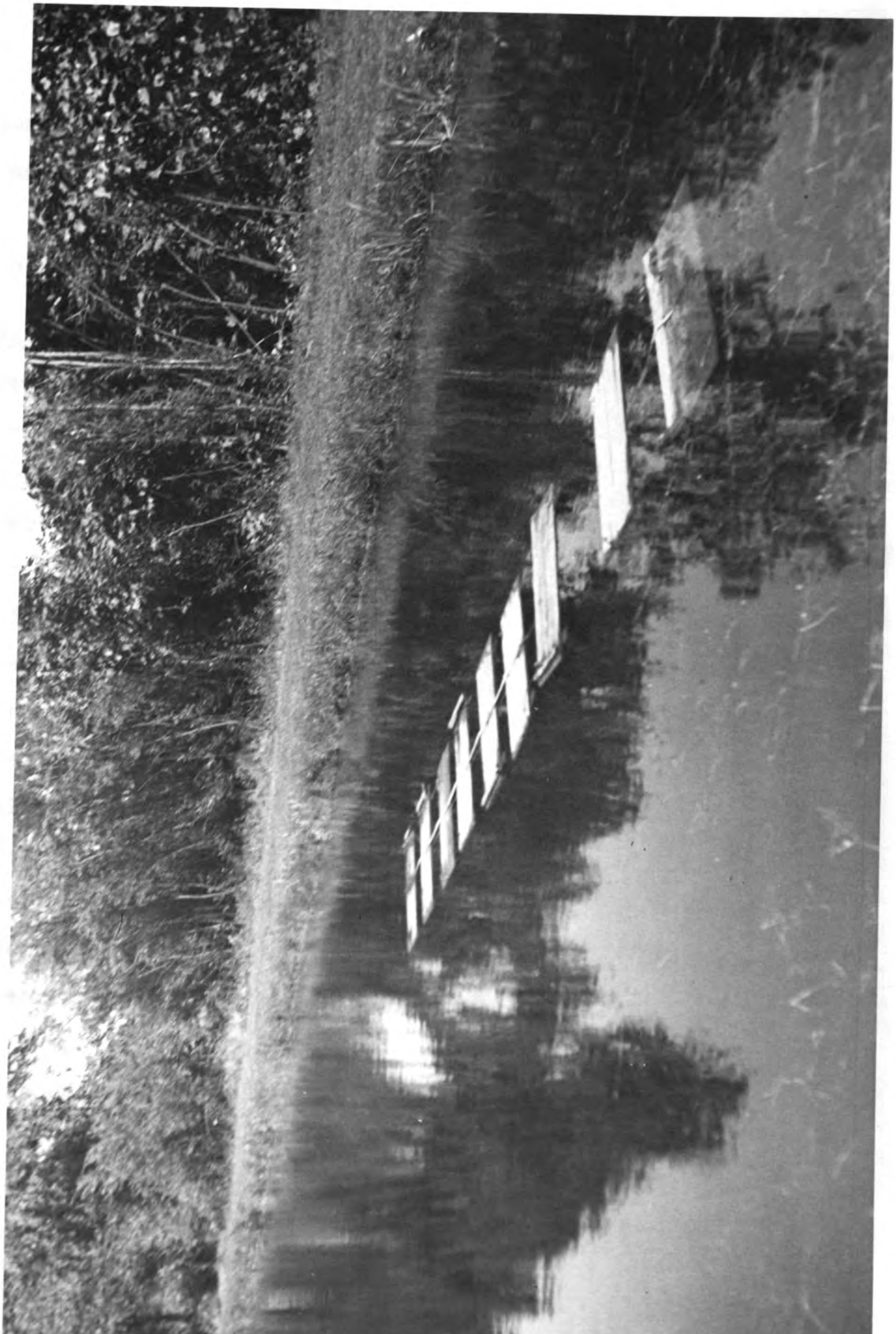
The fathead is relatively short lived. Apparently considerable mortalities of the spawners occur since only 1.6 per cent to 27.7 per cent of fin clipped breeders have been recovered at harvest.

Producing the fathead

Method of propagation.--Of all the bait fish species reared in these experiments, the fathead is the easiest of all to propagate. Mature fishes placed in the rearing pond soon populate the waters with thousands of fry. The number of spawning sites in the rearing pond may be greatly increased if spawning boards are placed in the shallows of the pond (Figure 11). Boards 10 X 12 inches, stapled to a rope or wire which is anchored at both ends will suffice. Boards swinging with the wind or placed in deeper water were used less often than those holding position in 2 to 4 feet of water. An alternate method for drainable ponds is to drive boards or shingles in the mud of the pond bottom at a 45 degree angle.

Stocking the rearing ponds.--The optimum number of breeders to stock depends somewhat on individual pond characteristics and local situations. From 900 to 1400 adults per acre of water is the recommended stocking rate. Under favorable spawning conditions 1000 breeders stocked one acre ponds in these experiments to the point of stunting the growth of the progeny. More fertile ponds or those where greater mortalities occur may, of course, require larger numbers of breeders. The bait minnow propagator having a demand for small minnows such as used for crappie fishing may intent-

Figure 11: Fathead Spawning Boards.



ionally overstock the pond to obtain greater numbers of the smaller sizes.

The adults should be placed in the rearing pond by the latter part of April.

Fathead production in fertilized and non-fertilized waters.-- Two ponds for three consecutive years were utilized in raising fatheads under fertilized and non-fertilized programs. Pond 4 Wolf Lake received an average of 550 pounds of 10-6-4 fertilizer per acre per year, while Pond 5 Wolf Lake received no fertilizer over the same period. The two ponds are quite similar in physical characteristics. The growth period varied from year to year but in each instance was equal for the fertilized and non-fertilized ponds. Examinations of fathead stomach contents showed considerable quantities of algae and small aquatic animals explaining in part the effect fertilization presumably had in increasing production. The average non-fertilized pond production obtained in this series is considered to be low. Table 18 summarizes the yearly production obtained from these ponds.

Two other ponds were fertilized to obtain fathead production data. Pond 2 Hastings received 600 pounds per acre of 10-6-4 fertilizer and 1000 adults. Pond 10 Wolf Lake received an application of 2000 pounds per acre of sheep manure and 3,400 breeders. The harvest, after a 3½ month growing period, is shown in Table 19.

Table 18

Comparison of Fathead Production from Fertilized and Non-Fertilized Ponds

Non-Fertilized Pond Production				Fertilized Pond Production		
Pounds per acre	Numbers per acre	Percent exceeding 1.5 inches length	Stocked (adults)	Pounds per acre	Numbers per acre	Percent exceeding 1.5 inches length
35	22,750	10	--590--	152	69,464	5
18	16,950	30	--3600--	110	97,306	38
45	30,710	42	--2000--	230	153,464	65
			--Average--			
32.7	23,470	27.3	2063	164	106,805	36

Table 19

Fathead Production from Fertilized Ponds

Production	Pond 10 Wolf Lake	Pond 2 Hastings
Pounds/acre	161	212
Numbers/acre harvested	141,462	251,375
Average length at harvest (in.)	1.2	1.1

The feeding of fatheads.--Only one attempt was made to feed fatheads. A Wolf Lake one acre rearing pond fertilized with 2000 pounds of sheep manure and fed 5,088 pounds of Diet 3 produced 461 pounds of fatheads. The 380,100 fish harvested resulted from 4000 breeders or an average of 95 young per adult. A growth of 1.8 inches was attained by 59 per cent of the fishes harvested with the remainder of the crop averaging less than 1.5 inches.

Fatheads reared in combination with other minnows.--Fatheads were reared in combination with golden shiners and northern creek chubs. The resulting production from these experiments have been discussed in sections dealing with golden shiner and chub production.

Overwintering fatheads.--Three populations of fatheads were placed in ponds to obtain information on survival rates. Of the 460,595 fish stocked in the fall 70.2 per cent survived the winter and were harvested the next spring (Table 20).

Table 20

Results of Overwintering Fatheads in Ponds

Introduced in Fall				Spring Recovery	
Pounds per acre	Average size (inches)	Number per acre	Pond	Per cent of number introduced	Average growth (in.)
225	1.8	109,575	8	83.2	.2
95	1.2	146,205	10	37.6	.4
130	1.1	204,815	2	89.8	.2

Tests designed to show the relative hardiness of fatheads to crowded conditions and low dissolved oxygen indicate that this fish reacts as well to these conditions as does the northern creek chub. The average overwintering survival rate obtained for chubs and fatheads in these experiments compare favorably. The fatheads held over the winter were young fish and since the life expectancy of fatheads is much shorter than for chubs the survival percentages obtained with adult populations might be lower.

Propagation of Other Bait Minnows

Chubsucker.--The chubsucker is an excellent bait minnow and the growth is comparable to the other larger bait species. These fish are reported to attain an age of 8 years (Underhill 1939). Sizes run to 10 inches.

Chubsuckers should overwinter very well. Tests showed ability to withstand crowding and low oxygen tensions comparable to the most resistant bait minnows tested.

Highly successful propagation and production of the chubsuckers was not attained in the experiments (Table 21). Cooper (1935) reports ovary counts of 3,000 to 20,000 eggs and yet the maximum number of young produced for each female in these tests was approximately 110. Much lower ratios of young produced to females stocked usually resulted. The future status of the chubsucker as a pond reared species depends on the developement of methods for obtaining fry.

Red belly dace.--The red belly dace is often used as bait for the smaller game fish. This minnow is attractively colored with a rich olive back, white below, and is doubly stripped with broad black bands along each side. Lower portions of breeding males are vermilion with red and yellow fins while breeding females are duller in color with noticeably distended abdomens. Females, attended by one or more males, spawn in filamentous algae from the latter part of May into August (Hubbs and Cooper 1936). Biologists report a longevity of about 3 years and growth to 2½ inches.

Attempts to propagate the red belly dace were not successful in these investigations, however this minnow does produce well in ponds under some circumstances (Table 21). In one or two instances red bellied dace occurred in considerable number as volunteer fish in the experimental ponds. The origin of the volunteers is not known but presumably a few adults may have been accidently introduced with other breeder stocks or the fish managed to penetrate screen barriers to river water supplies.

Cooper (1935) described ponds where successful reproduction took place as being supplied with water from springs and seepage. Owners with ponds having these characteristics may have success in raising the red belly dace.

Mudminnow.--The demand for this species of bait fish is local in nature in Michigan. Many fishermen confuse the mudminnow for the young of dogfish accounting in part for it's unpopularity in some places. The back is mottled brown or olive arranged in a manner that gives the impression of tranverse bars. The interspaces and undersides of cream to yellow are often flecked with lavender anteriorly. In these southern Michigan experiments spawning commenced before

Table 21

Chubsucker, Red Belly Dace and Brassy Production

Bait minnow species	Adults stocked** (per acre)	Pounds fish harvested (per acre)	Young fish harvested (per acre)	Length (inches)
Chubsucker	165	--	219	4.9
"	62	--	3,461	3.1
"	325F & 50M	--	5,925	2.6-3.7
"	300F & 25M	--	3,600	2.4-4.3
Red bellied dace (Cooper 1935)	2700	240*	128,000	1.3-2.2
Brassy	574	107	31,950	2.3

** F female
M male

* fertilized and fed

the middle of April. Eggs are laid on aquatic vegetation (Forbes and Richardson 1920). Ovary counts disclosed 425-450 eggs per female (Evermann and Clark, 1920).

The mudminnow displayed holding qualities and resistance to low oxygen tensions unmatched by any other bait minnow species. Overwintering should not be a problem with this fish.

Attempts to propagate the mudminnow in ponds have not been successful. Some reproduction invariably was obtained but has been insufficient in these tests to populate ponds. In some instances breeders were stocked after spawning had already begun which could have interfered with good reproduction. Breeding stock should probably be placed in the ponds during the last week in February.

Brassy minnow.--The brassy minnow attains a length of 3 to 4 inches and serves well as forage fish or bait minnow. Coloring is oliveaceous above with light lower portions reflecting a brassy or golden sheen. A dark band strips the body on each side and dorsal midline.

On the basis of preliminary studies the brassy minnow may prove to be a good species for pond culture. Ovaries from 15 fish averaging 2.8 inches in total length disclosed 6,830 eggs per female. The females, from which this sample was taken, were placed in a pond at Hastings where the spawning period extended from the middle of June to July 25. The number of females in the brood stock were estimated to be 384 and on this basis about 85 young were harvested for each female stocked (Table 21).

The growth of the brassy minnow throughout the summer period was compared to chub growth in a pond where a similar population density existed (Figure 12).

Although no production data are available from ponds artificially fed, feeding was attempted to determine the response of the fish to various methods. Food (Diet 4) placed in shallow water on the pond bottom soon attracted much feeding activity indicating that this method of management may be productive.

The brassy was more easily harvested by glass trap than any other minnow propagated. Baited glass traps often captured between 600 and 700 minnows per trap with one set of an hours' duration.

Some characteristics exhibited by the brassy must be considered objectionable. Records show that brassys succumb to roily waters and injuries occurring at harvest much more readily than some of the other bait minnows. To further substantiate these observations the holding qualities of the brassy are comparatively poor (Table 22).

Figure 12: A Comparison of Chub and Brassy Minnow Growth. (Adult brassy minnows and chub fry stocked. Growth occurring in ponds supporting similar populations.)

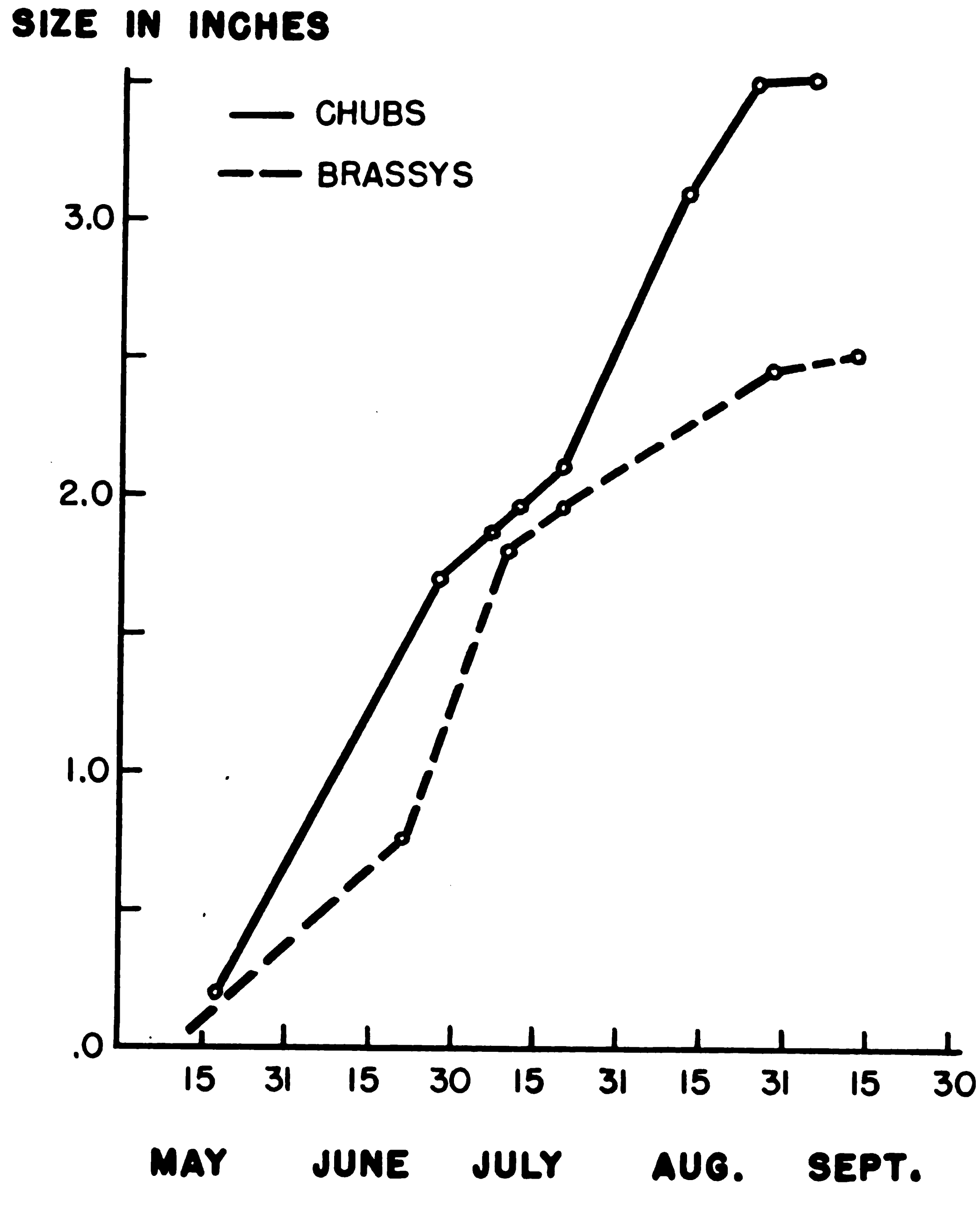

SIZE IN INCHES
CHUBS
BRASSYS
3.0
2.0
1.0
.0
15
31
15
30
15
31
15
31
15
30
MAY
JUNE
JULY
AUG.
SEPT.

Table 22

Comparative Holding Qualities

of Some Common Bait Minnows

Rating*		Bait Minnow Species
Best	1	mudminnow
	2	chubsucker
	3	golden shiner
	4	red belly dace
	5	chub
	6	fathead
Poorest	7	brassy

* Rating based on per cent survival of a 1 pound population in 2 quarts of water at 14.5° C.

<u>Northern</u> <u>pearl</u> <u>dace</u>.--Attempts to propagate this minnow in ponds were not successful.

DISCUSSION

The pond production of bait minnows in localities where inadequate supplies of these fish exist seems practical in view of the experimental findings. The four species of bait minnows which were most successfully reared in ponds fulfill fishermens needs for good bait. Chubs and suckers of proper sizes are highly desirable lures for nearly all piscivorous game fishes, they are long-lived on the hook and resistant to rough treatment. Although these species do not spawn in ponds, the fry may be purchased or the technique of culturing fry can be easily mastered. Properly stocked ponds with chub and sucker fry produce fishes suitable for bass bait the following fall.

The demands for bait minnows of a size suitable for the smaller game fishes can be supplied with stocks of fathead minnows or golden shiners. The natural reproduction of these fishes in ponds greatly facilitates their culture. Preliminary studies of the brassy minnow as a bait species are encouraging and warrant consideration where small minnows are desired.

The pond management techniques to be employed in producing minnow crops will depend on the bait demands to be fulfilled. Where the demand is great, the culturist will be interested in producing the maximum harvest possible from all ponds and to accomplish this a feeding program must be established. Only culturists operating on a large scale will find it possible to produce minnows by the feeding method since seasonal production costs are several thousand dollars per acre depending somewhat on local feed and labor markets. The experimental diets cannot be considered very satisfactory on the basis of the food conversions obtained.

Minnow dealers having more limited demands for bait or who wish to supplement minnow supplies obtained from natural waters with pond reared minnows, will find it more within their means to increase fish production through the enrichment of waters with fertilizers or rear a combination of species together. Labor and production costs are held to a minimum when these methods of pond management are employed.

On the basis of the findings of these experiments relative to the relationship between population densities and growth rate, the removal of minnows from rearing ponds as soon as they attain a salable size is advocated since this releases pond space and food organisms permitting a more rapid growth of the remaining fish population.

The phenomenon displayed by an equal area of small ponds in out producing larger ponds may be explained on the basis of their respective shore line lengths. The shore line of an acre of raceways is many times as great as that of a one acre pond. Minnows, like many other fishes, exhibit a tendency to travel the shore lines preferring to forage on the shoal areas.

In northern Michigan ponds where the period between last frost in spring and first frost in fall is short, the bait culturist must anticipate slower growth rates and lower pond production.

Those who contemplate the developement of an extensive bait minnow enterprise should plan the construction of drainable ponds. Experience with pond management has unmistakably shown that ponds which cannot be drained soon acquire an undesirable combination of fish species which interfer with efficient minnow production and are difficult to eliminate. A complete and less laborsome fish harvest is achieved from drainable ponds.

Unfortunately, there is a great disparity in the prices obtained for perch-size minnows and those suitable for pike or bass fishing in comparison to their respective production costs. The greatest shortages of bait minnows, in many localities, is for the larger sizes yet these fish are more costly to produce and bring a lower price per pound. If there is a ready market for minnows of a size suitable for perch or crappie fishing, ponds producing the smaller sizes of bait fishes will give a much greater financial return to the culturist.

Vital details of bait minnow life histories were included in this report to aid the prospective culturist in planning a sound propagation program. Information of this type was taken from the literature when it could be found and was supplemented to a large extent by observations made during these investigations.

SUMMARY

1. The facilities of seven state fish hatcheries were utilized to investigate the practicality of producing bait minnows. Production and propagation data were collected from 114 ponds representing a water surface area of 80.2 acres. Of the nine bait minnow species used in these experiments the most successful results were obtained with the northern creek chub, common white sucker, golden shiner and fathead minnow.

2. Several methods of pond management were used to obtain greater production. Waters were enriched with fertilizer, fish were fed and different species of fish were reared in combination.

3. Fertilizer added to pond waters increased the survival of young fish and gave significant increases in fish production. Increases in crayfish and tadpole production were much greater than increases in fish production.

4. The largest crops of bait minnows produced per unit water area resulted from artificial feeding. Diets supplied to suckers and chubs gave yields exceeding 1200 pounds of fish per acre. Chubs responded better to diets having a high liver content while suckers thrived best on the cereal diets. The ratio of food

supplied to each pound of fish harvested increased with higher feeding rates.

5. The space and natural food organisms of ponds were utilized more efficiently when several bait minnow species were reared in combination. Greater harvests of fish from ponds resulted.

6. An inverse relationship exists between the numbers of fish supported by a pond and the average growth rate of the population. Fish populations in ponds must therefore be regulated to obtain the desired growth rate and size of bait minnows at harvest.

7. The raceways and smaller ponds produced the largest crops of fish per unit of water surface area. This observation applied to waters supplied with feed and fertilizer as well as waters which received no added nutrients.

8. Bait minnow species which fail to spawn naturally in ponds should be stocked as advanced fry. The advanced fry survived from 3 to 6 times better than sac fry depending upon the species of fish stocked.

9. The culturist who wishes to supply spring and early summer fishing needs or bait minnows of a size suitable for pike fishing, must overwinter large populations of fish. The regular hatchery-type rearing ponds are not

well suited for holding fish populations through the winter.

10. The value of drainable ponds to an extensive bait minnow enterprise cannot be overemphasized. A complete and efficient harvest can be obtained.

LITERATURE CITED

Bacon, Edward H.
1951 Experimental use of carp pituitary in the production of fish. Unpublished M. A. thesis. Michigan State College, 80 numb. leaves.

Ball, Robert C.
1949 Experimental use of fertilizer in the production of fish-food organisms and fish. Mich. State Coll., Agr. Exp. Sta., Tech, Bull. 210, 28 pp.

Bean, Leslie S.
1936 Fish yield on the National Forests. Proc. N. Am. Wildlife Conf. (1): 301-304.

Carbine, W. F.
1940 Michigan minnow dealers. Mich. Dept. Cons., L. F. R. (Unpublished) Report No. 627.

Clark, Clarence F.
1940 Creek chub minnow propagation. Ohio Dept. Agr., Circ. 190-A 4 pp.

Cooper, Gerald P.
1935 Some results of forage fish investigations in Michigan. Trans. Am. Fish. Soc. 65: 132-142.

– – – 1936 – – Age, growth and suitability for propagation of the golden shiner (Notemigonus crysoleucas auratus). Papers Mich. Acad. Sci. Arts and Letters. Vol. 21, pp. 587-597.

Dobie, John R.
1948 Minnow propagation. Minn. Dept. Cons., Bull. 13, 25 pp.

Evermann and Howard Walton Clark
1920 Lake Maxinkuckee. Indiana Dept. Conserv. Vol. 1: 1-60.

Forbes, Stephen A. and R. E. Richardson.
1909 The fishes of Illinois. Nat. His. Survey of Ill. Vol. 3: 1-357.

Greeley, John R.
1930 A contribution to the biology of the horned dace, Semotilus atromaculatus Mitchill. Abstract of thesis, 3 pp.

Hedges, Sheldon B.
1951 Harvesting and production of bait fishes in ponds. (Unpublished Masters thesis, Mich. State College.)

Hubbs, Carl L.
1933 (Unpublished Mich. Dept. Cons. I. F. R. Report).

- - - - - - - and Gerald P. Cooper
1936 Minnows of Michigan. Cranbrook Inst. of Sci. Bull. 8: 1-95.

Hutchins, Lynn H.
1946 Bait minnows and their propagation. Nat. Hist. Survey of Ill., circ., 3 pp.

Lauff, George H.
1951 A survey of live-bait dealers in Michigan. (Unpublished Masters thesis, Mich. State College.)

Markus, Henry C.
1934 Life history of the blackhead minnow (Pimephales promelas). Copeia, 1934, No 3, pp. 116-122.

Patriarche, M. H. and Ball, R. C.
1949 An analysis of the bottom fauna production in fertilized and unfertilized ponds and its utilization by young-of-the-year fish. Mich. State Coll., Agr. Exp. Sta., Tech. Bull. 210, 35 pp.

Schaeperclaus, Wilhelm Translated by F. Hund.
1933 Textbook of pond culture. U. S. Dept. Int., F. and W. S., Fishery leaflet 311.

Swingle, H. S.
1947 Experiments on pond fertilization. Ala. Agr. Exp. Sta., Bull. 254, 34 pp.

Underhill, A. Heaton
1941 Estimation of a breeding population of chub suckers. N. Am. Wildlife Conf. Trans. 5: 251-256.

Van Deusen, R. D.
1947 Quantitative and qualitative evaluation of plankton from fertilized and non-fertilized ponds, with an appraisal of methods used. (Master's thesis, Michigan State College.)

Vessel, Matt F., and Samuel Eddy
1941 A preliminary study of the egg production of certain Minnesota fishes. Minn. Bur. Fish. Res. Invest. Rept. 26: 26 pp.

Wascko, H. and Clarence F. Clark
1948 Pond propagation of bluntnose and blackhead minnows. Ohio Dept. Cons., Bull. No. 4, pp. 15.

Washburn, George N.
1946 Minnow propagation program for 1946. Mich. Dept. Cons. I. F. R. Report 1052

_ _ _ _ _ _ _ _ Propagation of the creek chub in ponds with artificial raceways. Trans. Am. Fish. Soc. 75: 336-350.

Yoder, Troy C.
1947 Minnow propagation experiments for 1947. Mich. Dept. Cons., I. F. R. (Unpublished) Report No. 1267.