"FOOD STUDIES OF THREE
FISHES FROM NORTHERN MICHIGAN PONDS,
BLUEGILL (*Lepomis macrochirus*),
BRASSY MINNOW (*Hybognathus hankinsoni*) AND NORTHERN
BLACKNOSE SHINER (*Notropis heterolepis*)."

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This is to certify that the

thesis entitled

"Food studies of three fishes from Northern Michigan ponds, bluegill (Lepomis machrochirus), brassy minnow (Hybognathus hankinsoni) and Northern blacknose shiner (Notropis heterolepis)"

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"FOOD STUDIES OF THREE FISHES FROM NORTHERN MICHIGAN PONDS, BLUEGILL (*Lepomis macrochirus*), BRASSY MINNOW (*Hybognathus hankinsoni*) AND NORTHERN BLACKNOSE SHINER (*Notropis heterolepis*)."

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# INTRODUCTION

The food studies conducted on the three species of fish presented here represent a part of a long-range research problem constructed by Dr. Peter I. Tack, Head of the Department of Fisheries and Wildlife of Michigan State College. That problem concerns effects, direct and indirect, of fertilization of small ponds upon the aquatic environment and its population. This report will contribute to that original problem as a presentation of data collected from control ponds or unfertilized water and indicate what foods the fishes might normally take in their natural environment.

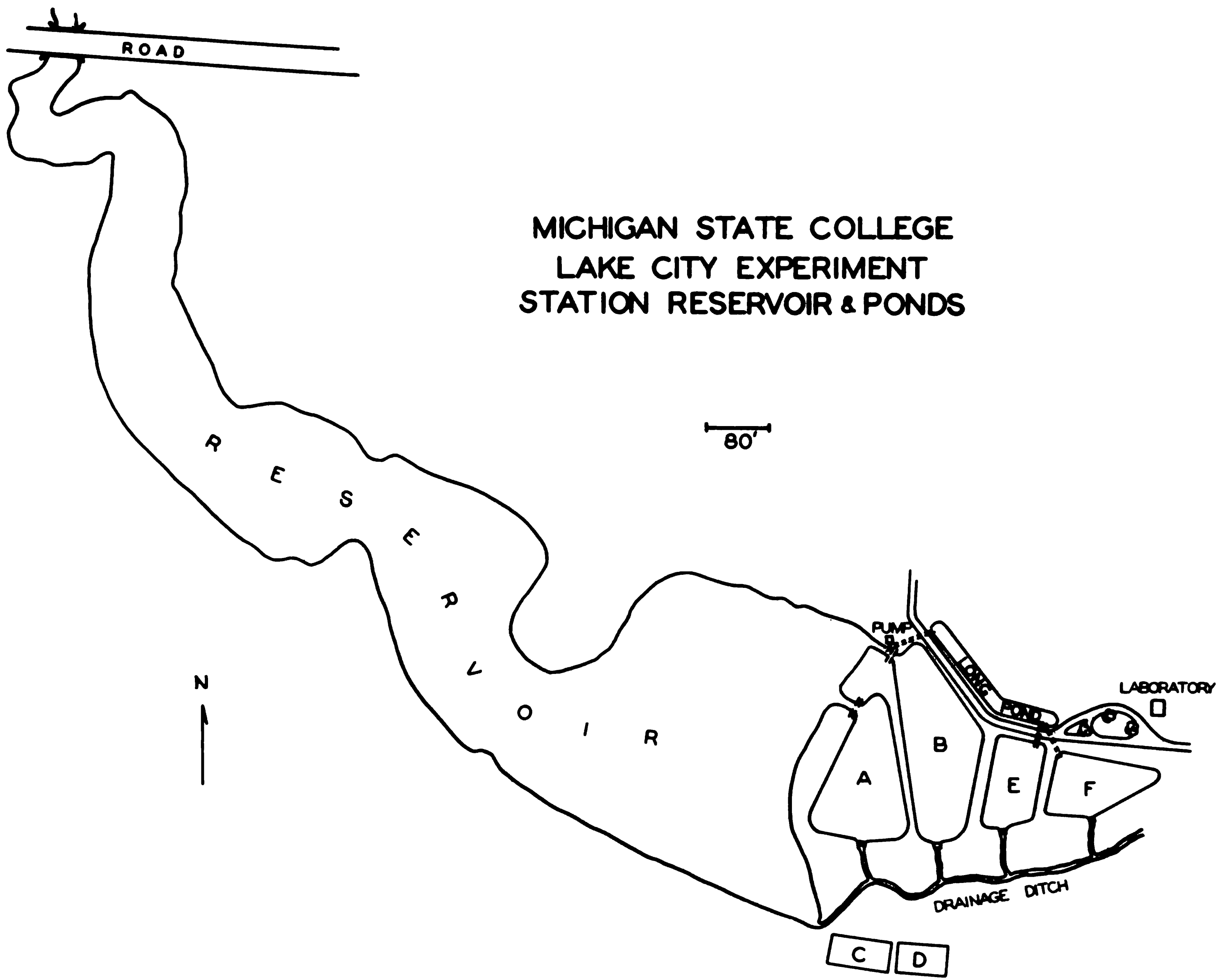
Couey (1935), Forbes (1883), Pearse (1915-16) and Reighard (1915) contributed much to the understanding of the food habits of the Common bluegill (*Lepomis macrochirus*) and have presented some results of the earlier work that was done in this country on the feeding habits of fish. Their contributions have possibly laid the groundwork for fertilization experiments and the accompanying food studies on Bluegills. Since the Bluegill is a popular sport fish and common in most of our ponds, lakes and streams it received much attention. As a prolific and easily propagated pond fish it has entered into the fertilization experiments on farm ponds that have received so much publicity in recent years (Howell, Swingle and Smith 1941, P. I. Tack 1946, Patriarche and Ball 1949). Much of this work was done in an effort to learn if fertilization caused an increase in the amounts of phytoplankton and zooplankton present in ponds. The food analyses were conducted on the fish present so as to ascertain if phytoplankton and zooplankton as well as invertebrate animals were being utilized by the fish with a subsequent increase in their size and weight.

The minnows of our inland lakes and streams have been seined and trapped so that their numbers have been seriously diminished. It is widely believed that the seining and trapping of these fish is a direct cause of a decrease in the food supply of our game fishes. For this reason restrictive laws have been passed by many states preventing indiscriminate harvesting of these important forage fish by commercial bait dealers.

Recently there has been much experimentation by the state departments of conservation of Michigan, Minnesota, Wisconsin and Ohio with the propagation of minnows in an effort to find species that can be easily reared for bait and forage in small ponds. With the great increase in fishing pressure that has come with the postwar years it is evident that more restrictive laws will be passed and there is a definite need for more biological studies on possible bait and forage species that can be recommended to the bait dealers.

PLATE I

A MAP OF THE MICHIGAN STATE COLLEGE; LAKE CITY, MICHIGAN, EXPERIMENT STATION RESERVOIR AND EXPERIMENTAL PONDS



ROAD
MICHIGAN STATE COLLEGE
LAKE CITY EXPERIMENT
STATION RESERVOIR & PONDS
80'
RESERVOIR
N
PUMP
LONG POND
LABORATORY
A
B
E
F
DRAINAGE DITCH
C
D

## DESCRIPTION OF POND A AND RESERVOIR

Plate I (page 4) is a map showing the experimental ponds and the reservoir located on property of the Michigan State College Experiment Station. The experiment station is located in Missaukee County of northern Michigan just a few miles south of Lake City.

Mosquito Creek arises from subsurface waters in the northwestern portion and flows in a southeasterly direction through the college property. During 1944 this creek was dammed near its upper end forming the reservoir which supplies a head of water for the four experimental ponds. The ponds lie on the downstream side of the reservoir and can be individually drained or filled.

The reservoir is shallow with a muck and peat bottom which overlays a sandy acid soil. The part representing the old creek bed is gravel covered with organic debris. The bottom is littered with many stumps and fallen trees. The shallow shore areas are well covered with emergent vegetation, most of which is alder, dead and alive. At the time of collection of the Bluegill specimens, huge beds of Potamogeton grew in the shallows and bordering a bed of Chara in the northwest end. Water smartweed also grew at that end on the north side and much filamentous algae was observed on the bottom in most places. The entire bottom then appeared silted which was in part due to drainage received from the high fields to the south.

The reservoir with its shore vegetation gives the appearance of a typical bog swamp. It is shallow with a maximum depth of approximately eight feet. It is from this water that the Bluegills were collected.

The minnow species were collected from Pond "A". This pond was constructed over sandy acid soil that was previously covered with a layer of muck. The muck was removed. The sandy soil was scooped out and with fill that was brought in formed the sides of the pond.

The bottom of Pond "A" is sand except for a few square yards of gravel at one end. It was covered with a heavy layer of plant ooze. This ooze was formed from mats of conjugating *Spirogyra* which floated upon one third of the pond's surface in August (Schmid 1949). Decaying *Chara* contributed to a lesser extent to the amount of ooze present. It is believed that the mats of *Spirogyra* shaded out the *Chara* and caused it to quickly decay. The ooze formed by this decaying algae was observed to be a foot thick when the pond was drained in April, 1949 (Schmid, 1949).

Ponds "A" and "B" were drained April 22, 1949. On April 23d, they were filled and 20 adult Bluegills were put in Pond "A" and 21 in "B". On May 5, 1949 when Pond "F" was being lowered, hundreds of minnows came up below the outlet of that pond. Pond "A" is subject to direct contamination by fish fry from the outlet of the reservoir (Plate I). It is from these sources that the Blacknose shiner and Brassy minnow fry originally entered Pond "A". Several schools of minnows were observed in "A" on May 27, 1949.

Pond "A", a control pond, has never been fertilized. No fish other than the Bluegills have been introduced into it.

## METHODS AND PROCEDURE

### Collection of Specimens

All of the young Bluegill and minnow specimens were glass-trapped. Their capture was successful without putting bait or decoys in the traps. The fish upon removal from the traps were immediately placed in jars containing ten per cent formaldehyde. The Bluegills were trapped in open spaces of the Chara bed at the northwest end of the reservoir, the traps often being placed on a submerged stump or log. In capturing the Brassy minnows and Blacknose shiner minnows, the glass traps were placed on the sandy bottom near the sides of Pond "A".

### Laboratory Procedure

Many stomachs were found to be empty due to digestion and regurgitation so it was decided that the contents of the intestines would also be included in the food analyses.

After being measured for total and standard lengths the fish were dissected and the entire digestive tracts carefully removed and each placed in a vial containing four per cent formaldehyde. A proper label was assigned each digestive tract until future examination.

The contents of a vial were later emptied onto a petri plate. Water was added and the stomach and intestines were cut open lengthwise. This necessitated much time and care being spent on the long coiled intestines of the Brassy minnows. Attention was given mucous which sometimes enveloped organisms and debris and a probe was used to separate the latter.

Analyses were performed by examination with a dissecting microscope. Examination of the Bluegill and Blacknose shiner stomach contents was made with fifteen power magnification while forty magnifications were used for identification of minute specimens. Examination of the Brassy minnow intestinal tracts required constant use of forty diameters magnification and the presence or absence of the smaller nonfilamentous algae was confirmed by examining five or six random samples taken from each digestive tract. This latter examination, under one hundred and fifty power and higher magnification, was made to learn if Diatoms or other nonfilamentous algae were being utilized to any appreciable extent.

All identifiable organisms were counted and recorded.

For partially digested organisms, care was exercised so as to eliminate the counting of other members from the same body.

## THE BLUEGILL

The Bluegill (_Lepomis macrochirus macrochirus_) is easily propagated and its habits adapt it especially to cultivation in ponds (Howell, Swingle and Smith 1941). It is easily caught by the angler at all times of the year and its firm flesh proves delicious when properly cooked. It grows quite rapidly and finds suitable habitat plentiful. For these reasons the Bluegill has received much attention in fertilization experiments.

There is some speculation as to whether the food a fish eats depends more upon its availability and its size or upon an actual preference exercised by the fish. Hess and Swartz (1940) emphasize the importance of preference in their suggested "forage ratio". The latter is a ratio of the percentage of occurrence of an organism in a population to the percentage of occurrence in the fish's stomach. In accordance with its difference from one, this ratio suggests that the difference is due to either availability or preference. It does not, however, consider availability in relation to fish so much as it does to the sampling device of the investigator.

Literature Survey

By use of the "forage ratio", Patriarche and Ball (1949) established an actual preference for midge larvae by young-of-the-year Bluegills. They found midges to be a staple in the diet of Bluegills taken from four small ponds.

Howell, Swingle and Smith (1941) concluded that for Bluegills weighing over one ounce, midge larvae and pupae were the most important food in Alabama lakes and ponds. They suggest that these fish resort to vegetable food only when the animal food is not available or denied them by reason of competition. Studies by Forbes (1883) and Reighard (1915) indicated this. and they reasoned that the vegetation was not taken accidentally by the Bluegill. McCormick (1940) in a study on 100 Bluegills collected from Reelfoot Lake, Tennesee found fifty two per cent of the food by volume was plant material, mostly Ceratophyllum and thirty four per cent by volume was chironomid larvae. Rice (1941) examining eighteen Bluegills of an average length of one hundred fifty millimeters found forty per cent was plant material consisting of filamentous algae and duckweed.

Leonard (1940) collected forty two bluegills in one day and separated them into size groups. Plankton, small mayfly nympths and Chironomids were the exclusive diet of nine specimens with an average standard length of 21.8 millimeters. Plankton, Chironomids and aphids bulked about the same in the diet of fifteen specimens with an average standard length of 40.4 millimeters but Odonata were almost as abundant. This group also took terrestial insects in small numbers and he concluded that they probably fed more on the surface at this length. Eighteen of his specimens with an average standard length of 117.8 millimeters fed almost exclusively on dragon-fly nymphs. Vegetation did not figure in the diet of these fish nor did water mites (Hydracarina).

Howell (1942) collected twenty Bluegills, all over ninety one millimeters in length, from an unfertilized pond and found the plant Najas to represent the greatest volume of the food in 40 per cent of the stomachs. The Najas was present in 70 per cent of the stomachs. Midge larvae ranked first by volume in 50 per cent of the stomachs. Hydracarina were found in 10 per cent of all stomachs. Thirty-three Bluegills, ninety one to one hundred fourteen millimeters long collected from a fertilized pond had fed predominately on insect larvae. These specimens, however, were collected at four different periods from June through November and the specimens collected in June when insects were abundant contained predominately insect larvae and vegetation did not represent a major portion of their diet.

Couey (1935) reported insects to be the predominate food of small Bluegills with chironomid larvae constituting twenty one per cent of the total. The insect food decreased in the contents of the medium size group and was again increased in the larger specimens. Plant food represented thirty four per cent of eighty two specimens ranging from ninety to one hundred forty millimeters in length. This was true for specimens collected from one lake and two hundred thirty three Bluegills taken from two other lakes had eaten no plant food and their contents showed 49.5 per cent insects and twenty per cent chironomid larvae.

Ewers and Boesel (1935) reporting on fifty three Bluegills, total length range of twenty one to thirty seven millimeters, taken from Buckeye Lake, Ohio, found Crustaceans constituting 86.2 per cent of the total contents. The percentage of Crustaceans was equally divided between Cladocera and Copepoda. They reported that the fish fed largely on small Crustaceans. Hyallela represented 14.5 per cent and insects 12.2 per cent of the total volume.

Bennett (1948) found Cladocera and chironomid larvae to be the staple diet of Bluegills of all sizes with Cladocera forming a large percentage of the stomach contents during the spring and fall. It is during these seasons that Cladocerans reach a peak in deep lakes. He reported only a trace of Hydracarina for one year.

Tanner and Ball (1951) reported midge and mayfly larvae by numbers and volume to constitute the major diet of twenty eight adult Bluegills taken from North Twin Lake in northern Michigan. Aquatic plants made up 20.2 per cent of the contents by volume, Hydracarina 8.3 per cent by numbers and two per cent by volume.

Food Analysis

The contents as found in the stomachs of ninety two Bluegills are presented in Table I on page 16. These fish ranged in total length from thirty eight to sixty one millimeters, averaging 50.4 millimeters. One hundred digestive tracts were originally examined, eight were found to be empty and were not included in the tabulations.

Crustaceans constituted 55.9 per cent of the total number of organisms and insects 33.1 per cent.

Cladocerans were observed to be the most abundant of all organisms forming approximately thirty four per cent of the total number. Copepods numbered one hundred twelve and comprised twelve per cent of the total number of organisms. Ostracods formed 8.6 per cent of the total. Of the Malacostraca, only thirteen Amphipods were found.

Chironomid larvae comprised almost the entire percentage of insects found and formed 28.3 per cent of all organisms. The next highest number of insects found were Trichoptera larvae (Microcaddis) which formed only 2.3 per cent of the total number of organisms. Zygoptera naiads were found in nine digestive tracts and constituted 1.3 per cent of all organisms. The mayfly naiads were not readily available and only one was found. All other insects, mature or immature, were insignificant in number.

Water mites (Hydracarina) were found in number to represent 10.5 per cent of all organisms. Like the Chironomids, the water mites seem to prefer a muck bottom with vegetation. Ninety eight were found in thirty six stomachs.

The higher aquatic vegetation listed represented small stem and leaf parts and represented a negligible volume appearing in significant amounts in only a few stomachs. It could be considered decayed vegetation taken in by the fish as they searched for midge larvae or mites in the bottom debris. This accidental ingestion also probably accounts for the inorganic debris found which consisted for the most part of small crystals of sand.

The filamentous algae were principally Oedogonium, Spirogyra and some Ulothrix, and always constituted an insignificant part of the total contents of any one stomach.

The terrestial vegetation recorded consisted entirely of the lemmas of reed canary grass which grew in abundance along the shores of the reservoir. They were found in nine stomachs and might have been ingested by the fish as possible insect naiads.

The Coleoptera and Hemiptera were digested beyond iden-

## TABLE I

STOMACH AND INTESTINAL CONTENTS OF 92 BLUEGILLS
COLLECTED FROM RESERVOIR, MICHIGAN STATE COLLEGE EXPERIMENT STATION;
LAKE CITY, MICHIGAN; SEPTEMBER 1, 1949

TABLE I

STOMACH AND INTESTINAL CONTENTS OF 92* BLUEGILLS

Total Length 38-61 mm. Average Total Length 50.39 mm.
Standard Length 29-57 mm. Average Standard Length 38.63 mm.

| | Total number of organisms | Number of individuals containing organisms | Percentage of individuals | Percentage of total number of organisms |
|---|---|---|---|---|
| MALACOSTRACA | | | | |
| Amphipoda | 13 | 11 | 11.96 | 1.39 |
| ENTOMOSTRACA | | | | |
| Cladocera | 317 | 57 | 61.96 | 33.98 |
| Copepoda | 112 | 47 | 51.09 | 12.00 |
| Ostracoda | 80 | 31 | 33.70 | 8.57 |
| | | | | Total 55.94 |
| AQUATIC INSECTS | | | | |
| Chironomid larvae | 264 | 49 | 53.26 | 28.30 |
| Zygoptera naiads | 12 | 9 | 9.78 | 1.29 |
| Trichoptera larvae | 21 | 14 | 15.22 | 2.25 |
| Hemiptera nympths | 5 | 5 | 5.43 | 0.54 |
| Diptera pupae | 2 | 2 | 2.17 | 0.21 |
| Ephemeridae naiads | 1 | 1 | 1.09 | 0.11 |
| Unidentifiable insects | 2 | 2 | 2.17 | 0.21 |
| Coleoptera | 2 | 2 | 2.17 | 0.21 |
| | | | | Total 33.12 |
| HYDRACARINA | 98 | 36 | 39.13 | 10.50 |
| OLIGOCHAETA | 4 | 2 | 2.17 | 0.43 |
| Higher aquatic vegetation | | 24 | 26.09 | |
| Inorganic debris | | 42 | 45.66 | |
| Filamentous algae | | 30 | 32.61 | |
| Nonfilamentous algae | | 3 | 3.26 | |
| Terrestrial vegetation | | 9 | 9.78 | |

*One hundred specimens were examined, eight found empty and not included in tabulations.

| | | |
|---|---|---|
| Nonfilamentous algae | [illegible] | [illegible] |
| Terrestrial vegetation | 9 | 9.78 |

*One hundred specimens were examined, eight found empty and not included in tabulations.

tification except for one water boatman (Corixidae).

The nonfilamentous algae were chiefly Diatoms and Desmids and were found to be quite scarce in numbers.

Discussion of Table I

Stomach analyses conducted on the fingerling Bluegills revealed that Entomostracans and chironomid larvae were the main staples of their diet. Together they represent 82.9 per cent of the total number of organisms taken by the ninety two fish. Scuds (Amphipods) represented only a small number of the crustaceans taken and only 1.5 per cent of the total number of organisms. The latter represent a subclass (Malacostraca), the larger-sized crustaceans and those observed were considered individuals of a small size. The cladocerans and chironomid larvae were all small-sized individuals.

Higher aquatic vegetation and algae appeared only in very small quantities indicating that these fish were not selecting plant items for food. This latter evidence is supported by reports on earlier studies conducted by Leonard (1940), Ewers and Boesel (1935), Moffet and Hunt (1942) and Bennett (1948). These investigators found cladocerans and chironomid larvae represented staples in the diet of small Bluegills.

All insects, other than the Chironomids, were found only in small numbers. The Trichoptera were the small microcaddis

larvae and represented the greatest number, twenty one individuals being found in fourteen stomachs. These adult insects were food organisms of a size too large for the fingerling Bluegills. The mayfly naiads (Ephemeridae) were evidently not available for the fish.

Hydracarina were taken in numbers by these small Bluegills and the study indicates that those Bluegills in an environment favoring the water mites, might choose these organisms as a relatively important part of the diet. The latter are found in abundance in water of a moderate depth with considerable plant growth. Tanner (1950) reported that water mites represented 8.3 per cent by number of the total organisms taken by twenty eight adult Bluegills.

The Bluegills of this study were collected from an environment that definitely favored an abundance of water mites and midge larvae. The midge is more likely to be taken by Bluegills of different environments due to its cosmopolitan range, distribution and abundance. It is generally found in great numbers in most fresh waters.

An interesting result of this study was the small number of scuds, Amphipoda, taken by these fish. Other studies by Ewers and Boesel (1935), Ball and Tanner (1951) and Leonard (1940) reveal similiar results.

A review of the previous studies did not reveal that fingerling Bluegills were taking vegetation, higher aquatic or algal, as a consistent part of their diet. Those investigators finding vegetation representing a considerable per cent of the contents (Couey 1935, Howell 1942, Rice 1941, and McCormick 1940) were examining specimens all of a longer length (over ninety millimeters) than those collected for this study. There appears to be quite some variation in the staple organisms taken by different size groups listed by investigators in the past but the above remarks pertain to all reviewed for this paper.

Table I indicates that the Bluegill fry soon after hatching subsist mainly on zooplankton but sufficient bottom dwellers were found so that the diet must certainly reflect the population of bottom fauna. It seems to indicate that size and structure of the organisms are limiting factors for fingerling Bluegills.

## THE NORTHERN BLACKNOSE SHINER

Minnows are an important link in the chain of food production of most waters. They are small fishes never reaching a size that allows them to seriously prey on game species. They represent natural forage for the game species and draw attention away from the fry of the latter. They compete with the latter for food organisms, mainly Crustaceans. It is believed that their numbers have been diminished in our lakes, streams and ponds through harvesting by bait dealers.

In a search for possible bait species much attention has been given their propagation in ponds. It seems particular attention should be given those species that are vegetable feeders or "bottom ooze" feeders assuming that they will offer little competition to the game fish. Also, it seems adviseable that the species should be prolific, spawning late and in numbers so great as not to be easily depleted by predators, game fish or others. The vegetable feeder would probably require less attention in the matter of feeding and selection of a pond.

The Northern fathead minnow, mainly a vegetable or "bottom ooze" feeder, has proved to be an excellent bait and forage fish easily reared in small ponds. Attention was also given the Eastern silvery minnow (*Hybognathus nuchalis regius*) with successful propagation in a pond devoid of vegetation (Raney 1941). The Bluntnose minnow (*Hyborhynchus notatus*) with feeding and breeding habits quite similiar to the Fathead minnow (*Pimephales promelas*) has also proved to be an ideal minnow for propagation in small ponds. The Bluntnose and Fathead minnows are not strictly "bottom ooze" feeders as is the Eastern silvery minnow which belongs to the same genus as the Brassy minnow (*Hybognathus hankinsoni*). Little is known of the habits of the Brassy minnow and Raney's success with the Silvery minnow has probably directed attention to its possibilities.

The Northern blacknose shiner (Notropis heterolepis heterolepis) has received little attention concerning its feeding habits. It has not been considered a possible bait species because it is not hardy enough to withstand long-distance hauling by truck or the close confinement of the minnow pail. In its natural environment it is a competitor or "weed species" and offers forage for the larger predators.

Everman (1901) reported that the Blacknose shiner was quite effective as a bait for Yellow perch and that some anglers found the larger ones very good for small Largemouth black bass. He mentioned that for Yellow perch there is no better minnow if the larger ones are selected.

Description

It is a rather small minnow reaching a length of a little over two inches. It is slender with a dark lateral band extending over the snout. Black spots bordering the lateral line pores converge ventrally to form cresent-shaped bars.

Distribution

Hubbs and Lagler (1947) reported that the Blacknose shiner was found in the waters of southern Canada from Saskatchewan eastward, including part of the Hudson Bay drainage; south to

Maine, New Hampshire and the Lake Champlain basin; to the headwaters of the Hudson and Susquehanna systems in New York and of the Ohio basin in New York and Pennsylvania. It extended westward to Iowa and North Dakota and was represented southward in the Mississippi Valley by another subspecies. It is found throughout the Great Lakes region its characteristic habitat being weedy glacial lakes and connecting streams.

Literature Survey

Little has been written of the feeding habits of the Northern blacknose shiner consequently information concerning shiner minnows of the same genus with a similiar range of distribution has been borrowed from the literature. Also in the past, the Blacknose shiner (Notropis heterolepis) and the Bridled shiner (Notropis bifrenatus) have been confused when they occurred in the same water and some information supposedly pertaining to the Blacknose shiner has been disregarded.

Hankinson (1920) reported that the alimentary tracts of Michigan blacknose shiners contained Entomostraca, insects, filamentous algae and Diatoms.

Forbes (1883) concluded that young Cyprinidae drew almost indiscriminately for their food supply upon protozoa, algae and Entomostraca.

Ewers (1933) examined the stomachs of fifty eight Lake emerald shiners (*Notropis atherinoides*) averaging 61.3 millimeters total length and found Crustacea to constitute 66.7 per cent by volume (Copepoda 29.5 and Cladocera 37.5 per cent) and insects making up 12.4 per cent with midge larvae predominating among the insects.

Boesel (1937) reported that sixty Mimic shiner stomachs (*Notropis v. volucellus*) contained 54.6 per cent by volume of mayfly naiads, midge pupae and adults while Crustaceans constituted 23.2 per cent with Entomostraca being abundant. These fish averaged 43.8 millimeters total length and ranged from twenty nine to seventy one millimeters. It was observed that the contents of the larger fish were mainly insects and those of the smaller were entirely Crustaceans. There was no evidence of a progression in this direction relating to the increased size of the fish.

In this same study, stomach contents of thirty seven Northern sand shiners (*Notropis deliciosus stramineus*) were examined and Crustaceans were found to be inconspicuous. The contents were in poor condition and debris was classed as sixty per cent of the total volume but insects made up most of the organisms found (33.5 per cent) and midge pupae and larvae were abundant. No vegetation was found other than a trace of algae in two stomachs. The contents of one hundred ten Spottail minnows (*Notropis hudsonius*) with total lengths ranging from nineteen to eighty seven millimeters were studied.

It was found that these fish had fed on different animals in different evnironments and the specific type of food did not vary regularly with the size of the fish. Cladocerans and insects (Diptera predominating) were equal in volume and comprised seventy five per cent of the total.

Concerning Shiners in the Des Moines River, Starrett (1950) mentioned that the Spotfin shiner, Central bigmouth shiner (Notropis d. dorsalis), Northern common shiner (Notropis cornutus dorsalis) and the Rosyface shiner (Notropis rubellus) tend to feed at or near the surface more than most of the Shiners commonly found in the river. The genus Notropis (Notropis deliciosus excepted) were classed as semi-specialized feeders and all drew heavily on insect larvae and adults throughout the four seasons. He did not list Crustacea in his tables but mentioned that the Central bigmouth shiner showed more of a preference for Entomostraca than any of the other minnows and fed occasionally on phytoplankton during the summer. However, the scarcity of Entomostraca and midge larvae in the river was recognized and Starrett considered that scarcity to be a limiting factor for some minnows.

Forbes and Richardson (1920) and Hubbs and Cooper (1936) in their investigations on minnows attempted to relate the feeding habits to the morphological adaptations of the fish. Forbes and Richardson (1920) mentioned that few and short gill rakers were characteristic of the mud-eating minnows. They also mention that fishes as small as the minnows do not need specially developed gill rakers, since the gill arches themselves are so small and the spaces between them so small that any object large enough for food would not go out through the gills with the respiratory current. However, they also mention that the Golden shiner (Notemegonis crysoleucas), and the Blackchin shiner (Notropis heterodon) took large numbers of Entomostraca and would make them their sole food in ponds where the latter were abundant. The Golden shiner has long fine gill rakers and those of the Blackchin are unusually developed. These species also have hooked pharyngeal teeth. Reporting on the food of eighteen Blackchin shiners, they mention that it was peculiar in respect to the large percentage of Entomostraca included and attribute the fact to the well developed gill rakers and the small size of the fish. Mention was also made of the abundance of small Crustaceans in the waters from which the two species were taken. These fishes, however, showed a varied diet with insect larvae and algae being principal items.

## Food Analysis

The intestinal tracts of forty Blacknose shiner minnows were examined and the contents classified and recorded. The intestinal tracts of four minnows were found to be empty and the percentages presented in Table II (page 27) were tabu-

TABLE II

STOMACH AND INTESTINAL CONTENTS OF 36 NORTHERN BLACKNOSE SHINERS COLLECTED FROM POND "A", MICHIGAN STATE COLLEGE EXPERIMENT STATION; LAKE CITY, MICHIGAN; OCTOBER 19, 1949

TABLE II

STOMACH AND INTESTINAL CONTENTS OF 36* NORTHERN BLACKNOSE SHINERS

Total Length 37-63 mm. Average Total Length 50.97 mm.
Standard Length 28-49 mm. Average Standard Length 39.38 mm.

| | Total number of organisms | Number of individuals containing organisms | Percentage of individuals | Percentage of total number of organisms |
|---|---|---|---|---|
| ENTOMOSTRACA | | | | |
| Copepoda | 277 | 34 | 94.4 | 39.86 |
| Cladocera | 395 | 34 | 94.4 | 56.84 |
| Ostracoda | 13 | 11 | 30.6 | 1.87 |
| | | | | Total 98.57 |
| AQUATIC INSECTS | | | | |
| Chironomidae larvae | 6 | 6 | 16.7 | 0.86 |
| Chironomidae adults | 1 | 1 | 2.8 | 0.14 |
| Psocidae | 2 | 2 | 5.6 | 0.29 |
| Diptera larvae | 1 | 1 | 2.8 | 0.14 |
| | | | | Total 1.43 |
| Filamentous algae | | 27 | 75.00 | |
| Nonfilamentous algae | | 4 | 11.11 | |
| Higher aquatic vegetation | | 5 | 13.89 | |
| Organic debris | | 30 | 83.33 | |
| Inorganic debris | | 23 | 63.89 | |

*Forty specimens were examined, four found empty and not included in tabulations.

lated on a basis of thirty six total specimens.

The average total length of the specimens was 50.97 millimeters, the range extending from thirty seven to sixty three millimeters. The average standard length was 39.38 millimeters with the range extending from twenty eight to forty nine millimeters. The females were slightly larger than the males with an average total length of 52.5 millimeters, the latter averaging 50.0 millimeters. The average standard length for each was 40.5 and 38.55 millimeters respectfully.

Entomostraca constituted amost the entire total of organisms by number, 98.57 per cent. Of this percentage, Cladocera represented 56.84 per cent, Copepoda 39.86 per cent and Ostracoda 1.87 per cent.

A Chironomid larvae was found in each of six digestive tracts and one adult was recorded. Two bark lice (Psocidae) were found and one dipterous larvae. All insects, larvae and adults, constituted only 1.43 per cent of the total number of organisms.

It was interesting to note that most of the Crustaceans observed in all digestive tracts were much smaller than those found in the tracts of the Bluegills taken from the reservoir and the Brassy minnows taken from Pond "A". Some of the Copepoda recorded were observed as the nauplius, metanauplius and other early stages. Also many young Cladocerans were recorded.

The filamentous algae found in seventy five per cent of the tracts, consisted mostly of *Spirogyra* with some *Oedogonium* and was observed as abundant in only a few of the specimens. It appeared as traces in all other specimens. The nonfilamentous algae found in four specimens were *Closterium* and *Merismopedium*, both appearing only as traces.

The higher aquatic vegetation recorded was observed as traces in five specimens.

The organic debris listed was most often parts of Crustaceans or their eggs. The contents of the specimens were in poor condition and more difficult to record than those of the other two species. In recording the number of Copepoda it was more or less a matter of matching tails with carapaces of these small animals. Organic debris was recorded for 83.33 per cent of the specimens but is relatively important only as an indication of the condition of contents.

The inorganic debris represents small crystals of sand found in twenty three specimens, 63.89 per cent of all specimens.

## Discussion of Table II

The food study conducted on the Blacknose shiner minnows from Pond "A" revealed that they subsisted mainly on Entomostracans. Insects represented only 1.43 per cent of all organisms found. None of the literature reviewed for any of the species of Notropis revealed such a high percentage of Crustaceans.

There is little information concerning the food of the Blacknose shiner. Forbes and Richardson (1920) reporting on a related species, the Blackchin shiner (Notropis heterodon) reported finding unusual amounts of Entomostraca and mentioned that perhaps the unusual development of the gill rakers accounts for this. Aquatic insect larvae, mainly Chironomid, represented the other organisms found in their eighteen specimens.

The gill rakers of the Blackchin shiner are well-developed and rather long while those of the Blacknose shiner are short, well-rounded and few in number (Plate II, Figure 1 on page 32). It appears that no relationship between the food and the gill rakers exists here. It is interesting to note that the pharyngeal teeth of the Blacknose shiner are hooked or recurved (Plate I, Figure 2 on page 32) as are those of the Blackchin shiner and Golden shiner. It is in these latter species that Forbes and Richardson (1920) reported finding Entomostraca appearing in abundance.

It appears that the specimens examined for this study fed almost exclusively on Entomostraca and this is not due to any development of the gill rakers. As for size, this species does compare with the Blackchin shiner and this might be a factor in the selection of the food organisms for it was ap-

## PLATE II

Figure 1. BLACKNOSE SHINER MINNOW DRAWING OF EXPOSED GILL CHAMBER TO SHOW STUBBY GILL RAKERS

Figure 2. DRAWING OF PHARYNGEAL ARCHES TO SHOW TERMINAL HOOK

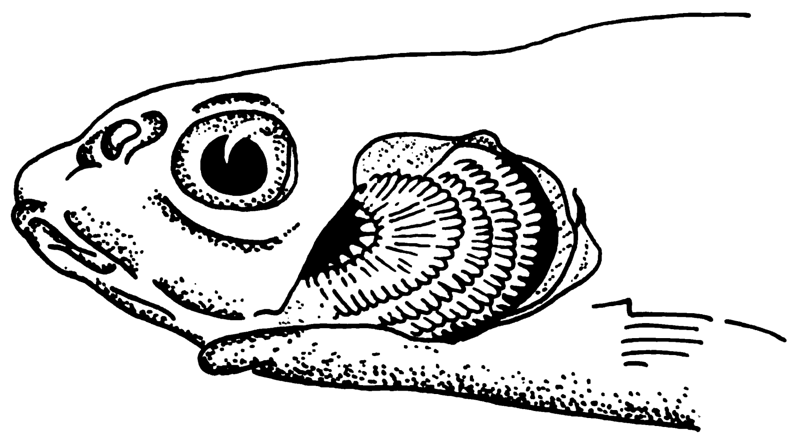


FIGURE 1.

BLACKNOSE SHINER
MINNOW

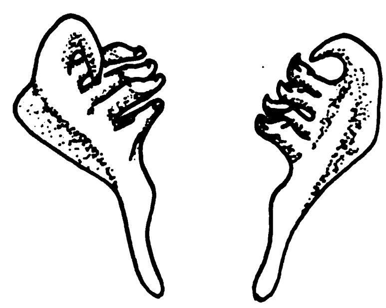


FIGURE 2.

parent that the latter were small in size.

Pond "A" has a sandy bottom that does not favor the growth of aquatic insects. However, considering the small size of the Entomostraca the availability of food organisms does not account for the lack of insects in their diet. It seems more likely that size of the food organisms rather than their availability has determined their selection. Though the Golden shiner includes a large percentage of crustaceans in its diet in some environments, its long fine gill rakers do not account for this entirely. The Golden shiner is quite omnivorous in its food habits.

The filamentous algae ingested by the specimens of this study were never large in volume and were most probably taken in accidentally.

The sand found in twenty three specimens does not particularly indicate bottom feeding habits of the fish. The shallow depth of the pond and its sandy slopes may account for this. The contents indicate that these fish fed more near the top than the Bluegill or Brassy minnow specimens.

# THE BRASSY MINNOW

The Northern fathead minnow (*Pimephales promelas promelas*) is an excellent bait species, easily propagated in small ponds and showing good production. It is mainly a vegetable or "bottom ooze" feeder. The Bluntnose minnow (*Hyborhynchus notatus*) with feeding and breeding habits quite similar to the Fathead minnow also shows good production when reared in ponds. Perhaps the success with these two species has pointed to the possibilities of the Brassy minnow (*Hybognathus hankinsoni*) and accounted for some attention given it in recent years (Wisconsin Fish Management Division, Minnesota Division of Game and Fish and Michigan Division of Fisheries).

Very little study has been made of the feeding habits of the Brassy minnow. Dobie, Wasburn and Meehean (1948) and Starrett (1950) have submitted data on the latter but it appears that further information is needed.

## Description

The Brassy minnow is small with large, easily removed scales. It closely resembles the Silvery minnow (*Hybognathus nuchalis*) and can be distinguished from the latter by its "brassy" or gold color. Its scales have many weak radii while those of the Silvery minnow have a few strong ones.

Also its head is more blunt and the fins more rounded than those of the Silvery minnow. The mouth is small, the peritoneal lining is black and the intestine more than twice the length of the body being coiled like a watchspring.

The pharyngeal teeth bear flat grinding edges (Plate III, Figure 4, on page 37) and only the inner row is present giving a 4-4 tooth formula. The teeth with their well defined grinding surfaces and the extremely long intestine are the adaptations of the plant-feeding minnows. Plant food is more difficult to digest than animal food and requires a longer time for digestion and assimilation. Hubbs and Cooper (1936) suggest that the Brassy minnow is evolved from the insect-eating shiners by reason of these morphological adaptations.

Distribution

Harlan and Speaker (1951) report that it is found in all major watersheds of Iowa where it attains a length of three to four inches and is much used as a bait for panfish.

Hubbs and Lagler (1947) define its range as extending from Montana through North Dakota, Minnesota, all of Wisconsin and both peninsulas of Michigan to southern Ontario and the Lake Champlain region. It is also found in the headwaters of the Hudson River in New York and extends southward in the west to Missouri, Nebraska and Colorado. It is present in all parts of the Great Lakes except the Lake Erie

PLATE III

Figure 3. BRASSY MINNOW DRAWING OF EXPOSED GILL CHAMBER TO SHOW SHORT GILL RAKERS

Figure 4. DRAWING OF PHARYNGEAL ARCHES TO SHOW TEETH WITH FLAT GRINDING SURFACES

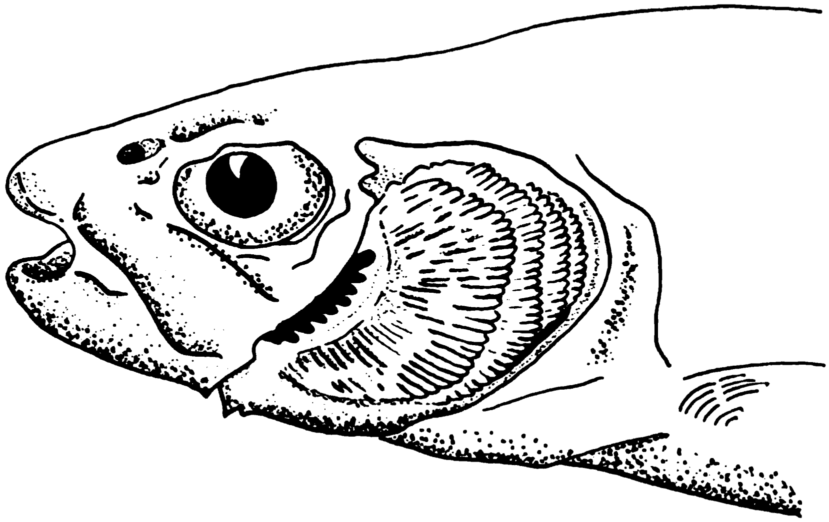


FIGURE 3.

BRASSY MINNOW

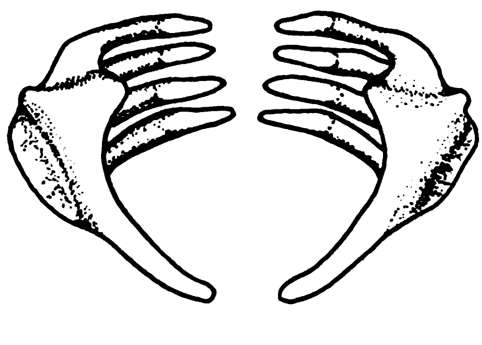


FIGURE 4.

basin of Ohio. It is found in creeks and lakes, most often in bog waters. Hubbs and Cooper (1936) listed its general habitat preference in Michigan as ponds and streams, its specific habitat as boggy waters. They mention that it is rare in the southern part of the lower peninsula, common in the northern part of the lower peninsula and common in the upper peninsula.

Literature Survey

Little is known of its feeding and breeding habits. It is suspected that it casts adhesive eggs over a sand bottom, mud or debris (Dobie, Washburn and Meehean, 1948). Starrett (1950) placed the Brassy minnow with the "early spawners" in the Des Moines River, those spawning in late spring or early summer. He summarized, "the Brassy minnow probably spawns in June, as is evidenced by the spent females". Turbidity of the water prevented direct observation of the spawning activities.

Some female Brassy minnows collected from the Michigan State College Experiment Station ponds at Lake City, Michigan were observed to have well developed eggs as early as May 5th (Schmid, 1949).

High total production with rapid growth and the vigor to withstand the lack of food while in the holding tanks are important aspects in the consideration of a commercial bait minnow. Dobie (1947) reported that one Minnesota hatchery successfully raised 212,500 Brassy minnows which represented 2.4 per cent of the total production possible from the planted number. It was not specifically stated whether eggs or fry were planted.

The Wisconsin Fish Management Division held Brassy minnows in tanks for sixty three days at forty degrees fahrenheit while feeding them all the canned Carp they could eat. Those receiving half as much Carp survived nearly as well and showed only slightly more loss of weight (Dobie, Washburn and Meehean, 1948). It appears that this minnow may show high production in ponds and appears to do well in holding tanks. The latter authors, however, did state that growth is slow and maturity was reached at an age of two years.

In his report on thirteen species of minnows from the Des Moines River, Starrett (1950) analyzed stomach and intestinal contents and concluded that phytoplankton was of little importance as a direct food for minnows. He also concluded that filamentous algae was taken only occasionally by most minnows. His examination of the contents from twenty six Brassy minnows revealed bottom microflora to comprise the entire volume of all food taken. Fathead minnows, eighteen in number, also showed nothing but "bottom ooze". Similiar results were given for the Bluntnose minnow and the Central stoneroller minnow (Campostoma anomalum) which, however, included a small percentage of aquatic insect larvae in the spring and summer. He grouped these species as "bottom ooze feeders". During high waters, this ooze was observed to be silt and mud with few or no Diatoms. Examination of the "bottom ooze" in the Des Moines River revealed it to be composed mostly of Diatoms distinguished from plankton in the digestive tract by the presence of fine sand and in some instances mud. The volume of ooze in the digestive tracts was found to decrease with rising water and increase with falling river water.

In reviewing the food of the Brassy it is probably well to include some comments on the Western silvery minnow (*Hybognathus nuchalis nuchalis*), a fish quite similiar in appearance and bearing the same morphological adaptations. According to observations of Forbes and Richardson (1920), the intestine is always filled with fine mud, containing only filamentous algae, Diatoms and other vegetable forms likely to be found on a mud bottom. They observed it in large schools of fifty to one hundred lying always nearer the bottom than the top, or moving slowly along the bottom as it fed. Hutchins (1947) reported that it did quite well in mud-bottom ponds devoid of vegetation as did Raney (1941) for the Eastern silvery minnow (*Hybognathus nuchalis regius*). Both of the latter investigators reported the species as spawning in late April through May. Raney (1941) reported a production of 6,650 per .15 acre pond and Hutchins (1947) 50,000 per acre.

Coyle (1930) concluded that the Fathead minnow feeds indiscriminately on a large number of algal species and mentioned that possibly the algal species found in the alimentary tract depend upon habitat but also that the number and size of gill rakers determines what forms are retained. He reported that this minnow required a pond rich in vegetation.

Ewers and Boesel (1935) found eleven Bluntnose minnow stomachs to contain material corresponding with that found by Starrett (1950) in the same species; 86.36 debris, insect remains 0.9 per cent and Crustacea 12.72 per cent by volume. Only a trace of algae was found to contribute to the total volume of the contents.

## Food Analysis

The digestive tracts of forty eight Brassy minnows were examined and it was observed that the contents of all consisted entirely of "bottom ooze". The intestines were well filled while only a few stomachs contained the ooze in significant amounts. It was apparent that many of the specimens had regurgitated the contents of the stomach.

The ooze consisted of plankton and autochthonous detritus (Welch, 1935). Table III on page forty three is submitted as an analysis of "bottom ooze" and offers only a limited interpretation of results unless considered as such.

TABLE III

STOMACH AND INTESTINAL CONTENTS OF 48 BRASSY MINNOWS
COLLECTED FROM POND "A", MICHIGAN STATE COLLEGE EXPERIMENT STATION;
LAKE CITY, MICHIGAN; OCTOBER 19, 1949

## TABLE III

STOMACH AND INTESTINAL CONTENTS OF 48 BRASSY MINNOWS
AN ANALYSIS OF BOTTOM OOZE*

Total Length 41-71 mm. Average Total Length 56.34 mm.
Standard Length 38-56 mm. Average Standard Length 44.5 mm.

| | Total number of organisms | Number of individuals containing organisms | Percentage of individuals | Estimation of volume |
|---|---|---|---|---|
| FILAMENTOUS ALGAE | | 42 | 87.50 | moderate |
| NONFILAMENTOUS ALGAE | | 33 | 68.75 | trace |
| HIGHER AQUATIC VEGETATION | | 36 | 75.00 | trace |
| ORGANIC DEBRIS | | 6 | 12.50 | trace |
| INORGANIC DEBRIS | | 37 | 37.00 | moderate |
| | | | | Number of organisms |
| CRUSTACEANS | | 8 | 16.67 | 18 |
| Ostracoda | | 4 | 8.33 | |
| Cladocera | | 4 | 8.33 | |
| Copepoda | | 5 | 10.41 | |

*Items of a size and condition permitting identification.
Greater part of volume represented decayed vegetable matter (ooze) and silt, not listed.

The writer believed that all vegetable matter, debris and Crustaceans recorded represented the "bottom ooze" consumed by the specimens. The algae and aquatic vegetation recorded was sufficiently well preserved as to be identifiable as such. For all practical purposes, the writer thought it wise to include all the forementioned items under the heading of "bottom ooze". To record the identifiable items (other than ooze) required much time being spent examining the contents of the entire length of the intestines.

The filamentous algae recorded was Spirogyra and was found in 87.5 per cent of the fish (42 by number). The vegetable ooze probably in considerable part represented decayed Spirogyra.

The species of nonfilamentous algae consisted mostly of Pediastrum with some Merismopedium, Diatoms, Desmids and a few Cosmarium. In no tract were they observed to be numerous or considered to represent an important part of the food. Random samples taken from each tract and examined under the compound microscope revealed the Diatomaceae to be so few as to be considered a scarce item.

Higher aquatic vegetation consisted of traces of small bits of leaf and stem portions. These bits of vegetation were found in seventy five per cent of the digestive tracts.

Unidentifiable remains of Crustaceans were classified as organic debris and were present in six specimens. Small crystals of sand were classified as inorganic debris and were present in thirty seven specimens.

The Crustaceans were not numerous, four Cladocerans being the most in any one stomach. Crustaceans were found in eight of the digestive tracts and do not represent a preference as a food item.

Discussion of Table III

The analysis of food taken by the Brassy minnows revealed that they had been feeding strictly on "bottom ooze" and supports the evidence presented by Starrett (1950).

This minnow bears the same morphological adaptations of the other bottom feeders: the Central stone-roller, the Fathead and the Bluntnose, bearing only pharyngeal teeth of the main row and having extremely long intestines. The teeth are not recurved (terminally hooked) and have the characteristic well-defined grinding surfaces. It is of interest that all these species possess a black peritoneal lining.

The volume of the "bottom ooze" represented silt and vegetable ooze. Close examination revealed that Diatoms were not present in appreciable numbers and were scarce when found in some digestive tracts. The Brassy minnow specimens contained algae in greater volume than the Bluegill and Blacknose shiner specimens. This algae was considered a component part of the "bottom ooze" as were the Crustaceans.

The contents corresponded with the food listed by Forbes and Richardson (1920) for the Western silvery minnow, a minnow of the same genus and of similiar appearance and morphology. It also corresponds with the data presented by Starrett (1950) for the Brassy minnow in the Des Moines River.

The data presented indicates that the Brassy minnow can be propagated in ponds devoid of higher aquatic vegetation and should prove it to be an excellent species for pond culture both as a bait and a forage fish. It could probably be raised with another species with a preference for an insectivorous or crustacean diet and offer no competition for the latter.

A bottom-feeder such as the Brassy might prove excellent forage for Black bass since they would not prey on the fry nor would they enter into food competition with the latter. Further experimentation is needed to support this view for the Brassy might prove to be easily depleted by the game fish as is the Fathead which Radcliff (1931) reported inferior to the Golden shiner for the same reason. The propagation of the Brassy as carried out by Michigan, Wisconsin and Minnesota proves that it can be successfully reared in small ponds.

It need not be fed to maintain high weights and it appears that there would be little danger of overstocking as can prove possible with some insectivorous species. It is doubtful that food would prove a limiting factor.

## SUMMARY

### Bluegill

1. Entomostracans and chironomid larvae were the main staples in the diet of the fingerling Bluegills. They comprised 55.94 and 28.30 per cent respectively of the total number of organisms recorded.

2. Hydracarina were found to comprise 10.50 per cent of the total number of organisms. All insects other than the Chironomids were found in so few numbers as to indicate they were rather insignificant as food organisms.

3. Higher aquatic vegetation and algae were found in only very small quantities indicating that these fish were not selecting vegetation as food.

### Northern Blacknose Shiner

1. Entomostracans made up almost the entire diet of the Blacknose shiners and represented 98.57 per cent of all organisms recorded. Ostracods made up only 1.87 per cent of the above percentage.

2. The Cladocerans and Copepods were mostly small individuals. Some of the Copepods were observed to be the nauplius and metanauplius stages.

3. Filamentous algae and higher aquatic vegetation was observed as only traces when found in the digestive tracts.

4. No relationship was found to exist between the diet and the development of the gill rakers.

Brassy Minnow

1. "Bottom ooze" represented the entire volume of the contents of all digestive tracts.

2. Filamentous algae was observed in quantity large enough to indicate that it formed a considerable part of the vegetable ooze present.

3. Diatoms and other nonfilamentous algae were scarce in numbers when observed.

4. The contents corresponded with data presented by Starrett (1950).

5. The short gill rakers, pharyngeal teeth with flat grinding surfaces and the long intestines appear to be the morphological adaptations of a "bottom ooze" feeder.

General

1. All three species studied should apparently benefit from the effects of fertilization for all feed on organisms

representing the base of the food cycle.

2. The Brassy minnow should be able to live in ponds devoid of vegetation and shows promise as a bait species.

3. The Northern blacknose shiner is not hardy enough to be considered as a commercial bait species.

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