FOOD HABITS OF THE SOUTHERN CHANNEL CATFISH (*ICTALURUS LACUSTRIS PUNCTATUS*) IN THE DES MOINES RIVER, IOWA[1]

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ABSTRACT

The stomach contents of 912 channel catfish (769 containing food) taken in a short section of the Des Moines River from September, 1940, to October, 1941, are analyzed. The physical and biotic characteristics of the study area are described; a partial list of the fishes present together with comments on their importance and relative abundance is included.

The channel catfish is omnivorous, as is revealed by a review of the pertinent literature and by this study. A wide variety of organisms is eaten (some 50 families of insects alone are represented—these are listed). Insects and fish serve as staple foods, plant seeds are taken in season, and various other items are eaten in limited numbers. The principal groups of foods (insects, fish, plants, and miscellaneous) are analyzed volumetrically, by frequency of occurrence, and numerically.

In the area studied, catfish grow at a rate of about 4 inches a year during the first 3 years of life (determined by length-frequency analysis). These natural size groups are utilized to establish the relationship between size and food habits. Young fish feed almost exclusively on aquatic insect larvae—chiefly midges, blackflies, mayflies, and caddis flies. In fish from 4 to 12 inches long insects continue to make up the bulk of the food, but at progressively greater size larger insects (mayflies and caddis flies) are eaten with increasing frequency and dipterans are of less importance than in the smaller size group; small fish and plant seeds become significant items of diet. In catfish more than 12 inches long, fish and large insects are of major importance, but many seeds and other items are taken. Although fewer insects are eaten by larger fish, those taken are more diversified and include a higher percentage of terrestrial forms.

Plant foods, chiefly of terrestrial origin, show the most striking seasonal trends of any of the food organisms. Seeds of the American elm in particular are taken in great numbers in May and June. Terrestrial insects are seasonal in appearance, being eaten at times of the principal flights. Aquatic dipterans are consumed consistently and in large numbers in the spring but progressively less frequently during the summer and fall; Trichoptera, however, are infrequently eaten in the spring but are of increased incidence in the summer and fall. These trends reflect changes in the numbers of organisms available. The numbers of the various species of forage fishes consumed are closely correlated with their relative abundance in the area. Several organisms which have been reported as important foods by other investigators (filamentous algae, microcrustaceans,

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crayfish, mollusks) are taken in insignificant quantity here, probably because these are rare in the Des Moines River.

In periods of low, relatively clear water, forage fish are eaten in sharply increased numbers—a reflection of their greater vulnerability. Feeding appears to be most active during the period from sundown until about midnight. Between 50° and 94° F., temperature does not seem to inhibit feeding, but in the winter the fish rarely feed. The available evidence indicates that adults do not feed during the breeding season.

In normal years reproduction of channel catfish is highly successful in prairie rivers. Efforts to increase production should be directed toward improvement of food supply and shelter facilities.

Introduction

The phenomena associated with or dependent on food and feeding relationships of fishes commonly dominate their ecological association. Growth rates are dependent to a large part on nutrition; the lack of an efficient population-limiting mechanism may result in such intense inter- or intraspecific competition for available food that growth cannot be maintained and stunting results. Food competition of undesirable species with game fish may effectively limit production of the more valuable forms. Similarly, predation on eggs, fry, or larger fish may reduce numbers or even eliminate species from a habitat. The mere mechanics of obtaining food by such bottom feeders as the carp and some suckers may, by increasing turbidity, profoundly alter the character of the environment to the detriment of valuable game species.

It becomes evident from these multiple and interrelated problems, still largely unanswered, that proper handling of the fishery resources calls for an understanding of the food-habit relationships of the chief game, non-game, and forage fishes.

The present investigation was designed as an intensive study of the food habits of the southern channel catfish, *Ictalurus lacustris punctatus* (Rafinesque), at a single locality. Thus, the results apply to one ecological situation and presumably are subject to more or less modification under other environmental conditions. The primary objectives of the investigation have been (1) to determine the qualitative and quantitative composition of the food eaten, including differences among young of the year, larger juveniles, and adults, (2) to determine daily and seasonal feeding trends, (3) to ascertain whether use of certain foods is favored, or if relative abundance, and size and habits of prey determine the quantities of various organisms consumed, and (4) to study the effects of such physical factors as temperature, fluctuation of water level, and turbidity on feeding behavior. Solution of all of these problems has not been fully achieved because of a necessary shortening of the contemplated period of field work and a sequence of heavy rains during the spring and early summer of 1941 when the specimens of certain sizes captured were too few for adequate determination of seasonal trends. The data presented are based upon analysis of the stomach contents of 912 channel catfish taken during September and October 1940 and from April to October 1941 from the Des Moines River. Their sizes ranged from less than an inch to 23 inches, total length.

A preliminary summary of this paper has been published by us (Bailey and Harrison, 1943).

The southern channel catfish is distributed throughout most of the Mississippi basin and the rivers of the South Atlantic states and the Gulf coast from Georgia to northeastern Mexico. In the Great Lakes drainage and northward it is replaced by the scarcely differentiated subspecies, *Ictalurus lacustris lacustris* (Walbaum), and in western Texas and parts of Mexico by *Ictalurus lacustris lupus* (Girard). Primarily a bottom-living inhabitant of moderate to swiftly flowing streams, it may nevertheless be locally abundant in sluggish rivers and in lakes. In contrast to the bullheads (*Ameiurus*), most of which occur over mud-bottomed areas, the habitat preference of the channel catfish is for bottom composed of sand, gravel, rubble, or a mixture of these with mud—where *Ictalurus* is found over mud bottom, the water is usually flowing. Toleration to low dissolved-oxygen content and high concentrations of the products of organic decomposition is less well developed than in the bullheads. The channel catfish ranks as one of the most important commercial fish in the Mississippi basin, and is much sought by anglers, especially in the prairie and plains states where it is the chief game fish in many rivers of moderate to large size.

Description of Study Area

The Des Moines River, a former glacial outlet, is the longest stream in Iowa excepting the Mississippi and Missouri rivers. Arising in the moraines of Murray County, Minnesota, at an elevation of 1,850 feet, it flows in a southeasterly direction across Iowa to its confluence with the Mississippi just below Keokuk, 535 stream miles away, at 476 feet above mean sea level. Except for wooded stream valleys the upper portion of the drainage basin was originally prairie, generously sprinkled with marshes and shallow lakes. At present 64 percent of the drainage area is in cropland, 29 percent is in pasture, and few lakes or marshes remain. As a partial consequence, rains are attended by rapid runoff and fluctuations of water level in the streams are pronounced (Figs. 1 and 2). The river, which is normally murky, becomes very turbid after heavy precipitation and approaches clarity only during drought periods and in the winter.

The study area is located in Section 17, Worth Township, Boone County, Iowa, about midway along the river. It is approximately three-fourths of a mile in length, limited by the Sixteen-to-One Bridge on the north and the outlet of the Ledges State Park stream on the south. This locality lies in Wisconsin glacial drift, which extends south to Des Moines, about 35 miles downstream. The elevation is

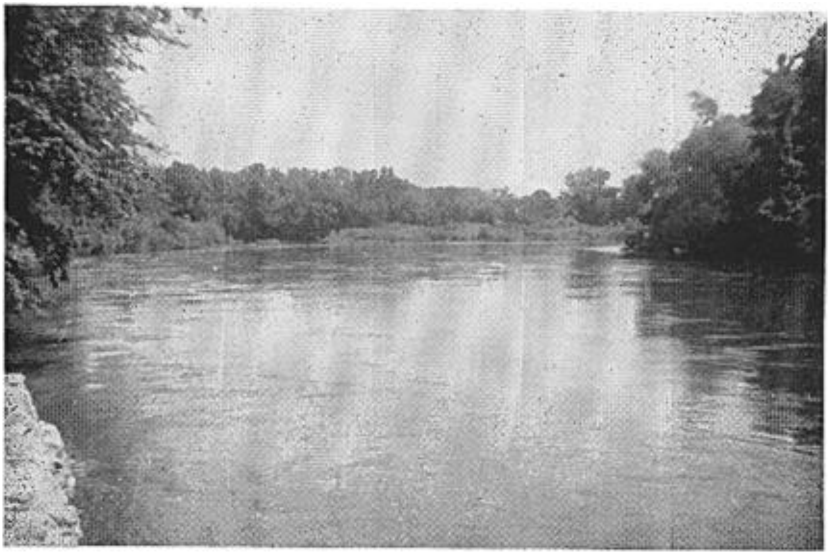

FIGURE 1.—A high-water stage of the Des Moines River. Down stream view of a portion of the study area.

FIGURE 2.—A low-water stage of the Des Moines River. Photograph taken from the same place as Figure 1, but at a slightly different angle. Note exposed rubble bottom (foreground) and drift jam (just left of center).

FIGURE 3.—Eroding bank on the outside of a meander of the Des Moines River. Floods may cut back several feet into such banks in a single year.

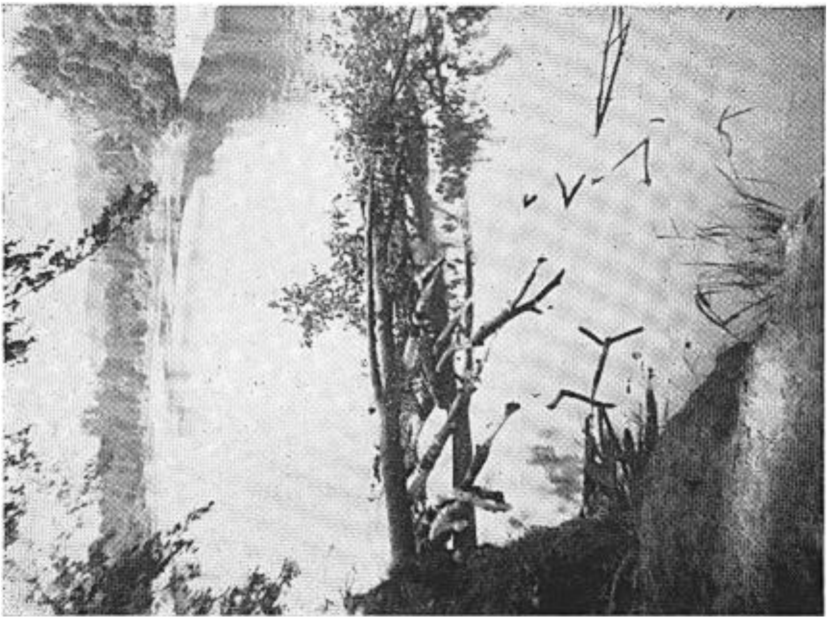

FIGURE 4.—Typical drift jam produced by a newly felled tree in which floating debris has been caught. Such sites harbor a rich insect fauna and provide excellent shelter for channel catfish.

855 feet and the stream gradient 2.53 feet per mile (computed from U. S. Geological Survey Topographic Maps). The adjacent bottomland and bluffs are for the most part heavily wooded, and, with the exceptions of sandbars, the shores are shaded by luxuriant undergrowth and willow, soft maple, American elm, box elder, ash, and basswood. On the outside of meanders the banks are nearly vertical, rising as much as 10 feet above the mean water level and falling steeply to a depth of 6 to 10 feet (Fig. 3). Water erosion along these banks periodically fells trees which accumulate floating brush and logs. The extensive masses of debris thus produced (Fig. 4) furnish ideal shelter conditions for fish and harbor a rich insect fauna. Wide, gradually sloping bars of sand and gravel are deposited on the inside of meanders. This section of the stream is a succession of long pools —about 8 feet deep—separated by rubble riffles and wide shallow bars of shifting sand. The channel is floored with coarse gravel and some boulders. Lateral bayous and lagoons are infrequent along the river and none is present in the area studied, but silt has been deposited in the backwaters and quite pools. The river averages about 200 feet in width during normal summer conditions, but fluctuations in depth and width are frequent and pronounced. The surface area of this portion of the stream is about 18 acres. Stream-flow records taken at the Boone Water Department (7 miles upstream and without important intervening tributaries) from 1921 to 1940 show the average discharge to be 1,240 second-feet—minimum 17 and maximum 24,300 (Crawford, 1942).

Biotic conditions are characterized by the rarity of aquatic vegetation and most invertebrates in contrast to the qualitative and quantitative richness of the fish fauna. Rooted aquatic vegetation is practically non-existent, but some algae occurs on rocks in riffle areas, and small quantities of a floating blue-green alga are evident in warm weather. The bottom fauna is very scanty. Only 461 organisms—total volume 11.45 cubic centimeters—were secured in 31 square-foot samples taken on all available bottom types from March to August with the Surber square-foot sampler. The square-foot sample average is 14.9 organisms with a mean volume of 0.37 cubic centimeter. With the exceptions of eight oligochaete worms, two gastropods and one isopod, all of the bottom organisms taken in the sampler were insects. Crayfish occur in small numbers. In contrast to the sparse bottom fauna, the down-timber, submerged brush, and log jams support a rich insect fauna and an abundance of the bryozoan, *Plumatella fungosa*. Although such situations occupy less than one percent of the stream area it would appear that they play a most important role in the production of fish food.

Fifty species of fishes have been collected in or adjacent to the study area in the Des Moines River (for a partial list and relative abundance of forage fishes see Table 4). More than half are small (predominantly minnows and darters) and of importance chiefly as forage organisms. As indicated in Table 4, the spotfin shiner (*Notropis spilopterus*) is the most abundant fish in the stream, followed by the sand shiner (*Notropis deliciosus*). Together they constitute about 60 percent of the total number of small fish. Among game fishes, the channel catfish is at once the most abundant and the recipient of the bulk of the anglers' efforts. The walleye (*Stizostedion v. vitreum*) and the smallmouth bass (*Micropterus d. dolomieu*) are both rather common, and, judging from reports, their numbers are increasing. Four additional game or pan fishes (black bullhead, *Ameiurus m. melas;* flathead catfish, *Pilodictis olivaris;* black crappie, *Pomoxis nigro-maculatus;* and white crappie, *Pomoxis annularis*) are uncommon, and three (northern pike, *Esox lucius;* eel, *Anguilla bostoniensis;* and yellow perch, *Perca flavescens*) are very rare, apparently occurring only as transients or stragglers. Although no precise data are available, it seems fairly certain that the poundage of the larger non-game fish present is greatly in excess of that of the game species. Probably chief among these non-game species is the carp. Although fished for by many anglers, it was taken infrequently in our nets, presumably because of its recognized adeptness in eluding small seines. Ten species of suckers are present. None is taken by fishermen in significant quantity, but results of seining indicate that three species of carpsuckers (*Carpiodes*), three of redhorse (*Moxostoma*), bigmouth buffalofish (*Megastomatobus cyprinella*) and hogmolly (*Hypentelium nigricans*) are numerous. Their ecological relationship with the game species (as potential food, egg predators, and competitors for food) would seem to merit careful investigation.

Previous Food Studies of Channel Catfish

One of the most informative accounts of the food of the channel catfish was published by Forbes (1888). It was based on 43 specimens from the Illinois and Mississippi rivers. Insects were the principal food; they constituted 44 percent of the volume and occurred in 28 of the fish; 5 had eaten insects only, and 9 others had taken 90 percent or more of insects. Aquatic insects were the more common, but several of the fish had fed on terrestrial forms. Mollusks, about equally watersnails and thin-shelled clams (mostly *Anodonta*), were important elements, being found in 15 of the 43 specimens. They amounted to about 15 percent of the food, and several catfish had eaten little else. As many as 120 watersnails, *Melantho* [=*Campeloma*] and *Vivipara*, were taken from a single stomach. The absence of mollusk shells in the stomachs led Forbes to conclude that the shells are cracked in the jaws (snails) or separated from the soft parts (bivalves) and voided from the mouth before swallowing. Fragments of fishes occurred in 11 examples. Some catfish had evidently secured food from dead fish but others had taken them alive. The animal materials consumed included a dead rat and pieces of ham. About one-fourth of the food consisted of vegetable matter, much of it miscellaneous and accidental. Three specimens had eaten nothing but algae; and fragments of pond-weed, *Potamogeton,* made up 20 percent of the diet of another three. The rarity of the floating *Lemma* was regarded as evidence of the strict bottom-feeding habits of the species.

McAtee and Weed (1915) studied the stomach contents of four adult channel catfish. The items found included the head and skin of an eel (*Anguilla*), seeds of the American elm, mayflies, a stonefly larva, a beetle, and vegetable debris.

Shira (1917) analyzed the stomach contents of 72 young channel catfish taken from rearing ponds at Fairport, Iowa. Midge larvae and mayfly nymphs were the most important items in the diet. The numbers of organisms eaten were roughly in proportion to their frequency in the ponds. At the same locality, Moore (1920) found insects (largely midges) and entomostracans to be the important items in the stomachs of 14 young catfish.

Three young specimens from New York examined by Sibley (1929) had eaten midges, other insect larvae, and *Gammarus.* Three adults had consumed fish, crayfish, insects, and plant fragments.

Ewers and Boesel (1935) investigated the stomach contents of five channel catfish (31 to 69 millimeters in total length) from Buckeye Lake, Ohio, and found the inclusions to consist of midges, copepods, and debris.

Aitken (1936) indicated that young quillback afford excellent forage for river catfish (presumably channel catfish).

Boesel (1938) studied the food of 61 channel catfish (34 to 101 millimeters in total length) taken at seven stations in Lake Erie between July 11 and August 29, 1929 and 1930. Insects (chiefly midge larvae and pupae and mayflies) made up 53 percent of the food by volume. Crustacea of many genera (principally cladocerans) constituted 33 percent of the diet. At some stations the food was composed predominantly of insects, at others of crustaceans. None of the larger catfish had fed to any extent on small crustaceans.

McCormick (1940) examined 14 specimens from Reelfoot Lake, Tennessee, and found caddis flies (38 percent by volume), filamentous algae (28 percent), and midge larvae (26 percent) to be the principal constituents of the food; fish made up 7 percent. In a continuation of this study at the same locality Rice (1941) analyzed 50 specimens and found 75 percent midge larvae and 25 percent caddis flies by volume.

On the basis of 38 specimens (3.1 to 10.6 inches long) from West Main Ditch, Imperial Valley, California, Dill (1944) found the catfish to be omnivorous. In analyses of frequency of occurrence and percentage volume midges, caddis fly larvae, Odonata, terrestrial insects and spiders, ooze (organic detritus and sand), and higher plants were of chief importance. Fish were infrequently taken but were exceeded in volume only by ooze. Five specimens from the Colorado River system had consumed substantial quantities of aquatic plants (mainly *Najas*) and some backswimmers.

Channel catfish taken in the Chickahominy River, Virginia, during August (Menzel, 1945) had fed principally on filamentous green algae. February specimens were found to have eaten blue crabs (*Callinectes sapidus*) and a white perch (*Morone americana*).

Dendy (1946) analyzed the stomach contents of 75 catfish (230 to 409 millimeters in standard length) from Norris Reservoir. Gizzard shad [*Dorosoma cepedianum*], undetermined fish remains, and insects (both aquatic and terrestrial) were taken most frequently. Dendy found that fish became more important in the diet as the catfish increased in length. The gizzard shad appeared to be the principal food item.

Procedure

In order to permit analysis of daily and seasonal feeding trends, collections were taken at various times of day and throughout the seasons of availability. Field plans called for samples taken at intervals not to exceed 2 weeks, but during periods of high water, fish could be caught only with such difficulty that collecting was postponed.

Three methods were employed in obtaining fish and fish stomachs for this study. Twenty-two stomachs of legal-sized fish (12 inches and more, total length) were procured from anglers. Seining proved to be the easiest way to collect young and juvenile catfish, but the difficulty of handling nets effectively in deep, swift water and the failure to capture adult fish in significant numbers limited their use. Seining was accomplished with a 25- by 6-foot net of ⅓-inch-square mesh, provided with a 7-foot bag of ¼-inch mesh.

Most of the adult catfish were secured by gear commonly known to anglers as bank poles. Three-foot chalk lines equipped with 2/0 Kirby hooks were attached to slender green willow poles about 4 feet long. These rigs were set at night along steep banks of the stream by forcing the butts of the poles into the mud just above the water line. The baits bobbed about on or just beneath the surface of the water near shore. Minnows, either dead or alive, were found to be the best bait, but cheese, doughballs, mussel bodies, and fresh shrimp tails were also utilized. In order to prevent error in stomach analyses minnow baits were fin-clipped. This angling technique was effective in taking large fish, and was adapted to use in deep water or about submerged brush piles.

Catfish small enough to be preserved in 2-quart jars were fixed immediately in 4-percent formalin; for longer fish, the necessary data were taken and the stomachs were placed in small cloth sacks and preserved. After fixation, specimens were transferred to 70-percent alcohol for storage and subsequent examination.

Following removal from each stomach, the contents were separated into four groups: (1) insects; (2) fish; (3) plants; and (4) miscellaneous items—including bryozoans, mollusks, crustaceans, birds, mammals, and debris. The fourth category included items which appeared infrequently and usually in such small quantities that further division was believed unnecessary. The volume of each of these groups was estimated as a percentage. The contents were then washed in a fine sieve (40 meshes to the inch) to remove amorphous material. Examination of the wash water of early analyses revealed that no essential materials were lost. The residue from the sieve was placed in water in a Petri dish and examined under a binocular dissecting microscope. All food organisms found in each stomach were identified and counted. The presence of elytra, head capsules, and other relatively resistant parts permitted a reasonably accurate count of insects. The numbers of fish and seeds were easily determined since they were seldom digested to a condition such that counts were impossible. The enumeration of plants, other than seeds, and of some of the miscellaneous items presented difficulties. All fragments of plants, mollusks, crustaceans, birds, mammals, and colonies of Bryoza that occurred in a single stomach were arbitrarily assigned a numerical evaluation of one.

The data are segregated by seasons, and the fish are grouped into four size classes. The first group includes fish less than 4 inches in total (overall) length, the second those from 4 to 7.9 inches, the third those from 8 to 11.9 inches, and the last those 12 inches or greater. Recently-hatched catfish first appeared in our nets during early July. June specimens had all passed through one winter, but were less than 4 inches in total length. By July, however, these yearlings were all more than 4 inches in length and thus fell in the second size group. Subsequent annual growth, as determined by length frequencies, was relatively uniform for at least 2 years. Therefore the first three size-groups are composed largely of fish in their first, second, and third years of life, respectively. The fourth group includes fish of legal length (in Iowa).

Qualitative Composition of the Food

An imposing variety of animals and plants was found in stomachs of channel catfish from the Des Moines River, and, as indicated by the works of others, the species may indeed properly be termed omnivorous. Plant materials are consumed when available and aquatic insects and fish appear to serve as staple foods, but the catfish utilize various other animals and occasionally resort to scavenging. As might be expected from the diverse diet, many items are found infrequently and are regarded as fortuitous and therefore insignificant.

Insects dominate the food, especially of the smaller catfish. Aquatic larvae are more commonly used, but terrestrial insects are frequently eaten by larger catfish. In the tables and much of the succeeding discussion the insects are lumped by orders for the sake of brevity and simplification. However, during the analyses identifications were carried as far as could be readily accomplished, and a list of the determinations is presented below. In order to indicate those species or categories of minor or incidental importance, an asterisk precedes each item which is represented in 10 or more of the 769 stomach containing food. The identifications in this list are our own.

List of Insects Contained in Catfish Stomachs

Orthoptera

- Locustidae
  - *Melanoplus differentialis*
  - *M. femur-rubrum*
- Tettigoniidae
  - *Orchelimum vulgare*

Neuroptera

- Corydalidae
  - *Corydalus cornutus*
- Myrmeleonidae
  - *Myrmeleon* sp.

*Ephemeroptera

- *Baetidae
  - *Ameletus* sp.
  - *Baetisca* sp.
  - *Brachycercus* sp.
  - *Caenis* sp.
  - *Isonychia* sp.
  - *Siphlonurus* sp.
- *Ephemeridae
  - *Ephoron* sp.
  - *Hexagenia atrocaudata*
  - *Hexagenia* sp.
  - **Pentagenia* sp.
  - **Potamanthus* sp.
- *Heptageniidae
  - **Heptagenia* sp.
  - **Iron* sp.
  - *Stenonema* sp.

Odonata

- Gomphidae
  - *Gomphus* sp.
- Cordulegasteridae
  - *Cordulegaster maculatus*

*Plecoptera

- Perlidae
  - *Acroneuria lycorias*
  - *Neophasganophora capitata*
  - *Perla hastata*
  - *Perlesta* sp.

*Hemiptera

- *Corixidae
  - **Arctocorisa* sp.
- Miridae
  - *Lygus pratensis*
- Pentatomidae
  - *Podisus maculiventris*
- Reduviidae

*Homoptera

- Aphididae
- Cicadellidae
- Membracidae
  - *Atymna querei*
  - *Cercsa diceros*
- Cicadidae
  - *Tibicen auletes*

*Coleoptera

- Buprestidae
- Carabidae
  - *Evarthrus colossus*
- Chrysomelidae
  - *Diabrotica duodecim-punctata*
  - *Lina interrupta*
- Coccinellidae
  - *Hippodamia* sp.
  - *Megilla maculata*
- Erotylidae
- Gyrinidae
  - *Gyrinus* sp.
- Haliplidae
  - *Peltodytes* sp.
- Hydrophilidae
  - *Berosus striatus*
  - *Hydrous triangularis*
  - *Enochrous* sp.

*Dytiscidae
  **Dytiscus* sp.
Curculionidae
*Elmidae
  **Elmis* sp.
Lathridiidae
Scarabaeidae
  Geotrupes sp.
  Phyllophaga sp.
Silphidae

*Trichoptera

*Leptoceridae
  **Setodes* sp.
*Hydropsychidae
  **Hydropsyche* sp.
Phryganeidae
Sericostomatidae
Brachycentridae
  Brachycentrus sp.
Helicopsychidae
  Helicopsyche borealis

Lepidoptera

*Diptera

*Tendipedidae (=Chironomidae)
Dolichopodidae
Muscidae
Psychodidae
  Psychoda sp.
Sarcophagidae
  Sarcophaga sp.
*Simuliidae
  **Simulium* sp.
Stratiomyidae
  Euparyphus sp.
  Stratiomyia sp.
Tabanidae
  Tabanus sp.
*Tipulidae
  **Antocha* sp.
  Pedicia sp.
  Ptychoptera sp.
  Rhamphidia sp.
  Rhaphidolabis sp.

Hymenoptera

Formicidae
Vespidae

Only four orders of insects contribute heavily to the food (see Table 2). Among the Diptera the tendipedids (chironomids) are of greatest importance, and indeed comprise the great bulk of the food of young catfish, but blackfly larvae (*Simulium*) are also commonly found. Mayflies (Ephemeroptera) are second in importance, chiefly because of the large number of nymphs of *Potamanthus* and *Pentagenia.* Caddis flies (Trichoptera) are of value largely through the abundant appearance of larval hydropsychids. The beetles (Coleoptera) most often taken are aquatic forms (*Elmis* and *Dytiscus*), but terrestrial species appear frequently.

The fishes, plants, and other organisms eaten are listed in Table 2. The relative importance of the various forms as determined on the basis of frequency of occurrence is indicated.

Minnows (Cyprinidae) are dominant among the fish foods, no less than 14 species being encountered. A sucker, a darter, and small channel catfish also were recorded.

Plant foods are not usually a major item except during the fruiting season of the American elm (*Ulmus americana*). At this time the seeds are eaten freely by all but the smallest catfish. The Des Moines River in this area is practically devoid of aquatic vegetation, a circumstance which explains the infrequent use of vegetable materials in contrast to the relatively greater importance of such foods as determined by Forbes (1888). Most of the records of plant materials are based on seeds, but an occasional leaf is found, and debris (often ingested incidentally from the cases of the caddis fly, *Setodes* sp.) is frequently noted.

Crustaceans, pelecypods, and gastropods—found to be significant foods in studies by Forbes (1888), Moore (1920), Ewers and Boesel (1935), and Boesel (1938)—are little used by catfish in the Des Moines River. The obvious explanation for this difference hinges on the rarity of these organisms in the area.

The bryozoan *Plumatella fungosa* is consumed commonly.

The stomach of one adult catfish was filled with coal, and another had ingested several small pieces. Sand, presumably taken accidentally, was encountered on several occasions.

Fish bait, such as doughball, liver, and shrimp tails taken either from the hook or from discarded bait cans, made up a considerable part of the stomach content of several fish.

Quantitative Composition of the Food

Students of food habits of animals differ in their methods of quantitative analysis. Some favor volumetric or weight measurement; others prefer to record presence or absence of a given item and use frequency of occurrence as a quantitative index. Still others endeavor to count the number of individual organisms in each sample. Proponents of the frequency-of-occurrence method contend that this is the easiest analysis to make, and hold that volumetric and item-count determinations are subject to gross inaccuracy because of differential digestion and the fragmentation of organisms, especially through mastication. These arguments appear often to be valid, as in analyses of feces or intestinal contents, and for those animals which chew the food thoroughly. For stomach analyses of most fish, however, the volumetric method seems usually to provide a more valuable index. By this method, for example, analysis of a stomach containing an adult crayfish and two midge larvae would emphasize the greater importance of the former. By the presence-or-absence criterion, both food organisms would be recorded simply as present, and by item count the midge would be given twice the value of the much larger crayfish. Multiplication of the mean size of an organism and its frequency in a stomach gives, in effect, a volumetric measurement. Digestion in the catfish stomachs was rarely so far advanced as to affect seriously volumetric analysis, but intestinal contents were rejected because of dissolution.

In this study the four principal categories of foods (page 118) are analyzed volumetrically, by frequency of occurrence, and numerically. The results, arranged by size-groups of the catfish, are summarized in Table 1. Comparison of the volumetric and frequency-of-occurrence analyses is given in Figure 5. Except for the small catfish, which feed almost entirely on insects, it is seen that the frequency of occur-

TABLE 1.——*Major foods of four size groups of the channel catfish from the Des Moines River.*
[Expressed as averages of the estimated percentage volumes, percentage frequencies of occurrence, and average numbers of items contained in the stomachs.]

Food group	Total length and number of stomachs containing food											
	Less than 4 inches			4.0-7.9 inches			8.0-11.9 inches			12 inches or more		
	410			221			59			79		
	Percentage volume	Percentage frequency of occurrence	Average number items	Percentage volume	Percentage frequency of occurrence	Average number items	Percentage volume	Percentage frequency of occurrence	Average number items	Percentage volume	Percentage frequency of occurrence	Average number items
Insects	98	99	6.0	77	97	11.1	58	90	11.3	28	80	7.2
Fish	1	4	....[2]	8	22	0.3	12	22	0.4	35	47	1.9
Plants	1	2	....[2]	11	34	5.3	23	46	29.5	19	46	23.3
Others	....[1]	2	....[2]	4	6	0.1	7	10	0.2	19	18	0.2

[1]Less than 0.5 percent.
[2]Less than 0.05 item.

rence magnifies the relative importance of small organisms (insects and plant seeds) in any size-group. Thus, in those catfish 12 inches

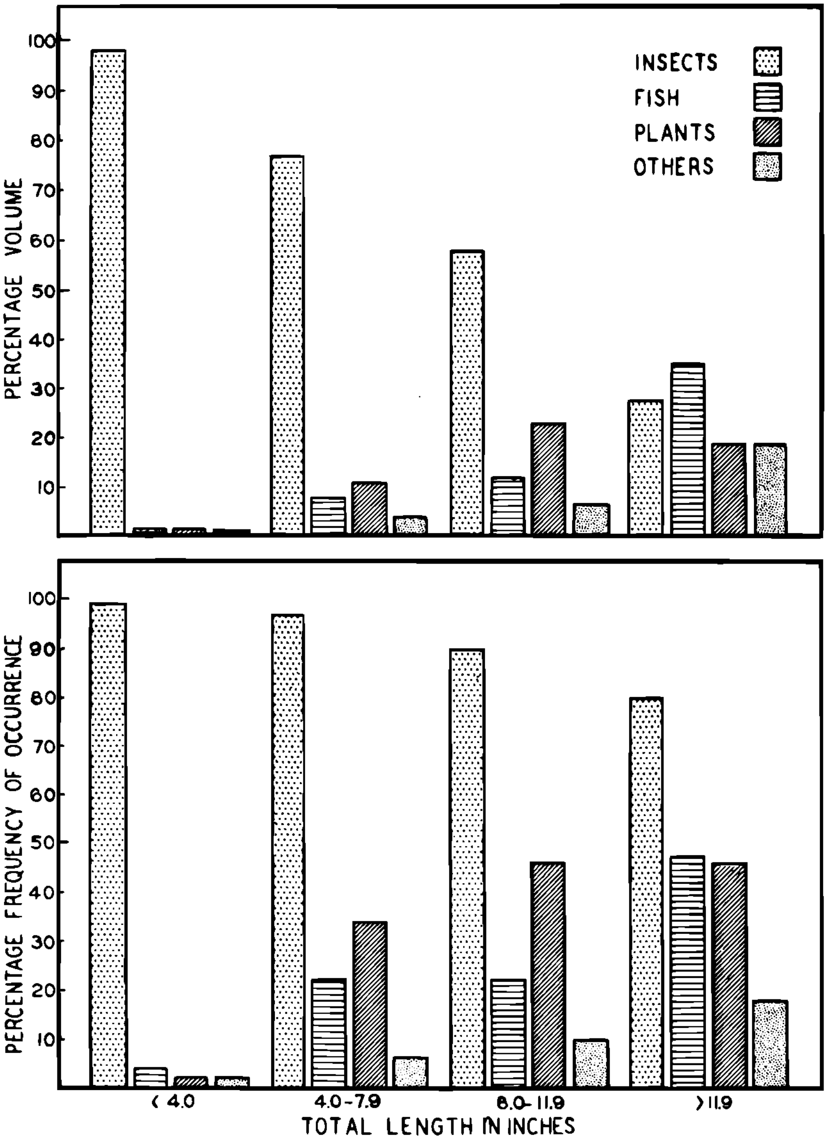

FIGURE 5.—Histograms giving comparative results of volumetric and frequency-of-occurrence analyses of the principal food groups of four size classes of channel catfish from the Des Moines River (data from Table 1).

or more in length, fish are less important than insects as determined by frequency of occurrence, but are more important as measured volumetrically. Miscellaneous foods are encountered less than half as often as plant materials, but bulk the same. The item count of organisms appears to be especially instructive in the discernment of seasonal trends and the relationship of size to food habits.

Although determination of volumes appeals to us as the best single method of stomach analysis, it was not used in this study in the breakdown to specific food organisms (Table 2). The wide variety of foods and their small volumes posed problems which are handled most effectively by use of frequency-of-occurrence and item-count methods.

Size in Relation to Foods Consumed

The food habits of small and large channel catfish are markedly different. Small insects constitute the bulk of the food of young fish, whereas the diet of adult fish is diversified and is dominated by organisms of larger size. Ninety-nine percent of catfish under 4 inches long had eaten insects amounting to 98 percent of the volume of food. In contrast, insects had been consumed by 80 percent of fish 12 inches or longer, but bulked only 28 percent of the food. The major groups of foods are compared in Table 1 and the percentage volumes and frequencies of occurrence of the various categories are presented as histograms in Figure 5. Counts of the number of individual organisms in the stomachs show an increase of from 6 insects in fish less than 4 inches in length to an average of more than 11 in fish from 4 to 12 inches, but larger specimens contain only about 7 insects. Forage fish, negligible in the smallest group, average about one to every two or three stomachs of half-grown fish, but legal catfish eat an average of almost 2 forage fish each. Young catfish rarely consume plant materials, but specimens 8 inches or longer average over 20 seeds (the precise average figures are not of great significance because of the marked seasonal appearance of American elm fruits and the occasional discovery of enormous numbers of these seeds in a stomach). Other foods never provide high item counts but appear most frequently and in greatest bulk in large fish.

It is indicated above that there is an inverse relationship between size of catfish and the importance of insects in the diet. There is also a positive correlation between size of fish and size of insect prey (Table 2). The dipterous larvae in the Des Moines River consist principally of small forms, chiefly tendipedids and simuliids. These, the most abundant small though macroscopic organisms in the river, make up 81 percent of the aquatic insects in the stomachs of catfish under 4 inches in length (Table 4). In successively larger size groups of fish, Diptera make up 65, 71, and 12 percent of the aquatic insects consumed. Frequency-of-occurrence analysis shows that 80, 77, 41, and 29 percent respectively of the fish in the four size groups had eaten Diptera. In the larger size groups dipterans sometimes equal the

TABLE 2.—*Percentage frequencies of occurrence of foods of different size groups of channel catfish, arranged to show seasonal trends.*

[Percentages are based on the number of stomachs containing food; totals are weighted averages, not averages of seasonal percentage frequencies]

Food	Size group[1] and number of stomachs containing food during:															
	April-June				July-August				September-October				All months			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
	16	83	16	5	133	47	26	39	261	91	17	35	410	221	59	79
Insects	100	98	100	100	98	98	88	90	99	97	82	66	99	97	90	80
Aquatic	100	98	94	80	94	96	69	85	97	85	71	66	96	92	76	76
Terrestrial	....	....	56	100	1	13	12	28	5	18	12	9	3	19	24	24
Undetermined	13	10	6	20	14	13	19	3	22	21	12	6	19	15	14	5
Determined	100	98	100	100	94	96	69	87	92	87	71	66	93	93	78	78
Orthoptera	....	....	....	....	1	....	....	5	....	1	12	....	....[2]	....[2]	3	3
Neuroptera	....	2	....	....	....	2	12	....	....	....	....	3	....	1	5	1
Ephemeroptera	63	73	75	60	30	74	42	44	36	41	24	14	35	60	46	32
Odonata	....	4	....	....	....	2	....	5	1	1	....	3	....[2]	2	....	4
Plecoptera	....	5	....	....	....	....	8	3	....[2]	....	....	3	....[2]	2	3	3
Hemiptera	....	16	....	40	1	4	....	15	2	13	....	3	1	12	....	11
Homoptera	....	6	....	....	....	....	4	5	2	5	....	....	1	5	2	3
Coleoptera	6	37	56	100	2	15	8	15	7	16	18	20	6	24	24	23
Trichoptera	25	35	19	40	19	81	58	74	38	49	41	29	31	51	42	52
Lepidoptera	6	2	....	....	....	....	....	....	....	1	....	3	....[2]	1	....	1
Diptera	94	81	63	20	86	79	31	38	77	73	35	20	80	77	41	29
Hymenoptera	....	4	....	....	....	4	8	5	3	2	....	....	2	3	3	3
Fish scales	....	14	....	40	....	13	12	10	5	10	24	11	3	12	12	13
Fish eggs	....	6	....	....	....	....	....	....	....	....	....	....	....	2	....	....
Fish	....	4	6	40	1	11	15	31	1	8	24	46	1	7	15	38
Undetermined	....	....	....	....	1	....	4	3	1	....	....	9	1	....	2	5
Determined	....	4	6	40	....	11	12	31	....	8	24	43	....	7	14	37
Catostomidae (undetermined)	....	....	....	....	....	....	....	3	....	....	....	....	....	....	....	1
Carpiodes spp.	....	....	....	....	....	....	....	3	....	....	....	....	....	....	....	1
Cyprinidae (undetermined)	....	....	....	20	....	....	4	10	....	....	....	....	....	....	2	6
Erimystax sp.	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	1
Extrarius aestivalis	....	1	....	....	....	....	....	....	....	....	....	....	....	....[2]	....	....
Notropis (undetermined)	....	1	....	....	....	....	....	10	....	1	6	....	....	1	2	5
Notropis a. atherinoides	....	....	....	....	....	....	....	....	....	....	6	9	....	....	2	4
Notropis rubellus	....	....	....	....	....	2	....	....	....	1	....	6	....	1	....	3
Notropis cornutus frontalis	....	....	....	....	....	....	....	....	....	....	12	14	....	....	3	6
Notropis d. dorsalis	....	....	....	....	....	....	....	5	....	....	....	14	....	....	....	9
Notropis spilopterus	....	1	....	20	....	9	4	8	....	5	18	37	....	5	7	22
Notropis d. deliciosus	....	....	....	....	....	....	4	5	....	....	12	29	....	....	5	15

TABLE 2—*continued*

[Percentages are based on the number of stomachs containing food; totals are weighted averages, not averages of seasonal percentage frequencies]

Food	Size group[1] and number of stomachs containing food during:															
	April-June				July-August				September-October				All months			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
	16	83	16	5	133	47	26	39	261	91	17	35	410	221	59	79
Notropis topeka	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	1
Phenacobius mirabilis	....	....	....	....	....	....	....	....	....	....	....	6	....	....	....	3
Ceratichthys perspicuus	....	....	....	....	....	....	....	....	....	1	6	17	....	....[2]	2	8
Hyborhynchus notatus	....	....	6	....	....	....	....	....	....	....	....	11	....	....	2	5
Pimephales p. promelas	....	....	....	....	....	....	....	3	....	....	....	11	....	....	....	6
Ictalurus lacustris punctatus	....	....	....	....	....	....	....	3	....	....	....	....	....	....	....	1
Boleosoma n. nigrum	....	....	....	....	....	....	....	....	....	....	....	6	....	....	....	3
Plant	....	58	69	60	....	19	42	59	3	20	29	29	2	34	46	46
Debris	....	11	13	....	....	11	27	41	....	10	6	20	....	10	17	29
Undetermined	....	2	....	....	....	6	12	15	2	5	6	3	1	5	7	9
Determined	....	52	56	60	....	2	4	18	....[2]	5	18	23	....[2]	22	22	23
Vaucheria sp.	....	1	6	....	....	....	....	....	....	....	....	....	....	....[2]	2	....
Poa pratensis	....	....	....	....	....	....	....	3	....	....	6	....	....	....	2	1
Zea mays	....	....	....	....	....	....	....	8	....	....	....	14	....	....	....	10
Salix sp.	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	1
Quercus sp.	....	....	....	....	....	....	....	3	....	....	....	....	....	....	....	1
Ulmus americana	....	51	56	60	....	....	....	....	....	....	....	....	....	19	15	4
Celtis occidentalis	....	....	....	....	....	....	4	....	....	....	....	....	....	....	2	....
Polygonum perspicaria	....	1	6	....	....	2	....	....	....	2	6	....	....	2	3	...
Amaranthus sp.	....	1	....	....	....	....	....	....	....[2]	1	....	....	....[2]	1	....	....
Acer negundo	....	1	....	....	....	....	....	....	....	....	....	....	....	....[2]	....	....
Vitis sp.	....	....	....	....	....	....	....	....	....	2	12	3	....	1	3	1
Cornus sp.	....	....	....	....	....	....	....	3	....	....	....	....	....	....	....	1
Ambrosia artemisiifolia	....	....	....	....	....	....	....	3	....	....	....	....	....	....	....	1
Ambrosia trifida	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	1
Bryozoa (*Plumatella fungosa*)	....	1	....	....	2	6	4	....	....	3	....	....	....[2]	3	2	....
Gastropods	....	....	....	....	....	2	....	....	....	3	6	....	....	2	2	....
Amnicola sp.	....	....	....	....	....	....	....	....	....	2	....	....	....	1	....	....
Planorbis sp.	....	....	....	....	....	2	....	....	....	1	....	....	....	1	....	....
Cambarinae	....	1	....	....	....	....	4	8	....	....	18	9	....	....[2]	8	8
Hydrachnidae	....	1	....	....	....	....	....	....	1	....	....	....	1	....[2]	....	....
Birds	....	....	....	....	....	....	....	5	....	....	....	3	....	....	....	4
Gallus gallus	....	....	....	....	....	....	....	5	....	....	....	....	....	....	....	3
Passerine (undetermined)	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	1
Mammal (hair)	....	1	....	....	....	....	....	13	....	....	....	....	....	....[2]	....	6

[1]Size-group 1 includes catfish less than 4 inches in total length, group 2 those from 4.0 to 7.9 inches, group 3 individuals from 8.0 to 11.9 inches, and group 4 fish 12.0 inches or longer.

[2]Less than 0.5 percent.

number or frequency of ephemeropterans and trichopterans, but are regarded as less important because of their smaller bulk. The Ephemeroptera are somewhat larger; the forms most commonly consumed are nymphs of *Potamanthus*, *Pentagenia*, and *Heptagenia*. It appears that they are utilized most by the yearling and 2-year-old fish. Of all the aquatic insects eaten, mayflies constitute 9, 15, 18, and 13 percent in increasingly larger size groups, and 35, 60, 46, and 32 percent of the fish in the several groups feed on them. Trichoptera are small insects, but because of their protective cases only the larger catfish prey on them effectively. *Hydropsyche* sp. is easily the dominant caddis fly; *Setodes* sp. appears only about one-tenth as often and other forms even less frequently. Trichopterans make up only 8 percent of the aquatic insects eaten by young catfish, but comprise 72 percent of those taken by fish 12 inches or longer (Table 3). That all size groups eat caddis flies, at least in small numbers, is indicated by the percentages of occurrence: 31, 51, 42, and 52 (Table 2). Other insects are eaten in small numbers; no more than 2 percent of the aquatic insects eaten by any size group belong to an order other than the Diptera, Ephemeroptera, and Trichoptera. Nevertheless, nearly one-fourth of the catfish in each of the three larger size groups consume Coleoptera (chiefly *Elmis* sp. and *Dytiscus* sp.), and they often take Hemiptera (especially *Arctocorisa* sp.)—see Table 2. Insects provide a smaller proportion of the diet in large than in young catfish, but a wider variety is consumed: most of the numerous kinds taken infrequently (see pp. 120-121) are encountered only in the half-grown to adult fish.

Aquatic insects predominate over terrestrial species in all size groups, but the latter are taken more frequently by the larger fish (Table 2). Aquatic species are found in 96 percent of the stomachs of catfish less than 4 inches long, terrestrial insects in only 3 percent. Among legal fish 76 percent contain aquatic insects, 24 percent terrestrial kinds. The explanation for the increased use of terrestrial insects by larger fish involves the mechanical advantage of greater size, more favorable choice of habitat, and probably less restriction to bottom feeding. Many terrestrial insects are available to large catfish, but are too large for the young fish to engulf. Larger catfish most often inhabit deep water, which is usually near the eroding banks on the outside of meanders. Here much vegetation overhangs the stream and terrestrial insects frequently drop to the water, where they are available to the large catfish. In contrast, the shoal areas preferred by young catfish lie in the middle of the stream or near shelving sand bars on the inside of meanders, and few terrestrial insects drop to the water, although some float by. We know little of the feeding behavior of young catfish from direct observation, but suspect that they do most of it on the bottom. The nature of the food eaten confirms this belief. The adult fish, though characteristically bottom feeders, frequently rise to the surface to eat (see description of one method used to take adult catfish for this study, p. 118). This apparently greater latitude in feeding behavior explains in part the higher incidence of terrestrial insects in the diet.

Fish scales not associated with other remains are encountered rarely in young catfish, frequently in the larger size-groups. It is possible that some of these scales represent specimens which have otherwise passed into the intestine, but we believe that they are ingested chiefly when scavenging or, more commonly, as single isolated scales. Because of their insignificant volume and questionable nutritive value they are segregated from the fish eaten (Table 2). Fish eggs occur in five catfish between 4 and 8 inches in length taken during May, but no stomach contains more than three eggs. It is apparent that at this locality channel catfish are of minor importance as egg predators.

Fish are negligible in the food of young catfish and of limited importance to yearlings and 2-year-olds, but on a volumetric basis constitute the principal food group in the adults. Three young catfish (2.0, 2.2, and 2.3 inches in length) of the 410 with food contain fry which are too badly mutilated to permit identification. Minnows occur in 7 percent of catfish 4.0 to 7.9 inches long and in 14 percent of those from 8.0 to 11.9 inches. Thirty-seven percent of the adults contain fish (Table 2). Forage fish are constantly present in abundance, but because of their size and agility are not vulnerable to predation by small catfish. These safeguards are less effective against the larger, faster, and stronger adults.

Plant materials are virtually absent from the stomachs of catfish less than 4 inches in length, but the larger fish use them commonly when available. Plants, among all catfish foods, are most sharply seasonal in appearance. This situation is readily understandable since (except for debris, an occasional leaf, or a strand of *Vaucheria*) the materials consist of seeds from terrestrial plants. Because of differences in the seasonal distribution of samples among the several size groups of catfish, the overall averages are subject to error. Vegetable debris becomes increasingly frequent in the larger fish. It usually occurs in small volume, and is probably taken incidentally or in cases of the trichopteran, *Setodes* sp. (*Setodes* also appears with increasing frequency in successively larger fish.) Fruits of the American elm dominate the plant foods (Table 2). They are not eaten by catfish less than 4 inches long, but occur with approximately equal frequency in spring samples of the three other size groups. It is of interest that these fruits usually appear without their seed coats. Presumably the seed covers are removed in a manner comparable to that described by Forbes (1888) for the separation of mollusk shells from the soft parts. Occasionally over 100 elm seeds occur in a single stomach. One catfish 12.5 inches long contains 1,129 of these seeds, and three smaller specimens have 647, 576, and 262. Corn (*Zea mays*), found only in the stomachs of seven legal fish, is usually represented by not more than one or two kernels.

Miscellaneous animal foods are taken rarely by catfish less than 4 inches in length, not infrequently by fish from 4 to 12 inches long, and rather commonly and in appreciable quantity by legal-sized fish (Table 2). Most of these organisms are too large to be consumed by small catfish. It is probable that if crayfish and snails were common in the area they would contribute heavily to the food of the large fish.

Seasonal Food Trends and Availability of Food Organisms

Seasonal changes in the food of the channel catfish are gradual and, usually, slight. For the most part they are characterized by a shift in the relative importance of certain items or groups of organisms rather than by a sharp break from or to a different diet. Plant foods, which are almost entirely of terrestrial origin, present the most marked seasonal fluctuations (Table 2). Seeds of the American elm are eaten abundantly during May and sometimes in June, but never at other times. Seeds of the wild grape (*Vitis* sp.) appear only in the fall, corn in late summer and fall. Terrestrial insects, too, are seasonal in appearance. During May, the month of the principal beetle flights, these insects are more common than at other times, but most species of other aerial insects are eaten only or chiefly during the late summer and fall.

We have attempted to determine the seasonal relationship between the numbers of aquatic insects present in the Des Moines River and their relative frequency in the stomachs of channel catfish. Toward this end, samples were taken from representative bottom types each month from April through September. The total numbers of insects secured, together with the percentage composition of each order represented, are recorded by seasons in Table 3.[3] Diptera, which constitute 68 percent of the total in the spring, decrease in relative numbers as the season progresses so that by September they make up only 16 percent. Simultaneously the Trichoptera increase from 10 to 81 percent, and the Ephemeroptera decrease from 11 to 2 percent. Other groups are of relatively minor importance. In line with these marked changes in the bottom fauna, it is noted that the number of insects in catfish stomachs varied too (Table 3). Diptera, although not eaten in large numbers by legal fish, are of major importance in the spring in fish under 12 inches in length. In the summer and fall, however, fish of all sizes eat relatively smaller numbers of them. Trichoptera are of little importance as a spring food, but become very numerous in the stomachs during the summer and fall, far outnumbering the Diptera in fish over 8 inches long. Despite the decrease in numbers of Ephemeroptera noted in the bottom samples as the season progresses, there is no reduction in their frequency in the stomach contents, and they are eaten most often in the summer. Examination

[3]It is a matter for regret that we failed early enough to recognize the important role which floating log jams and large masses of branches and debris play in the production and harboring of aquatic insects. The contribution of such areas may materially alter the relative figures determined from bottom sampling alone.

TABLE 3.—*Comparison of the numbers of aquatic insects eaten by channel catfish with the numbers in the Des Moines River (determined by bottom sampling in 1941).*

[Numbers are expressed as percentages to facilitate comparison]

Order	Size group of fish[1] and number of insects taken in the river and in stomachs during:																			
	April-June					July-August					September					All months				
	River	Stomachs				River	Stomachs				River	Stomachs				River	Stomachs			
		1	2	3	4		1	2	3	4		1	2	3	4		1	2	3	4
	237	174	1,168	394	19	245	851	410	79	260	323	278	180	18	115	805	1,303	1,758	491	394
Neuroptera	....	....	....	....	....	1	....	....[2]	4	....	....[2]	....	....	....	....	....[2]	....	....[2]	1	....
Ephemeroptera	11	7	12	14	68	5	8	25	38	12	2	13	13	11	6	5	9	15	18	13
Odonata	2	....	....[2]	....	....	1	....	....[2]	....	1	....	....[2]	....	....	2	1	....[2]	....[2]	....	1
Plecoptera	....[2]	....	....[2]	....	....	....[2]	....	....	4	....[2]	....[2]	....	....	....	....	....[2]	....	....[2]	1	1
Hemiptera	6	....	1	....	5	1	....[2]	1	....	....[2]	....	....	....	....	....	2	....[2]	1	....	1
Coleoptera	2	1	2	....	5	3	3	1	3	....[2]	....	2	2	11	....	1	2	2	1	1
Trichoptera	10	3	4	1	....	36	6	48	42	73	81	15	24	44	82	46	8	16	9	72
Diptera	68	88	80	85	21	53	83	25	10	13	16	69	61	33	10	43	81	65	71	12

[1]Size group 1 includes catfish less than 4 inches in total length; group 2, those from 4.0 to 7.9 inches; group 3, individuals from 8.0 to 11.9 inches; and group 4, fish 12.0 inches or longer.

[2]Less than 0.5 percent.

of the floating masses of debris reveals large numbers of mayflies, and this source, which is available to the fish, probably explains the apparent lack of correlation in numbers available and insects eaten.

It is recognized that the relative numbers of various organisms present in a habitat do not constitute a true ratio of availability (Hess and Swartz, 1941; Allen, 1942; Leonard, 1942). Some (trichopterans) have cases which need to be broken to release the larva—a difficult task for a small fish; others seek seclusion in the bottom or beneath objects, and thereby realize a measure of protection; still others gain advantages because of size, speed, or protective adaptations. Nevertheless, and within the limits of our admittedly inadequate data, it seems to be true that the predation of channel catfish on aquatic insects is roughly correlated with their relative abundance.

In order to ascertain the relative numbers of various species of potential forage fishes occurring in the study area, the catch of several seine hauls was counted each month from May to September. The largest fish included in the enumeration are approximately 3 inches in total length, since larger specimens are not eaten by the catfish. The area sampled extends from a sand and gravel meander bar to a depth of about 5 feet, and is easily seined. (The majority of the catfish which where seined for the study were caught in the same area, and those taken on hook and line were captured along the opposite bank in deeper water.) Although the samples vary somewhat among themselves they are surprisingly consistent in that they exhibit no apparent seasonal trend, and the overall percentage composition, based on 1,485 specimens, is regarded as reliable for the specific area.

Of the 157 fish taken from stomachs 16 are from catfish 4 to 7.9 inches in total length, 17 from those 8 to 11.9 inches, and 124 are found in legal-sized catfish. The great majority (124) are in September samples, partly because more large catfish were secured in September than during any other month, but also because forage fish were more vulnerable than earlier in the year (see p. 134).

The spotfin shiner (*Notropis spilopterus*) is the dominant small fish in the river (49 percent) and provides 43 percent of the fish eaten by channel catfish (Table 4). The sand shiner (*Notropis d. deliciosus*) ranks second in abundance (18 percent) as well as in catfish food (17 percent). The bullhead minnow (*Ceratichthys perspicuus*) composes 5 percent of the fish seined and 10 percent of the fish food of catfish. These three species together include 72 percent of the forage fish and 70 percent of the fish eaten. A comparison of the corresponding figures for the species listed in Table 4 reveals a remarkably close correlation throughout, and it is evident that no marked preference or selection of specific fish foods is practiced by the catfish. The slightly greater use of some species than their appearance in seined samples would suggest, might be interpreted as indicating a close habitat association with, and increased vulnerability of these

TABLE 4.—*Comparison of the numbers of fish eaten by channel catfish with the numbers present in the study area of the Des Moines River (determined by random seining).*

[Tabulated counts include only fish smaller than the largest found in catfish stomachs]

Item	Number of fish in river and in catfish stomachs							
	May-June		July-August		September		All months	
	River	Stomachs	River	Stomachs	River	Stomachs	River	Stomachs
	516	4	512	29	457	124	1,485	157
Carpiodes sp.[1]	3	....	2	3	....	....	2	1
Erimystax sp.	....	....	....[3]	....	....	1	....[3]	1
Extrarius aestivalis	....	25	....[3]	....	....[3]	....	....[3]	1
Notropis a. atherinoides	2	....	3	....	4	4	3	3
Notropis rubellus	1	....	2	3	1	2	1	2
Notropis cornutus frontalis	1	....	1	....	1	8	1	7
Notropis d. dorsalis	1	....	....[3]	7	2	4	1	4
Notropis spilopterus	50	50	51	62	46	38	49	43
Notropis d. deliciosus	16	....	17	10	23	19	18	17
Notropis topeka	....	....	1	....	....[3]	1	....[3]	1
Phenacobius mirabilis	1	....	2	....	2	2	2	1
Ceratichthys perspicuus	7	....	4	....	4	13	5	10
Hyborhynchus notatus	8	25	6	....	5	4	6	4
Pimephales p. promelas	3	....	3	3	3	3	3	3
Ictalurus lacustris punctatus	1	....	1	10	4	....	2	2
Boleosoma n. nigrum	2	....	1	....	2	2	2	1
Other species[2]	6	....	6	....	3	....	5	....

[1]Young specimens of *Carpiodes* are identified with difficulty; *C. c. carpio*, *C. cyprinus*, and *C. velifer* occur in the study area.

[2]*Moxostoma anisurum*, *M. erythrurum*, *M. aureolum*, *Hypentelium nigricans*, *Semotilus a. atromaculatus*, *Notropis blennius*, *Notemigonus crysoleucas auratus*, *Hybognathus hankinsoni*, *Campostoma anomalum pullum*, *Lepomis cyanellus*, *L. humilis*, *Hadropterus maculatus*, *H. phoxocephalus*, *Ammocrypta clara*, and *Poecilichthys flabellaris lineolatus*. Several additional species in the area were not represented in catfish stomachs or in the enumerated random seining.

[3]Less than 0.5 percent.

forms to, catfish, either in deep water (*Notropis cornutus frontalis* and *Ceratichthys perspicuus*) or close to the bottom (*Notropis d. dorsalis*), where large catfish do much of their feeding. Conversely, *N. spilopterus*, which is especially abundant in shallow water, might thereby be partially isolated from predation. However, in view of the small sample size of stomach specimens and the necessarily approximate determination of forage-fish percentages, these deviations are perhaps insignificant.

Young catfish make up 2 percent of the small fish population in the random sampling and comprise 2 percent of the fish found in stomachs. It appears that cannibalism is practiced in direct proportion to the relative abundance of young catfish and other small fish. Young game fish of species other than channel catfish are rare in the study area, and none was encountered in the stomach analyses.

Feeding Behavior and its Relationship to Certain Extrinsic Factors

Feeding behavior in the channel catfish is modified or controlled by several, or perhaps many, functional and structural adaptations. These adjusting mechanisms display complex interrelationships, and in a field study such as this the control of variables has not been possible; hence, recognition of the responses to simple environmental stimuli is not clear. There have been raised in our minds many interesting problems to which controlled experimentation could provide answers. What role does light intensity play in the initiation or inhibition of feeding? Of what importance is vision in the capture of food organisms? What are the comparative values of scent and taste in the location of food? Is there a minimum temperature below which feeding ceases, and what is the relationship between temperature and food demand? Is the apparent preference of the channel catfish for life in flowing water the result of feeding adaptions? These and other questions seem to provide profitable subjects for investigation.

In prairie streams it is rarely possible to dissociate the environmental factors of turbidity and water level: high water levels accompany high turbidity; low water levels are periods of reduced turbidity. Decrease in water level concentrates the available food organisms, and greater clarity of water makes them more vulnerable to predators which feed by sight. It is debatable whether channel catfish utilize vision in feeding, but the relatively large eyes (for an ameiurid) may be assumed to have functional significance. The water level during the first half of September 1941 (when most of our sample for the month was secured) was the lowest during the period of study, and the turbidity was greatly reduced. Legal fish taken in the month had eaten an average of 3.5 forage fish, in contrast to 0.7 in August and 0.5 in July—months of higher water level and increased turbidity. Concentration of forage fish plus improved conditions of visibility clearly permit more effective predation on free-swimming prey.

The ameiurids are essentially nocturnal, and all (except, perhaps, the blind subterranean species) are most active and probably do most of their feeding at night, despite the fact that channel catfish can occasionally be taken on hook and line at any hour of the day. On several occasions we fished with numerous baited hooks (see p. 118) continuously from dusk until dawn. Fish taken at or shortly after dark frequently had empty stomachs, but those taken later usually were at least partially full. The hourly catches from dusk until shortly after midnight were roughly twice as heavy as those preceding dawn. The difference was so marked that we eventually gave up fishing after about 2 a.m. because of the low return. We believe that the reduced catch reflects early appetite satiation of a large portion of the population. If food is scarce, feeding might be expected to continue throughout the night or into daylight. The stomachs of catfish seined in the forenoon usually contain food which is in an early stage of digestion, whereas those taken in the afternoon most often are empty or have food which is in an advanced stage of decomposition. Our data are inadequate to determine the effects of bright moonlight nights or dull, overcast weather on daily feeding trends. But evidence secured by the junior author in 1946 indicates that bright moonlight during periods of relatively clear water has an inhibiting effect on nocturnal feeding of channel catfish. At times of turbid water, however, normal night feeding is apparently not modified.

Within the limits available for analysis from this study, no temperature thresholds which restrict digestion or feeding are apparent. Fish were caught at water temperatures between 50° F. and 94° F., and there is no sharp correlation between temperature and quantity of food contained in the stomach. At temperatures in excess of 90° F. 64 percent of the fish taken have the stomach at least one-fourth filled with food. Some 54 percent of the fish taken at temperatures between 50°and 60° F. have the stomach equally full. It is probable that there is a minimum threshold, perhaps between 40° and 50° F., below which channel catfish eat little or not at all. Only 2 of 17 large catfish taken in the Des Moines River at Fraser, on February 10, 1940, contain food; one has a caddis fly larva, the other a small quantity of green algae—the intestines of all specimens are empty. At the time, the river was frozen except in a pool beneath a low dam where the fish were seined. The water temperature was 32° F.

Food intake is apparently nonexistent, or sharply curtailed, in adult channel catfish during the breeding period. A single large male removed from a burrow while guarding his nest was found to have an empty stomach. Information obtained from commercial fishermen on the Mississippi River indicates that baited traps are widely used and highly effective in taking catfish during spring prior to the breeding season (June), and again after early July. But this same gear is ineffective when the fish are spawning. In June, adult catfish are substituted in the traps for the customary cheese-scrap bait. A trap "baited" with a male catfish will, we are told, catch females almost exclusively, but if a female is provided as a lure the take consists largely of males. Why after one fish of the opposite sex is entrapped the additional fish are not attracted irrespective of sex we were not informed. Nevertheless fishermen who persist in using food-baits catch few if any catfish during the breeding season. We take this fact as strongly suggestive evidence to indicate a temporary cessation from feeding.

Management Considerations

No attempt is made here to outline a program for the management of the channel catfish in the Des Moines River or other comparable streams, since the limiting factors are usually not known, and probably vary from year to year and from stream to stream. Yet certain conclusions, drawn from this study and general experience gained in Iowa over a period of several years, seem justified.

In moderate-sized to large prairie rivers, such as the Des Moines, natural reproduction and early survival are usually attended by high success in years of normal water level. (We have some evidence to indicate that severe floods during the early and middle part of the summer result either in poor reproduction or low survival of the young fish.) It appears, then, that production of a large number of legal-sized catfish depends chiefly on favorable shelter conditions and an adequate food supply.

Neither of these essentials is met by long, straight stretches of stream of monotonously uniform depth and with a bottom of shifting sand. Yet precisely these conditions obtain along untold miles of our prairie rivers. Diversity of environment is needed to supply the catfish with the requisites for maximum production. Suitable shelter may take the form of deep pools, lateral lagoons and backwaters (especially valuable for retreat in time of flood), or protected sites such as those offered by old stumps, submerged logs, drift jams, and boulders. Food production is highest in quiet protected areas, in masses of floating or submerged debris, and on rock riffles. In addition, the presence of bushes and trees overhanging the stream adds measurably to the supply of terrestrial insects.

Under existing conditions of intensive land use, with the attendant soil erosion and drainage, material improvement of conditions may appear to be impractical. But improvement for fishing is not the only stake—other recreational and aesthetic values of our watercourses are intertwined with the need of the agriculturist for the preservation of his uplands from denudation and of his bottomlands from bank erosion and flooding. Soil conservation is making great strides, pollution abatement is progresing rapidly in Iowa (Speaker and Bailey, 1945), and there are positive measures which can be taken to improve habitat conditions in and adjacent to the streams.

Masses of branches, logs, and half-submerged trees (see Fig. 4) which occasionaly accumulate along the banks prove to be favored shelters for catfish, and perhaps the richest areas of food production. Typically these drift jams owe their origin to trees which have been undercut by floods and felled into the stream. They may persist for years, but are commonly washed away by succeeding floods. Since they are characteristically located along eroding banks, maintenance of their position serves the additional function of shore protection. Anchoring of such trees (perhaps by means of cables, attached either before or after felling) appeals to us as a simple, inexpensive method of environmental improvement. Many of the constructions now in use for the improvement of trout streams (Hubbs, Greeley, and Tarzwell, 1933) might be adapted for use in small catfish rivers. Bank protection, achieved through plantings and elimination of streamside grazing, is another method of improvement which should prove practical on an extensive scale.

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