BOTTOM FAUNA UTILIZATION AND DISTRIBUTION OF 10 SPECIES OF FISH IN POOL 19, MISSISSIPPI RIVER

by

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Signatures have been redacted for privacy

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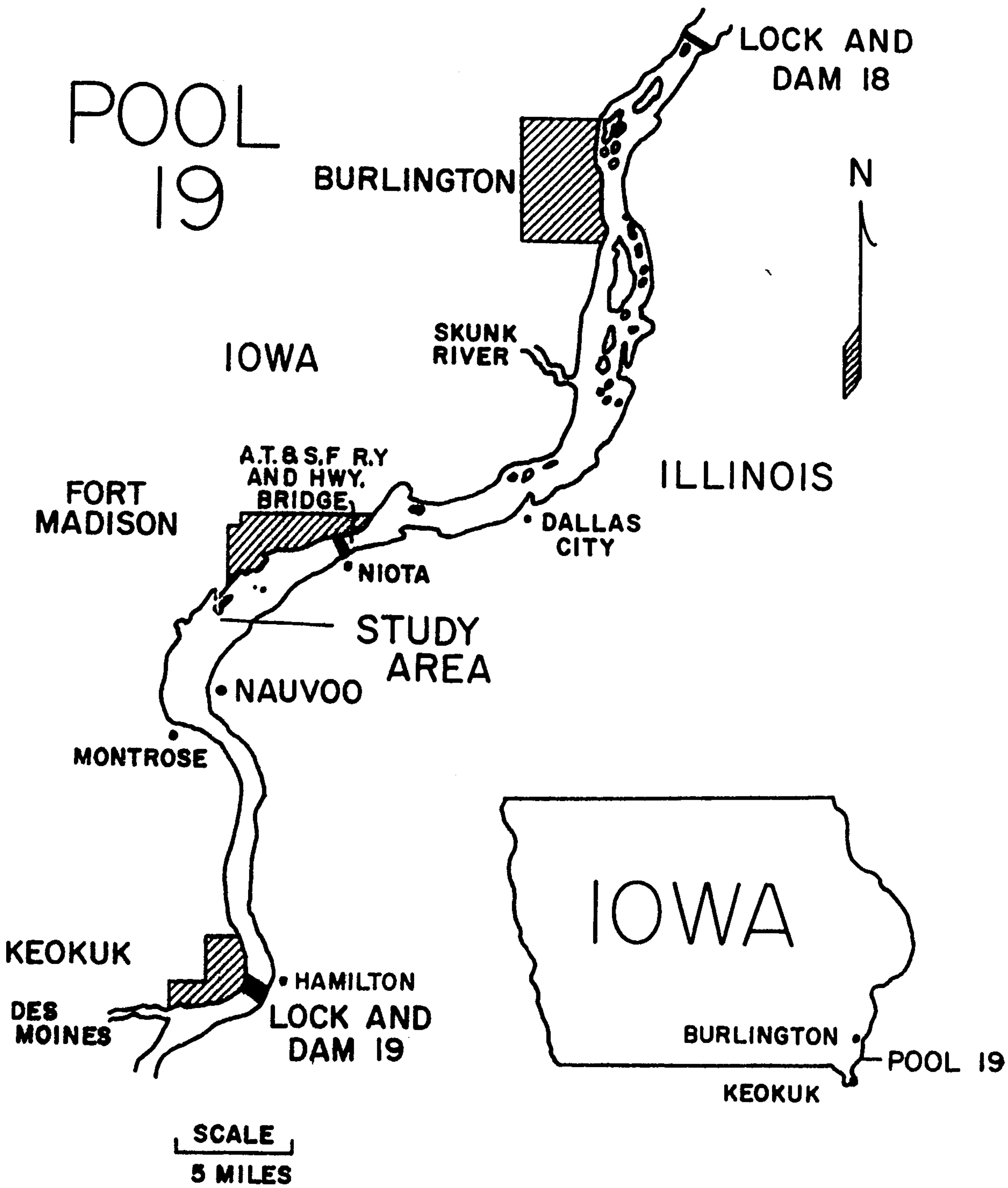
INTRODUCTION

In July, 1966, a study was initiated to determine the composition of bottom fauna and fish populations in the Fort Madison section of Pool 19, Mississippi River. This pool extends 47 miles from Burlington, Iowa south to Lock and Dam 19 at Keokuk, Iowa (Figure 1). Of the pools in the Upper Mississippi, it is the longest and ranks second in surface area with 33,500 acres. Its greatest width of 2 miles is found within the Fort Madison section of the pool. This area is extensively fished by Iowa and Illinois commercial fishermen who sold a total of 1,217,344 pounds of marketable fish (Nord, 1967). People from surrounding states also enjoy sport fishing to a limited extent. Nord reported the estimated catch in 1956-8 to be 4 and 1.7 pounds per acre for Iowa and Illinois respectively. One of the largest fall concentrations of diving ducks migrating through the Mississippi Flyway depends upon the area for food. In the fall of 1966 (October 17-December 29) and the spring of 1967 (March 3-April 15) the duck days of use for diving ducks on the pool were reported at 10,688,210 and 8,389,670 respectively (Thompson, James Douglas, Ames, Iowa. Data from a study on the diving ducks of Pool 19, Mississippi River. Personal communication, 1968.) It is in addition, the only major stopover place for these ducks between Minnesota and the Gulf of Mexico (Mills, Starrett and Bellrose, 1966, Bellrose, Frank C., Jr., Illinois Natural History Survey, Urbana, Illinois. From studies on waterfowl on the Illinois and Mississippi Rivers. Personal Communication, 1968.) Barge traffic is a feature of the river which occurs from ice breakage in March until the latter part of December. In 1966, there were 3,046 lockages (including pleasure and passenger craft) which consisted of

Figure 1. Map of Pool 19, Mississippi River showing the study area in the Fort Madison section of the river. (Insert map indicates position of Pool 19 in Iowa)


POOL 19
LOCK AND DAM 18
BURLINGTON
N
IOWA
SKUNK RIVER
ILLINOIS
A.T.& S.F R.Y AND HWY. BRIDGE
FORT MADISON
DALLAS CITY
NIOTA
STUDY AREA
NAUVOO
MONTROSE
KEOKUK
HAMILTON
DES MOINES
LOCK AND DAM 19
SCALE
5 MILES
IOWA
BURLINGTON
POOL 19
KEOKUK

14,840,092 tons of cargo passing through the lock at Keokuk. In 1967, there were 3,026 lockages representing 14,993,832 tons of cargo (Pullen, D. D., U.S. Lock No. 19, Keokuk, Iowa. From data compiled during 1966 and 1967. Private communication, 1968.) In conjunction with the use of the Mississippi River for barge travel, a dredging project was proposed for a 9-foot channel to a developing industrial complex southwest of Fort Madison. The proposed canal, to be located in the middle of the study area, would be 1.6 miles long.

Since this area is important as an irreplaceable natural resource, studies were initiated to survey the present ecological conditions prior to dredging. The data and results of the investigation should then aid in future comparisons after the area is dredged. The information gained should also be helpful in evaluating future dredging plans for similar habitats.

Since bottom fauna data were gathered concurrently with the stomach content analyses, an opportunity was available to correlate the benthos present with the organisms found in fish stomachs. Statements regarding utilization and selectivity could then be made as to the importance of the various faunal groups to fish and thus the necessity for their protection if threatened with destruction.

To accomplish the study objectives, four graduate students were assigned to the area: one conducting research on the bottom fauna, one studying the water-fowl, and two studying the fishes. Two investigators were needed for studies on the fishes because of the large number of species present, and the need for more than one person to set and check nets. The responsibility for families of fish was divided between the investigators on the basis of predators versus the more bottom-type feeders, so that an approximate equal number of fish were assigned to each. The collection and recording of data were done cooperatively. The species included in the present study, total number captured and sampled are shown in Table 1.

Table 1. Common name and scientific name[a], numbers captured and sampled from the 10 major species and 4 other rarely caught species under investigation in Pool 19, Mississippi River

Common Name	Scientific Name		Captured	Sampled
Gizzard shad	Dorosoma cepedianum (LeSueur)	1966	647	206
		1967	721	141
Carp	Cyprinus carpio Linnaeus	1966	332	113
		1967	289	112
Mooneye	Hiodon tergisus LeSueur	1966	352	169
		1967	259	192
		1968	25	5
Goldeye	Hiodon alosoides (Rafinesque)	1966	24	24
		1967	10	10
Channel catfish	Ictalurus punctatus (Rafinesque)	1966	122	122
		1967	206	198
		1968	6	6
Black bullhead	Ictalurus melas (Rafinesque)	1966	62	54
		1967	152	123
Yellow bullhead	Ictalurus natalis (LeSueur)	1966	19	19
		1967	18	17
Bigmouth buffalo	Ictiobus cyprinellus (Valenciennes)	1966	22	17
		1967	31	26
Smallmouth buffalo	Ictiobus bubalus (Rafinesque)	1966	39	22
		1967	14	13
River carpsucker	Carpiodes carpio (Rafinesque)	1966	20	18
		1967	12	12
Flathead catfish	Pylodictis olivaris (Rafinesque)	1966	0	0
		1967	9	6
Northern redhorse	Moxostoma macrolepidotum (LeSueur)	1966	0	0
		1967	1	1
White sucker	Catostomus commersoni (Lacépède)	1966	1	1
		1967	0	0
Skipjack herring	Alosa chrysochloris (Rafinesque)	1966	1	0
		1967	0	0
Totals			3394	1627

[a]American Fisheries Society. 1960. A list of common and scientific names of fishes from the United States and Canada. Spec. Publ. No. 2.

STUDY AREA

A stretch of rapids existed at Keokuk, Iowa prior to 1913, when a dam was erected for the generation of electricity (Carlander, 1954). This is the only lock and dam on the river used for generating electric power and as a result is not used for flood control. After impoundment, the formerly narrow and swift river widened out and has continually become more silted and shallow. These processes have created favorable environmental requirements for the burrowing mayfly, Hexagenia, while the dams have provided suitable habitat for caddisflies. These insects have created serious problems for cities along the Mississippi during emergences. These problems and their relationships to fish have been investigated by Fremling (1959), Hoopes (1959), Carlson (1960, 1963), and Wenke (1965). Their results were relied upon in the conduct of the present study.

On July 15, 1966, nine transects, which extended over the approximate 11 miles of the chosen study area, were selected for sampling benthos and fish (Figure 2). They were numbered progressively down river from one to eight. Transect 9 was added later and is therefore upstream from transect 1. Stations for bottom fauna were more numerous on most of the transects than fish sampling stations because more effort per station was required in procuring fish data. Stations were chosen to include as many ecological habitats as possible (Table 2). Conditions considered were water depths, currents, aquatic vegetation, and bottom type. A number of stations, which was predetermined after considering these physical factors and time available, was allocated to each of the transects. Because of the long distances between transects and the time necessary for travel, the number of

Figure 2. Composite map of the Fort Madison section of Pool 19, showing the nine transects used in sampling fish populations and the three sections of the study area, above, in, and below the proposed dredging site (adapted from Army Corps of Engineers Map, 1953)

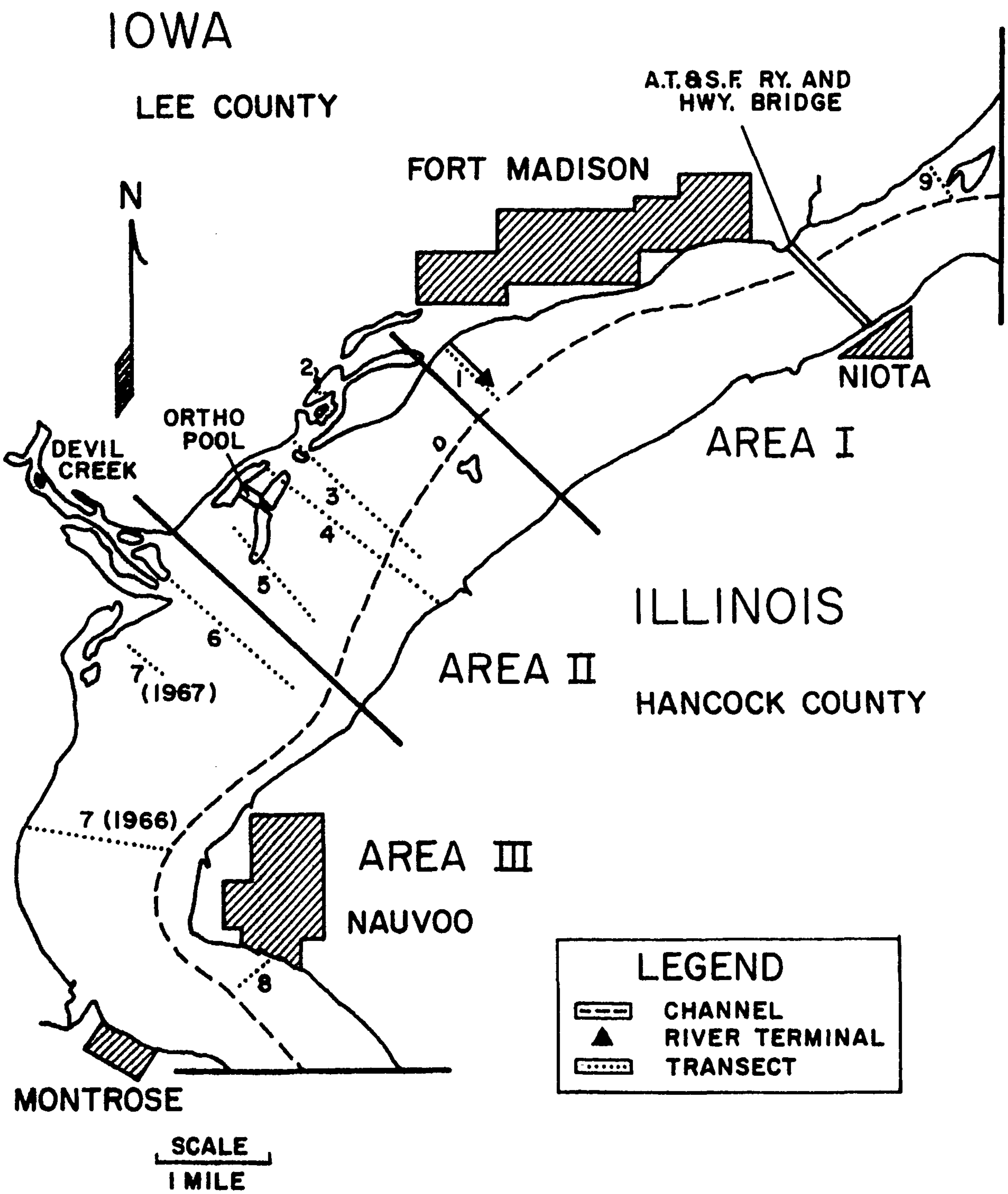

IOWA
LEE COUNTY
N
FORT MADISON
A.T.&S.F. RY. AND
HWY. BRIDGE
9
NIOTA
1
2
ORTHO
POOL
DEVIL
CREEK
0
AREA I
3
4
5
ILLINOIS
6
7
(1967)
AREA II
HANCOCK COUNTY
7 (1966)
AREA III
NAUVOO
8
MONTROSE
LEGEND
CHANNEL
RIVER TERMINAL
TRANSECT
SCALE
1 MILE

Table 2 A description of the transects and stations in 1966 with respect to depth, location, vegetation, bottom type, and current in the Fort Madison section of Pool 19, Mississippi River

Transect & Station	Depth (feet)	Habitat type	Bottom type	Current (fps)	Vegetation (density)	From net to nearest shore (yards)
T1S1	0-1	flats	mud	0.7	absent	0
T1S2	5 5-7	flats	mud	0.8	absent	450
T2S1[a]	1.5-2	shallow	mud	0	heavy[cd]	40
T2S2[a]	0.5-1	shallow	mud	0	heavy[cd]	35
T3S1	1	shallow	sandy mud	0	light[d]	80
T3S2[b]	5.5-9	flats	sandy mud	1.0	absent	75
T3S3	3	flats	mud	1.2	absent	800
T3S4	6	flats	mud	1.0	absent	1,050
T3S5	18	channel	mud	1.7	absent	1,200
T4S1	1-3	shallow	sandy mud	0	light[c]	20
T4S2[b]	4-14	flats	sandy mud	0.7	absent	150
T4S3	4-5	flats	sand	0.9	absent	1,000
T4S4	3-8	flats	mud	1.0	absent	150 (Ill.)
T5S1	0.5-1	shallow	shells & sandy mud	0	light[cd]	300
T6S1	1	shallow	mud	0.2	absent	30
T6S2	7-8	flats	mud	0.9	absent	1,000
T7S1	1.5-3	shallow	mud	0.4	heavy[d]	300
T7S2	3	flats	sand	0.6	absent	1,300
T7S3	18-22	channel	mud	1.7	absent	2,000
T8S1	1	shallow	mud	0.2	absent	600 (Ill.)
T8S2	4-19	channel	mud	1.0	absent	660 (Ill.)
T9S1	17-19	channel	sandy mud	1.6	absent	30
T9S2	0.5-1	shallow	mud	0.1	light[d]	200
T9S32	21-24	channel	mud & detritus	1.7	absent	300

[a]Transect 2 was atypical river habitat since the two stations were located in a backwater area away from the river's influence.

[b]Transect 3 station 2 and transect 4 station 2 were located in "guts" or old silted-in channels located on the flats.

[c]Ceratophyllum.

[d]Potamogeton.

stations was reduced from 24 to 17 in 1967.

Transects 1 and 9 were selected upstream of the dredging area (Figure 3) Transect 9, located one mile above the Atchison, Topeka and Santa Fe Railroad and Highway Bridge in Fort Madison, had three station locations, while transect 1 consisted of two stations on river flats.

Four transects were placed in the future dredging area (Figure 4). Transect 3 was the major transect with five stations for sampling fishes. Four stations were located on transect 4. Two stations were allocated to a backwater area, Honig's Slough, designated as transect 2. Transect 5, with one station, was located in a sheltered-bay region, heavily vegetated with *Lotus*.

In the future spoil area, a considerable distance down river from the main study area, three transects were established (Figure 5). On transect 6, one station was placed in the sandy shallows and one on the flats. Three stations were used on transect 7 with one located in a *Potamogeton* weed bed in the open river. The Nauvoo flats was the location of transect 8 which had two stations, one in shallow water and one on the edge of the channel. In 1967, transect 8 and 9 were eliminated and transect 7 was moved about one mile upriver from its 1966 location.

Selection of the 1967 stations (Table 3A) was based on the same considerations as the 1966 stations along with data from the bottom fauna and fish studies in 1966. Stations in Tables 2 and 3 were divided into three habitat types: shallow (areas less than 3 feet deep, usually with some vegetation present or nearby), flats (extensive areas of the river without vegetation, muddy bottom, and a depth usually between 3 and 8 feet), and channel (deep areas of the river including both the navigational channel and

Figure 3. Upper portion of the Fort Madison section of Pool 19, Area I, showing the transect and stations of transects 1 and 9 (Adapted from Army Corps of Engineers Map, 1965)

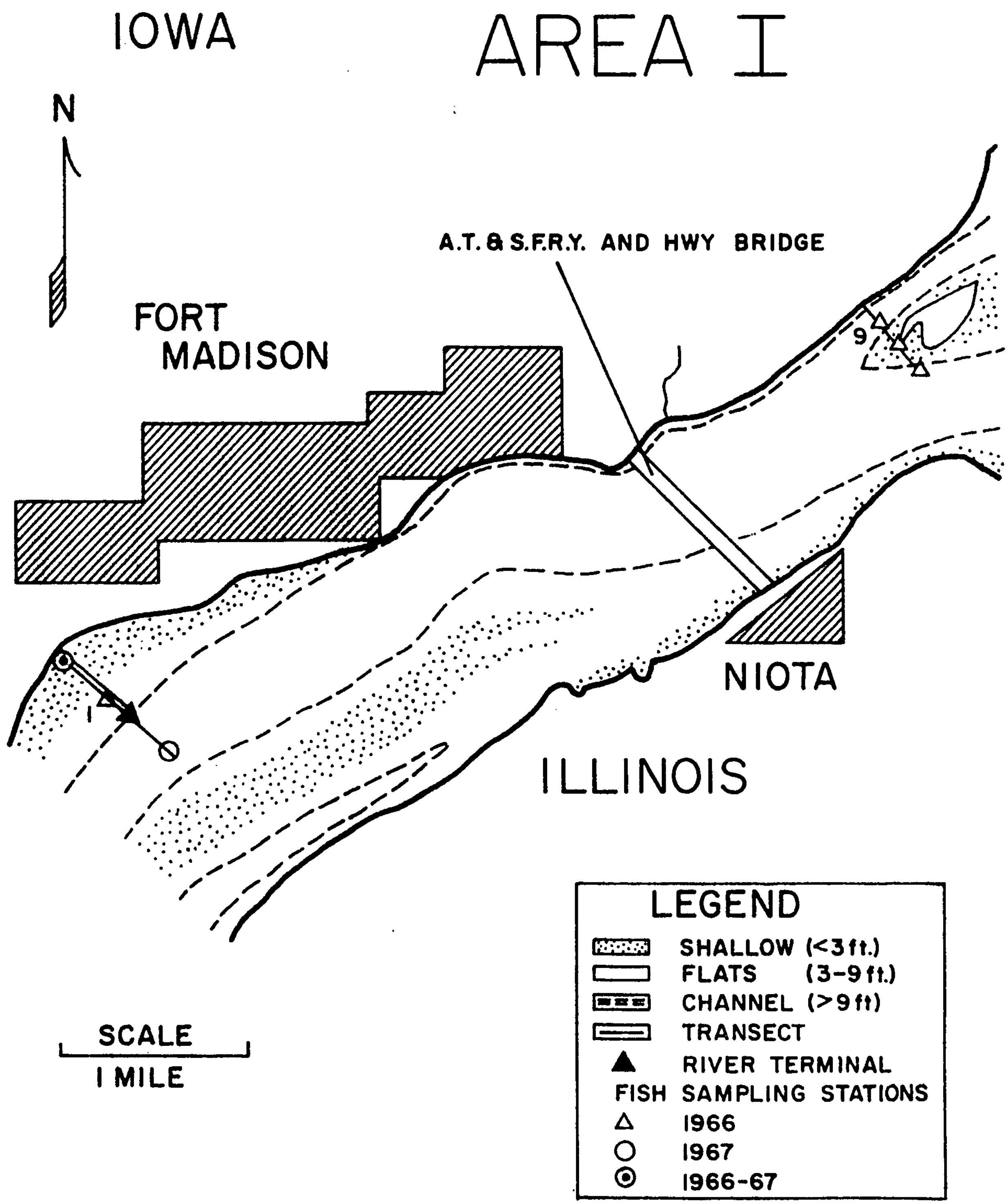

IOWA
AREA I
N
A.T. & S.F.R.Y. AND HWY BRIDGE
FORT MADISON
9
1
NIOTA
ILLINOIS
LEGEND
SHALLOW (<3 ft.)
FLATS (3-9 ft.)
CHANNEL (>9 ft)
TRANSECT
RIVER TERMINAL
FISH SAMPLING STATIONS
1966
1967
1966-67
SCALE
1 MILE

Figure 4. Middle portion of the Fort Madison section of Pool 19, Mississippi River (Area II), showing the proposed dredging channel and transects 2, 3, 4, and 5 with their respective stations (Adapted from Army Corps of Engineers Map, 1965)

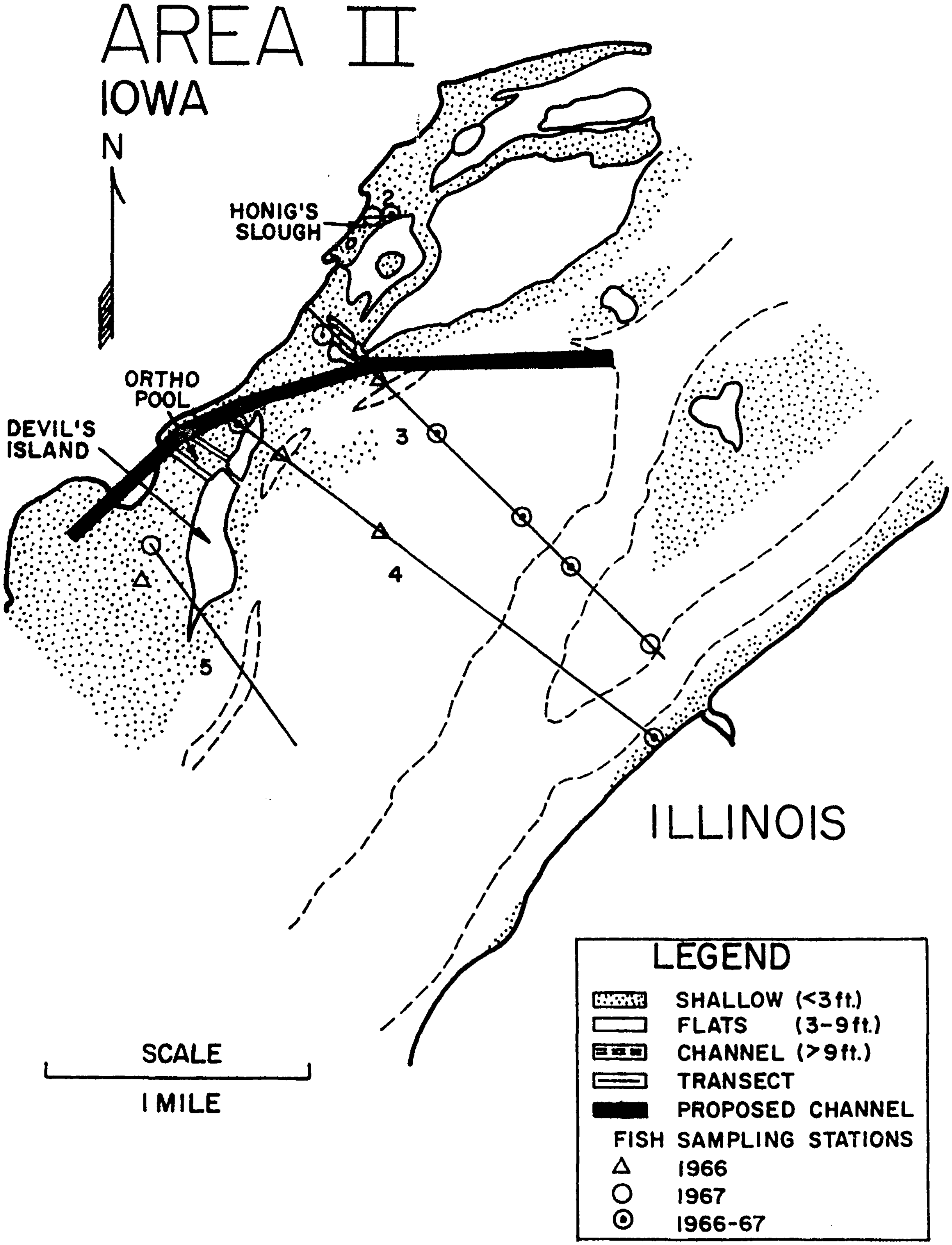

AREA II
IOWA
N
HONIG'S SLOUGH
ORTHO POOL
DEVIL'S ISLAND
2
3
4
5
ILLINOIS
SCALE
1 MILE
LEGEND
SHALLOW (<3 ft.)
FLATS (3-9 ft.)
CHANNEL (>9 ft.)
TRANSECT
PROPOSED CHANNEL
FISH SAMPLING STATIONS
1966
1967
1966-67

Figure 5. Area III, the lower portion of the Fort Madison section of Pool 19, Mississippi River including transects 6, 7, and 8 with their respective stations (Adapted from Army Corps of Engineers Map, 1965)

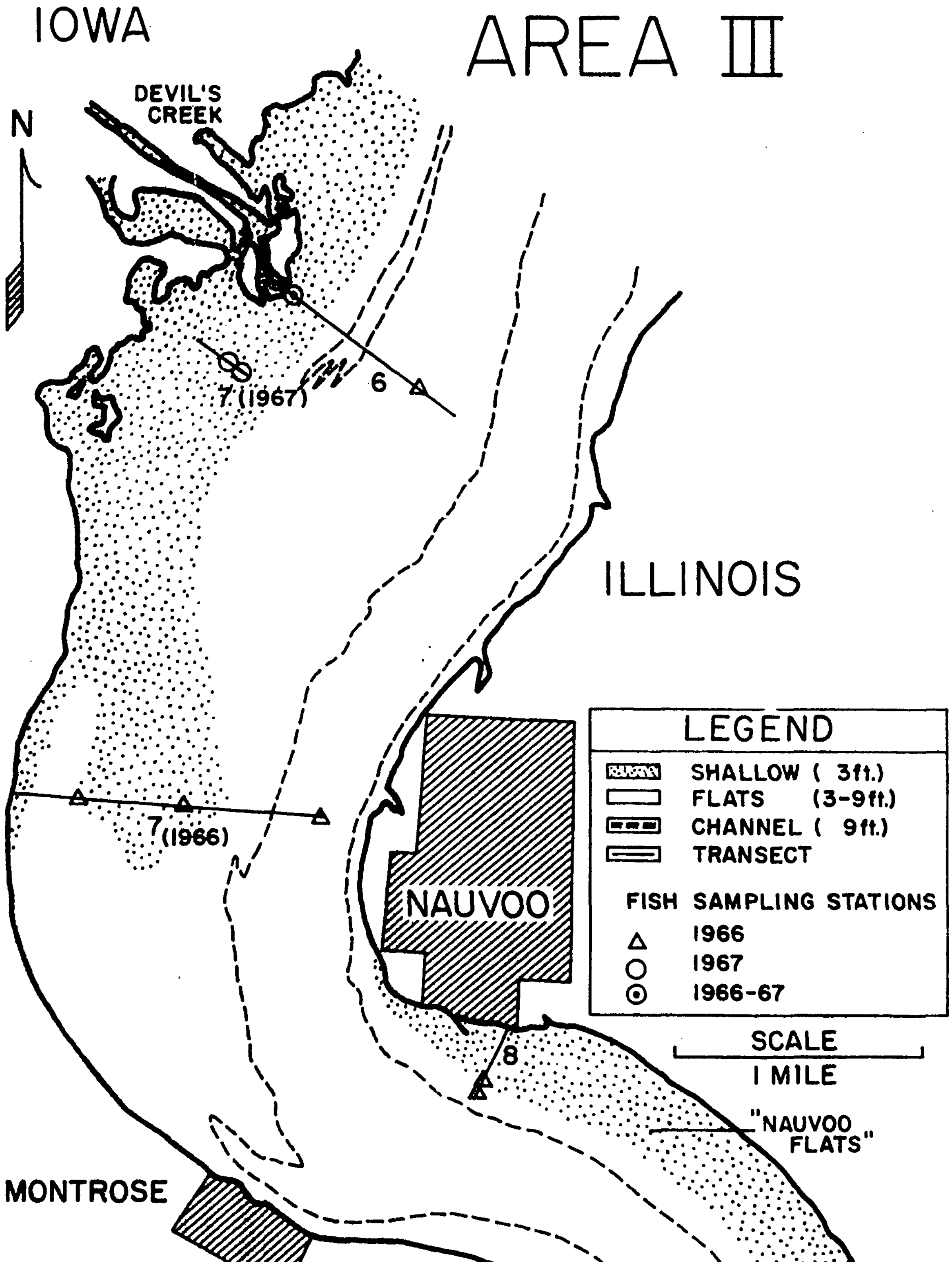

IOWA
AREA III
DEVIL'S CREEK
N
6
7 (1967)
ILLINOIS
7 (1966)
LEGEND
SHALLOW (3ft.)
FLATS (3-9ft.)
CHANNEL (9ft.)
TRANSECT
FISH SAMPLING STATIONS
1966
1967
1966-67
NAUVOO
8
SCALE
1 MILE
"NAUVOO FLATS"
MONTROSE

Table 3A. Transects and stations for 1967 with respect to depth, location, vegetation, bottom type, and current for the Fort Madison section of Pool 19, Mississippi River

Transect & Station	Depth (feet)	Habitat type	Bottom type	Current (fps)	Vegetation (density)	From net to nearest shore (yards)
T1S1[a]	1-1.5	flats	mud	0.7	absent	0
T1S3	18-21	channel	sandy mud	1.7	absent	1,200
T2S1[ab]	1.5	shallow	mud	0	light[de]	20
T2S2[ab]	1	shallow	mud	0	heavy[de]	30
T3S1[a]	1	shallow	mud	0	light[d]	80
T3S2[c]	0-4.5	flats	sand & mud	0.2	absent	0
T3S3[a]	3	flats	mud	1.2	absent	900
T3S4[a]	5	flats	sandy mud	1.0	absent	1,200
T3S5[a]	18-19	channel	sandy mud	1.7	absent	700 (Ill.)
T3S6	8-9	channel	mud	1.3	absent	600 (Ill.)
T4S1[a]	4.5-5	shallow	mud	0	absent	60
T4S3[a]	3	flats	sandy mud	0.9	absent	200
T4S4[a]	2.5-5	flats	mud	1.0	absent	150 (Ill.)
T5S1	1	shallow	mud	0	heavy[fe]	300
T6S1[a]	0.5	shallow	sand	0.2	absent	40
T7S1[a]	1	shallow	mud	0.3	heavy[d]	650
T7S2	1	shallow	mud	0.3	absent	600

[a]Indicates that the station was located in essentially the same area and habitat type as the 1966 station of the same name.

[b]Transect 2 was atypical river habitat since the 2 stations were located in a backwater area away from the river's influence.

[c]Transect 3 station 2 was placed in a channel about 10 yards wide and 4 feet deep which was dredged through shallow water for the placement of a pipeline.

[d]Potamogeton.

[e]Ceratophyllum.

[f]Lotus.

old chutes). For discussions on depth distribution the categories of less than 3 feet deep (shallow), 3-8 feet deep (flats), and greater than 8 feet (channel) were strictly followed. Some overlap in depths was experienced when the stations were being categorized by depth, especially for the flats category in 1966. Personal judgment on the basis of the fish captured and the average depth was used to classify stations showing characteristics of both categories. These categories of depth and habitat type were the same for all stations except two. Transect 1 station 1, which was classified as flats habitat, was considered shallow for depth distribution calculations. Transect 4 station 1 in 1967 was considered shallow habitat, but its greater depth (5 feet) put it in the flats category for distribution studies.

The current velocity in feet-per-second, shown for each station was assigned after considering the plotted velocities from a 1963 Army Corps of Engineers' map and from field observation where data were not available. Floods in the spring increased the current velocity immensely, but values recorded in the tables are indicative of normal conditions during the latter part of summer and fall.

Vegetation was classified as absent, light, or heavy to give a relative index of density and if present, plant genera were determined.

MATERIALS, EQUIPMENT, AND PROCEDURES

Location and Marking of Transects and Stations

In 1966, a number of bottom fauna stations were selected for fish sampling activities. Stakes and plastic bleach bottles were used for markers in shallow and deep water respectively. In 1967, random stations were chosen within the habitat type selected. An area chosen on the transect was traversed with the boat at a constant speed and the travel time in seconds recorded. A number was taken from the table of random numbers corresponding to a particular point between time 0 seconds and the total time needed to cross the area. The boat was driven for this amount of time from the starting point and the station was located where this time was reached.

Stations were marked in a variety of ways in 1967. Large, square Styrofoam markers were anchored with cement blocks on transects 3 and 4 for semi-permanent transect identification. For specific location of the stations, large stakes, distinctive landmarks, and a cement block and plastic bleach bottle were used. For the channel sets, the station was located by using the same randomization procedure. A channel bouy was selected near or on the transect and the motor was run at a constant speed to approximately mid-channel and the time recorded. A random number indicated the time from the bouy that the motor had to travel at this constant speed to relocate the station.

Methods of Fish Capture

Standard 125-foot experimental gill nets were used to collect the majority of fish. These nets are 6 feet deep consisting of five sections of

25 feet of netting with the following mesh sizes: 3/4, 1, 1-1/4, 1-1/2 and 2 inches (bar measure). The net mesh was constructed of nylon and the lead line was enclosed by a nylon rope. Nets were always set on the bottom, perpendicular to current flow. If no current was present, nets were set at right angles to the shoreline. The larger mesh was placed in the deepest water or water furthest away from shore. Nets were reset in the same manner each time.

In 1966, nets were staked in shallow water with 10-12 foot poles. At stations in deep water or where current was intense, large T-shaped anchors were used to maintain the net's position. Plastic bleach bottles were used as net markers with varying lengths of 1/2-inch nylon line connected to them. Nets anchored and marked in this manner seldom moved. Little trouble was experienced with people moving or checking nets, but occasionally a barge or boat would destroy the floats. In these cases, dragging usually recovered the net.

Attempts were made in 1966 to use flashlights mounted on innertubes, and reflective tape on the bleach bottles to aid in locating the nets at night. A spot-light attached to a generator was also used, but difficulty was still experienced in finding the nets. In 1967, battery-powered highway flashers mounted in large Styrofoam blocks were attached to the gill nets and proved effective for relocation of the stations, except in fog.

Selectivity and efficiency of experimental gill nets affect data on distribution and food habits in various ways (Barnickol and Starrett, 1951, Berst, 1961, McCombie and Fry, 1960). Different fish have different susceptibilities to gill nets; therefore, they may or may not occur in the catch proportional to their abundance (Carlander, 1953; Heard, 1962). Since gill nets are passive fishing gear in which the fish must entangle themselves, catch is dependent upon factors other than the randomness of the sampling procedure and size of population sampled (Moyle, 1950). Catch in any particular mesh size is correlated most closely with girth of the fish (Berst, 1961; McCombie and Fry, 1960); however, more fish of some species are captured through "random entanglement" because of maxillae, teeth or spines which make them more vulnerable. Movement of fish, shape and structure of the fish, and the associative pattern of grouping of individuals of any species or assemblage of species of fish will determine the quantity of each species caught (Heard, 1962; Van Oosten, 1935). The larger fish may move more than the smaller ones in satisfying their food or other requirements, resulting in proportionally larger catches (Latta, 1959). This may be true in the case of gizzard shad feeding activity. Watt (1956) noted that increased movement with increase in length should be considered in setting up any models involving different age classes.

When gill net catches are evaluated on a comparative basis, uniqueness of fish shape and structure, which causes nets to be selective for certain species, can be disregarded (Moyle, 1950). On the basis of these findings, relationships derived from catch between stations, habitat preferences, and activity patterns should remain valid over time, regardless of the degree of susceptibility, since it is assumed uniform for a species.

Gill nets set in shallow water were probably more efficient due to folding of the 6 foot deep net. Attempts to avoid this as much as possible were made by staking the nets so as to make them as taut as possible. Another factor, which was considered, but about which nothing could be done, was that nets set in the channel were only sampling the bottom 6 feet or possibly less. Nomura and Nozawa (1955) found that there was definite deformation of nets in current which decreased fishing efficiency. Conclusions based on number of fish caught according to depth will therefore be biased upwards in shallow water and downwards in deeper water.

Any differential ability on the part of the fish to distinguish the net was probably decreased considerably by the turbidity (highest secchi disc reading recorded was 8 inches), which has been shown to impair the escape of fish from nets in laboratory studies (Hunter and Wisby, 1963).

Size of catch in gill nets does not necessarily increase in direct proportion to the time that they are left in the water (Van Oosten, 1935; Kennedy, 1951). This was considered in summarizing the catch-per-effort data and in establishing the sampling program. Seasonal catch-per-effort data were plotted for the most abundantly captured fish. Catch was adjusted to a 24-hour basis and averaged over 15-day intervals. All data used were from fish taken in experimental gill nets, and effort expended was indicated by gill net hours, defined as one experimental gill net set for one hour.

Eight other means of collecting fish were used to supplement the catch of species not usually caught in numbers or sizes desired. Electroshocking with a 2,500-watt, 220-volt AC generator connected to three copper electrodes was the second most often gear used. Electrodes were located at the ends of two 15-foot booms attached to the front of the boat. A dead man switch, operated by the man netting, was used to open and close the circuit. Shocking was ineffective in water greater than 3 feet, and was very selective for carp and gizzard shad, though it did shock buffalo and carpsuckers occasionally. Mooneyes were rarely taken and catfish and bullheads were never shocked in the river proper, although catfish were captured in considerable numbers in an effluent stream canal in the spring.

A 70-yard trammel net was used in an attempt to catch larger fish. During the summer this particular gear proved to be the most efficient gear for catching carp and gizzard shad when set in shallow water. A few mooneyes were captured in deep water in the fall, while catfish were taken in nets set early in the spring The trammel net was seldom used since it captured fish which were already adequately sampled.

Trot line catches from one of the local sport fishermen were sampled regularly throughout the summer. This gear was very selective for channel catfish and up to 40 fish were taken from 200 baited hooks set overnight on the flats. The stomach samples were inferior to those taken from fish captured in gill nets, since the frequency of empty stomachs from these samples was much higher than gill net captured catfish. The bait used by the fisherman was recorded and if found in stomachs it was disregarded in the analysis. These samples were readily secured and supplemented gill net data which at times were inadequate for this species.

A 15-foot otter trawl was used in late summer and fall of 1967 and seemed to be very inefficient in the areas where it was tested. Small sizes of channel catfish and mooneyes, which were not captured previously, were taken in hauls during the summer and winter.

One hoop-net was given limited use, but caught only carp, some bullheads, and two flathead catfish. Standard baskets, used by commercial fishermen, were also tried in an attempt to capture flathead and channel catfish. They were baited with a commercial preparation of cheese. Baskets were not placed in the water early enough in the spring of 1967 to coincide with flathead catfish spawning when large numbers are taken. Many channel catfish and three small flatheads were caught in August. Most proved unsatisfactory for stomach analysis, since they had consumed varying amounts of the cheese bait or had regurgitated their stomach contents while in the baskets.

Program of Gill Netting

In order to gather quantitative data which would be useful for distribution and feeding patterns, a program of netting using experimental gill nets was devised. Nets were set for 2-hour periods so that digestion by fish in the nets was kept to a minimum. Reduced efficiency from leaving a net in the water continuously was also eliminated (Kennedy, 1951). Nets were set for alternating 2-hour intervals at a given station so that fish would be taken during or shortly after feeding activities in at least one of the collection periods. It also allowed time to record data and remove stomachs from fish collected in the previous period. In 1966, three stations were set during a given day or night, starting from the upper part of the pool (transect 9), and working down to the lower end (transect 8). In 1967, the order of netting at stations was randomized for both the day and night sampling.

The day (considered as 8 AM to 8 PM) was divided into three 4-hour periods: 8 AM-12 noon, 12 noon-4 PM, and 4 PM-8 PM. The night (8 PM-8 AM) was similarly divided into three 4-hour periods which were: 8 PM-12 midnight, 12 midnight-4 AM, and 4 AM-8 AM. Nets were set at a number of stations for two hours during each of the three periods during one day and continued in succeeding days until all the stations were sampled. In 1966, this required almost two weeks. Then, night sampling in the same manner was performed until all the stations were similarly completed. A net was thus being set at the same station for 6 hours during the day and for 6 hours during another night, but not during a continuous 24-hour period. This led to data being collected at one station for the day to be separated by a number of days from data collected at the same station during the night sampling. Because the activity patterns are thought to be fairly fixed (Carlander, 1949), and feeding habits were not expected to change radically, this was thought acceptable in the analysis of the data for diurnal distribution and food habit patterns. However, to reduce any differences between data collected at one station during the day, and the time elapsed before the same station was sampled at night, the 1967 program was conducted in a shorter time period. This allowed two such programs to be completed, one in June and July, and one in August.

Nets were lifted after each 2-hour interval and placed in a gill net box from which they were removed again when reset. In 1966, after one series of nets were checked, the fish were taken to shore. If the distance to our shore facilities was too great, stomachs were removed on location and data recorded. In 1967, all fish were transported to the laboratory on shore. Because of complications in night sampling in 1966, some fish stomachs collected 12-2 AM and 4-6 AM were removed as late as noon that day. Errors may have been introduced through deterioration of stomach contents. It was corrected by better organization of the program in 1967.

On July 14, 19, and September 6, 1967, three experimental gill nets were set for 24 hours at one station and the fish were removed at the end of even, 2-hour periods. The purpose of this special netting was to cross-check results from the major sampling programs and gain additional data on food habits, distribution, and catch-per-effort.

Experimental gill nets were also used for collecting data during spring, fall, and winter before and after the 24-hour sampling program. Nets were set for varying lengths of time to catch fish for stomach content analysis and distribution studies. Most of the nets during these times were set in the late afternoon and checked the next morning. Gill nets set during the summer could very seldom be set overnight because of large catches and extreme deterioration of the fish, making them unsuitable for stomach analysis.

Length and weight was recorded for all fish captured in both years except when large numbers of gizzard shad or carp were taken. Total length was recorded to the nearest 0.1 inch. Weight was recorded to the nearest gram if the fish was less than 1000 grams, and to the nearest ounce if greater than 1000 grams. Stomachs and sex data were collected from selected fish. In 1966 and 1967, all of the less abundant species captured were taken for analysis. For the more abundant fishes collected in 1966, individuals were selected so as to sample the entire range of lengths. A random scheme was introduced in 1967 for sampling these more abundant fish. The number chosen was based on previous sizes, numbers caught, and time available for recording information and removing stomachs.

A fullness factor for the degree of stomach distention was also introduced in 1967 and part of 1966. Estimation of the factor was made visually with five categories selected: 0, 1/4, 1/2, 3/4, and 1. This is very subjective, but needed to give another indication of intensity of feeding in fish.

Scale samples were removed from just below the dorsal fin in the softrayed fish, while for channel catfish and black and yellow bullheads, the left pectoral spine was extracted. Scales and spines were placed inside the envelope, while the other data collected on each fish was recorded on the front.

Stomach Analysis

Various methods for the collection and analysis of stomach contents have been proposed (Hynes, 1950; Markus, 1932; Lagler, 1952; Pearse, 1915 and 1918) Kutkuhn (1954) also gives a literature review of the many analyses available. The method chosen for fish with definite stomachs was a volumetric technique similar to Moffett and Hunt (1943), while that used in determining the gizzard shad, buffalo, and carpsuckers followed that of Tester (1932) and Ricker (1941).

In 1966, stomachs were removed from the fish, tied off at both ends with nylon string, and injected with 10% formalin. An "Astro Gun" which dispensed plastic tape with a letter-number combination was used in making tags for identifying individual stomachs. After injection with formalin, the stomach with identifying tag was placed in cheesecloth and tied shut, then placed in a larger container with 10-40% formalin. In 1967, greater efficiency was promoted by placing each stomach and tag into an individual vial or baby food jar filled partially with 10% formalin.

For channel and flathead catfish, black and yellow bullhead, mooneye, and goldeye, the digestive tract from the upper part of the esophagus to the plyoric spincter was removed from the fish. In carp, the front part of the alimentary canal to the first severe bend, plus a length equal to the first section past this bend, was removed for analysis. At times this second half was lost or not taken. For the gizzard shad, the alimentary tract to and including the gizzard was removed. The existence of pharyngeal pockets was not recognized until the end of the study; therefore, they were not analyzed. Buffalos and carpsuckers have a bulbar enlargement directly behind the oral cavity with little or no esophagus present. This bulbar enlargement and a small section of alimentary tract posterior to it were taken for analysis. Attempts to inject these indefinite stomachs with formalin in 1966 proved unsuccessful, so the entire structure was placed in the cheesecloth or baby food jar without incisions or other means of allowing formalin to enter. Digestion of smaller, more delicate organisms, such as zooplankton or algae may have occurred. However, Diaptomus sp. and Daphnia sp. were easily distinguished in samples from shad and buffalo, and slides of material from stomachs frequently revealed the presence of algae. Material, which was designated as unidentifiable, especially in the case of gizzard shad, had quantities of algae present ranging from a few diatoms to thousands per ml.

Analysis of the stomach contents involved determining the number and volume of each species, or in some cases family of organisms present. For the mooneye, goldeye, black and yellow bullhead, channel catfish, carp and part of the gizzard shad, each group found in the stomach was counted, separated, and the volume determined. For the remaining gizzard shad, carpsuckers, and bigmouth and smallmouth buffalos, the total volume of the entire stomach contents was determined and the percentage composition of the various elements estimated.

The method used to determine the volume of the stomach contents for fish with a definite stomach was an alcohol displacement technique, selected because it gave the greatest precision in the least amount of time. Volume was determined using three test tubes each with a different diameter. They were cut off at about 45 mm, and a reading line etched on them. To calibrate, each was filled to the reading line eight times from a burette reading to 0.01 ml. Tube No. 1 had an average volume equal to 1.08 ± 0.01 ml, and was used to measure the volume of items from about 0.01 to 0.60 ml. Tube No. 2 had an average volume of 4.65 ± 0.02 ml and was used to determine volumes from 0.40 to 4.00 ml. Tube No. 3 had a volume of 9.97 ± 0.05 ml. This tube was used in obtaining volumes from 3.00 ml to 9.00 ml. In addition, a 100 ml graduated cylinder read to the nearest 0.1 ml was used for volumes over 10 ml. This resulted in recording volumes of the different groups with differing degrees of accuracy. In the treatment of data, the actual volume recorded was used in calculating percentage composition by volume, but totals are recorded only in terms of the least significant measurement

In the analysis, a given stomach was taken out of the formalin, cut open, and the contents washed into a petri dish and put under a binocular scope (30X maximum). In cases where the contents were loose in a baby food jar, or a detritus sample needing concentrating, the sample was poured through a cheesecloth screen. This screen effectively filtered the contents, but some of the finer detrital matter was lost. The sample was then scraped from the screen and placed on a paper towel to dry or in a petri dish for counting.

All groups, and species where possible, were enumerated with the aid of a dark-lined grid glued to the bottom of the petri dish. When large numbers of plankters or water boatmen were present, four or five squares out of 30 on the grid were counted after thorough mixing. This number was multiplied by a factor to give an estimate of the total number.

After being counted, the separated fauna groups were placed on paper towels from 4 to 8 minutes, or until most of the excess moisture was absorbed. These separated components were placed in the test tube into which they would conveniently fit and still give the greatest accuracy. Alcohol was added from a burette until the reading line was reached. The volume of the particular element was found by subtracting the burette reading from the test tube volume at the line. Any volume less than 0.01 ml was recorded as trace.

The problem of detritus or unidentifiable matter was prominent. Material present with a major bottom fauna element, such as Hexagenia naiads or Potamyia larvae could after experience be readily identified. This material was pooled with the major component present. Any other material or substance which could not be positively determined was recorded as unidentifiable material. Caddisfly larvae with cases were counted on the basis of the number of cases present. All individual cases were not examined, but seldom was a case found without a larvae present. Difficulty was experienced in distinguishing chironomid pupae from Chaoborus pupae, so that in tables they were referred to as dipteran pupae. However, in graphs and for purposes of showing the importance of midge larvae they were pooled with Chironomidae, since Chaoborus larvae were relatively rare in the stomachs.

For bigmouth and smallmouth buffalo, carpsucker, and gizzard shad, an alternate method for stomach analysis was used because of the difficulty of applying the alcohol displacement technique. Most of the stomach contents of gizzard shad were less than 0.15 ml, and the animal components present, such as plankton, fingernail clams, and ostracods, were extremely difficult to separate from other material present. The dense nature of the sand and fingernail clams usually present suggested that volumes would be similar to those determined by the displacement technique, if measured as a settled volume. To implement this, a graduated centrifuge tube which could be read to the nearest 0.01 ml to the 1 ml mark was used. A given stomach sample was removed from the formalin, cut open, and washed with alcohol until all the contents were in a petri dish. The number of organisms in each group was counted using a binocular scope, and percentage composition by volume of the various elements estimated. For the carp, gizzard shad, buffalos, and carpsuckers, a single slide mount of the material from each stomach was examined under highpower (100X) and the present or absence of algae was noted. No volumetric estimate was attempted which resulted in material designated as unidentifiable to be composed of different percentages of algae.

After counting and estimation of percentage composition had been completed, the stomach contents were washed into a centrifuge tube through a glass funnel using 95% alcohol and the settled volume measured. The volumetric estimates of each food component in the stomach could then be computed by multiplying estimated percentage volume of each food item times the total measured volume.

The method was eventually deemed unsatisfactory because of the flocculent nature of certain organisms which tended to give higher volumes, relative to the other method. Conversion factors were calculated to transform these data into displacement technique volumes. To correct the centrifuge values, 15 gizzard shad samples were analyzed by both methods, and a factor was calculated for different types of food present in the stomachs. Fingernail clams, whole and crushed, along with unidentified material (including algae), were the most common components in gizzard shad stomachs. The value of 0.3 for this material in gizzard shad was calculated. This is the ratio of displaced volume to settled volume. The centrifuge tube volume multiplied times this factor gave the volume in terms of the alcohol displacement technique. Other factors were calculated for the different components of the stomachs. Stomach contents of 200 gizzard shad, 10 bigmouth buffalo, 7 carpsuckers, and 4 smallmouth buffalo were converted using these factors.

RESULTS

Mooneye

The mooneye, Hiodon tergisus, one of the more common fish species inhabiting Pool 19, is found in all pools of the river and ranked 13th and 17th in the sport fishermen's catch in Pool 17 and 18 respectively (Nord, 1967). It is usually looked upon as a trash fish by local fishermen, though it is readily caught with sport fishing gear. Commercial fishermen take small quantities of them in their efforts at catching more commercially important species. Its importance in the ecosystem is the effect it exerts through competition with more commercially important fish. Its role as a forage fish is minimal, since predators were found to utilize gizzard shad most extensively (Ranthum, 1968).

Because mooneyes were readily captured with experimental gill nets and nearly always contained food in their stomachs, some emphasis was placed on this fish during the study. This resulted in the data collected to be generally the most extensive for all species captured. Of the 169 specimens selected for stomach analysis in 1966, 64% were between 9 and 12 inches long. The average size was 10.2 inches, with a range from 5.8 to 13.0 inches. In 1967, the average size of the 192 fish examined was 10.1 inches, with a range from 4.8 to 12.9 inches, and 75% were from 9-12 inches long.

Distribution

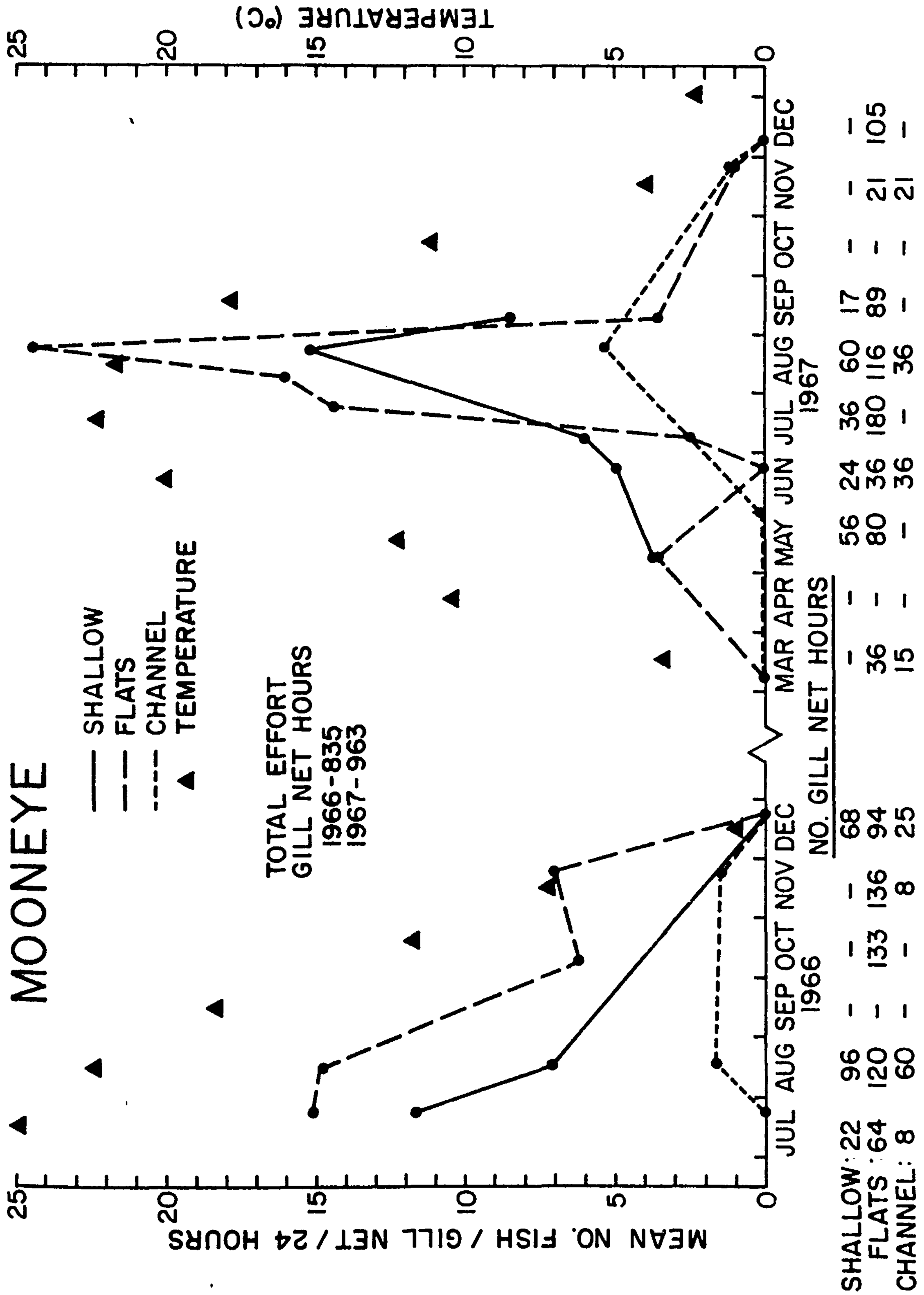
In 1966 and 1967, a total of 1,585 gill net hours was expended in capturing mooneyes. The number of fish captured per day (24 hours) averaged over 15-day intervals for shallow, flats and channel habitat gave an indication of seasonal activity for the 2 years of the investigation

(Figure 6). Most of the data for the summer months were taken from the 24-hour gill net studies which consisted of an experimental gill net set for 12 hours out of the 24 hours at a given station. In this case the catch was multiplied by 2 to give the total number of mooneyes captured per day. For the other times of the year gill nets were usually set from 16-20 hours and the value for catch per 24 hours was obtained by adjusting the catch to a 24-hour basis. Fifteen-day intervals were chosen for the grouping of data for all of the discussions. The activity of the mooneye, as reflected in the catch-per-effort statistics varied directly with average monthly water temperatures over the two years. Temperature data were obtained from Ortho Chemical Company, whose personnel recorded water temperature daily at their inlet stream. Some differences are apparent when the three habitat types are considered. Catch-per-effort for the flats was consistently higher than either the shallow or the channel habitat values indicating a preference for the flats by this species. Nets set in the channel may not sample fish as efficiently because of the effect of current on the nets and fish. The catch-per-effort values for August, 1966 are lower than in 1967 for the flats and for the shallow habitat. This may be due to a change in abundance of fish in 1967 or to an increased catch because of the elimination of less productive stations of 1966. In 1967, catch-per-effort during June for the flats was zero despite the 36 gill net hours fished, while catch-per-effort in shallow habitat continually rose from 4 in May to a mean of 15 fish per net per day for August. Flood conditions on the river in June probably forced mooneyes into the quieter, shallower water. Mean water flow values (Table 3B) at the Keokuk dam were 31,268 cubic feet per second in August, 1967, while the flow was 119,233 cubic feet per second in the latter part of

Table 3B. Mean monthly flows at Keokuk, Iowa, in cubic feet per second during 1966 and 1967. (Data from the United States Geological Survey)

Month	1966	1967
January	57,270	32,020
February	90,690	40,890
March	104,400	60,360
April	136,300	170,500
May	111,300	74,140
June	84,280	91,370
July	53,050	74,900
August	36,640	31,270
September	28,350	27,750
October	31,300	
November	29,170	
December	28,600	

Figure 6. Water temperature and mean catch of mooneyes per 24 hours in experimental gill nets averaged over 15-day intervals. Catch-per-effort for the shallow, flats, and channel habitat are shown


MOONEYE
SHALLOW
FLATS
CHANNEL
TEMPERATURE
TOTAL EFFORT
GILL NET HOURS
1966-835
1967-963
MEAN NO. FISH / GILL NET / 24 HOURS
TEMPERATURE (°C)
JUL AUG SEP OCT NOV DEC
1966
MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1967
NO. GILL NET HOURS
SHALLOW: 22 96 - - - 68 - - 56 24 36 60 17 - - -
FLATS: 64 120 - 133 136 94 36 - 80 36 180 116 89 - 21 105
CHANNEL: 8 60 - - 8 25 15 - - 36 - 36 - - 21 -
0 5 10 15 20 25

June. The extreme current and flood conditions along with increased turbidity of a clayish color in the water was quite evident at the time of net setting.

The depth distribution of the mooneye during three 24-hour sampling programs further demonstrated the mooneye's preference for the flats habitat during August 1966 and 1967 (Table 4). The number of fish captured during the June 24-hour program (16), was lower than for the August program (119) which was probably due to the normal increase in activity which occurs with increased water temperature. There was a definite change in depth preference between the June and August sampling programs in 1967. This was associated with the increased flow rates at that time (Table 3B) which were probably prohibitive for mooneyes in and near the channel. The fish from the June program showed about equal preference for water less than 3 feet deep (shallow) and water 3-8 feet deep (flats). No fish were captured in the channel during June. During the August program mooneyes became more widely distributed with a larger proportion occurring in the flats and in channel habitat.

In July, 1966, the position of 22 mooneye captured in gill nets was recorded. Twenty-one of these were found in the top one-third of the net. In August, 79% of 119 fish were found in the upper one-third of the net, 13% in the middle third, and 8% in the lower third of the net.

Mooneyes in Pool 19 are most active at night reaching a peak at 8-10 PM, a decrease around 12-2 AM, and then another increase at 4-6 AM (Figure 7). Data collected for these 24-hour programs may have been biased because samples for the day at one station were collected on a different day, sometimes two weeks apart from samples collected during the night. Therefore,

Table 4. The average catch of mooneyes taken in experimental gill nets set for 24 hours for three depth categories and three 24-hour sampling programs in Pool 19, Mississippi River. The average number of fish caught per station (12 hours of actual netting) was multiplied by two to give the data in terms of catch per 24 hours. The two 1967 programs were determined with equal effort

Date	No. Fish	Number Stations	Depth Category	Average catch per experimental gill net per 24 hours
August 3-28, 1966	107	10	<3 ft.	5.8
		9	3-8 ft.	16.4
		5	>8 ft.	1.6
June 25-July 10, 1967	16	8	<3 ft.	2.5
		6	3-8 ft.	2.3
		3	>8 ft.	0
August 17-28, 1967	119	8	<3 ft.	11.5
		6	3-8 ft.	22.0
		3	>8 ft.	5.3

extra netting on a continuous 24-hour sampling scheme starting at 6 PM was performed to see if sampling on different days affected data collected (Figure 8). Since catch-per-effort decreased initially and then increased the next day, it can be generally assumed that a significant local depletion of mooneyes did not occur and that fish taken were essentially randomly moving fish. Activity curves for these times show the same general pattern of activity as determined from the main sampling program, though there appears to be an increased period of activity at 10 AM-2 PM which was not evident in the 4-hour curves. Total catch on July 19 was greater than the catch on July 14 because the three nets were set perpendicular to the current on July 19, and parallel to the current on July 14. The low total catch for September (5 fish) was due to decreased activity of the fish.

Figure 7. Activity period for the mooneye, as reflected in the total catch of fish for gill nets set for 2 hours during three 24-hour sampling programs in 1966-67, Pool 19, Mississippi River

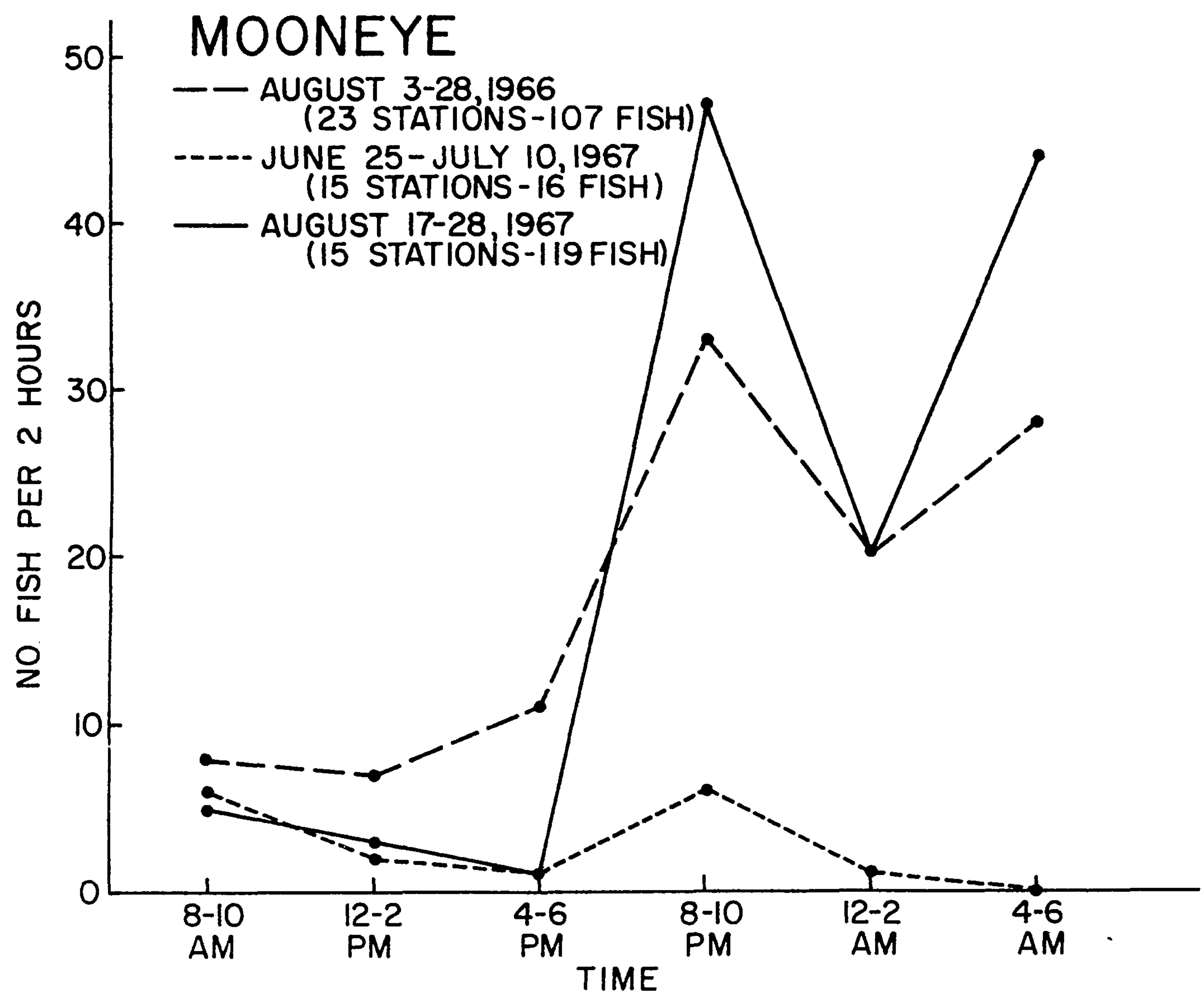
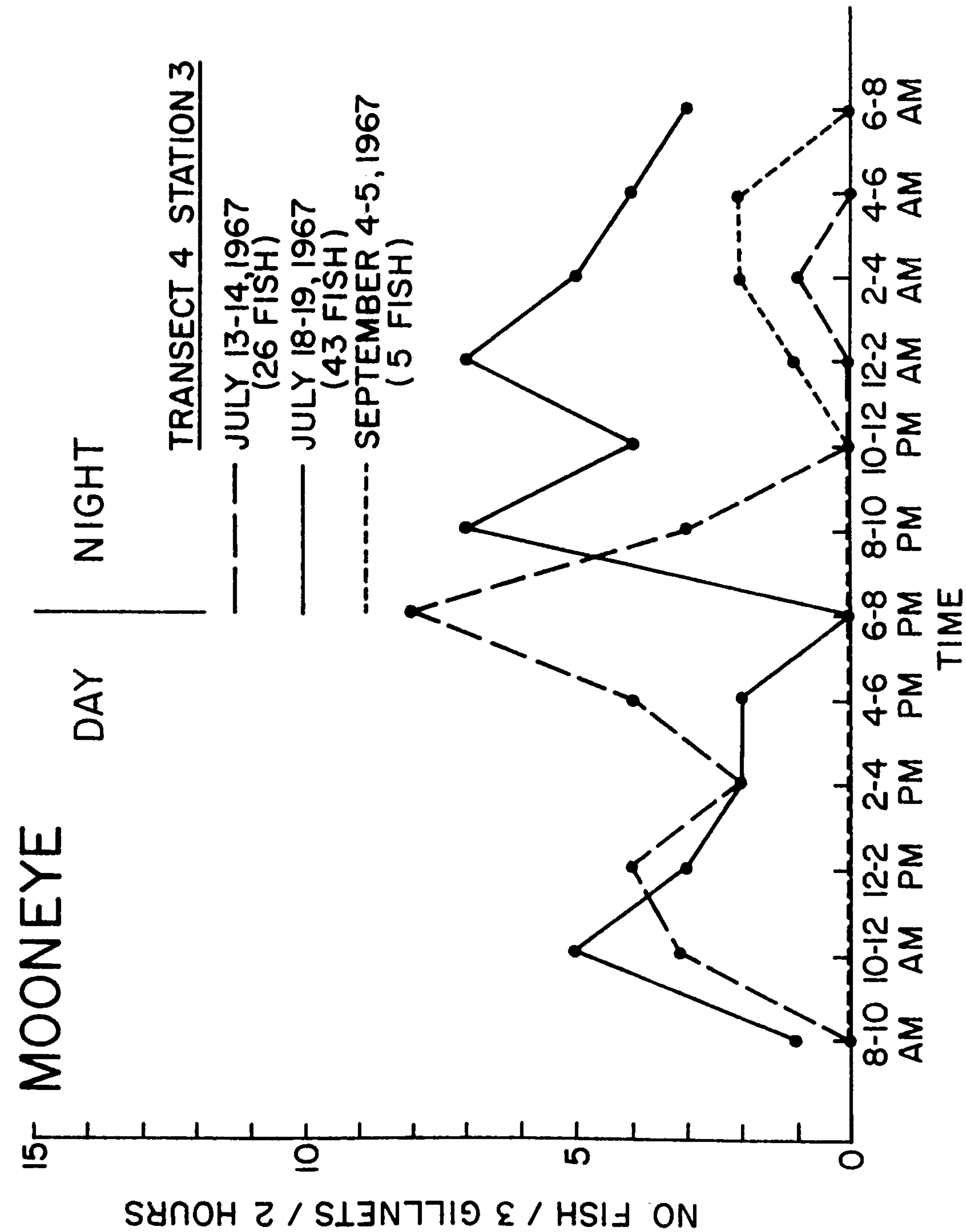

MOONEYE
AUGUST 3-28, 1966 (23 STATIONS-107 FISH)
JUNE 25-JULY 10, 1967 (15 STATIONS-16 FISH)
AUGUST 17-28, 1967 (15 STATIONS-119 FISH)
NO. FISH PER 2 HOURS
0
10
20
30
40
50
8-10 AM
12-2 PM
4-6 PM
8-10 PM
12-2 AM
4-6 AM
TIME

Figure 8. Activity period for the mooneye, as reflected in the number of fish captured in three experimental gill nets checked every two hours at transect 4 station 3 in Pool 19, Mississippi River (July 13-14, 18-19, and September 4-5, 1967)

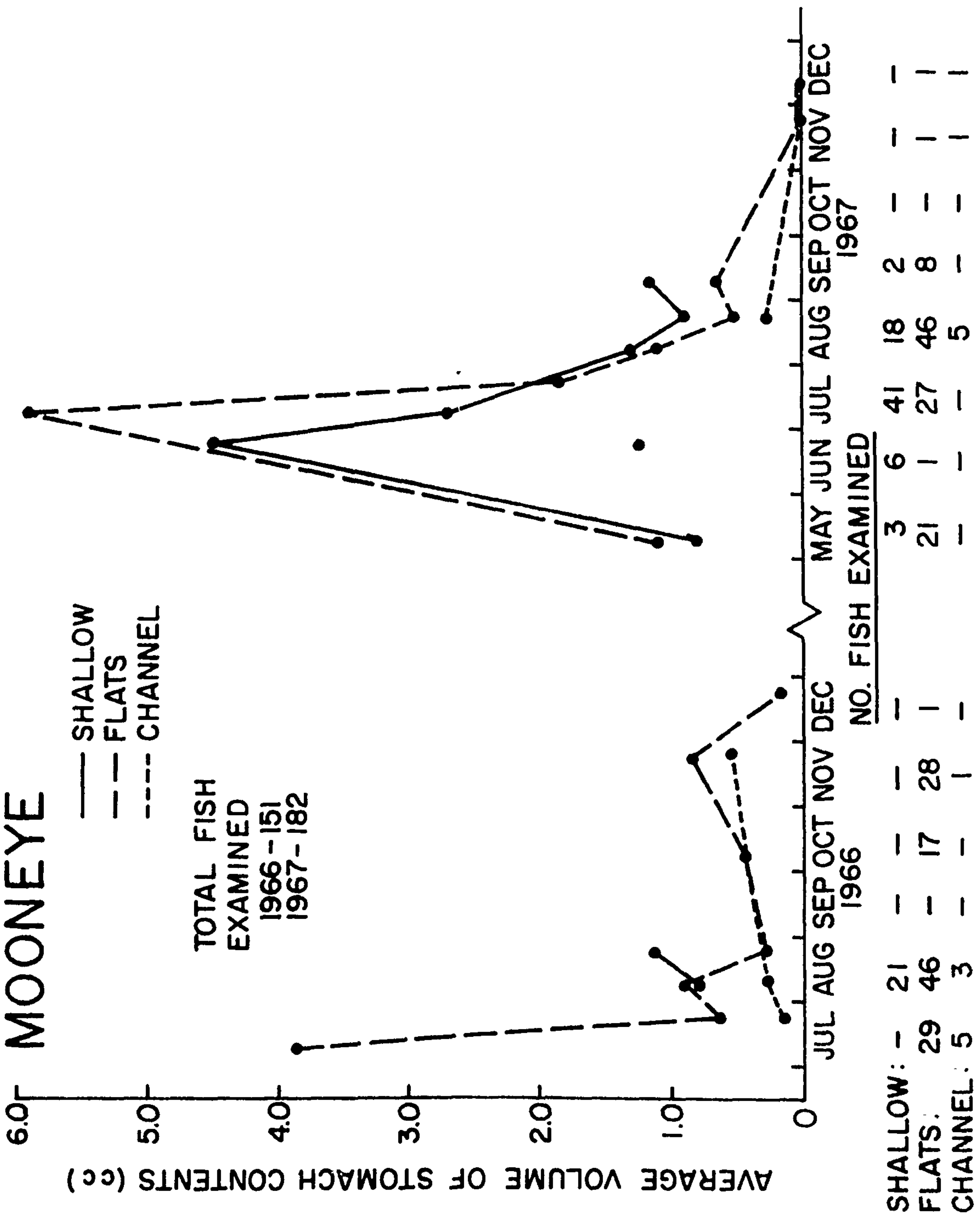

MOONEYE
DAY
NIGHT
TRANSECT 4 STATION 3
JULY 13-14, 1967 (26 FISH)
JULY 18-19, 1967 (43 FISH)
SEPTEMBER 4-5, 1967 (5 FISH)
NO FISH / 3 GILLNETS / 2 HOURS
0
5
10
15
8-10 AM
10-12 AM
12-2 PM
2-4 PM
4-6 PM
6-8 PM
8-10 PM
10-12 PM
12-2 AM
2-4 AM
4-6 AM
6-8 AM
TIME

Food habits

Mooneyes were captured from July to December 1966, from May to December, 1967, and one small sample in May, 1968. Few empty stomachs were found in a given sample and no seasonal trends were apparent. For the mooneye, food habits of fish captured in the same net for given areas were comparatively homogeneous and partially full stomachs usually contained food similar to stomachs which were full. The food habits of fish less than 7 inches are discussed; however, only fish less than 5.8 inches were found to be eating food different from larger fish and were therefore not included in the analysis.

The amount of food eaten per fish shows a distinct peak in June and July when the fish stomachs contained a maximum average of 6.0 cc of material, mostly Hexagenia (Figure 9). Some of the stomachs at this time contained as much as 21.0 cc of Hexagenia naiads and pharate adults (last instar naiads with black wingpads). Stomach content volume then declined from this peak in June and July to average levels around 0.50 cc for the rest of the months in 1966 and 1967. The mean amount of food eaten in the shallows was lower than the amount eaten on the flats during this peak period in June. Hexagenia pharate adults composed 100% of the diet at this time. Since the flats are the preferred habitat for Hexagenia (Fremling, 1959), fish would be expected to have more of these mayflies available there than fish in shallow habitat. The few mooneyes taken in the channel indicated low consumption of food material from July to December in 1966 and 1967. It is interesting to note that the highest catch-per-effort or peak activity (Figure 6) occurred in August, one month after the maximum amount of food consumed was recorded. Eleven inch mooneyes have eaten up to 21.0 cc of

Figure 9. The average volume of stomach contents for mooneyes taken in shallow, flats and channel habitat. Values are averaged over selected 15-day intervals from July, 1966 to December, 1967 in Pool 19, Mississippi River


MOONEYE
SHALLOW
FLATS
CHANNEL
TOTAL FISH EXAMINED
1966 - 151
1967 - 182
AVERAGE VOLUME OF STOMACH CONTENTS (cc)
6.0
5.0
4.0
3.0
2.0
1.0
0
JUL AUG SEP OCT NOV DEC
1966
MAY JUN JUL AUG SEP OCT NOV DEC
1967
NO. FISH EXAMINED
SHALLOW: - 21 - - - - 3 6 41 18 2 - - -
FLATS: 29 46 - 17 28 - 21 - 27 46 8 - - -
CHANNEL: 5 3 - - - - - - - 5 - - - -

food material in June. Since an average of only 0.9 cc is found in August, it may indicate that increased activity was associated with increased effort required to obtain the less available caddisfly larvae and water boatmen found in the stomachs at this time. These insects, though probably as available as Hexagenia, are considerably smaller than the mayfly, and probably more difficult to capture. The increased metabolism, and energy required to maintain a fish at the higher August temperatures is also a factor which would increase the movement of fish at this time, thus leading to increased food-getting activities. However, with the higher digestion rates expected during August the total amount of food eaten per day could be the same for June and August. The large decline in mean volume per stomach in June on the flats (5.9 cc) to values around .5 cc during August would tend to support the belief that more food is eaten in June.

Mean consumption of food followed a definite diurnal rythm. Data from three of the 24-hour sampling programs conducted in August, 1966, and June and August of 1967, indicated minimum feeding around 4-6 PM and 8-10 PM, an increase beginning at 12-2 AM, and then reaching maximum volumes around 4-6 AM and 8-10 AM (Figure 10). There was good agreement between August curves for 1966 and 1967, even though some of the stations from 1966 were changed in 1967. The difference in magnitude between the June-July, 1967 curve and the August curves in 1966 and 1967, was due to Hexagenia hatches and naiad activity in June and July.

The additional 24 hours of continuous sampling was again used to check results found in the major sampling programs. The average amount of food eaten determined by 2-hour intervals again follows the same trends as found in the major sampling program (Figure 11). The lowest amount of food

Figure 10. Average volume of stomach contents over a 24-hour period for mooneyes taken in Pool 19, Mississippi River during August 3-28, June 25-July 10 and August 17-28, 1967

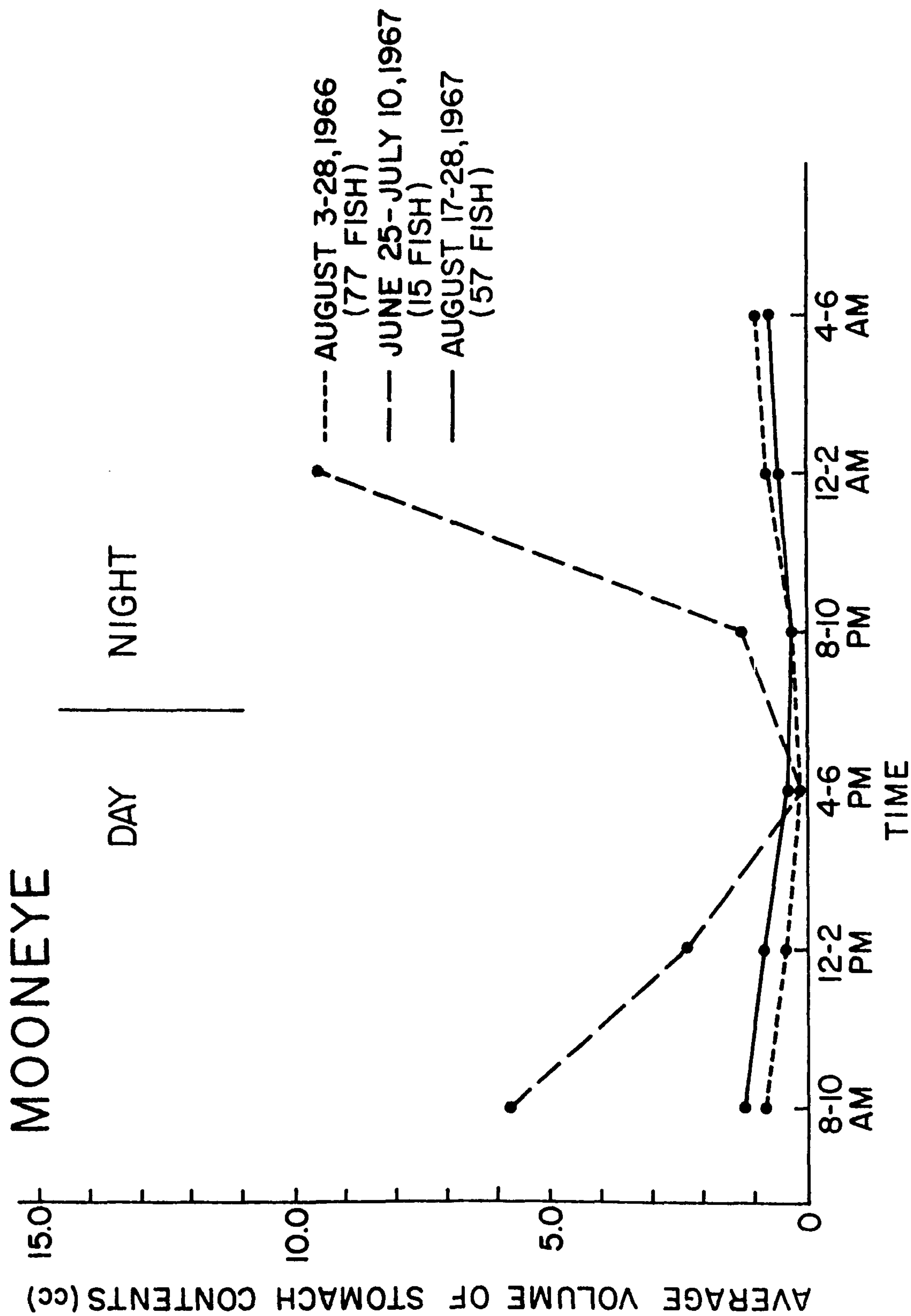
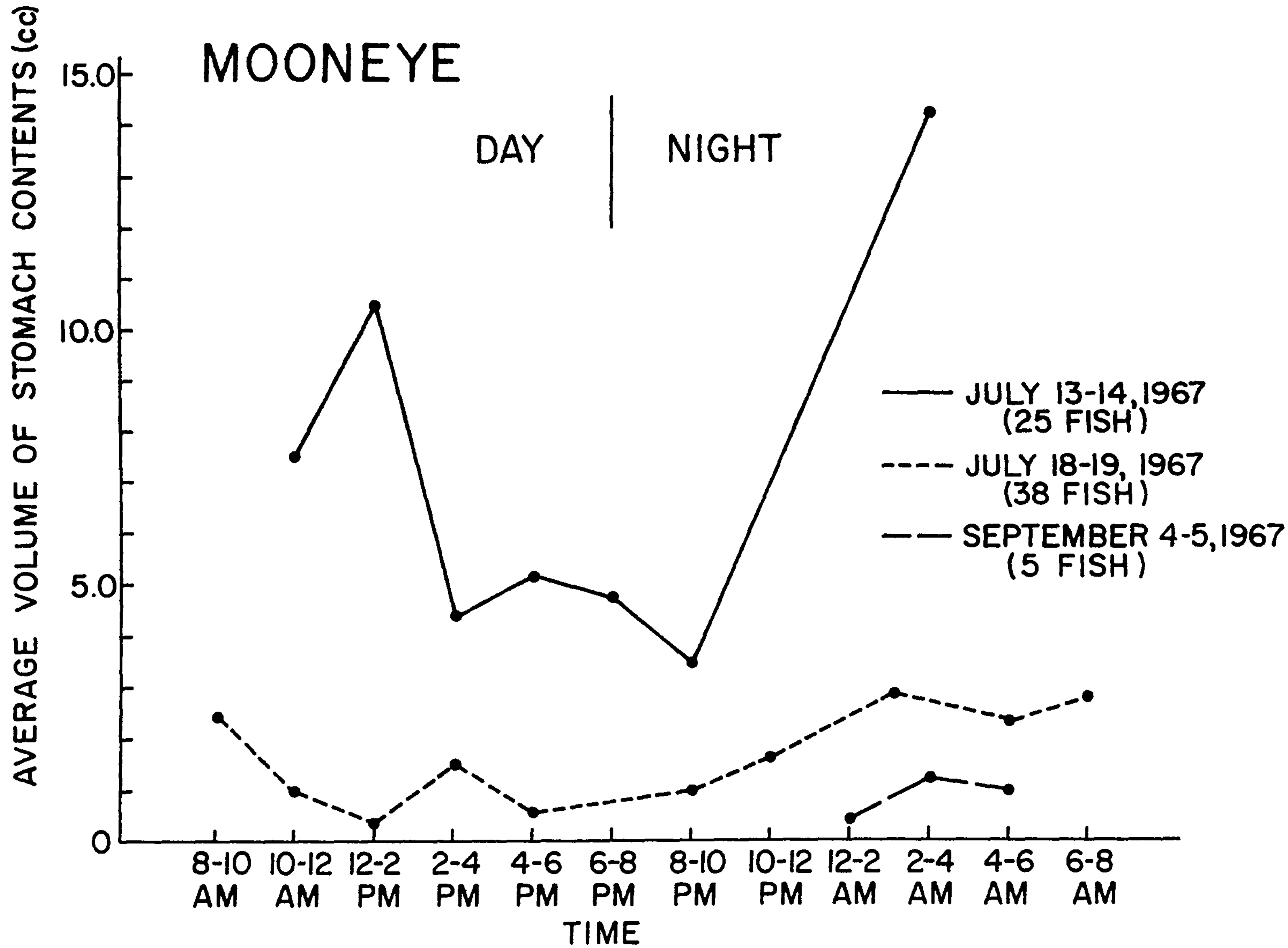

MOONEYE
DAY
NIGHT
AUGUST 3-28, 1966 (77 FISH)
JUNE 25-JULY 10, 1967 (15 FISH)
AUGUST 17-28, 1967 (57 FISH)
AVERAGE VOLUME OF STOMACH CONTENTS (cc)
15.0
10.0
5.0
0
8-10 AM
12-2 PM
4-6 PM
8-10 PM
12-2 AM
4-6 AM
TIME

Figure 11. Average volume of stomach contents over a 24-hour period for mooneyes taken in Pool 19, Mississippi River during July 13-14, 18-19 and September 4-5, 1967

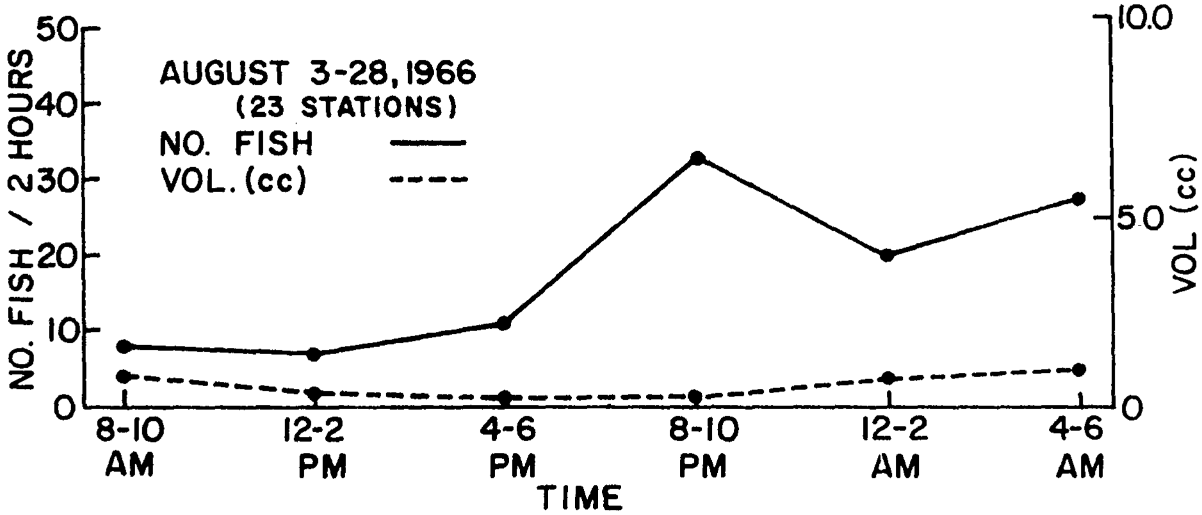

MOONEYE
DAY
NIGHT
JULY 13-14, 1967 (25 FISH)
JULY 18-19, 1967 (38 FISH)
SEPTEMBER 4-5, 1967 (5 FISH)
AVERAGE VOLUME OF STOMACH CONTENTS (cc)
15.0
10.0
5.0
0
8-10 AM
10-12 AM
12-2 PM
2-4 PM
4-6 PM
6-8 PM
8-10 PM
10-12 PM
12-2 AM
2-4 AM
4-6 AM
6-8 AM
TIME

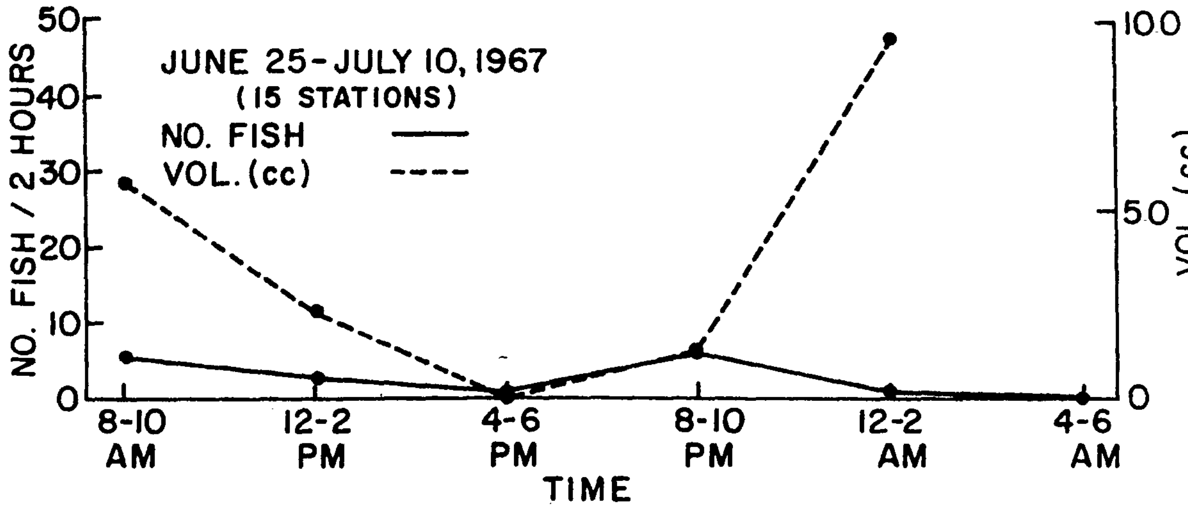
eaten occurred around 4-6 PM and 8-10 PM followed by an increase to maximum values at 12-2 AM and 4-6 AM. All three curves were determined with equal effort, so that the decreased amount of food eaten between the July and September samples can be noted. The difference in the mean amount of food eaten on July 14th and July 19th was due to a Hexagenia hatch observed on July 14. On July 19, the diet had shifted to the caddisfly, Potamyia flava, which appears to be somewhat more difficult to obtain.

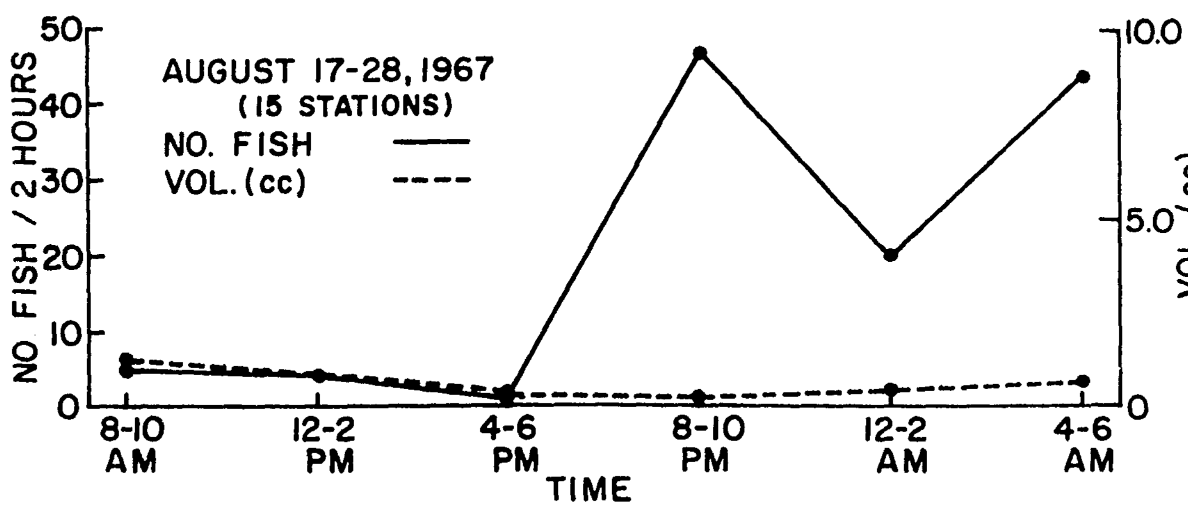
Activity curves (Figure 8) and the average volume per fish over 24 hours for these July samples (Figure 11), indicated that peak activity at 8-10 PM was followed by the maximum amount of food contained in stomachs in the next period, 12-2 AM. This was also evident in the 24-hour samples for August, 1966 and 1967 where the activity of the fish and average amount of contents eaten was plotted (Figure 12). Activity appears to be associated closely with feeding during July and August. The fish probably feed most at night in response to night time activity and emergences of insects.

The food habits of the mooneye have not been investigated extensively. Forbes (1878, 1888), Pearse (1921), Sibley (1929), Coker (1930), Bajkov (1932b) and Boesel (1938) all reported that mooneyes were generally insectivorous, relying heavily upon Ephermoptera, especially Hexagenia. None, however, conducted comprehensive seasonal studies. Hoopes (1959), who worked on Pool 19 near Burlington and Keokuk found generally a winter and spring diet of Hexagenia, with equal utilization during summer and early fall of Hexagenia and Potamyia flava larvae. Wenke (1965) who also worked on Pool 19 near Keokuk, found generally similar results, except that another caddisfly, Hydropsyche orris, characteristically found near dams and channel markers, was also found in stomachs. Potamyia flava was said to inhabit

Figure 12. Activity curves and average volume of stomach contents over a 24-hour period for mooneyes taken in Pool 19, Mississippi River, August 3-28, 1966, June 25-July 10 and August 17-28, 1967


AUGUST 3-28, 1966
(23 STATIONS)
NO. FISH
VOL. (cc)
NO. FISH / 2 HOURS
VOL (cc)
8-10 AM
12-2 PM
4-6 PM
8-10 PM
12-2 AM
4-6 AM
TIME


JUNE 25-JULY 10, 1967
(15 STATIONS)
NO. FISH
VOL. (cc)
NO. FISH / 2 HOURS
VOL (cc)
8-10 AM
12-2 PM
4-6 PM
8-10 PM
12-2 AM
4-6 AM
TIME


AUGUST 17-28, 1967
(15 STATIONS)
NO. FISH
VOL. (cc)
NO. FISH / 2 HOURS
VOL. (cc)
8-10 AM
12-2 PM
4-6 PM
8-10 PM
12-2 AM
4-6 AM
TIME

sand, silt-free areas of the river where current is considerable.

Five categories were chosen to summarize the many food items eaten by the mooneye, and in addition fish were separated by habitat type (flats, shallow, and channel) to demonstrate any apparent differences in type and amount of food eaten (Table 5A, 5B, 5C). Hexagenia, which made up the bulk of the diet of this species in the spring and latter part of fall, were the naiads and adults of two species, Hexagenia bilineata and Hexagenia limbata, with the former being by far the most numerous (Fremling, 1959). No attempt was made to distinguish between these two species, which undoubtedly have a one year life cycle in Pool 19.

Since Hexagenia are burrowing mayflies and lie deep in the mud in "U" shaped burrows (Fremling, 1959), the manner of acquisition by fish has been a matter of conjecture by many authors. Studies by Wenke (1965), demonstrated that naiads show a marked degree of nocturnal activity and that movement was in a downstream direction. The naiads are most vulnerable during and prior to emergence and Fremling (1959) observed some swimming around at the surface of an aquarium for one-half hour before they emerged. Those which emerged successfully did so in a few minutes. The author has also observed swimming naiads in the river.

Hexagenia were found in the stomachs of fish from shallow habitat during August, 1966, but not 1967. A major emergence coinciding with this August, 1966 sample was probably responsible. After the July and August emergences, few pharate adult mayflies are left in the bottom fauna. Fish again resume feeding on Hexagenia in September when naiads from eggs laid in the spring and summer grow to a size large enough for consumption. Mayflies were fed upon in 1967 during May, June and July when the maximum amount of

Table 5A. Volume and occurrence of the material ingested by the mooneye from August, 1966 to May, 1968 in shallow habitat, Pool 19, Mississippi River. (T = trace)

Date	No. Stations	Stomachs Examined		Hexagenia		*Potamyia flava*		Corixidae		Other		Unidentifiable		Total Volume
		No. w/Food	No. Empty	Vol. (cc)	Occur. (No.)	Vol. (cc)	Occur. (No.)	Vol. (cc)	Occur. (No.)	Vol. (cc)	Occur. (No.)	Vol. (cc)	Occur. (No.)	
Aug. 1-15, 1966	4	13	0	.28	7	.21	9	.19	5	.03	12	.09	13	.80
Aug. 15-31, 1966	3	8	1	0	0	t	3	.97	8	t	5	.17	1	1.14
May 1-15, 1967	2	3	0	.42	3	0	0	t	2	.36	3	.03	1	.81
June 15-30, 1967	2	6	0	4.5	6	0	0	0	0	.02	1	0	0	4.52
July 1-15, 1967	2	6	0	2.68	6	0	0	0	0	.02	3	0	0	2.70
Aug. 1-15, 1967	1	1	0	0	0	0	0	.26	1	.60	1	.43	1	1.29
Aug. 15-31, 1967	2	17	1	.03	5	.06	11	.63	14	.03	15	.16	9	.91
Sept. 1-15, 1967	1	2	1	0	0	.01	2	1.03	2	.01	2	.11	1	1.16
May 1-15, 1968	1	3	2	.01	2	0	0	.01	3	.68	3	.29	1	.99

Table 5B. Volume and occurrence of the material ingested by the mooneye from July, 1966 to October, 1967 in flats habitat of Pool 19, Mississippi River. (T = trace)

Date	No. Sta-tions	Stomachs Examined		*Hexagenia*		*Potamyia flava*		Corixidae		Other		Unidenti-fiable		Total Volume
		No. w/Food	No. Empty	Vol. (cc)	Occur. (No.)	Vol. (cc)	Occur. (No.)	Vol. (cc)	Occur. (No.)	Vol. (cc)	Occur. (No.)	Vol. (cc)	Occur. (No.)	
July 1-15, 1966	2	1	0	3.83	1	t	1	0	0	t	1	0	0	3.83
July 15-31, 1966	8	28	2	.11	7	.39	21	0	0	.01	22	.16	21	0.67
Aug. 1-15, 1966	8	33	1	.37	13	.30	31	t	2	.02	30	.20	26	0.89
Aug. 15-31, 1966	8	13	3	0	0	.13	8	.09	3	.01	9	.09	11	0.32
Oct. 15-31, 1966	2	17	2	.33	14	.01	10	0	0	t	4	.10	3	0.44
Nov. 15-31, 1966	8	28	0	.80	27	0	0	t	1	t	7	.07	9	0.87
Dec. 15-31, 1966	1	1	0	.18	1	0	0	0	0	0	0	0	0	0.18
May 1-15, 1967	1	21	0	1.10	19	0	0	0	0	.01	8	0	0	1.11
June 15-30, 1967	1	1	0	1.25	1	0	0	0	0	0	0	0	0	1.25
July 1-15, 1967	2	27	0	5.9	19	t	1	0	0	t	2	0	0	5.9
July 15-31, 1967	1	35	2	.21	28	1.62	34	t	3	.02	28	0	0	1.85
Aug. 1-15, 1967	2	17	0	.88	5	.15	10	t	4	.13	12	.06	7	1.22

Table 5B. Continued

Date	No. Sta-tions	Stomachs Examined No. w/Food	No. Empty	*Hexagenia* Vol. (cc)	Occur. (No.)	*Potamyia flava* Vol. (cc)	Occur. (No.)	Corixidae Vol. (cc)	Occur. (No.)	Other Vol. (cc)	Occur. (No.)	Unidenti-fiable Vol. (cc)	Occur. (No.)	Total Volume
Aug.15-31, 1967	5	29	3	t	6	.08	18	.04	19	.08	25	.28	25	0.48
Sept.1-15, 1967	2	8	2	.02	2	.03	6	.04	7	.21	6	.36	8	.66
Oct.15-31, 1967	1	1	0	t	1	0	0	0	0	0	0	0	0	t

Table 5C. Volume and occurrence of the material ingested by the mooneye from July, 1966 to December, 1967 in channel habitat of Pool 19, Mississippi River. (T = trace)

Date	No. Sta-tions	Stomachs Examined No. w/Food	No. Empty	*Hexagenia* Vol. (cc)	Occur. (No.)	*Potamyia flava* Vol. (cc)	Occur. (No.)	Corixidae Vol. (cc)	Occur. (No.)	Other Vol. (cc)	Occur. (No.)	Unidenti-fiable Vol. (cc)	Occur. (No.)	Total Volume
July 15-31, 1966	2	5	4	0	0	.02	2	.01	2	.01	3	.11	2	0.15
Aug. 1-15, 1966	2	3	2	t	1	.18	3	0	0	t	3	.10	2	0.28
Nov.15-31, 1966	1	1	0	.55	1	0	0	0	0	0	0	0	0	0.55
Aug.15-31, 1967	2	5	0	.01	3	.03	4	0	0	t	5	.23	3	0.27
Dec. 1-15, 1967	1	1	0	t	1	0	0	0	0	0	0	0	0	t

food was found in stomachs.

For the flats habitat, where most mooneyes were obtained, a similar pattern of feeding was evident. *Hexagenia* are fed upon in large numbers in the spring and early summer, when many are moving around out of their burrows, preparatory to emergence. The decline in August and subsequent increase in the volume of mayflies found in the stomachs during October and November was again the result of growth of the young hatched in June. The data of 1967 do not show the increased utilization of *Hexagenia* in October, November and December because data were not collected in October, 1967 and fish were difficult to catch in November and December. The 1966 data, however, show the increased reliance at this time on *Hexagenia*, which undoubtedly occurred in 1967 also. The data collected by Hoopes (1959), and Wenke (1965) also show this change.

Only nine fish from the channel habitat were examined, because netting was difficult and fish appeared to be less abundant. Fish in July and August were eating only 0.01 cc *Hexagenia*, and one captured there in November contained 0.55 cc which is comparable to volumes eaten on the flats.

To find out if fish eating *Hexagenia* were selecting for certain large sized individuals, the average volume of a *Hexagenia* individual was calculated for periods when data were available (Table 6). *Hexagenia* were small in May (.02 cc in 1967 and .01 cc in 1968), increased in size to a maximum around 0.09 cc in July, then decreased in August. The reasons for this August decrease could be emergences and an increased reliance on smaller larvae. The average size gradually increases in the fall to around 0.05 cc per individual. *Hexagenia* eaten are subject to selectivity by fish, but

Table 6. The average calculated size in cc of Hexagenia found in mooneye stomachs for selected 15-day intervals in 1966-1968

	Total number	Total volume	Mean size (cc)
1966			
July	73	5.85	.08
August 1-15	282	13.24	.05
October	88	2.01	.02
November	641	29.20	.05
December	4	.18	.05
1967			
May	544	11.76	.02
June	221	27.60	.12
July	1,863	176.06	.09
August 1-15	163	14.51	.09
August 15-31	42	.72	.02
1968			
May	2	.02	.01

some of the data presented by Carlson (1960) on size distribution would tend to support the results, since he found similar trends in sizes of larvae measured. Digestion of the naiads could definitely be a problem in these determinations, but every effort was made in the analysis to separate the Hexagenia contributions into naiads, adults, pharate adults, and digested material from Hexagenia present in the same stomach.

Three caddisflies were identified from mooneye stomachs. Oecetis sp. (Leptoceridae) was found in one stomach in 1966. Another member of the Leptoceridae family, Leptocella candida (Hagen) was found occasionally in mooneye stomachs, but was not significant numerically or volumetrically. Potamyia flava (Hydropsychidae) was the major species of caddisfly eaten by mooneyes in this section of the river. One Hydropsyche orris was present in a sample of about 400 P. flava from mooneye stomachs sent for verification to Dr. David Etnier, University of Tennessee. H. orris may not have been detected in other samples; however, it is believed that if present, they make up a negligible portion of the total volume and number eaten. Hoopes (1960) reported H. orris and Cheumatopsyche camplya to be eaten in limited numbers, while Wenke (1965) found H. orris in stomach samples taken near the dam at Keokuk where this species is prevalent.

In the present study, P. flava were eaten in the latter part of July, August, and to a limited extent in September in all three habitat types. This coincided with the decline in mayfly numbers and the drift phenomen which is suspected for this larvae. Evidence for this was the appearance during August of hundreds of P. flava larvae on gill nets and in the stomachs of mooneyes from shallow habitat (transect 9 station 2) and flat habitat (transect 4 station 3), when the preferred habitat of P. flava is channel environment. Commercial fishermen from Pool 19 also found caddisflies on nets, but the species involved was not stated (Fremling, 1959). To further investigate the phenomenon, a drift net was constructed and placed on the bottom facing the current in the flats habitat of transect 4 station 3. In two overnight sets on July 3 and July 11 it contained Hexagenia (pharate adults), P. flava, several members of the family Ephermeridae, and chironomids. Subsequently, it was stolen and no more sampling was initiated.

Utilization of P. flava in shallow habitat was low to absent in August and September, and as a result increased usage of Corixidae (water boatmen) occurred at this time. Water boatmen were eaten in large amounts only in shallow habitat, where these insects abound in August and September. Limited amounts of corixids were found in stomachs examined from flat and channel stations, but these were probably fish which had previously fed in shallow habitat.

The "other" category was comprised of 46 different types of organisms, almost exclusively Insecta. Elmids (Stenelmis), mayflies of the subfamily Baetinae and Siphlonurinae, Stenonema (Heptagenidae), Chironomidae, and Ceratopogonidae all occurred regularly in stomachs collected during the summer. Plecoptera nymphs (Isoperla sp.) were found in stomachs collected in the spring. The volume made up by the "other" category was generally low. Chironomids made up the largest part of the diet in the shallow habitat during May. Though only six stomachs were actually examined during this period, the author field-checked several other stomachs in May, 1968 and found all distended with chironomids. Most of the chironomids fed upon at this time were pupae, which apparently became more susceptible to predation with increased activity prior to emergence. Higher than average values in the "other" category found in some months were caused by one large item influencing results.

The unidentifiable category was found to contain the greatest volume during the latter part of July, August and September when the total amount of food consumed is low, and the number of different species eaten diverse (Table 5A). It is during these times that the mooneye must actively search for food since Hexagenia are apparently less available. Rapid digestion and feeding during this time led to a percentage of the stomach contents to be comprised of a homogeneous mass of insects, legs, heads, and other debris which defied categorization.

During July and August, 1966, two fish less than 7 inches (6.2 and 5.9 inches) were captured. Both contained food similar to fish greater than 7 inches. During 1967, 20 fish were taken that were less than 7 inches. Fourteen showed feeding habits similar to adults. Three small fish from 1 to 2 inches taken from a walleye stomach on July 4 in shallow habitat contained chironomids. Another three were taken with a trawl on the flats and near the channel on transect 3. The two taken on August 28 contained 1,023 and 555 copepods, respectively. The other (5.6 inches) taken in December was eating trace amounts of Hexagenia. Boesel (1938) reported that mooneyes from Lake Erie less than 39 mm fed upon Entomostraca.

The degree to which each of the various categories contributed to the diet of the mooneye in a given 15-day interval was well demonstrated by calculating the percentage composition by volume for each interval on the shallow, flats, and channel (Figure 13A, 13B, 13C). Hexagenia were eaten almost exclusively in May, June and July, while P. flava were present in stomachs during August. There was a return again to Hexagenia in the fall and early winter. In general, adults and last instar naiads (pharate adults) comprised almost 100% of the diet in the latter part of June and the first part of July. Reduced amounts were taken in latter July and early August on the flats, when the last of the large emergences occurred. Differences between habitat types were apparent. In shallow areas fish were depending on Chironomidae in May while on the flats fish were eating 100% Hexagenia. Water boatmen were taken during August and part of September by fish in the shallow water, while fish from the flats were relying more heavily on P. flava. Food utilization in the channel, though based on limited numbers of fish, appears to follow the same trends as fish captured on the flats.

Figure 13A. Percentage composition by volume of the material ingested in shallow habitat by the mooneye from August, 1966 to May, 1968 in Pool 19, Mississippi River. (For *Hexagenia* and Trichoptera shaded portion of graph represents percentage of larvae or naiads, while open spacing indicates adults or last instar naiads)

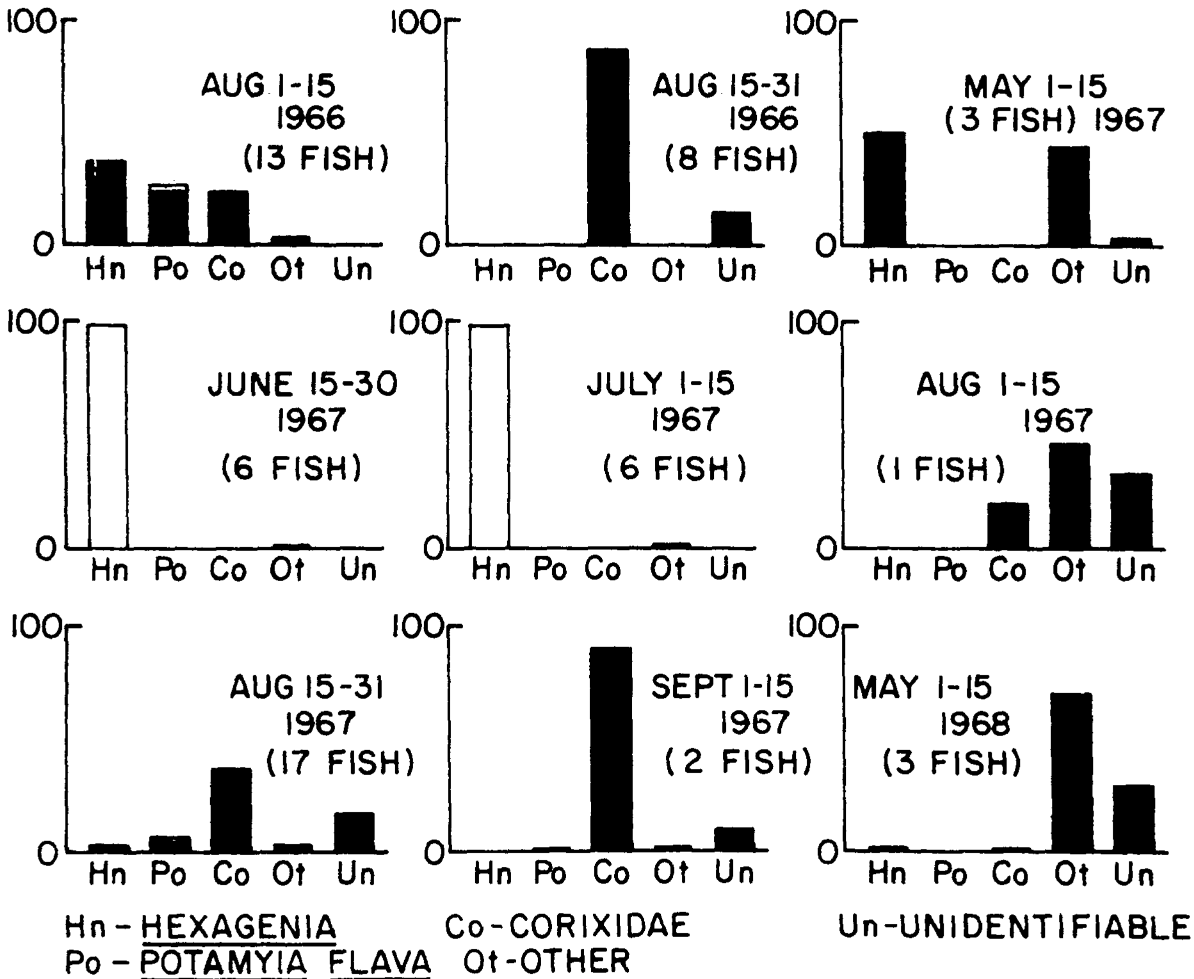
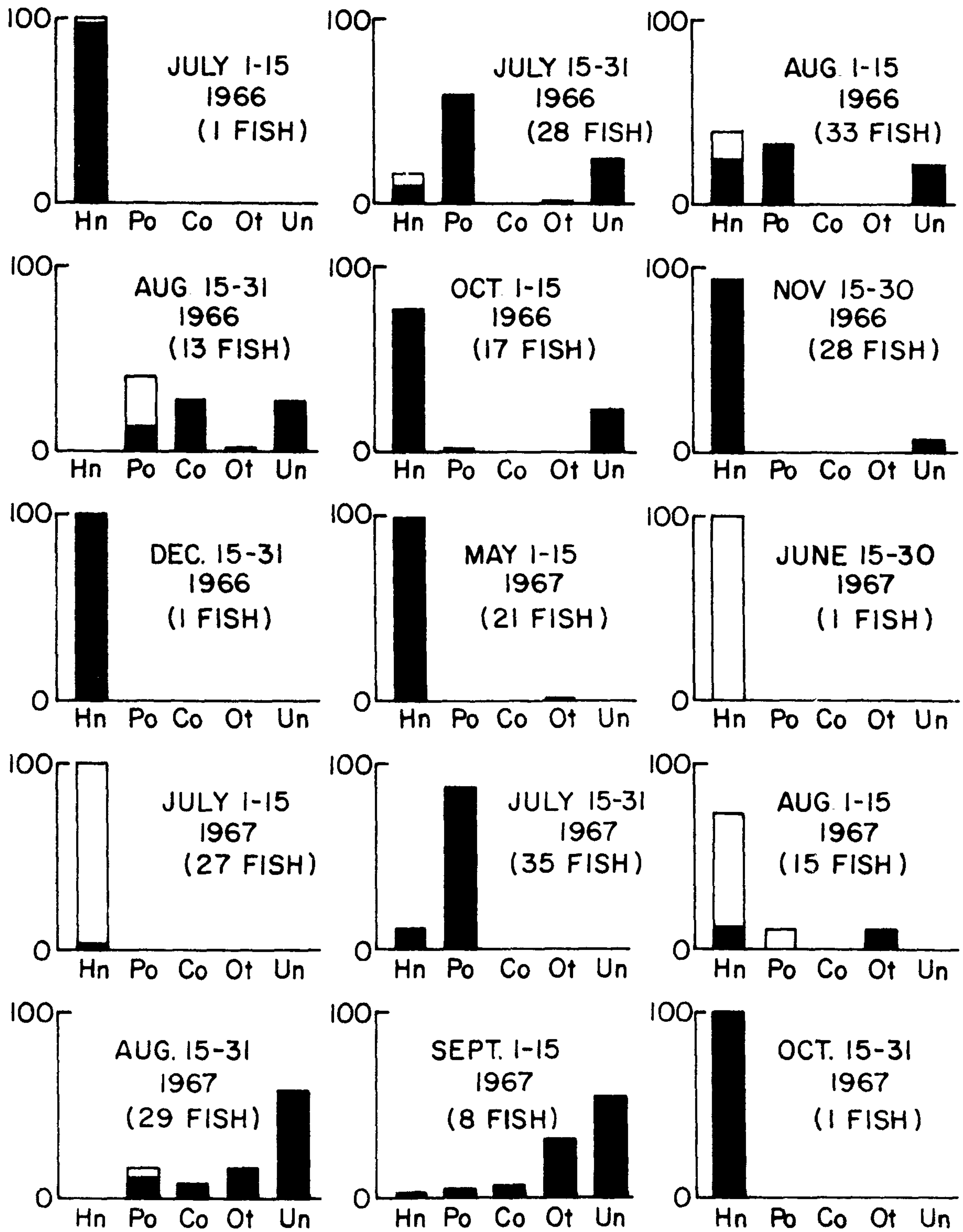
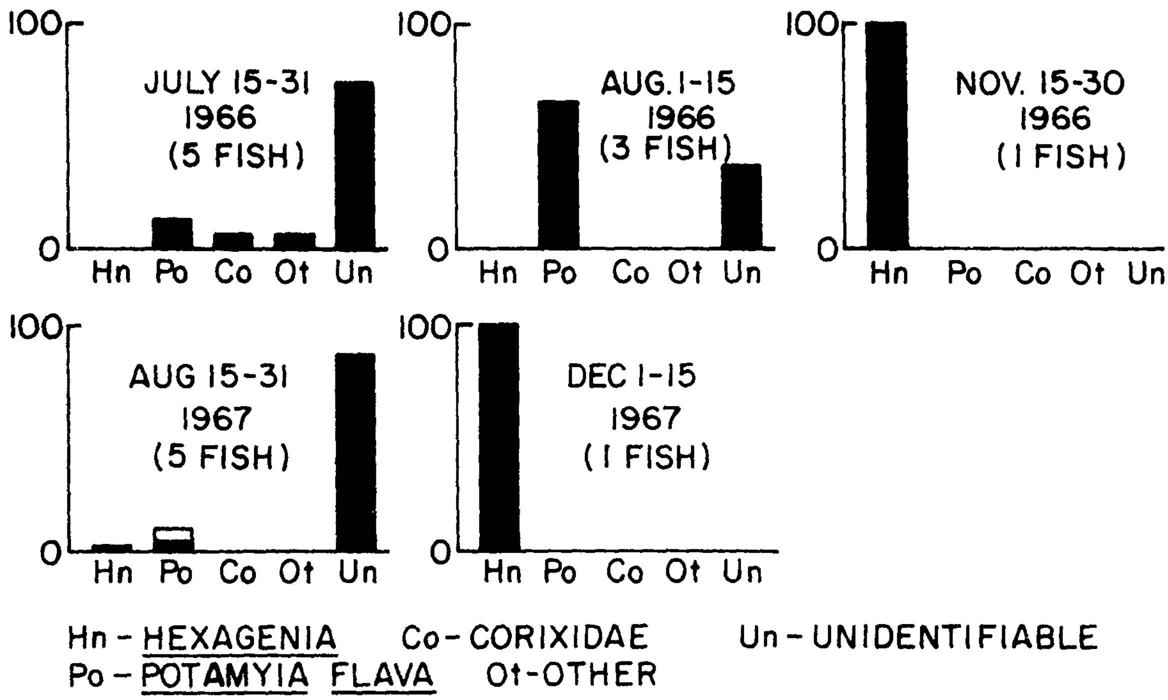

100
0
AUG 1-15
1966
(13 FISH)
AUG 15-31
1966
(8 FISH)
MAY 1-15
(3 FISH) 1967
JUNE 15-30
1967
(6 FISH)
JULY 1-15
1967
(6 FISH)
AUG 1-15
1967
(1 FISH)
AUG 15-31
1967
(17 FISH)
SEPT 1-15
1967
(2 FISH)
MAY 1-15
1968
(3 FISH)
Hn Po Co Ot Un
Hn - HEXAGENIA
Po - POTAMYIA FLAVA
Co - CORIXIDAE
Ot - OTHER
Un - UNIDENTIFIABLE

Figure 13B. Percentage composition by volume of the material ingested in flats habitat by the mooneye for selected periods from July, 1966 to December, 1967 in Pool 19, Mississippi River. (For *Hexagenia* and Trichoptera shaded portion of graph represents percentage of larvae or naiads, while open spacing indicates adults or last instar naiads)



Hn - HEXAGENIA   Co - CORIXIDAE   Un - UNIDENTIFIABLE
Po - POTAMYIA FLAVA   Ot - OTHER

Figure 13C. Percentage composition by volume of the material ingested in channel habitat by the mooneye for selected periods from July, 1966 to December, 1967 in Pool 19, Mississippi River. (For *Hexagenia* and Trichoptera shaded portion of graph represents percentage of larvae or naiads, while open spacing indicates adults or last instar naiads)


100
0
JULY 15-31
1966
(5 FISH)
AUG. 1-15
1966
(3 FISH)
NOV. 15-30
1966
(1 FISH)
AUG 15-31
1967
(5 FISH)
DEC 1-15
1967
(1 FISH)
Hn Po Co Ot Un
Hn - HEXAGENIA
Co - CORIXIDAE
Un - UNIDENTIFIABLE
Po - POTAMYIA FLAVA
Ot - OTHER

Bottom fauna utilization

One of the unique aspects of the present study was the joint collection of bottom fauna data at the same stations where fish were captured. These data were gathered by William Gale with three types of gear: an Ekman dredge (6x6 square inches), a Petersen dredge (12 square inches), a core sampler (3 inches diameter), and a large, circular tin sampler which was used for vegetation surveys. The data have been summarized by 15-day intervals for the shallow, flats, and channel habitat (Table 7). Oligochaetes and fingernail clams made up more than 90% of the bottom fauna by number in almost every sample, but were utilized only sparingly by the 14 species of fish investigated. Since these two groups and at times other organisms reached large numbers, only the specific groups eaten in highest numbers by a particular fish species were plotted against bottom fauna data to show the degree of utilization. Forage ratios and availability factors (Allen, 1942), were deemed unsatisfactory for the same reason.

Hayne and Ball (1956) found that centrachids significantly reduced the populations of benthos in the ponds in which they were introduced. They found that after the fish were removed from the pond bottom fauna numbers increased. Productivity of the benthos was increased in the presence of fish. Smith (1961) in Canada found a definite selection by trout for certain components in the fauna, and rejection of others, particularly Hyalella and sphaeriids, which made up a large part of the bottom fauna. Similar results were reported for trout in a Michigan trout stream (Ellis and Gowing, 1957). Asellus, the aquatic sowbug, was found to comprise 1% by volume in the bottom samples, but 48% in the stomachs.

For the mooneye, four groups were selected for correlations:

Table 7A. Numbers of bottom fauna summarized over 15-day intervals for the shallow habitat. Data are from Gale (1968). (E - Ekman dredge, P - Petersen dredge, C - Core sampler, and Cy - circular cylinder)

Date	Number of Stations	Sampling Units	Hexagenia	Trichoptera	Chironomidae	Corixidae	Ceratopogonidae	Other Ephermeroptera	Hirudinae	Hyalella	Odonata	Sphaeriidae	Oligochaete	Gastropoda	Chaoborus
7/15-31/66	6	12E	0	14	484	190	32	58	98	408	8	315	11,555	44	0
8/1-15/66	10	22E	2	20	358	0	0	0	179	0	0	1,909	15,408	116	0
8/15-31/66	1	1CY	0	1	2,319	1,600	7	19	16	557	338	4	35	19	0
11/15-31/66	3	6E	7	36	1,442	0	345	195	172	1,751	0	36	1,157	0	7
4/1-15/67	1	2E	65	0	866	0	7,112	151	22	1,207	65	5,172	0	604	97
6/1-15/67	1	4C	658	0	329	0	384	0	219	0	0	12,827	0	219	0
6/15-31/67	2	8C	244	0	494	0	165	0	55	0	0	1,426	0	0	0
7/1-15/67	1	4C	0	0	494	0	0	0	0	0	0	9,155	0	603	0
8/1-15/67	3	12C	0	0	475	43	123	0	55	37	18	8,278	0	342	0
9/1-15/67	1	4C	0	329	1,207	0	329	165	165	55	0	8,991	0	2,084	0
10/1-15/67	1	4C	55	0	713	0	55	55	55	329	55	16,719	0	2,359	0
11/1-15/67	1	4C	329	0	2,039	0	329	0	0	3,620	0	29,384	0	3,456	0
12/1-15/67	1	4C	0	55	1,919	110	55	55	110	4,113	55	29,987	0	2,797	0

Table 7B. Numbers of bottom fauna summarized over 15-day intervals for the flats habitat. Data are from Gale (1968). (E - Ekman dredge, P - Petersen dredge, C - core sampler, and Cy - circular cylinder)

Date	Number of Stations	Number of Sampling Units	*Hexagenia*	Trichoptera	Chironomidae	Corixidae	Ceratopogonidae	Other Ephermeroptera	Hirundinea	*Hyalella*	Odonata	Sphaeriidae	Oligochaete	Gastropoda	*Chaoborus*
7/1-15/66	6	12E	11	0	164	0	22	0	180	4	0	8,205	18,284	837	0
7/15-31/66	12	24E	0	36	300	0	0	1	222	0	0	6,688	2,186	487	0
8/1-15/66	12	24E	2	42	177	0	0	4	142	0	0	5,752	1,555	291	0
11/15-31-66	14	28E	11	646	970	0	13	13	148	48	0	2,359	8,646	638	66
3/15-31/67	6	6P	205	58	404	0	8	5	365	0	0	11,891	-	289	0
4/1-15/67	7	7P	166	241	705	0	93	8	105	4	0	5,119	-	125	14
5/1-15/67	6	6P	435	17	276	0	57	2	48	15	0	5,810	-	231	0
6/1-15/67	5	20C	0	0	197	0	0	0	33	0	0	-	-	307	0
6/15-31/67	1	4C	1,646	0	823	0	0	0	55	55	0	12,599	-	0	0
7/1-15/67	6	24C	146	677	155	0	9	0	201	0	0	26,816	-	352	0
8/1-15/67	6	24C	0	100	238	0	9	46	174	0	9	63,299	-	775	0
8/15-31/67	3	12C	0	91	27	0	18	0	2,377	0	0	-	-	274	0
9/1-15/67	6	24C	45	384	1,563	0	18	28	1,298	0	0	62,452	-	535	0
10/1-15/67	6	24C	105	584	381	0	0	18	1,664	28	0	62,130	-	704	0
11/1-15/67	5	20C	44	403	1,646	0	55	0	14,239	307	11	63,844	-	457	0
12/1-15/67	5	20C	197	296	1,481	0	132	0	1,690	329	0	61,475	-	393	0

Table 7C. Numbers of bottom fauna summarized over 15-day intervals for the channel habitat. Data are from Gale (1968). (E - Ekman dredge, P - Petersen dredge, C - core sampler, and Cy - circular cylinder)

Date	Number of Stations	Number of Sampling Units	Hexagenia	Trichoptera	Chironomidae	Corixidae	Ceratopogonidae	Other Ephermeroptera	Hirudinea	Hyalella	Odonata	Sphaeriidae	Oligochaete	Gastropoda	Chaoborus
7/15-31/66	1	2E	0	22	65	0	0	0	194	0	0	32,417	4,000	732	0
8/1-15/66	3	6E	0	36	130	0	0	0	296	0	0	3,920	959	50	0
5/1-15/67	2	2P	293	7	267	0	39	0	39	26	0	2,257	-	26	0
6/1-15/67	2	8C	246	0	233	0	0	0	41	0	0	5,509	-	55	0
7/1-15/67	2	8C	27	0	41	0	0	0	41	0	0	1,354	-	110	0
8/1-15/67	2	8C	0	0	41	0	0	0	795	0	0	31,741	-	466	0
9/1-15/67	2	8C	27	0	410	0	0	0	1,179	0	0	25,491	-	27	0
10/1-15/67	1	4C	55	0	0	0	0	0	603	0	0	8,168	-	0	0
11/1-15/67	1	4C	110	0	329	0	0	0	932	0	0	8,333	-	165	0
12/1-15/67	1	4C	384	0	1,207	0	0	55	1,262	823	0	15,294	-	0	0

Hexagenia, Trichoptera (P. flava, L. candida, and Oecetis sp.), Corixidae, and Chironomidae. The data for Hexagenia and Chrionomidae appear to be adequately determined by the bottom fauna sampling, with two exceptions for Hexagenia which require further explanation. In June 1-15, 1967 (Table 7B), no Hexagenia were found in 20 core samples taken on the flats. As previously noted during this period, floods had been quite prevalent and sand was found at stations where previously mud had been present, indicating a massive destruction of habitat near the channel. Naiads probably dispersed downstream and to the periphery of the flats where mud was more stable. Numbers of naiads observed for shallow habitat during June support this belief, since an average of 658 and 244 naiads per square meter were found in the first and second part of June. This same phenomenon was recorded by Carlson (1963).

The other inconsistency is the 1,646 Hexagenia naiads per square meter found during June 15-31, 1967 (Table 7B) on the flats during this severe flooding. This average was determined using the data from only one station, which was not sampled in the first 15 days of the month, when no Hexagenia were found at other flats stations. Unfortunately, the highest numbers of Hexagenia were consistently found at this station.

Numbers of the individual species making up the Trichoptera category in the bottom fauna have not been compiled. Cursory examination of the samples and personal communication with William Gale indicated that P. flava was taken infrequently in the bottom samples. In order to make a correlation, the numbers of Potamyia and Leptocella in the mooneye stomachs were grouped and plotted against this Trichoptera category of the bottom fauna in hopes that the population trends for these larvae would be similar to those found in the bottom samples. Drift samples may have given a better correlation for it is believed that mooneyes feed extensively upon P. flava when the phenomenon of drift is exhibited in July and August.

Corixidae presented a problem in sampling, which was probably also experienced with Chaoborus because they do not live in the bottom sediments, but actively swim around in the water above the bottom. Thus, the numbers presented for Corixidae and Chaoborus are subject to large error, and in most cases, their number would be underestimated. The bottom fauna data from August 15-31, 1966 in shallow habitat (Table 7A) should be representative for these groups, since it was obtained with the large metal circular sampler which samples the entire column of water in addition to the bottom sediments. Water boatmen were observed in large numbers in shallow weedy areas at transect 3 station 1, as well as the sandy bottom at transect 6 station 1 during July and August. Few to none were taken in bottom samples.

The numbers of Hexagenia, Trichoptera, and Corixidae in the stomachs of the mooneye closely follow the numbers found in the bottom fauna (Figure 14A, 14B, 14C). Numbers of chironomids, which were important to fish only in shallow habitat, do not coincide with those found in the bottom fauna.

Hexagenia naiads were eaten whenever they were abundant in the bottom fauna of the shallow habitat. Numbers in the bottom fauna decreased to zero in the first part of July, 1967, while consumption of naiads by fish in the shallows was still high and remained so until the first part of August. These fish were probably eating naiads and adults from the flats where numbers in the bottom fauna were still comparatively high until August 1-15, 1967.

For flats habitat, a similar trend of eating Hexagenia proportional to

Figure 14A. Utilization of four benthos groups by the mooneye during 1966-67 in shallow habitat, Pool 19, Mississippi River

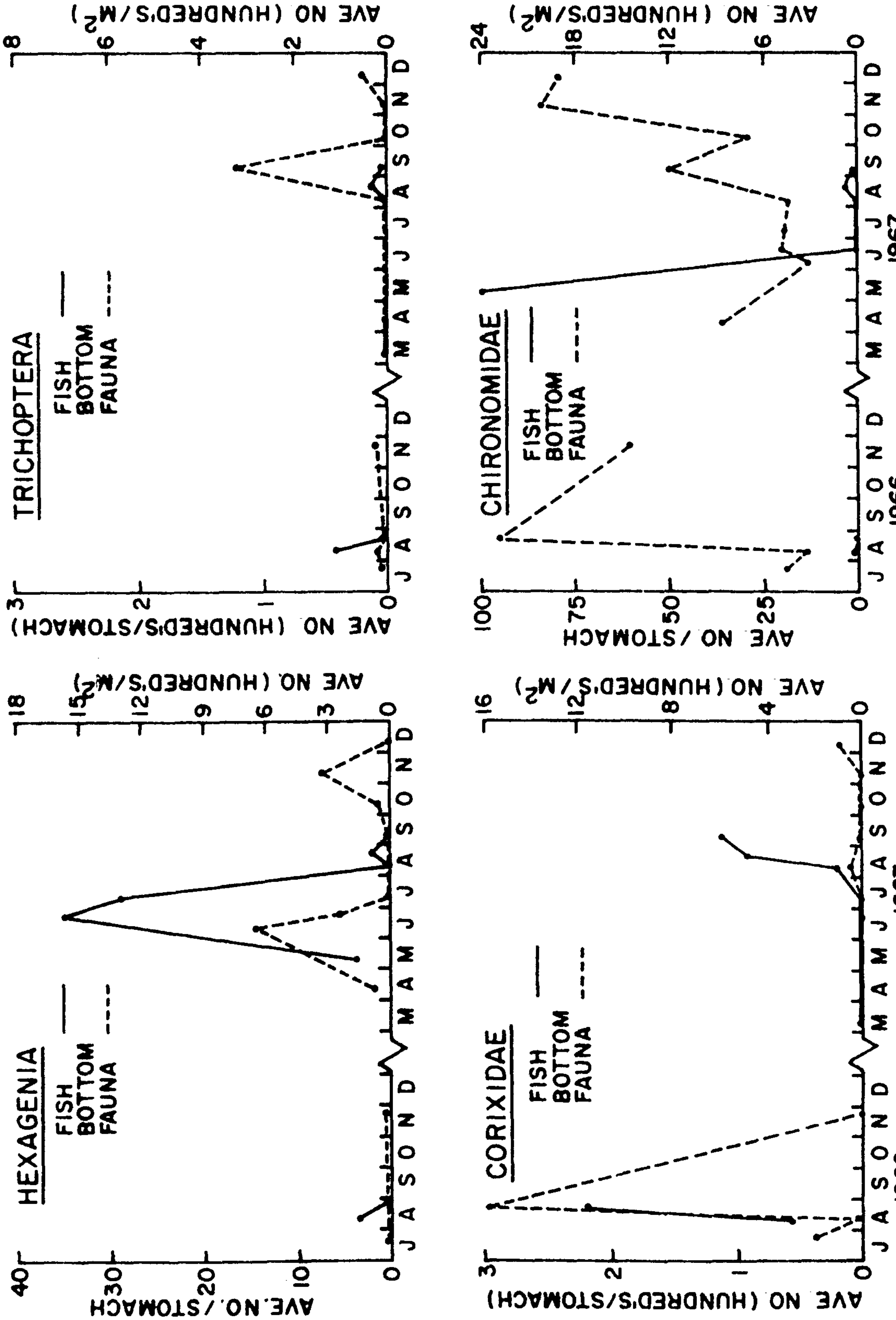

HEXAGENIA
FISH
BOTTOM
FAUNA
AVE. NO./STOMACH
AVE NO (HUNDRED'S/M2)
TRICHOPTERA
FISH
BOTTOM
FAUNA
AVE NO (HUNDRED'S/STOMACH)
AVE NO (HUNDRED'S/M2)
CORIXIDAE
FISH
BOTTOM
FAUNA
AVE NO (HUNDRED'S/STOMACH)
AVE NO (HUNDRED'S/M2)
CHIRONOMIDAE
FISH
BOTTOM
FAUNA
AVE NO /STOMACH
AVE NO (HUNDRED'S/M2)
J A S O N D M A M J J A S O N D
1966
1967

Figure 14B. Utilization of four benthos groups by the mooneye during 1966-67 in flat habitat, Pool 19, Mississippi River

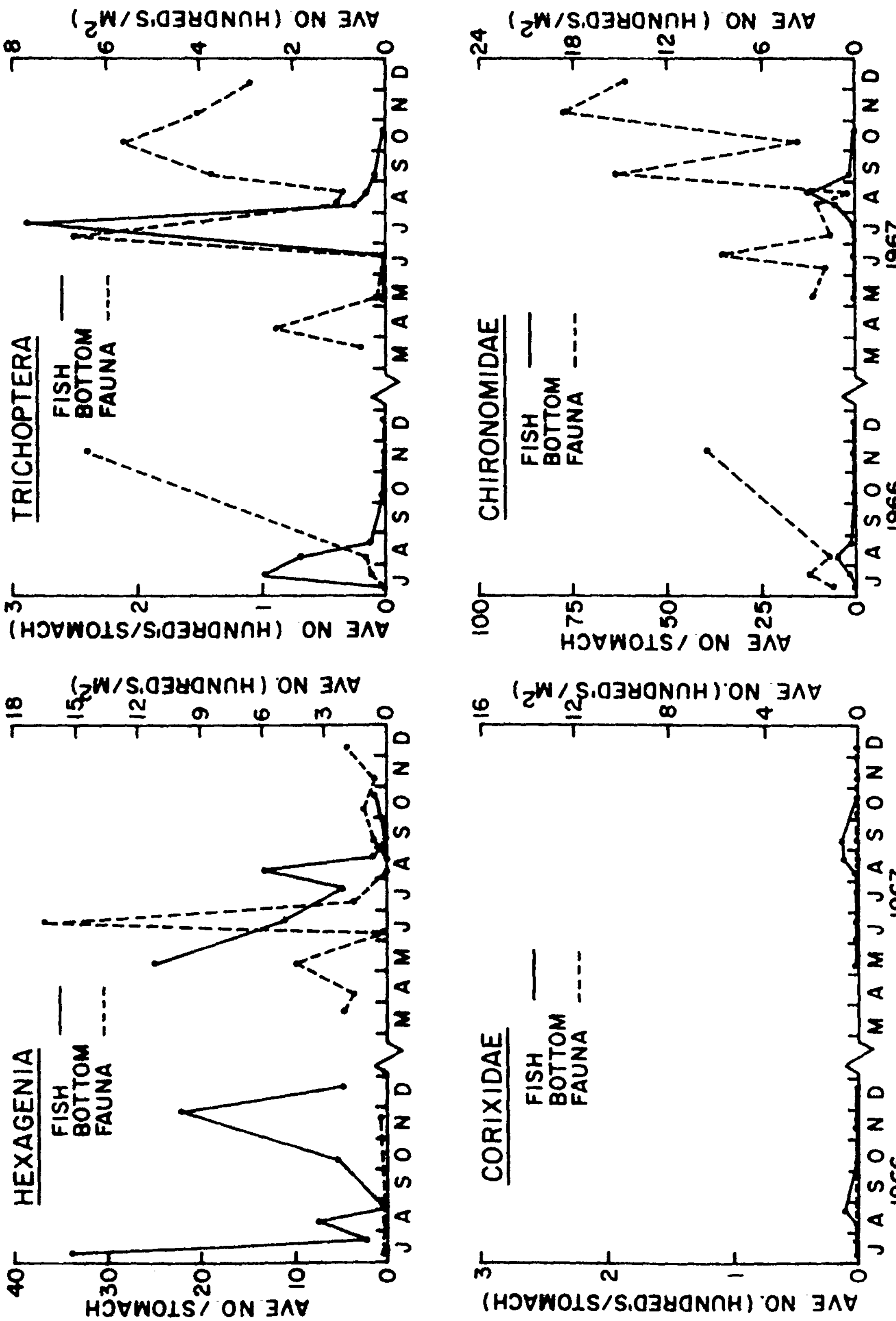
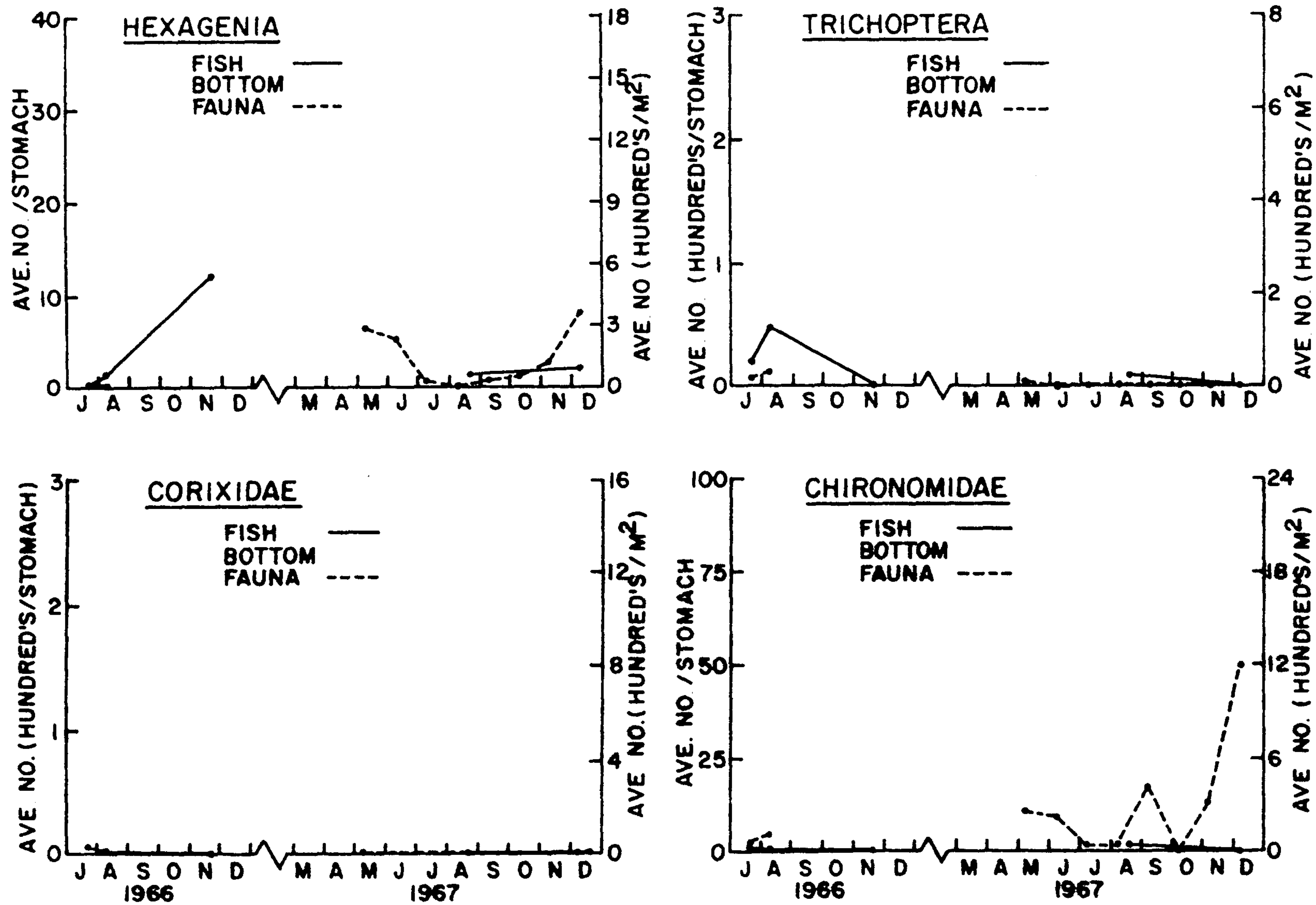

HEXAGENIA
FISH
BOTTOM
FAUNA
AVE NO./STOMACH
AVE NO. (HUNDRED'S/M2)
TRICHOPTERA
AVE NO. (HUNDRED'S/STOMACH)
CORIXIDAE
AVE NO. (HUNDRED'S/STOMACH)
CHIRONOMIDAE
AVE NO./STOMACH
J A S O N D
M A M J J A S O N D
1966
1967

Figure 14C. Utilization of four benthos groups by the mooneye during 1966-67 in channel habitat, Pool 19, Mississippi River


HEXAGENIA
FISH
BOTTOM
FAUNA
AVE. NO. /STOMACH
AVE. NO (HUNDRED'S/M^2)
TRICHOPTERA
FISH
BOTTOM
FAUNA
AVE. NO. (HUNDRED'S/STOMACH)
AVE. NO. (HUNDRED'S/M^2)
CORIXIDAE
FISH
BOTTOM
FAUNA
AVE. NO. (HUNDRED'S/STOMACH)
AVE. NO. (HUNDRED'S/M^2)
CHIRONOMIDAE
FISH
BOTTOM
FAUNA
AVE. NO. /STOMACH
AVE. NO. (HUNDRED'S/M^2)
J A S O N D M A M J J A S O N D
1966
1967

their abundance was evident. The peculiar increase in consumption from July to August which occurred in both 1966 and 1967 defies explanation. Some long term trends in emergences of mayflies, which occur in the first part of August, could increase numbers consumed. Utilization of Hexagenia increased again for the flats as winter approached in 1966. Since the stomach samples during 1966 consisted of 28 fish, which all contained Hexagenia, it is reasonable to assume increased consumption until December when temperature probably decreased feeding activities. The bottom fauna data for 1966 do not show an increase in the number of Hexagenia as do the data from all habitats in 1967. Undoubtedly, this increase in Hexagenia naiads also occurred in the bottom fauna during 1966, but was not detected with sampling. This increased usage of Hexagenia in the fall and early winter is also shown in channel habitat.

Trichoptera were fed upon heavily in July and August in the three habitat types. Very few trichopterans were consumed in shallow habitat, but peak numbers eaten by mooneyes there corresponded with a peak in numbers found in the bottom in 1966 and 1967. This same correlation was very pronounced for the flats habitat, where Trichoptera were most extensively eaten during the summer. Less Trichoptera than expected were found in the channel habitat bottom samples, probably because few samples were taken, and those were not from the channel proper, but from deep water near it. Stomachs from fish captured in channel habitat also contained few trichopterans.

Corixidae were associated with the shallow habitat, and were inadequately sampled in the bottom fauna. However, peak numbers in the benthos samples were associated with a similar peak in numbers in fish stomachs examined from shallow habitat. Water boatmen were not found in the bottom fauna of the flats or channel, but did occur in minimal amounts in the stomachs of fish captured from both habitats. These fish probably made excursions into shallow water and fed on corixids there.

Chironomid consumption of any magnitude by fish was also associated with the shallow habitat. An almost inverse correlation between peak numbers in stomachs and peak numbers in the benthos existed. Numbers were quite high in the bottom fauna of April, but reached a minima in May and June, when the peak numbers of Chironomidae appear in fish stomachs. Since most chironomids eaten were in the pupae stage and the number present in the bottom fauna is at a minimum for the year, it is postulated that emergence took place in April, May and June which would make the chironomid larvae more susceptible to predation.

The same trends for Chironomidae were observed for channel and flats habitat. Peak consumption on the flats by fish occurred during August when numbers of chironomids in the bottom fauna were the lowest and most Hexagenia had emerged. Since mooneyes must presumably search more for their food then, chironomids are eaten in addition to P. flava which are their main staple. Many small chironomid larvae were found in drift net samples so they may be captured in the same manner as P. flava.

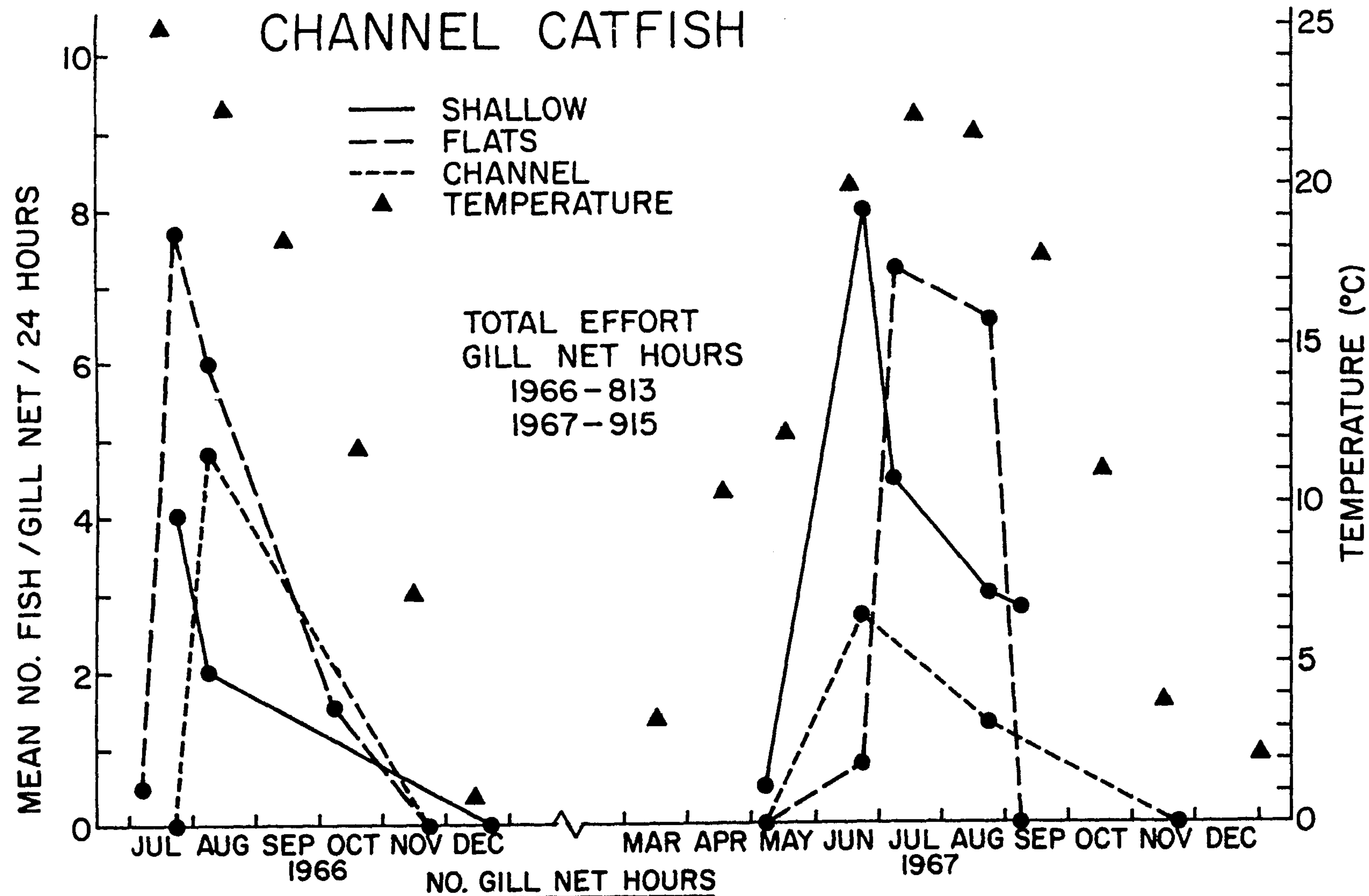
Channel Catfish

The channel catfish, _Ictalurus punctatus_, is one of the most important fish in Pool 19, both to sport and commercial fishermen (Nord, 1967). In 1967 the commercial catch of catfish was the second highest for all pools in the impounded Mississippi (UMRCC, 1967). Pool 18 catch of catfish was first with 134,362 pounds. Catfish were taken commonly in gill nets during this study, their spines making them more vulnerable than they otherwise might be. All channel catfish captured in 1966 (122) and 204 of 212 channel catfish taken in 1967 and 1968 were examined for stomach contents. Fish sampled during 1966 ranged from 6.3 to 19.5 inches. Only two were between 6 and 7 inches long and one was greater than 16 inches. In 1967, six were less than 6 inches in length, 170 were between 6 and 16 inches long, and 30 were greater than 16 inches. They ranged from 2.4 to 21.3 inches.

Distribution

Channel catfish are found in all pools of the Upper Mississippi River (Nord, 1967). In Pool 19, fish were captured in all three habitat types: shallow, flats, and channel. Their activity as shown by catch-per-effort data appeared to follow the same trends as average temperature in 1966 and 1967 (Figure 15). The lower catch-per-effort values found during July, 1966, for the flats compared to those of July, 1967, were probably the result of small sample size during 1966. Catch-per-effort was generally higher during the spring for shallow habitat, and for the flats during most of the summer. The high values observed in the spring for shallow habitat compared to the lower values for the flats and channel may have been caused

Figure 15. Water temperature and mean catch of channel catfish per 24 hours in experimental gill nets averaged over 15-day intervals. Catch-per-effort for the shallow, flats and channel habitat is shown



NO. GILL NET HOURS

	JUL	AUG	SEP	OCT	NOV	DEC	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SHALLOW:	8	84	-	-	-	65	-	-	56	24	48	72	17	-	-	-
FLATS:	73	120	-	133	136	94	36	-	80	36	108	116	89	-	21	105
CHANNEL:	4	60	-	-	8	25	-	-	14	36	-	36	-	-	21	-

by flood conditions. However, since larger numbers were taken in the channel where current velocity was greatest, spawning activity was probably responsible. Bailey and Harrison (1945) and Nord (1967) report that spawning takes place in May and June when the water temperature is around 75 degrees Fahrenheit. Evidence gathered while sampling fish and discussions with commercial fishermen during this time confirmed this belief. Shocking in an outlet stream revealed the presence of large numbers of channel catfish of different sizes. In addition larger catfish were captured in trammel nets and many were darker-colored breeding males and gravid females, typical of spawning individuals. After spawning in June, catfish showed an increased preference for the flats. Channel catfish were never captured in the backwater area of Honig's Slough, despite a large number of gill net hours expended and shocking operations which were conducted there. Catch-per-effort values and awareness that gill nets are least efficient indicated that catfish captured from the channel were abundant in this habitat type during June, July and August.

Data compiled into mean catch per 24 hours per station for three depth categories showed a definite preference by catfish for flats habitat (Table 8). Channel habitat and shallows ranked second and third respectively. Flood conditions appeared to have little effect on catfish distribution during June 25-July 10, 1967.

The diurnal activity of channel catfish as shown by the number captured with equal effort over 24 hours indicated peaks at 8-10 PM and 4-6 AM for the 24-hour sampling programs (Figure 16). In general there was good agreement between the numbers captured during August samples in 1966 and 1967. During the two 1967 programs essentially the same number of

Figure 16. Daily activity pattern for the channel catfish, as reflected in the total catch of fish from gill nets set for 2 hours during three 24-hour sampling programs in 1966-1967, Pool 19, Mississippi River

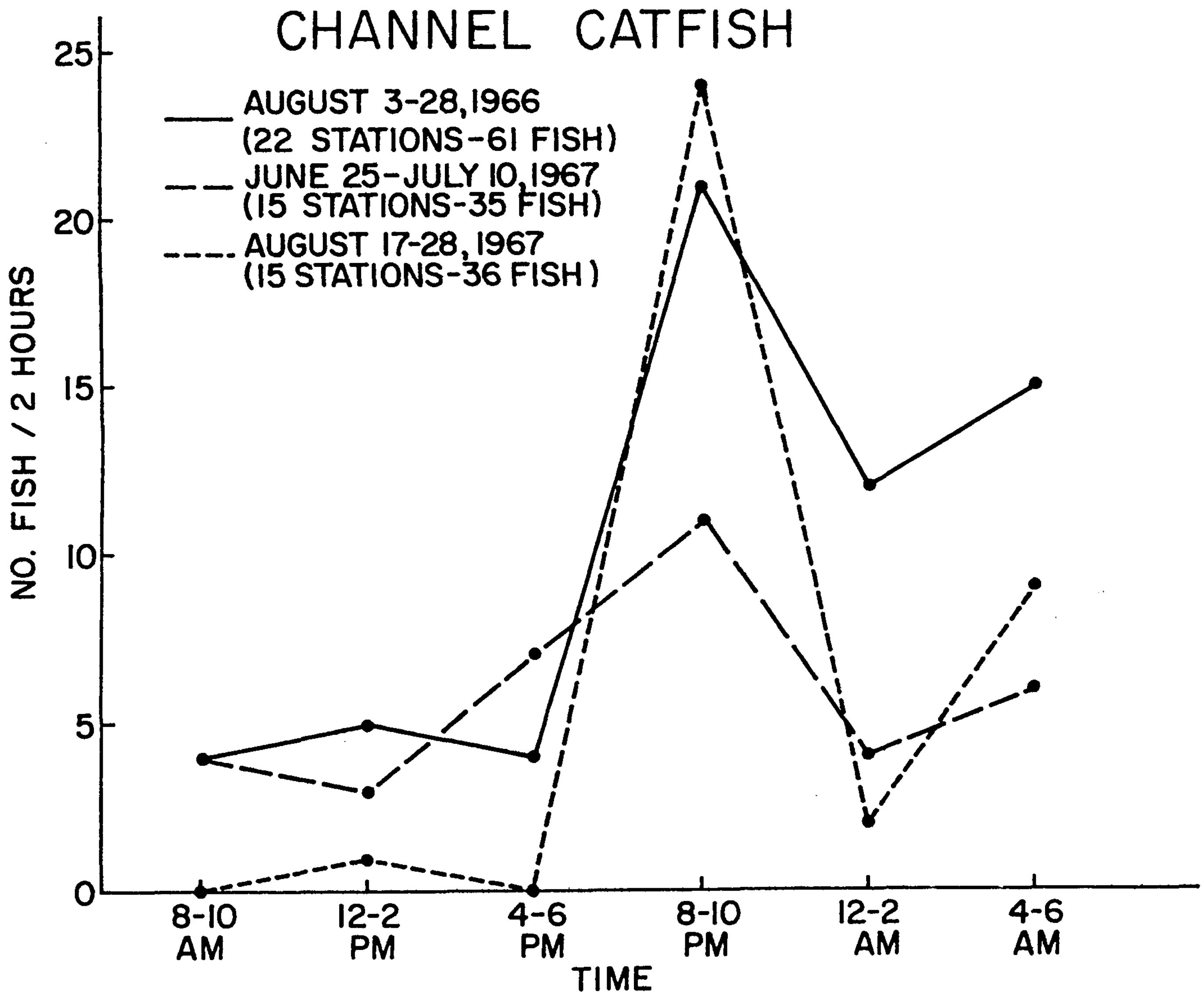

CHANNEL CATFISH
AUGUST 3-28, 1966
(22 STATIONS-61 FISH)
JUNE 25-JULY 10, 1967
(15 STATIONS-35 FISH)
AUGUST 17-28, 1967
(15 STATIONS-36 FISH)
NO. FISH / 2 HOURS
0
5
10
15
20
25
8-10 AM
12-2 PM
4-6 PM
8-10 PM
12-2 AM
4-6 AM
TIME

Table 8. The average catch of catfish per experimental gill net per 24 hours for three depth categories and three 24-hour sampling programs in Pool 19, Mississippi River. The average number of fish caught per station (12 hours of actual netting) was multiplied by two to give the data in terms of catch per 24 hours. The two 1967 programs were determined with equal effort

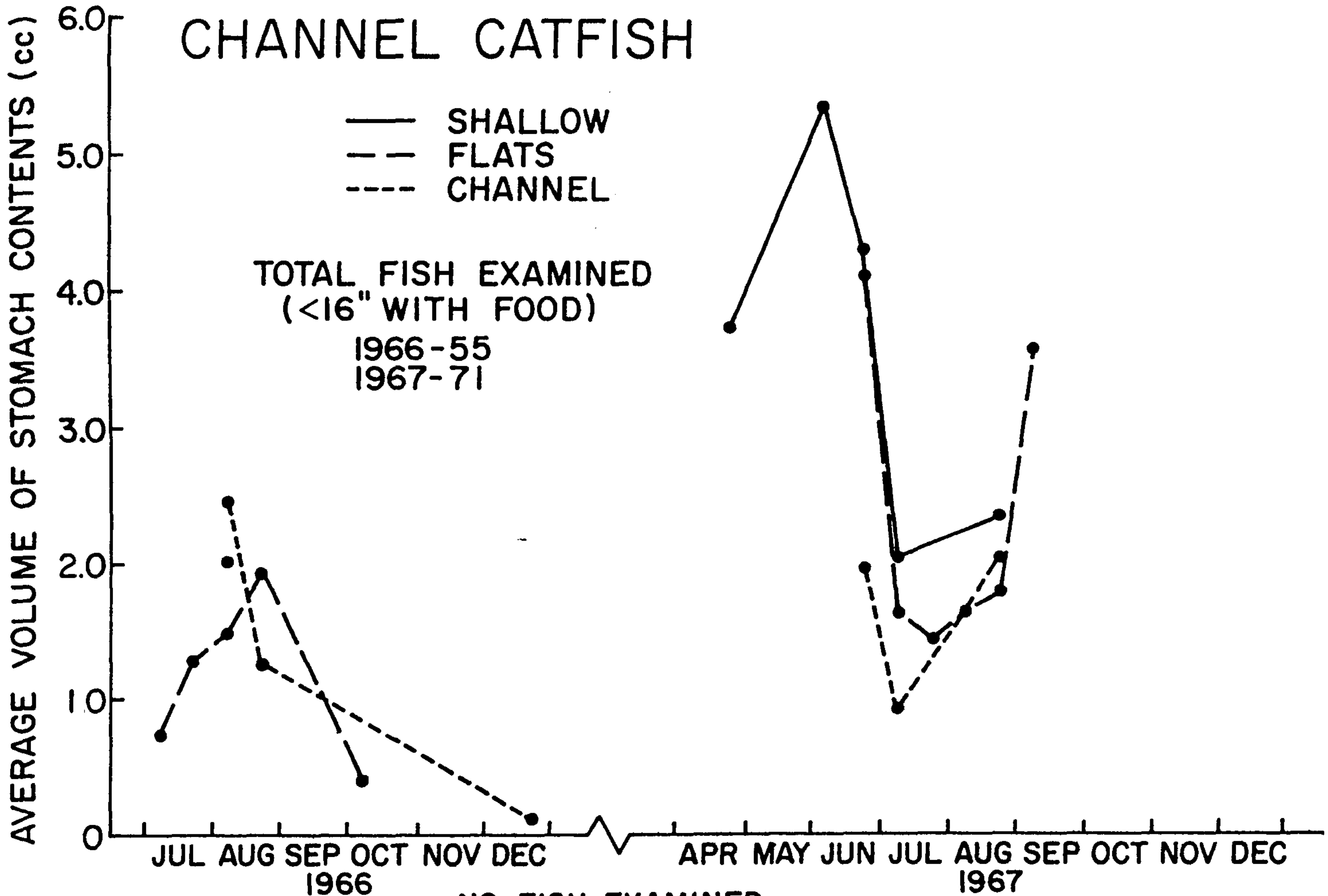
Date	No. Fish	Number Stations	Depth Category	Average catch per experimental gill net per 24 hours
August 3-28, 1966	68	10	<3 ft.	2.8
		9	3-8 ft.	7.6
		5	>8 ft.	6.8
June 25-July 10, 1967	36	8	<3 ft.	2.5
		6	3-8 ft.	8.4
		3	>8 ft.	2.6
August 17-28, 1967	32	8	<3 ft.	0.4
		6	3-8 ft.	9.4
		3	>8 ft.	1.4

catfish were taken, but numbers from June 10-July 25 showed a much higher catch during the 8-10 PM period. Bailey and Harrison (1945) noted that channel catfish were nocturnal and greatest catches from bank poles were taken from dusk until shortly after midnight.

Food habits

The average volume of stomach contents from channel catfish less than 16 inches was highest during April, May, and June, then declined gradually to lows around .50 cc in the winter months (Figure 17). In 1967 there was an increase in the amount of food eaten in all three habitat types in the latter part of August and September. Chironomids and *Hexagenia* comprised most of the food in April, *Hexagenia* in June and July. The seasonal activity of catfish (Figure 15) was found to be highest on the flats during

Figure 17. The average volume of stomach contents for the channel catfish taken in shallow, flats and channel habitat. Values are averaged over selected 15-day intervals from July, 1966 to September, 1967 in Pool 19, Mississippi River



NO. FISH EXAMINED

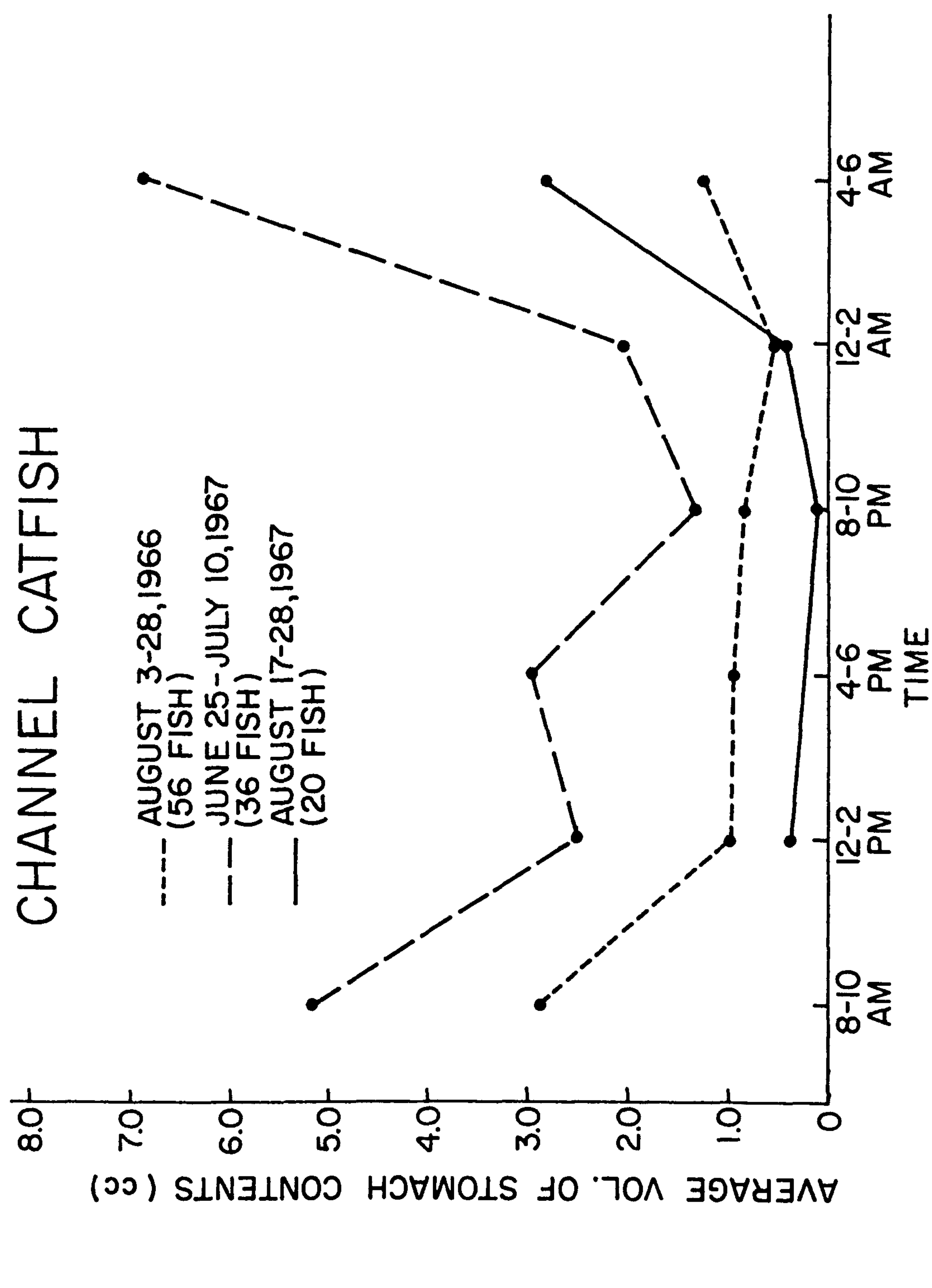
	JUL	AUG	SEP	OCT	NOV	DEC	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SHALLOW :	-	6	-	-	-	-	7	-	13	7	2	-	-	-	-
FLATS :	17	18	-	6	-	-	-	-	4	11	20	2	-	-	-
CHANNEL :	-	7	-	-	-	1	-	-	1	2	2	-	-	-	-

July and August, a time when less than maximum amounts of food were eaten (Figure 17). The lower quantity of food found during August may be due to higher digestion rates. However, there is an average difference of 3 cc in the average stomach volumes between June and August, which is a considerable amount to attribute to digestion alone. It is thought that increased movement during the summer months is because of the need to search more actively for food which is taken in lesser amounts than in the spring when Hexagenia and chironomids are more easily obtained.

The average volume of stomach contents found in catfish over a 24-hour period showed a single peak at 4-6 AM (Figure 18). Only the stomach volumes from fish less than 16 inches were used and empty stomachs were included in the averages. The average amount of food was somewhat higher, but trends remained unchanged if empty stomachs were not included. Any cheese bait found in stomachs was disregarded from the calculations. In general, good agreement between the three 24-hour sampling programs was found. The June 25-July 10, 1967 volumes eaten were on the average much higher than during August because of the preponderance of Hexagenia eaten at this time. Apparently food became difficult to obtain during August as shown by the lower amounts ingested compared to the much larger amounts eaten when acceptable food was abundant in June. Rapid digestion in August may also be a factor.

The peak diurnal activity at 8-10 PM (Figure 16) was followed by maximum amounts of food found in stomachs at 4-6 AM (Figure 18), demonstrating that activity was closely correlated with feeding. The much higher peak in activity at 8-10 PM during June compared to that of August may be related to the consumption of Hexagenia during June. The increased

Figure 18. Average volume of stomach contents over a 24-hour period for channel catfish taken in Pool 19, Mississippi River during August 3-28, 1966, June 25-July 10 and August 17-28, 1967


CHANNEL CATFISH
AUGUST 3-28,1966 (56 FISH)
JUNE 25-JULY 10,1967 (36 FISH)
AUGUST 17-28,1967 (20 FISH)
AVERAGE VOL. OF STOMACH CONTENTS (cc)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8-10 AM
12-2 PM
4-6 PM
8-10 PM
12-2 AM
4-6 AM
TIME

activity of naiads and subsequent emergence of subimagos may have triggered intensive feeding leading to the high peak in movements observed. Stomach contents in the next and succeeding periods substantiate this, since the highest amount of food eaten was 6.9 cc recorded for 4-6 AM. The high catch at 8-10 PM in August, 1966 was the result of a larger number of stations used in sampling.

Studies on the food habits of catfish have been conducted by many individuals. Dill (1944) reporting on the feeding habits of catfish from the Colorado River noted that fish were generally omnivorous and relied on plant material, but were not major fish predators. McCormick (1940) and Rice (1941) noted similar results for larger catfish (13-20 inches) taken in Reelfoot Lake. They found the food of catfish to be mainly comprised of insects and algae. Boesel (1938) studying small catfish (34-101 mm) captured in Lake Erie during July and August found them to be mostly insectivorous with some contribution being made to their diet by Crustacea. Bailey and Harrison (1945) in studies of catfish from the Des Moines River found that small fish were omnivorous in food habits, depending heavily on insects. Fish became increasingly important in the diet of larger catfish. Of the food contents eaten by fish greater than 12 inches; 35% was made up of fish, 28% was insect, and 19% was plant material. Forbes (1888) examined the stomach contents of 43 fish from the Illinois and Mississippi Rivers and found channel catfish to be generally omnivorous. Specimens examined were captured during spring, summer, and autumn. He found a fourth of the food to be vegetable matter consisting mostly of the alga Cladophora. Pieces of fish derived from those already dead were found in 11 of the stomachs studied, while mollusks made up 15% of the total diet.

Leeches were found in three specimens. Insects made up the principal food of this species comprising 44% of the total but few Hexagenia were found. Hoopes (1959) found that catfish from Pool 19 relied almost exclusively upon Hexagenia during the spring and summer months. Fish collected during October fed mainly upon Hexagenia naiads and filamentous algae. Overall, the stomach contents of 143 fish contained 68% Hexagenia naiads, 3% Potamyia flava, and the remainder included Plecoptera, Diptera, clams, snails, and algae. Studies by Wenke (1965) based on 58 fish containing food indicated food of the smallest catfish (2.4 inches) was not different from larger fish (up to 22.3 inches). Generally insects were the major constituent of most stomachs examined. Hexagenia made up 32% of the volume of food eaten in the overall diet. Trichoptera made up 31%, but only 2% of this was attributed to Oecetis sp. Chironomids comprised 3% and fish comprised 6% of the total diet. General agreement with Hoopes (1959) and Wenke (1965) was found in the present study, though the importance of Mollusca seems to have been less in the other investigations. Oecetis sp. was also a significant part of the diet of catfish examined in this study. Differences may be due to location, since these investigators worked near the dams at Keokuk and Burlington, Iowa, which have been shown to support different faunal populations.

Food habits of the channel catfish were found to be diverse in the present study. In general, fish from 4 to 22 inches were eating food qualitatively the same. In some cases, such as the limited samples in the spring, smaller fish were not available for comparison. However, larger catfish tended to eat more clams and greater amounts of food than smaller fish so that a separation by size was deemed desirable. Food habits of fish 16 inches or less and fish greater than 16 inches will be discussed separately.

Almost every bottom fauna element was encountered in the stomachs of channel catfish less than 16 inches (Table 9A, 9B, 9C). Catfish were not dependent on any single item during the year, but consumed a variety of foods at any given time. Hexagenia naiads were found in the stomachs of catfish captured during April, May, June, and July, at which time there was probably increased activity by these larvae prior to and during emergence. Adults were eaten during emergences in June and July.

Three Trichopterans, Potamyia flava, Leptocella candida, and Oecetis sp. were found in the stomachs of fish collected, but only Oecetis sp. was important. This insect was identified by Hoopes (1959) and Wenke (1965) as Oecetis inconspicua, while Carlson (1963) listed it as "species b" of Ross (1944). Attempts at identification by the author indicated Oecetis inconspicua. In verifying this identification, Dr. David Etnier, University of Tennessee stated that it could be O. inconspicua, however, the color pattern on the head did not agree identically with his specimens, and other species closely related to it have undescribed larvae This made him hesitant to accept the identification as positive. One female larvae was successfully lab-reared to the adult stage, but again identification proved impossible since most determinations are made on the basis of males. In any further discussions, this species is referred to as Oecetis sp.

The Oecetis sp. larvae were eaten with their cases and comprised a large percentage of the volume of food found in individual catfish from July to September. In shallow habitat they were only important in diets of fish caught during June. Oecetis sp. were not found in the stomachs of

Table 9A. Volume (cc) and occurrence of the material ingested by channel catfish less than 16 inches in shallow habitat for selected periods between August, 1966 and May, 1968. (t=trace, p=present)

Date	No. Stations	No. stomachs with food		*Hexagenia* naiads	*Hexagenia* adults	*Oecetis* sp.	*Potamyia flava*	*Leptocella candida*	Sphaeriidae	Other Mollusca	Chironomidae	Algae	Hirudinea	Fish	Oligochaete	Other	Unidentifiable	Total Volume per Fish
1966																		
Aug. 1-15	1	6	Vol.	.02	.01	.01	0	0	0	1.64	t	.28	0	0	0	.05	t	2.01
			Occur.	2	1	2	0	0	0	3	3	3	0	0	0	3	1	
1967																		
Apr. 15-30	1	7	Vol.	.26	0	t	0	0	0	.12	2.44	0	.88	0	0	t	.04	3.74
			Occur.	4	0	1	0	0	0	1	6	0	2	0	0	2	1	
May 1-15[a]	1	8	Vol.	0	0	t	0	0	0	0	.30	.04	.01	.30	0	.01	.02	.68
			Occur.	0	0	1	0	0	0	0	7	1	1	3	0	2	3	
June 1-15	1	4	Vol.	4.27	.04	.71	t	.02	0	.31	t	0	0	0	0	t	0	5.35
			Occur.	4	1	2	1	1	0	3	4	0	0	0	0	1	0	
June 15-30	3	9	Vol.	3.26	.50	.14	0	0	0	.01	t	0	.01	.37	0	0	.01	4.30
			Occur.	9	4	3	0	0	0	1	1	0	2	1	0	0	1	
July 1-15	3	7	Vol.	.62	1.23	0	0	0	0	.16	t	0	0	0	0	.02	0	2.03
			Occur.	3	6	0	0	0	0	1	2	0	0	0	0	1	0	
Aug. 15-31[a]	2	5	Vol.	.01	0	.54	t	0	0	.18	.04	.80	.25	.25	0	t	0	2.07
			Occur.	1	0	1	1	0	0	2	4	2	1	2	0	4	0	
May 1-15	1	2	Vol.	.28	0	0	0	0	0	t	t	0	7.98	0	0	t	.05	8.31
			Occur.	2	0	0	0	0	0	1	1	0	1	0	0	1	1	

[a]Ortho Outlet fish were included in the averages.

Table 9B. Volume (cc) and occurrence of the material ingested by channel catfish less than 16 inches in flats habitat for selected periods between July, 1966 to April, 1968. (t=trace, p= present)

Dates	No. Stations	No. Stomachs with Food		*Hexagenia* naiads	*Hexagenia* adults	*Oecetis* sp.	*Potamyia flava*	*Leptocella candida*	Sphaeriidae	Other Mollusca	Chironomidae	Algae	Hirudinae	Fish	Oligochaete	Other	Unidentifiable	Total Volume per Fish
1966																		
July 1-15	1	2	Vol.	0	0	t	.51	0	0	.01	t	0	0	0	0	0	.22	.74
			Occur.	0	0	1	2	0	0	1	1	0	0	0	0	0	1	
July 15-31	5	15	Vol.	t	.48	.26	.08	0	t	.41	t	.01	t	0	0	t	.03	1.27
			Occur.	1	3	10	5	0	2	4	5	1	1	0	0	3	4	
Aug. 1-15	7	10	Vol.	0	.22	t	t	.54	.20	.01	t	.07	0	0	.16	.25	.02	1.47
			Occur.	0	5	1	1	7	4	7	1	5	0	0	1	1	5	
Aug. 15-31	4	8	Vol.	0	t	.14	t	0	0	.82	.02	.76	t	0	.18	t	.02	1.94
			Occur.	0	1	5	3	0	0	5	6	2	1	0	2	3	4	
Oct. 1-15	1	6	Vol.	.14	0	t	t	0	.08	.13	t	0	t	0	0	0	.05	.40
			Occur.	4	0	1	2	0	1	4	1	0	1	0	0	0	1	
1967																		
June 15-30	2	4	Vol.	3.39	.74	0	0	0	t	0	t	0	0	0	0	t	0	4.13
			Occur.	3	2	0	0	0	1	0	1	0	0	0	0	1	0	
July 1-15	4	8	Vol.	.16	.98	0	0	0	0	.35	t	0	0	0	t	t	.14	1.63
			Occur.	2	7	0	0	0	0	2	1	0	0	0	1	2	1	
July 15-31	1	3	Vol.	1.28	0	0	.10	0	0	.05	t	0	0	0	0	t	0	1.43
			Occur.	3	0	0	1	0	0	1	1	0	0	0	0	1	0	
Aug. 1-15	3	6	Vol.	0	.04	1.01	t	0	.11	.40	.01	0	.06	0	0	t	0	1.63
			Occur.	0	1	4	1	0	3	3	3	0	2	0	0	2	0	

Table 9B. Continued

Date	No. Stations	No. Stomachs with Food		*Hexagenia* naiads	*Hexagenia* adults	*Oecetis* sp.	*Potamyia flava*	*Leptocella candida*	Sphaeriidae	Other Mollusca	Chironomidae	Algae	Hirudinae	Fish	Oligochaete	Other	Unidentifiable	Total Volume per Fish
Aug. 15-31	2	14	Vol.	t	0	.70	0	0	t	.49	t	.24	.21	.15	0	t	0	1.79
			Occur.	2	0	10	0	0	3	11	9	1	5	1	0	7	0	
Sept. 1-15	1	2	Vol.	0	0	.12	t	0	0	1.10	t	0	2.30	0	0	.06	0	3.58
			Occur.	0	0	2	1	0	0	1	2	0	2	0	0	2	0	
1968																		
Apr. 1-15	1	6	Vol.	t	0	.01	0	0	0	0	1.04	0	0	2.52	0	t	.01	3.58
			Occur.	1	0	1	0	0	0	0	6	0	0	2	0	3	1	

Table 9C. Volume (cc) and occurrence of the material ingested by channel catfish less than 16 inches in channel habitat for selected periods between August, 1966 and August 1967. (t=trace, p=present)

Date	No. Stations	No. Stomachs w/food		*Hexagenia* naiads	*Hexagenia* adults	*Oecetis* sp.	*Potamyia flava*	*Leptocella candida*	Sphaeriidae	Other Mollusca	Algae	Hirudinea	Fish	Other	Unidentifiable	Total Volume per Fish
1966																
Aug. 1-15	3	4	Vol.	0	0	.10	.02	.01	t	.04	1.49	.01	0	t	.78	2.45
			Occ.	0	0	1	3	2	1	2	2	2	0	3	2	
Aug. 15-31	2	3	Vol.	0	0	0	t	.03	.66	.31	0	.23	0	0	.02	1.25
			Occ.	0	0	0	1	1	2	3	0	2	0	0	1	
Dec. 15-31	1	1	Vol.	.12	0	0	0	0	0	0	0	0	0	0	0	.12
			Occ.	1	0	0	0	0	0	0	0	0	0	0	0	
1967																
June 15-30	1	1	Vol.	.91	0	t	0	0	0	0	0	.51	.53	t	0	1.95
			Occ.	1	0	3	0	0	0	0	0	1	1	1	0	
July 1-15	2	2	Vol.	.21	.43	.23	0	0	0	0	0	0	.05	0	0	.92
			Occ.	2	1	1	0	0	0	0	0	0	1	0	0	
Aug. 15-31	1	2	Vol.	0	0	.03	t	0	0	.18	0	1.80	0	0	0	2.01
			Occ.	0	0	1	1	0	0	1	0	1	0	0	0	

channel catfish captured on the flats habitat during July, though they consistently appeared in stomach samples in August and September. P. flava occurred in large numbers in stomachs from flats habitat during July of both years, which was also the time when these larvae are suspected to exhibit a drift phenomenon.

Mollusca ingested consisted of large pieces of unionid clams which were probably dead when eaten. The soft inner parts of snails, members of the family Viviparidae were also ingested, as were many whole sphaeriids (fingernail clams). Fingernail clams were found mostly in stomachs collected during August from flats and channel habitat, which was also noted by Wenke (1965) near Keokuk. Snail and large clam shells were never found in any of the fish stomachs examined. Forbes (1888) noted that catfish from the Mississippi River which had eaten snails of the Viviparidae family contained no shells. His opinion was that shells were cracked in the catfish's jaw and the soft inner parts removed. This is a possibility, but never was a fragment of a shell found in any stomach examined. They may be getting them in the same manner as the larger clams by extracting the insides from dead snails. Many dead clams and a few snails were observed during the summer floating on the surface of the river.

The greatest volume of chironomids was eaten during April and May in the shallow and flats habitat. Large numbers were also eaten during August, but they were usually associated with the algae which was eaten at this time. Algae, mostly Cladophora, appeared in greatest quantities in stomachs of catfish during August, a time when most food is apparently less available although pieces of clams were also found in stomachs at this time.

Hirundinea (leeches) were found in stomachs from the shallow habitat in the months of April and May. They appeared to show little seasonal periodicity in the food. Leeches were important in the diet of fish from the flats during the latter part of August and September

Fish were very seldom found in channel catfish stomachs except in the spring and in catfish which were electroshocked in the effluent stream of Ortho Pool. In both cases forage fish were readily available for consumption. In the effluent stream many forage fish (Notropis athernoides and young-of-the-year gizzard shad) abounded. Up to 7 shad and 4 minnows were found in individual catfish shocked from this stream. Channel catfish stomachs from Ortho outlet were included in the analysis because any other items eaten, except crayfish, should be characteristic of the open river food habits, since bottom fauna was scarce in the stream bottom. Ortho outlet was also the only location where catfish were taken in any number in May. Forage fish and crayfish eaten by shocked channel catfish were excluded, however, from the graphs depicting percentage composition.

Fish eaten during the spring were mainly chunks of dead gizzard shad which littered the shore after ice breakup. They were found mainly in one large catfish taken in April. Lack of samples prevents any generalizations, but reports from commercial fishermen confirm the belief that this type of feeding is widespread during April and May. Three channel catfish taken in the open river had eaten fish. Two of these catfish were captured during June, 1967 in shallow and channel habitat and one was taken during July in channel habitat. The fact that many forage fish were eaten in the effluent stream, where fish are concentrated, indicated a lack of ability by the catfish to capture them in the open river, either because high water turbidity or lack of forage fish. The latter appears to be untrue since many thousands of young-of-the-year gizzard shad were observed in the water. They were also captured regularly in gill nets during the summer of 1967. Therefore, it is thought that turbidity was the limiting factor on catfish predatory activities. Bailey and Harrison (1945) in the Des Moines River catfish studies found an increased incidence of forage fish in stomachs after periods of low water and decreased turbidity.

Oligochaetes were eaten during August, 1966, by catfish captured at transect 1 station 1 where, like most flats' stations, these aquatic worms were found in numbers up to thousands per square meter. No catfish were captured there in 1967, and oligochaetes were not eaten at any of the other fish sampling stations.

Unidentifiable material was usually minimal in catfish, since most food could be readily categorized. One sample from the channel habitat during August, 1966 however, defied identification. The "other" category was included to summarize the many food items which occurred regularly, but which made up negligible volumes, and those larger items, such as mice which occurred infrequently.

Cheese, which is used for the baiting of baskets for trapping catfish, was found on occasion in fish captured in experimental gill nets. Some fish stomachs were distended with up to 21.00 cc of this material. Catfish with cheese in their stomach were captured on the flats and in the channel where most traps are maintained. Presumably they gather up chunks of the bait as the current washes them from traps.

Only one catfish greater than 16 inches was captured in 1966, while 25 were taken in 1967 <u>Hexagenia</u> were again eaten in large quantities during

April, June, and July (Table 10A, 10B). The capacity to consume 32.0 cc of adult mayflies was demonstrated for one catfish 17.2 inches in length during the first part of July. Oecetis sp. were eaten in minimal quantities during August in both flats and shallow habitat.

Mollusca, mostly large pieces of clam, occurred as a major part of the diet in almost every month during which large catfish were captured. Mollusks constituted their main food for most of the year, except during spring and early summer, when Hexagenia were heavily fed upon.

Chironomids, as in the case of fish less than 16 inches, were important in the diet of fish taken from shallow habitat during April, 1967. Algae usually occurred in stomachs collected during August, while leeches appear to be an important item in April, May and August.

Fish contents eaten during April, as previously noted, were the remains of dead gizzard shad, while one other fish eaten on August in shallow habitat was apparently captured by that individual catfish.

To show the degree of importance of the different food items to channel catfish less than 16 inches, the percentage composition by volume of four groups, an unidentifiable category, and an "other" category was calculated for each of the three habitat types (Figure 19A, 19B, 19C).

For the shallow habitat, in May the "other" category was composed mainly of Chironomidae. In June and July the importance of Hexagenia to catfish was shown, while in August the diversity of catfish food habits was exhibited as the fish seem to depend on small amounts of all groups.

In flat habitat for July and August of 1966 no single food item dominated the diet with the exception of mollusks which make up between 20 and 40% during this period. There was a shift in the winter months, when a

Table 10A. Number, volume (cc) and occurrence of the material ingested by channel catfish greater than 16 inches in shallow habitat for selected periods between August, 1966 to September, 1967. (t= trace, p=present)

Date	No. Stations	No. Stomachs w/food		Hexagenia naiads	Hexagenia adults	Oecetis sp.	Potamyia flava	Mollusca	Chironomidae	Algae	Hirudinea	Fish	Other	Unidentifiable	Terrestrial Annelida	Total Volume per Fish
1966																
Aug. 15-31	1	1	No.	0	0	0	0	1	86	-	0	0	25	0	0	
			Vol.	0	0	0	0	.37	.01	1.92	0	0	.01	0	0	2.31
			Occ.	0	0	0	0	1	1	1	0	0	1	0	0	
1967																
Apr. 15-30	1	2	No.	24	0	0	0	0	46	0	10	1	0	-	57	
			Vol.	1.09	0	0	0	0	.64	0	1.84	5.4	0	.71	5.1	14.8
			Occ.	2	0	0	0	0	1	0	2	1	0	1	1	
May[a] 1-15	1	2	No.	0	0	3	0	p	145	0	4	0	1	0	0	
			Vol.	0	0	.04	0	6.6	2.37	0	1.06	0	t	0	0	10.0
			Occ.	0	0	1	0	1	2	0	2	0	1	0	0	
June 1-15	2	3	No.	9	0	13	p	0	0	0	0	0	0	0	0	
			Vol.	1.09	0	.08	t	0	0	0	0	0	0	0	0	1.17
			Occ.	2	0	2	1	0	0	0	0	0	0	0	0	
June 15-30	2	3	No.	25	1	0	0	p	0	0	0	0	0	0	0	
			Vol.	4.02	.03	0	0	.85	0	0	0	0	0	0	0	4.90
			Occ.	3	2	0	0	1	0	0	0	0	0	0	0	
July 1-15	2	3	No.	64	89	0	0	0	0	0	0	0	0	0	0	
			Vol.	8.22	11.5	0	0	0	0	0	0	0	0	0	0	19.7
			Occ.	2	3	0	0	0	0	0	0	0	0	0	0	
Aug. 1-15	1	1	No.	0	0	0	0	1	0	0	0	1	0	0	0	
			Vol.	0	0	0	0	16.8	0	0	0	1.94	0	0	0	18.7
			Occ.	0	0	0	0	1	0	0	0	1	0	0	0	
Aug. 15-31	2	3	No.	0	0	16	p	2	20	-	10	0	10	0	0	
			Vol.	0	0	.19	t	.94	.01	1.23	1.14	0	.01	0	0	3.52
			Occ.	0	0	2	1	1	3	2	3	0	1	0	0	
Sept. 1-15	1	2	No.	0	0	0	0	1	2	-	0	0	9	0	0	
			Vol.	0	0	0	0	3.12	t	1.59	0	0	t	0	0	4.7
			Occ.	0	0	0	0	2	1	1	0	0	1	0	0	

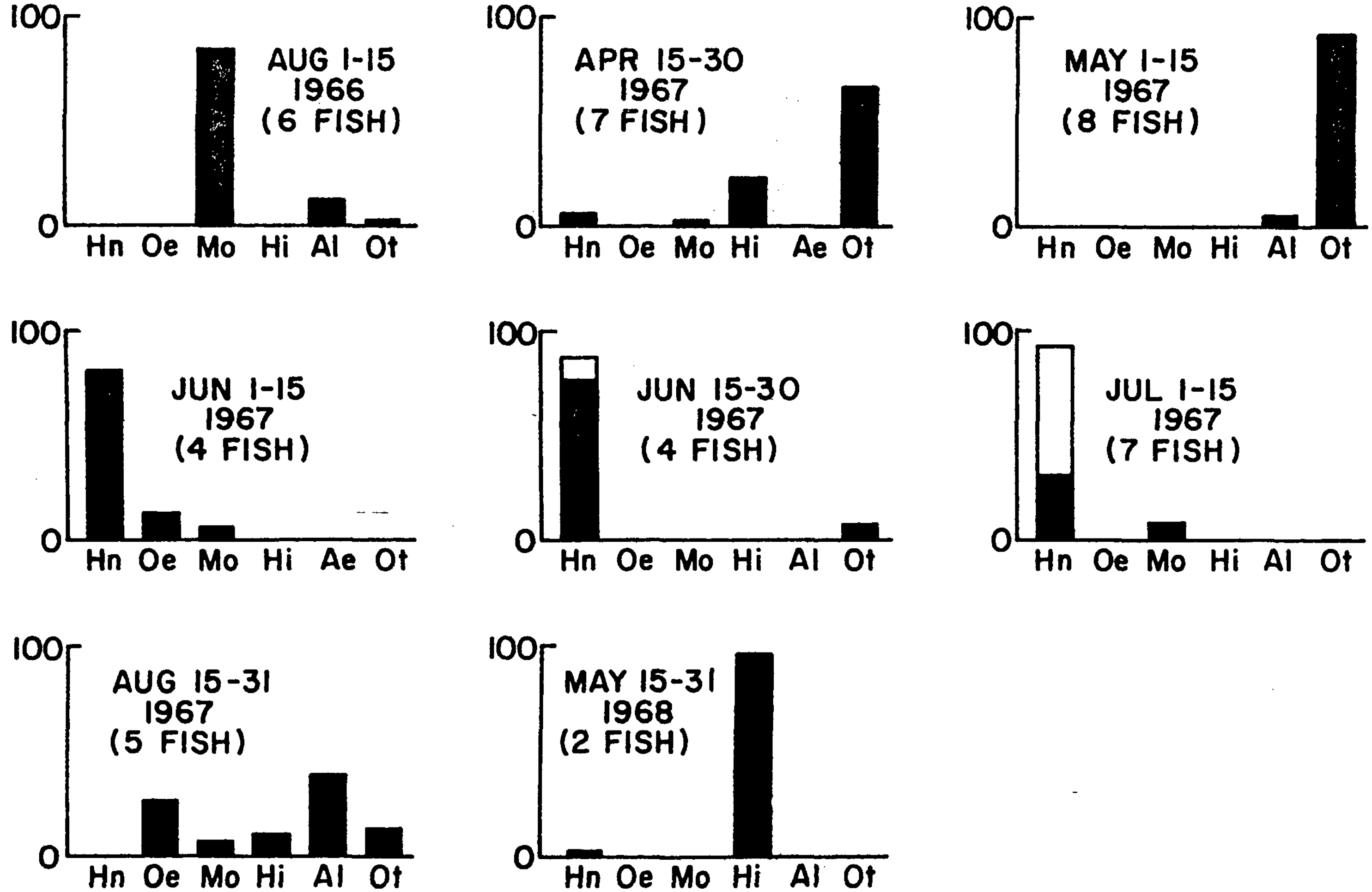
[a]Includes fish captured in Ortho outlet.

Table 10B. Number, volume (cc) and occurrence of the material ingested by channel catfish greater than 16 inches in flats habitat for selected periods between July, 1966 to August, 1967. (t=trace, p=present)

Date	No. Stations	No. Stomachs w/food		*Hexagenia* naiads	*Hexagenia* adults	*Oecetis* sp.	*Potamyia flava*	Mollusca	Total Volume per Fish
1967									
July 1-15	1	1	No.	1	17	0	0	1	
			Vol.	1.03	3.60	0	0	1.17	4.8
			Occur.	1	1	0	0	1	
Aug. 1-15	2	4	No.	0	1	33	p	3	
			Vol.	0	.04	.39	t	4.35	4.8
			Occur.	0	1	2	1	4	
Aug. 15-31	1	1	No.	0	0	0	0	1	
			Vol.	0	0	0	0	4.21	4.21
			Occur.	0	0	0	0	1	

Figure 19A. Percentage composition by volume of the material ingested in shallow habitat by the channel catfish from August, 1966 to May, 1968 in Pool 19, Mississippi River. (For *Hexagenia* and Trichoptera shaded portion of graph represents percentage of larvae and naiads while open spacing indicates adults or last instar naiads)

CHANNEL CATFISH - SHALLOW HABITAT



Hn - HEXAGENIA   Oe - OECETIS   Mo - MOLLUSCA
Hi - HIRUDINEA   Al - ALGAE   Ot - OTHER

Figure 19B. Percentage composition by volume of the material ingested in flats habitat by the channel catfish from July, 1966 to April, 1968 in Pool 19, Mississippi River. (For *Hexagenia* and Trichoptera shaded portion of graph represents percentage of larvae and naiads while open spacing indicates adults or last instar naiads)

CHANNEL CATFISH – FLATS HABITAT

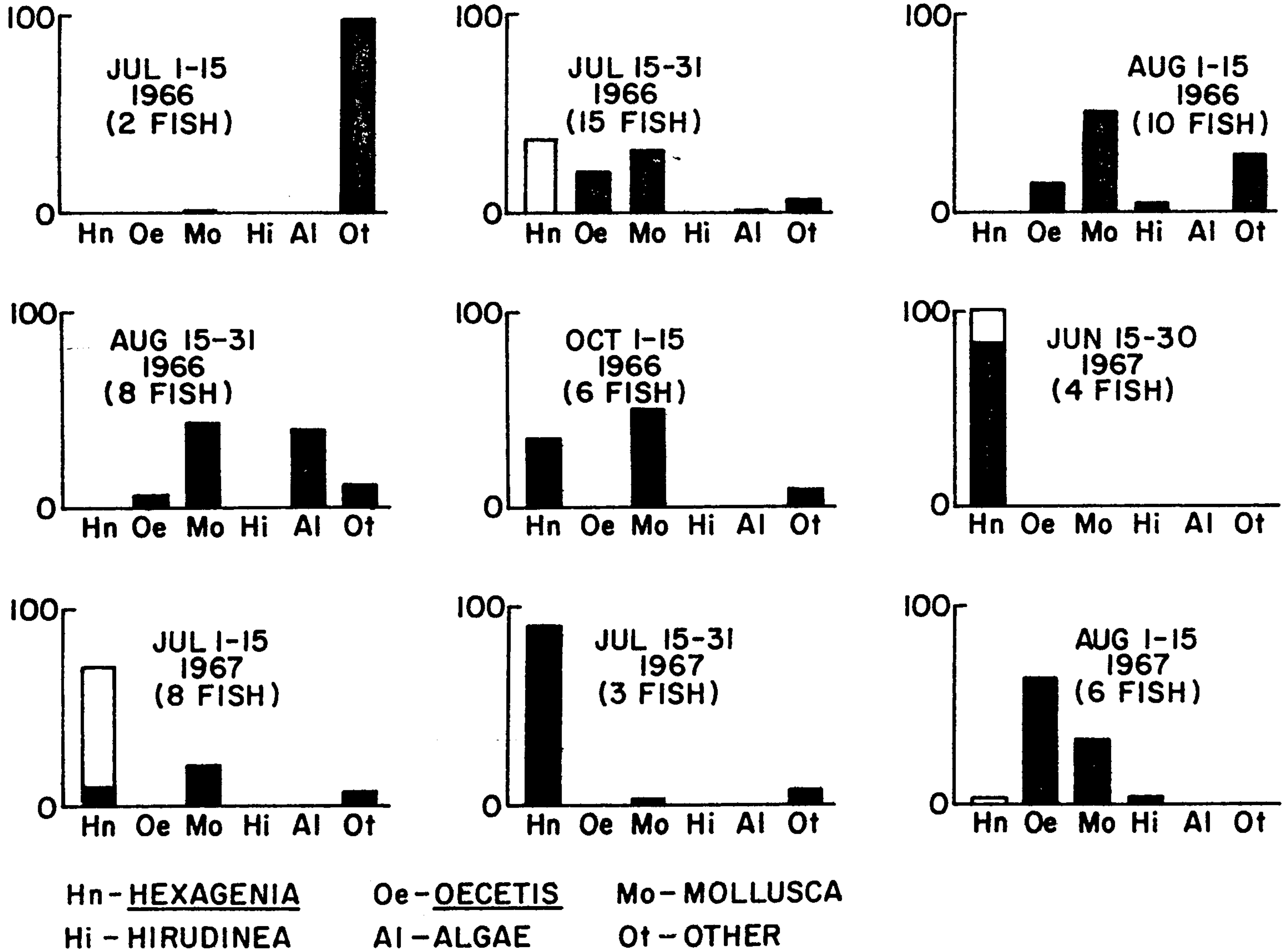


Figure 19B. Continued

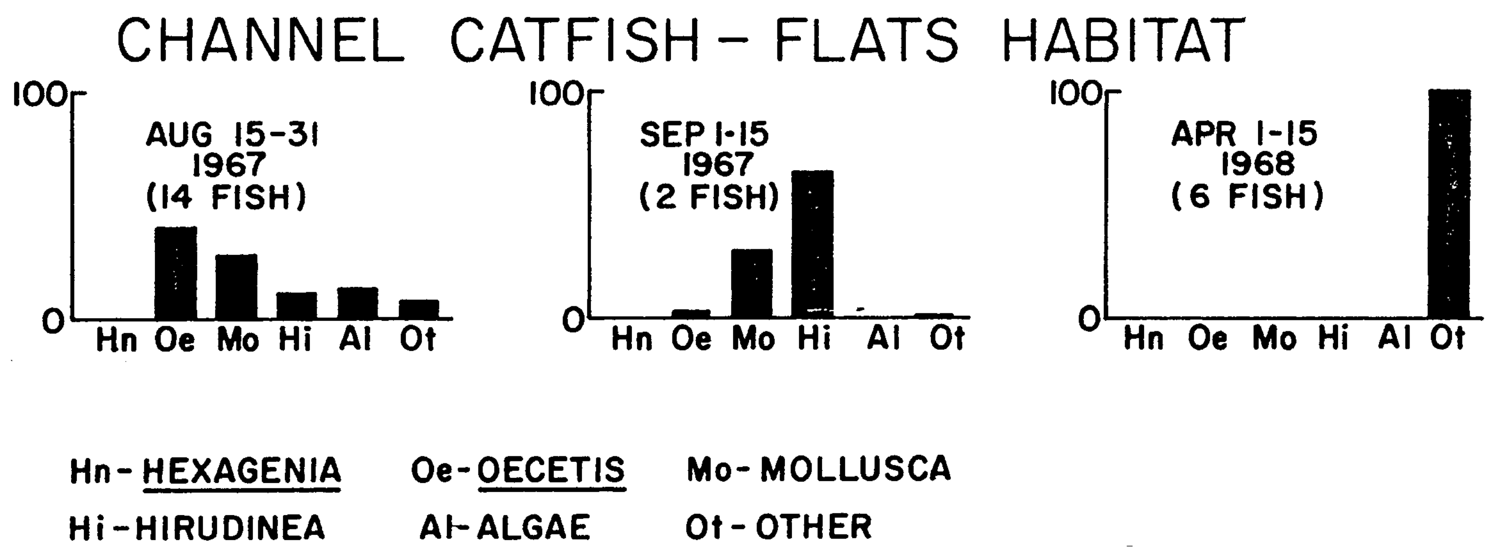
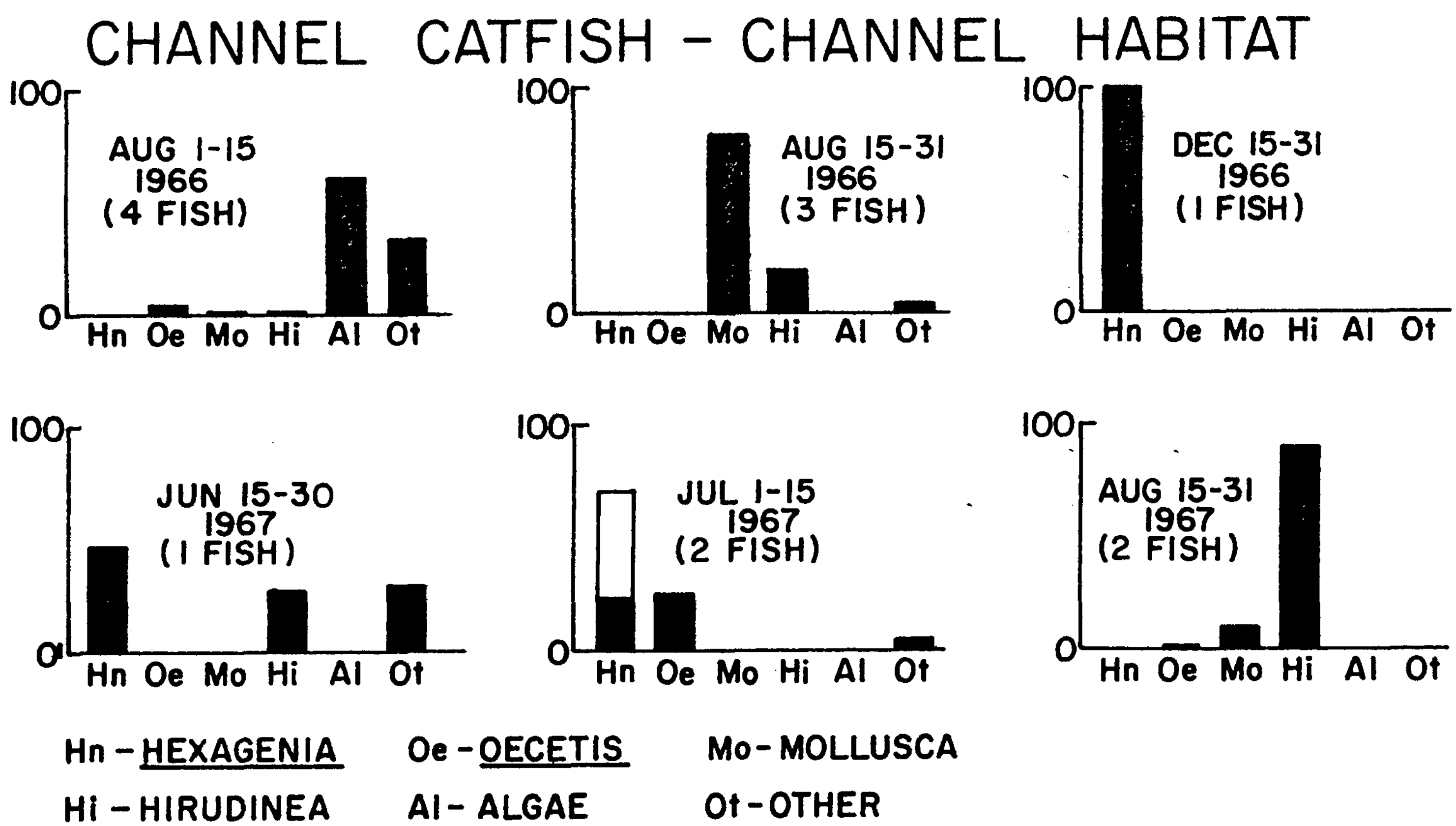

CHANNEL CATFISH - FLATS HABITAT
100
0
AUG 15-31
1967
(14 FISH)
SEP 1-15
1967
(2 FISH)
APR 1-15
1968
(6 FISH)
Hn Oe Mo Hi Al Ot
Hn - HEXAGENIA
Oe - OECETIS
Mo - MOLLUSCA
Hi - HIRUDINEA
Al - ALGAE
Ot - OTHER

Figure 19C. Percentage composition by volume of the material ingested in channel habitat by the channel catfish from August, 1966 to August, 1967 in Pool 19, Mississippi River. (For *Hexagenia* and Trichoptera shaded portion of graph represents percentage of larvae and naiads while open spacing indicates adults or last instar naiads)


CHANNEL CATFISH - CHANNEL HABITAT
AUG 1-15 1966 (4 FISH)
AUG 15-31 1966 (3 FISH)
DEC 15-31 1966 (1 FISH)
JUN 15-30 1967 (1 FISH)
JUL 1-15 1967 (2 FISH)
AUG 15-31 1967 (2 FISH)
100
0
Hn Oe Mo Hi Al Ot
Hn - HEXAGENIA
Oe - OECETIS
Mo - MOLLUSCA
Hi - HIRUDINEA
Al - ALGAE
Ot - OTHER

larger part of the diet was composed of Hexagenia although mollusks were still very important. In 1967, the importance of Hexagenia in the diet during June and July can again be noted for the flats habitat. Oecetis sp. and mollusks made up most of the diet in August. The major constituents of the stomach contents of two fish captured during September were mollusks and leeches. Samples from April of 1968 were again composed of chironomids and pieces of gizzard shad, derived from fish which died the previous winter.

Limited stomach samples from channel habitat indicated fish depended on mollusks, leeches, and algae during August, 1966. One fish out of five captured from hoop nets during December by a commercial fisherman contained a small amount of Hexagenia naiads, indicating they may shift to them towards winter. The June and July samples from channel habitat were largely composed of Hexagenia, while two fish taken in August contained predominately leeches.

Bottom fauna utilization

The relationship of the number of organisms in four chosen groupings found in channel catfish stomachs compared to the numbers of the same groups found in the bottom fauna gives an indication of utilization and an insight into the possible reasons why certain food items are eaten. The bottom fauna data (Table 7A, 7B, 7C) and some of its vagaries were discussed in the section on mooneyes. Bailey and Harrison (1945) attempted a similar correlation between the numbers of aquatic insects present in the Des Moines River and their relative frequency in the stomachs of channel catfish. The frequency of Diptera and Trichoptera found in stomachs followed the benthos trends in the Des Moines River; whereas, Ephemeroptera were eaten about the same from April to October, despite changes in numbers in the bottom sediments.

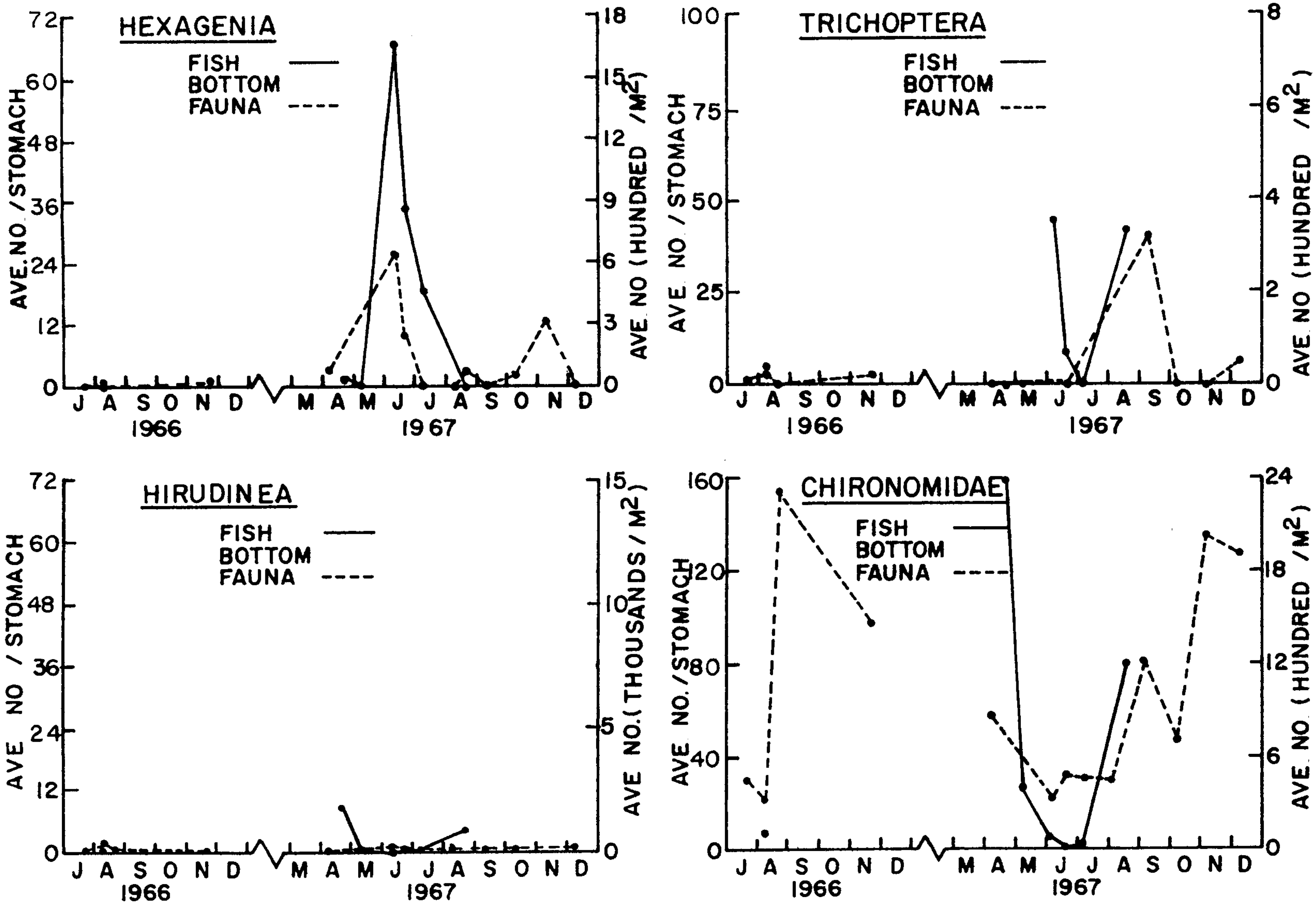
For the channel catfish in this study, Hexagenia, Trichoptera (including Oecetis sp., Potamyia flava, and Leptocella candida), Hirudinea (leeches), and Chironomidae were selected to show how numbers in stomachs were related to numbers in the bottom fauna (Figure 20A, 20B, 20C). Hexagenia were eaten in proportion to their abundance in the bottom fauna in all three habitat types. Peak numbers appeared in stomachs from fish captured during June.

The Trichoptera category as previously explained, was not separated to species in the bottom fauna, so that an exact correspondence was not possible. However, trends in Trichoptera abundance in the bottom fauna were followed very well in flats and channel habitat where Oecetis sp. was found to be a fairly important part of the diet during July and August. Few were eaten in shallow habitat.

The consumption of leeches appeared to increase from lows in June and July to a peak in August and September. Benthos numbers also increase in a similar fashion with greatest abundance reached in November. The only catfish captured during the winter months was from channel habitat. This fish had eaten minimal amounts of Hexagenia naiads, so little can be said regarding food habits after September.

Chironomids were an important part of the diet of catfish only in shallow habitat during April and May. Since numbers in the bottom fauna are decreasing in March to lows in May and June, it is probable that fish are utilizing the more active chironomid larvae prior to emergence.

Figure 20A. Utilization of four benthos groups by the channel catfish during 1966-67 in shallow habitat, Pool 19, Mississippi River



HEXAGENIA
FISH
BOTTOM
FAUNA
AVE. NO./STOMACH
AVE. NO (HUNDRED /M²)
J A S O N D
1966
M A M J J A S O N D
1967
TRICHOPTERA
FISH
BOTTOM
FAUNA
AVE. NO / STOMACH
AVE. NO (HUNDRED /M²)
HIRUDINEA
FISH
BOTTOM
FAUNA
AVE. NO / STOMACH
AVE. NO.(THOUSANDS / M²)
CHIRONOMIDAE
FISH
BOTTOM
FAUNA
AVE. NO./STOMACH
AVE. NO (HUNDRED /M²)

Figure 20B. Utilization of four benthos groups by the channel catfish during 1966-67 in flats habitat, Pool 19, Mississippi River

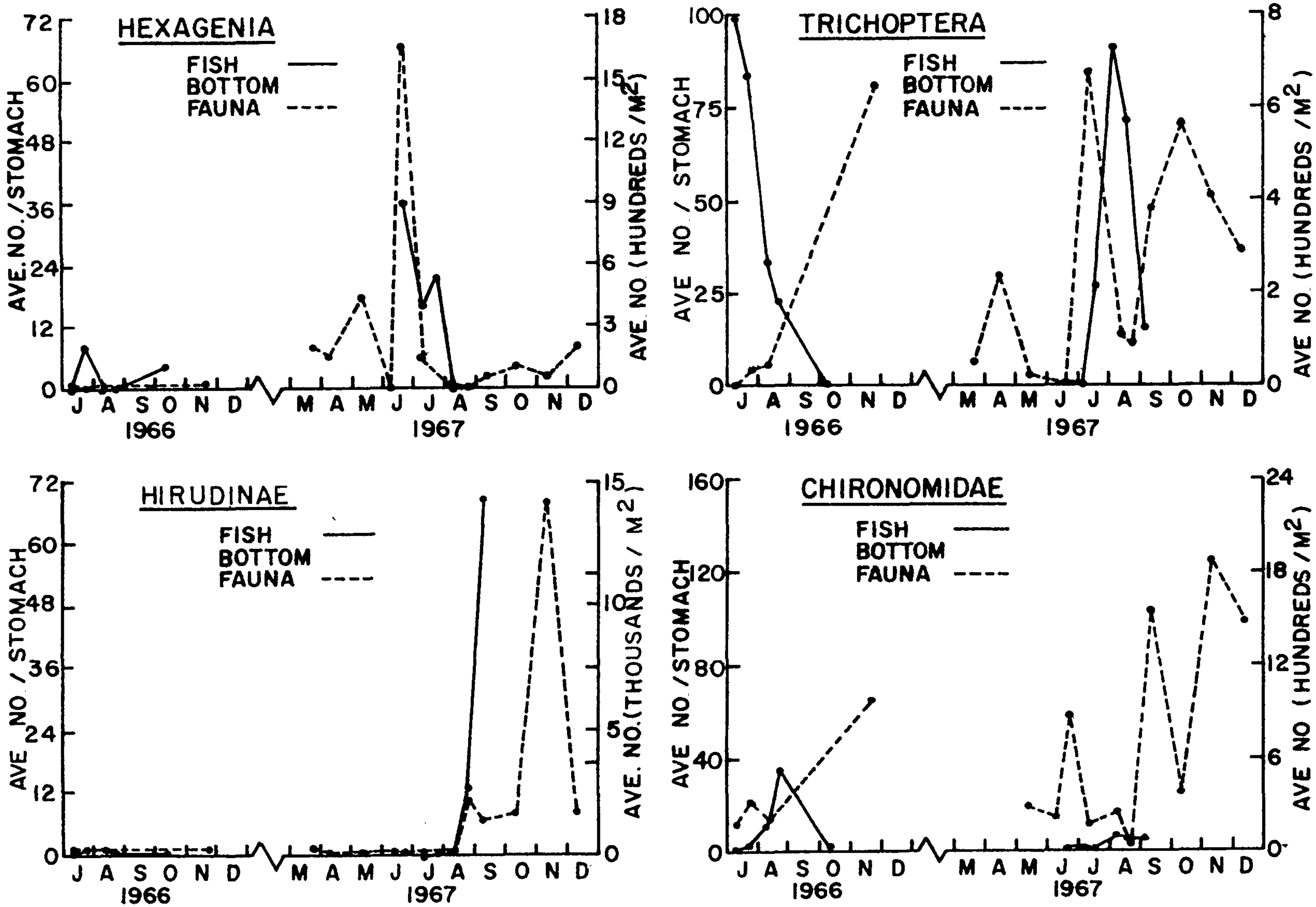
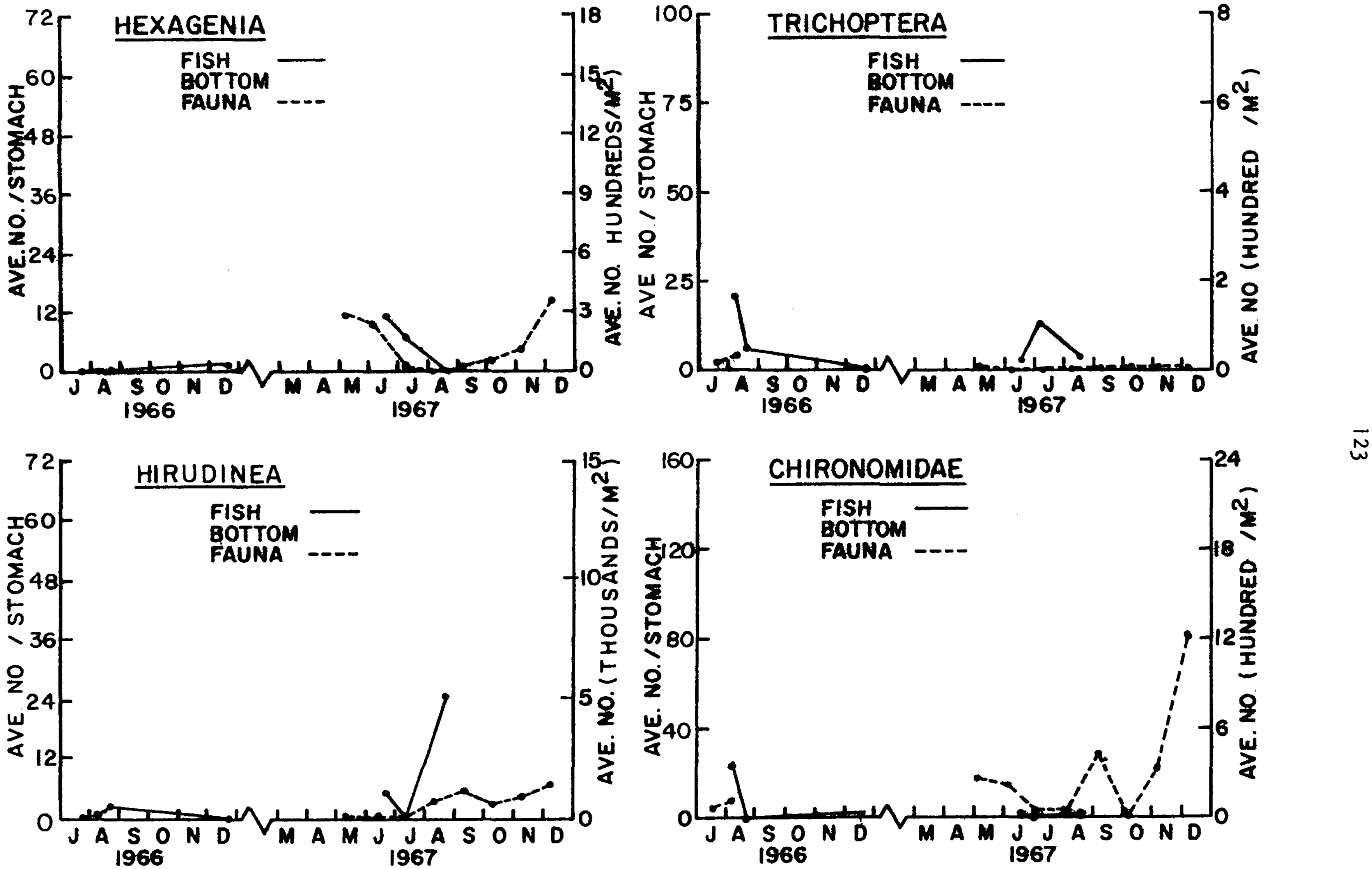

HEXAGENIA
FISH
BOTTOM
FAUNA
AVE. NO./STOMACH
AVE. NO (HUNDREDS /M²)
J A S O N D
1966
M A M J J A S O N D
1967
TRICHOPTERA
FISH
BOTTOM
FAUNA
AVE NO / STOMACH
AVE NO (HUNDREDS /M²)
HIRUDINAE
FISH
BOTTOM
FAUNA
AVE NO / STOMACH
AVE. NO.(THOUSANDS / M²)
CHIRONOMIDAE
FISH
BOTTOM
FAUNA
AVE NO /STOMACH
AVE NO (HUNDREDS /M²)

Figure 20C. Utilization of four benthos groups by the channel catfish during 1966-67 in channel habitat, Pool 19, Mississippi River


HEXAGENIA
FISH
BOTTOM
FAUNA
AVE.NO./STOMACH
AVE.NO. HUNDREDS/M2
J A S O N D
1966
M A M J J A S O N D
1967
TRICHOPTERA
FISH
BOTTOM
FAUNA
AVE NO / STOMACH
AVE NO (HUNDRED /M2)
HIRUDINEA
FISH
BOTTOM
FAUNA
AVE NO / STOMACH
AVE. NO. (THOUSANDS/M2)
CHIRONOMIDAE
FISH
BOTTOM
FAUNA
AVE. NO./STOMACH
AVE. NO (HUNDRED /M2)

Evidence for this is contradictory, however, since nine catfish stomachs examined during the second part of April, 1967 contained only chironomid larvae; whereas, six stomachs from the first part of April, 1968 contained mostly pupae. The increase in the numbers of chironomids found in stomachs during July in shallow habitat resulted from many small larvae ingested with algae eaten during this period. Volumetrically these larvae were negligible.

Black Bullhead

Black bullheads were taken only in shallow habitats during this study. In 1966, 54 specimens captured ranged from 6.3-12.7 inches with a mean of 9.6 inches. In 1967, 123 fish were captured ranging from 5.2-12.4 inches (average 9.5 inches). Black bullheads do not contribute significant poundage to the commercial catch, but the combined species of bullheads ranked fifth in the overall fishery and eighth in the sport fishery of the Mississippi River during 1963 (Nord, 1967).

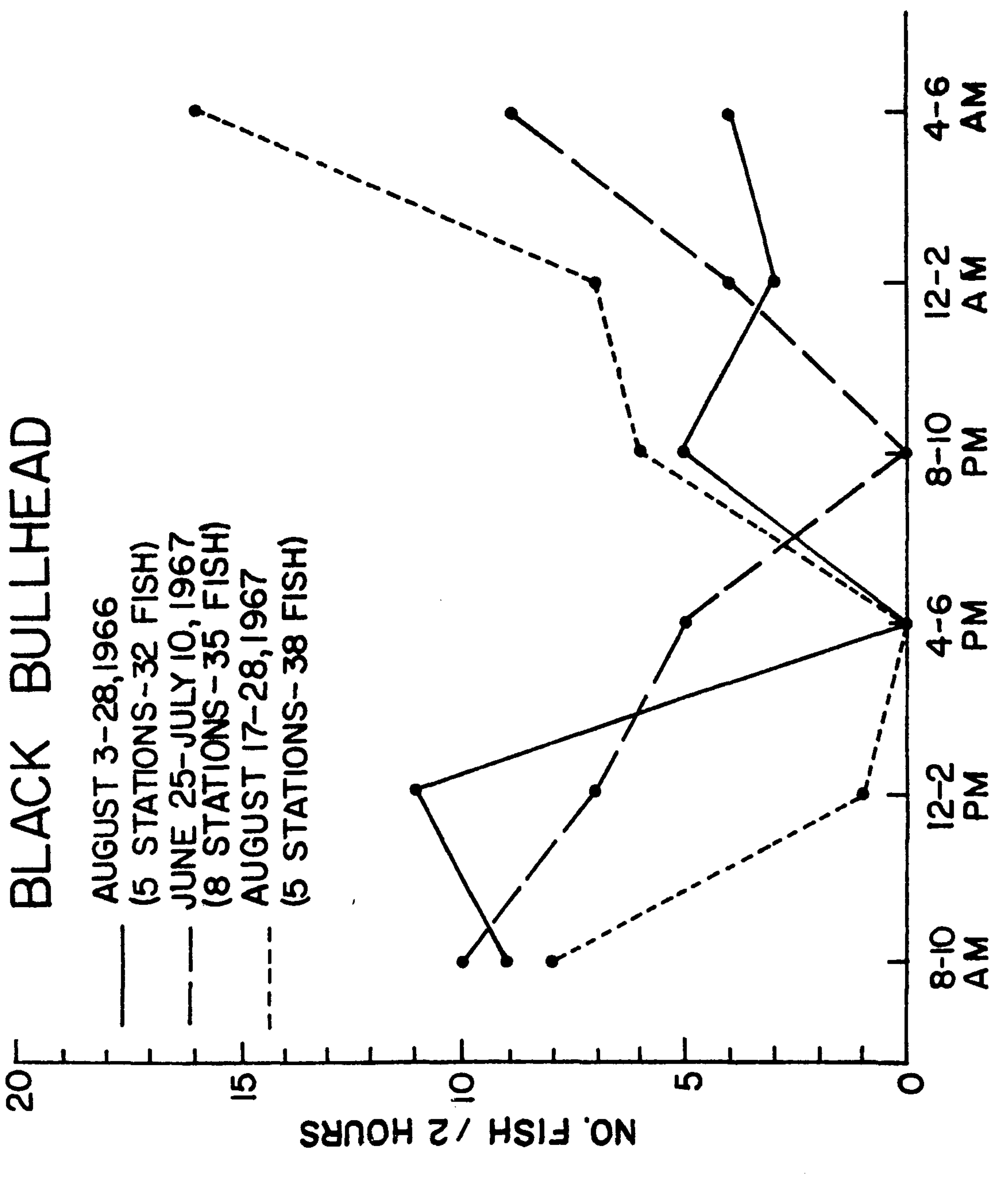
Distribution

The bullhead is found in all pools of the Upper Mississippi River, thus exhibiting a favorable reproductive capacity. However, Nord (1967) felt that its populations have been significantly reduced since the construction of navigation dams.

The fish captured in 1966 were taken at 6 of the 24 sampling stations and vegetation was present at 5 of these stations. Transect 1 station 1 was the exception. In 1967 fish were captured at 8 of the 17 stations sampled and all but 2 of them had vegetation present.

No seasonal catches-per-effort were compiled because of insufficient data. The highest catch-per-effort value (104 fish per 24 hours) was recorded in Honig's Slough in May. This high value was probably related to spawning activities. Catch-per-effort values during August for the slough were around 40, although 60 fish per 24 hours were taken at transect 4 station 1. A diurnal activity curve constructed for the three 24-hour sampling programs showed a peak period of activity in the morning hours at 4-6 AM and 8-10 AM (Figure 21). In the August samples of 1966 and 1967,

Figure 21. Daily activity pattern for black bullheads as reflected in the total catch of fish from gill nets set for 2 hours during three 24-hour sampling programs in Pool 19, Mississippi River


BLACK BULLHEAD
AUGUST 3-28,1966
(5 STATIONS-32 FISH)
JUNE 25-JULY 10, 1967
(8 STATIONS-35 FISH)
AUGUST 17-28,1967
(5 STATIONS-38 FISH)
NO. FISH / 2 HOURS
20
15
10
5
0
8-10 AM
12-2 PM
4-6 PM
8-10 PM
12-2 AM
4-6 AM
TIME

fish appeared to become active earlier (8-10 PM) than fish captured during June of 1967 when increased numbers occurred 4 hours later at 12-2 AM. Essentially the same numbers were captured during each of the three 24-hour programs. The 1967 samples indicated that catch-per-effort or activity of the bullhead remained the same from June to the latter part of August. Carlander and Cleary (1949) and Carlander (1953) noted that black bullheads captured at Clear Lake, Iowa exhibited a pronounced nocturnal activity. Some indication of movements into shallow water at night were also reported.

The depth distribution of the bullheads captured during the three 24-hour sampling programs demonstrated their presence in shallow water less than 3 feet (Table 11). In 1967, mean catch per 24 hours per station was considerably higher in depths of 3 to 8 feet. The increased catch in deeper water was due to the contribution made by fish captured at transect 4 station 1, which was near vegetation, but whose depth placed it in the 3-8 foot category. Black bullheads were not captured in water over 6 feet deep.

Preference by bullheads for vegetated areas was also shown in the 24-hour sampling program in 1966 since only one fish was captured at a non-vegetated station. In 1967, during the June-July sample, 85% of the fish were taken from vegetated areas; whereas, 95% of the bullheads caught during August, 1967 were from stations with various amounts of aquatic vegetation. In Honig's Slough during 1966, the catch during the 24-hour sampling at transect 2 station 1 was 48 fish, while only 6 were taken at station 2. During August, 1967, the catch was 22 bullheads at station 1 and 6 at station 2, indicating that bullheads favored the more heavily vegetated area near shore at station 1. Station 2, located in more open water than station

Table 11. The average catch of black bullheads per experimental gill net per 24 hours for three depth categories and three 24-hour sampling programs in Pool 19, Mississippi River. The average number of fish caught per station (12 hours of actual netting) was multiplied by two to give the data in terms of catch per 24 hours

Date	No. Fish	Number Stations	Depth Category (ft.)	Mean catch per 24 hours per station
1966				
August 3-28	32	10	<3	6.4
		9	3-8	0
		5	>8	0
1967				
June 10 - July 25	35	8	<3	7.5
		6	3-8	3.3
		3	>8	0
August 17-28	38	8	<3	4.8
		6	3-8	5.7
		3	>8	0

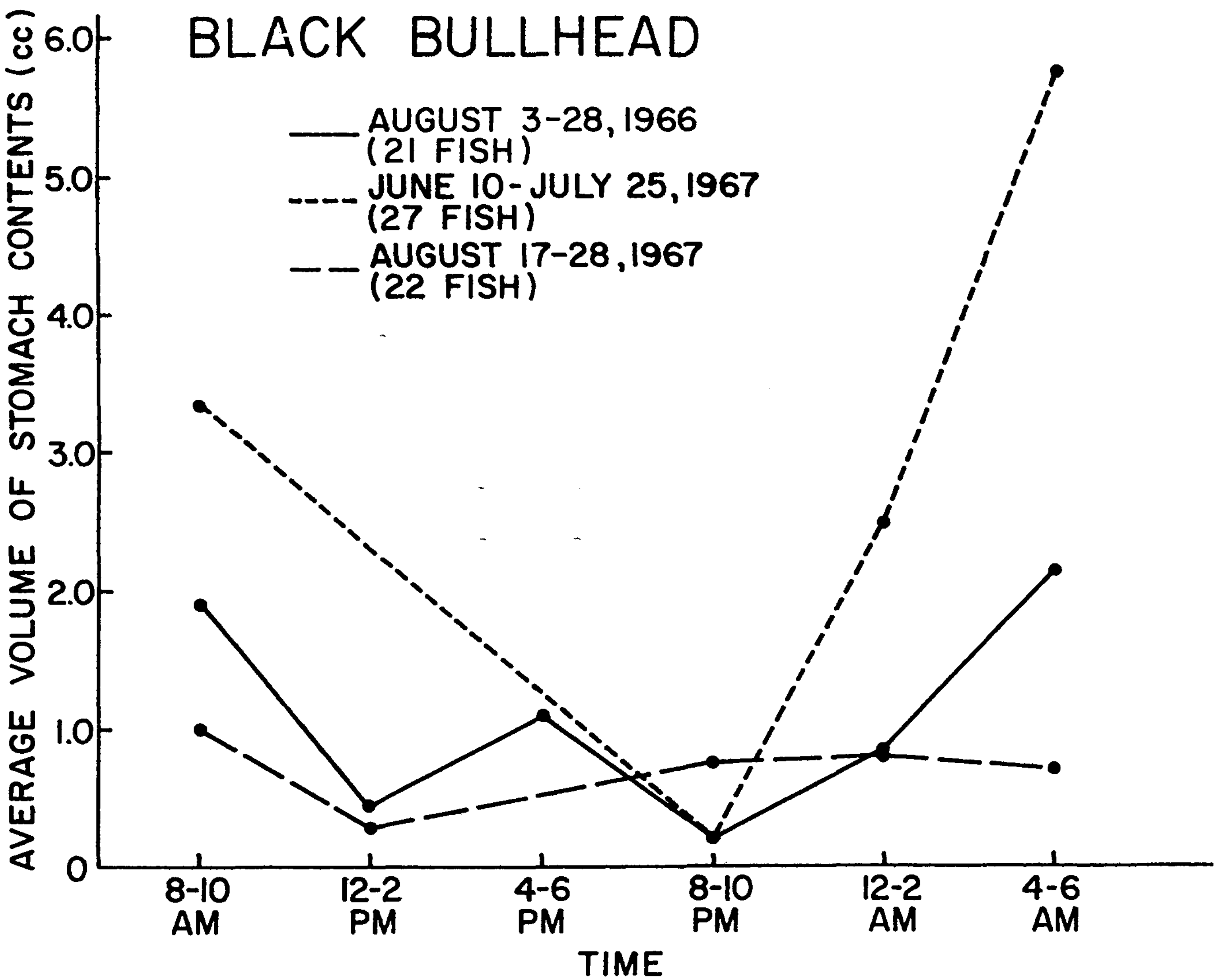
1, contained less vegetation. During June, 1967, the catch at both stations was similar, approximately 18 fish.

Food habits

The stomach contents from 177 black bullheads were examined and of these, 48 were empty, 12 of which were taken from trot lines. The problem of regurgitation by bullheads captured in gill nets was encountered in this study as well as in studies by Kutkuhn (1954) and Forney (1955). The short period of net setting (2 hours) partially alleviated the problem. However, water filled stomachs containing some food were found. For calculations of the average amount of food eaten only stomachs with food present were used. However, like the catfish, trends in the amount of food eaten over time remained relatively similar if empty stomachs were included in the analysis The average volume of food eaten by black bullheads attained a diurnal maximum around 4-6 AM (Figure 22) Data from all three 24-hour programs were in general agreement The larger volumes eaten during August, 1967 were due to the large contribution made by fingernail clams eaten at this time These volumes were much higher than the amounts eaten during June, 1967, when Hexagenia were eaten. During June most other species such as the mooneye and catfish, contained maximum amounts in their stomachs However, bullheads, unlike other species studied, initiated a period of active feeding during the latter part of August and September in open river habitat Since the daily activity pattern of the bullhead (Figure 21) also showed a peak at 4-6 AM, the amount of food eaten may be directly related to feeding Peak activity in other fish was usually followed in the next 4 hours by the maximum amount of food found in stomachs Bullheads apparently initiated most of their feeding when they first became active at 8-10 PM

Pearse (1915) studying bullheads averaging 118 8 mm (4 7 inches) in Wisconsin lakes found the diet to be 45.1% insects and 21 4% oligochaetes Ewers and Boesel (1935) at Buckeye Lake, Ohio examined the stomachs of 28 bullheads less than 3 inches in length Their diet was mainly composed of crustaceans with a minor contribution by insects, mostly chironomids Bullheads from Clear Lake, Iowa, in this size range were eating essentially similar types of foods (Forney, 1955) Food of larger fish was composed mainly of chironomids, minor numbers of other faunal organisms and organic detritus Kutkuhn (1954) found considerable variation in the food composition of bullheads from North Twin Lake, Iowa during July and August Forage fish were important in fish from 9-10 9 inches long, while insects (chirono-

Figure 22. Average volume of stomach contents over a 24-hour period for black bullheads taken in Pool 19, Mississippi River during August 3-28, 1966, June 25-July 10 and August 17-28, 1967


BLACK BULLHEAD
AUGUST 3-28, 1966
(21 FISH)
JUNE 10-JULY 25, 1967
(27 FISH)
AUGUST 17-28, 1967
(22 FISH)
AVERAGE VOLUME OF STOMACH CONTENTS (cc)
6.0
5.0
4.0
3.0
2.0
1.0
0
8-10 AM
12-2 PM
4-6 PM
8-10 PM
12-2 AM
4-6 AM
TIME

mids) were the principal food of smaller fish Algae, almost entirely Stigeoclonium, occurred regularly, but in small amounts in most size groups Three black bullheads captured during April in Pool 19 near Burlington, Iowa, were eating 90% Hexagenia (Hoopes, 1959)

No separation by size groups was deemed desirable for bullheads captured during this investigation since most fish collected at one time were generally eating similar food In addition, the size range of captured fish was small All black bullheads sampled were in excellent shape as evidenced by plump abdomens and general large size for a given length, indicating an abundant food supply for this species. Fish captured in Honig's Slough, transect 2, compared to those caught at more open river stations, showed differences in kind and amount of food eaten probably reflecting differences in abundance or availability of bottom fauna from these two habitats. As a result the food habits analyses of fish captured from these two locations were treated separately.

Bullheads from the open river consumed a large variety of different foods (Table 12). In 1967, the amount of food eaten was high during May, June, and July, then decreased during the first part of August In the latter part of August and September, seasonal maximum in amount of food eaten (5 61 cc) was encountered. The major food items contributing to the May-July volumes were Hexagenia and oligochaetes, while during August and September large numbers of fingernail clams were found in stomachs

In general, bullheads from open river areas had eaten Hexagenia mostly during June and July, with adults making up the greatest proportion in the diet during July The trichopteran, Oecetis sp., was found in fish during every period in which bullheads were captured, with the exception of the

Table 12. Volume (cc) and occurrence of the material ingested by the black bullhead in open river, shallow habitat, July, 1966 to September, 1967. (t=trace)

Date	No. Stations	No. Stomachs w/food		*Hexagenia* naiads	*Hexagenia* adults	*Oecetis* sp.	Sphaeriidae	Oligochaete	Algae	Chironomidae	Odonata	Fish	Hirudinae	Other	Unidentifiable	Total Volume per Fish
1966																
July 15-31	2	7	Vol.	t	0	.06	t	.63	.06	t	.06	.27	.04	.03	.05	1.20
			Occ.	1	0	3	3	6	1	6	3	3	4	5	1	
Aug. 1-15	1	2	Vol.	.02	0	.15	0	0	.54	.01	.01	0	0	.19	.04	.96
			Occ.	1	0	1	0	0	2	1	2	0	0	2	1	
Aug. 15-31	2	4	Vol.	0	0	0	.01	.07	.14	t	t	0	0	t	0	.22
			Occ.	0	0	0	1	1	3	2	1	0	0	1	0	
1967																
May 1-15	4	20	Vol.	.17	0	.10	0	1.03	.02	.37	.01	0	.10	.03	.22	2.05
			Occ.	15	0	6	0	13	2	19	4	0	8	12	6	
June 15-30	5	9	Vol.	1.51	.43	.02	t	.03	0	t	0	0	.03	t	.08	2.10
			Occ.	9	2	3	3	2	0	2	0	0	1	2	1	
July 1-15	5	11	Vol.	.91	2.29	t	0	.08	0	t	t	.01	.03	t	0	3.32
			Occ.	8	8	1	0	1	0	5	1	1	2	2	0	
Aug. 1-15	1	3	Vol.	0	0	.19	.38	0	.14	.04	.30	0	.03	.04	.20	1.32
			Occ.	0	0	3	3	0	1	3	2	0	2	3	1	
Aug. 15-31	2	13	Vol.	0	.01	1.56	3.90	0	0	.04	t	0	.04	.06	0	5.61
			Occ.	0	1	13	11	0	0	11	3	0	8	8	0	
Sept. 1-15	1	4	Vol.	0	0	.08	2.48	0	1.22	.03	0	0	.10	.03	.04	3.98
			Occ.	0	0	4	4	0	1	4	0	0	3	3	2	

latter part of August, 1966. They were only important volumetrically during August and September, 1967. The reason for the presence of <u>Oecetis</u> in fish during August of 1967 and not 1966 is due to station differences since most bullheads captured during 1967 were taken at transect 4 station 1. In 1966 not as many bullheads were captured at transect 4 station 1 and none were taken there during August.

Fingernail clams as already noted were eaten in large quantities during August and September of 1967. Almost all fish eating sphaeriids came from transect 4 station 1, though smaller amounts were also ingested at transect 3 station 1. One 11.7 inch fish contained 799 large fingernail clams having a volume of 15.4 cc.

Bullheads were the only fish other than channel catfish which had eaten any significant amount of oligochaetes. The presence of mud and the tendency of oligochaetes to fragment made only rough numerical counts possible. Volumes reported included the mud associated with oligochaetes, which sometimes made up half of the total volume. Oligochaetes appeared to be important only during July, 1966 (.63 cc) and May, 1967 when an average of 1.03 cc was found in bullhead stomachs.

Algae appeared in bullhead stomachs mainly during August, although one fish in September was recorded eating 4.87 cc of Cladophora.

Chironomids were present in the stomachs of fish from the open river during every period of the study but were seldom important. The largest volumes were eaten during May, when chironomids are also consumed in large numbers by mooneyes and catfish, particularly in shallow habitat.

Fish, damselflies and leeches, were never significant volumetrically as food of bullheads during this investigation. Fish appeared only during

July in four bullheads captured from the open river habitat. Fish eaten by the bullheads (6.5-11.2 inches) consisted of: 7 freshwater drum, 1 centrachid, 3 gizzard shad and 2 unidentified forms. It would appear that bullheads can readily capture forage fish although only 4 of 73 bullheads containing food had done so.

Unidentified material was not as great a problem as would be expected for a bottom feeder such as the bullhead. Most of the stomach contents classified as unidentifiable was mud and other bottom detritus.

To demonstrate the relative importance of six different types of food eaten by black bullheads from the open river during a given 15-day interval, the percentage composition by volume was determined (Figure 23). During May, oligochaetes and chironomids were the major constituents of the diet, while Hexagenia were eaten almost exclusively during June and July. Oligochaetes and algae were the important items in the diet of bullheads during the latter part of July and August of 1966, whereas, fingernail clams comprised almost 50% of the volume of all food eaten during August and September, 1967.

The diet of fish captured in Honig's Slough was composed mainly of chironomids although an abundance of other foods was also eaten (Table 13). Hexagenia naiads were an important part of the diet of black bullheads during the first part of July, 1966. Bottom sampling was only conducted during the first part of July and August, 1966, and no naiads were found. The environment of the slough does not correspond to the preferred habitat as described for Hexagenia by Fremling (1950), though there might be areas where their requirements are met. Ranthum (1968) also found Hexagenia naiads in some of the fishes he examined. The other possibility is that the

Figure 23. Percentage composition by volume of the material ingested in open river habitat by black bullheads from July, 1966 to September, 1967 (For *Hexagenia* shaded portion of graph represents percentage of naiads while open spacing indicates adults or last instar naiads)

BLACK BULLHEAD - OPEN RIVER

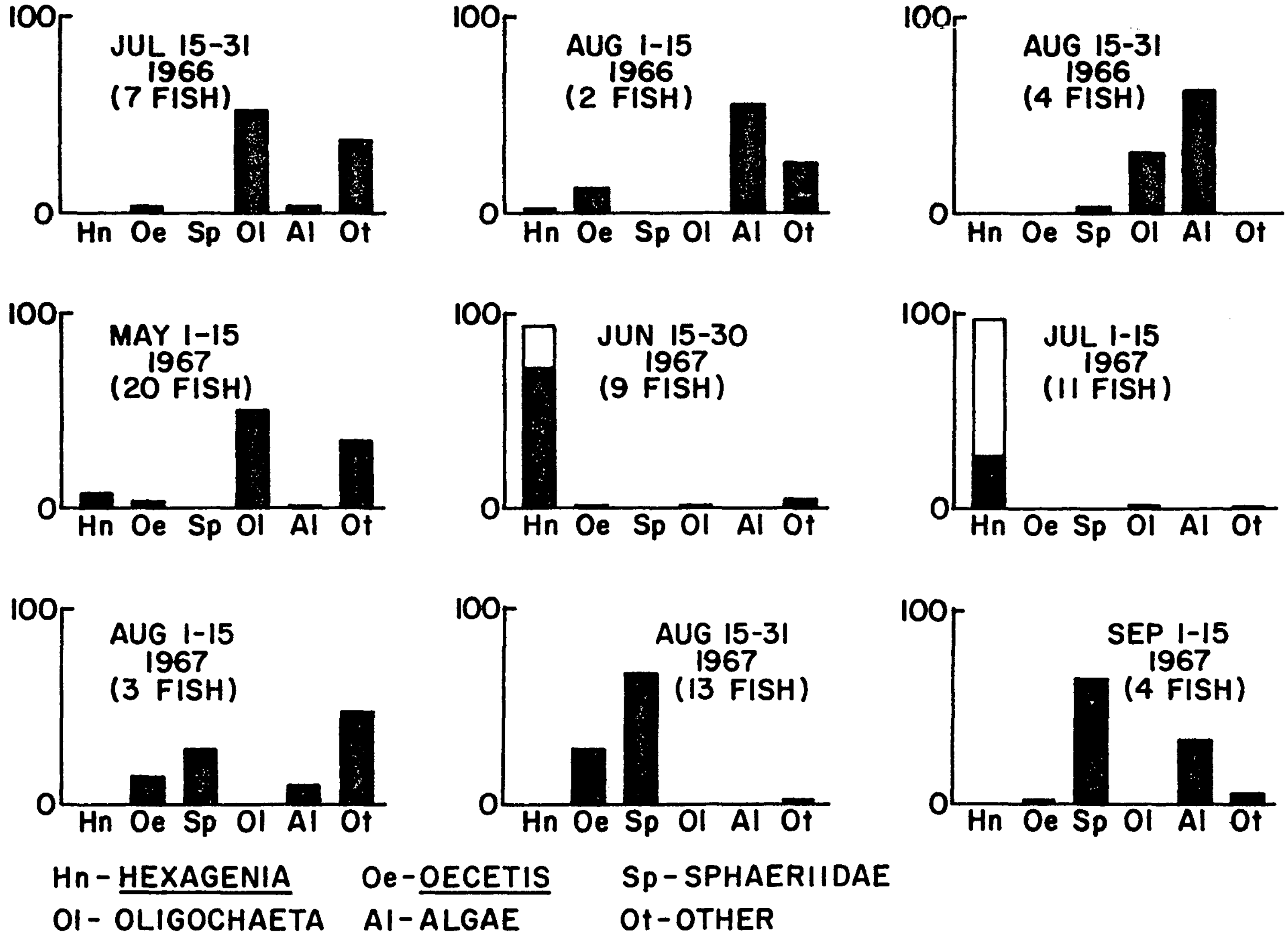


Table 13. Volume (cc) and occurrence of the material ingested by the black bullhead in the backwater area of Honig's Slough August, 1966 to August, 1967. (t=trace)

Date	No. Stations	No. Stomachs with food		Hexagenia	Oecetis sp.	Algae	Chironomid larvae	Dipteran pupae	Odonata	Fish	Cladocera	Other	Unidentifiable	Total volume per Fish
1966														
August 1-15	2	10	Vol.	0	0	0	.56	.05	.05	.05	0	.08	0	.82
			Occur.	0	0	0	9	9	7	1	0	9		
August 15-31	1	14	Vol.	0	0	t	.19	.10	t	.08	0	.01	.01	.39
			Occur.	0	0	1	13	8	1	2	0	6	1	
November 15-31	1	2	Vol.	0	0	0	.55	0	0	0	0	0	.10	.65
			Occur	0	0	0	2	0	0	0	0	0	2	
1967														
May 1-15	1	10	Vol.	0	.01	0	.33	.71	.02	0	t	.06	.28	1.41
			Occur.	0	2	0	9	10	3	0	2	9	7	
June 15-30	2	8	Vol.	.02	t	0	.11	.01	t	.14	0	.01	.13	.42
			Occur.	1	1	0	7	8	2	3	0	1	6	
July 1-15	2	4	Vol.	65	0	t	.01	.01	t	.09	.39	t	t	2.15
			Occur.	2	0	1	4	3	1	2	4	4	1	
August 1-15	2	6	Vol.	0	.65	.10	.01	1.06	.01	t	0	.09	t	1.92
			Occur.	0	3	1	6	6	2	1	0	5	1	
August 15-31	1	1	Vol.	0	0	.88	.13	0	0	0	0	0	0	1.01
			Occur.	0	0	1	1	0	0	0	0	0	0	

two bullheads captured during July, 1966, had eaten naiads from open river habitat, and then migrated the approximately 300 yards into the slough where they were subsequently caught.

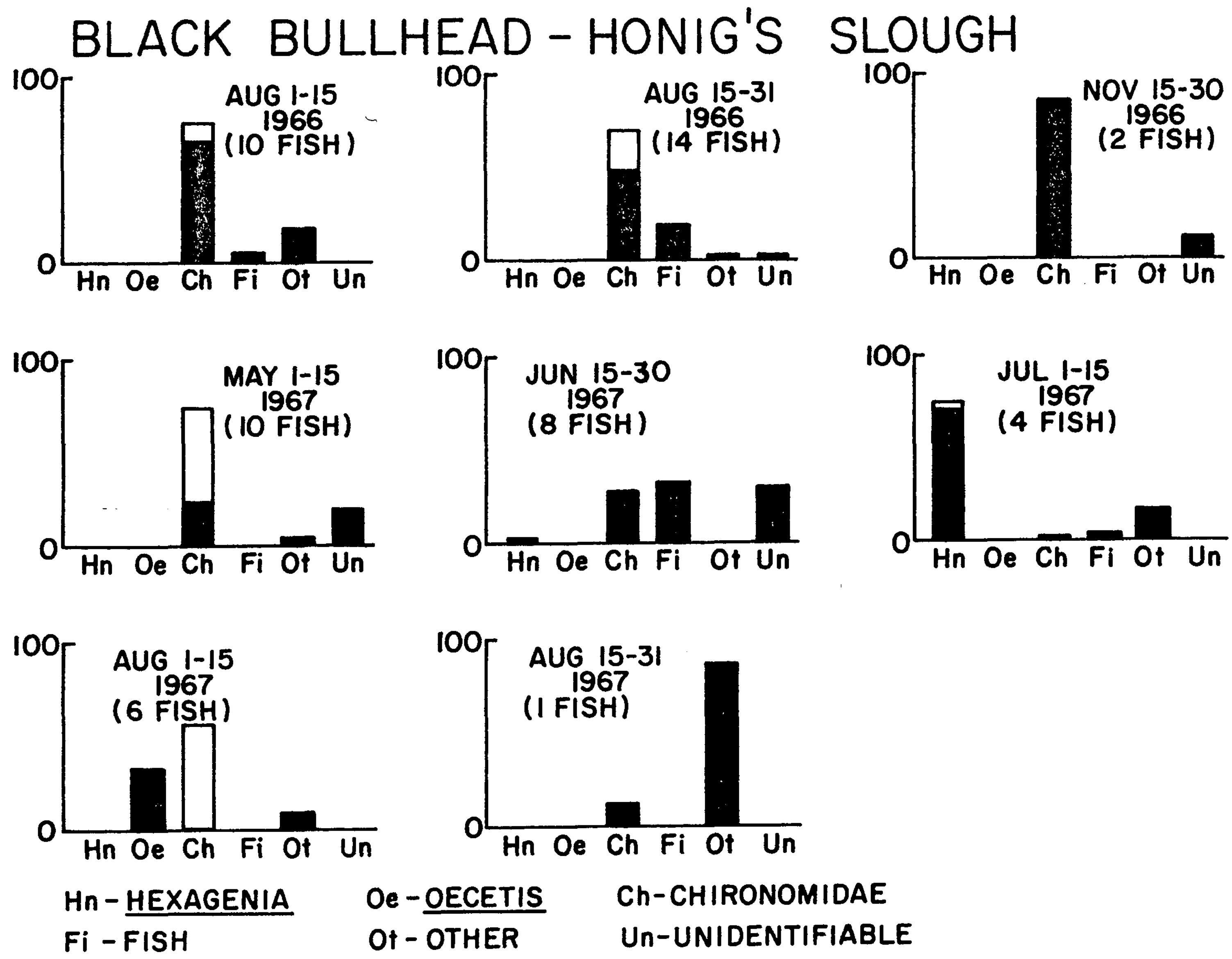
Oecetis sp. and algae eaten by fish in the slough occurred in only three and one bullhead stomach respectively, where they comprised a large part of the food consumed. Chironomids along with dipteran pupae (probably also chironomids) made up almost 60% of the volume of food eaten by bullheads in 1966 during August and November. In 1967, the same trend was apparent though midge larvae were not as significant during June and July.

Fish were eaten mostly during June, July and August by 9 bullheads of the 55 specimens examined at transect 2. Of the 12 forage fish eaten, one was identified as bigmouth buffalo, several were small fry, and the remainder were digested past recognition. It was concluded that predatory activities by bullheads from Honig's Slough were limited.

The percentage composition by volume of food eaten by bullheads in Honig's Slough demonstrated the importance of Chironomidae in their diet (Figure 24). Midges comprised the major portion of the total volume of food ingested in all periods except July, 1967, when they were eating Hexagenia, and the latter part of August, 1967, when a large amount of algae eaten by one fish was found. Chironomid pupae were a significant percentage of the volume of midges eaten during May and August. Fish and Oecetis sp. were important constituents of the diet during June and August 1-15, 1967, respectively.

Cladocera and Ostracoda appeared to be slightly more important to bullheads found in Honig's Slough than to fish captured from the open river Oligochaetes and fingernail clams were never eaten by bullheads in the

Figure 24. Percentage composition by volume of the material ingested in Honig's Slough by black bullheads from August, 1966 to August, 1967. (For _Hexagenia_ and Chironomidae shaded portion of graph indicates naiads or larvae while open spacing indicates adults or last instar naiads)

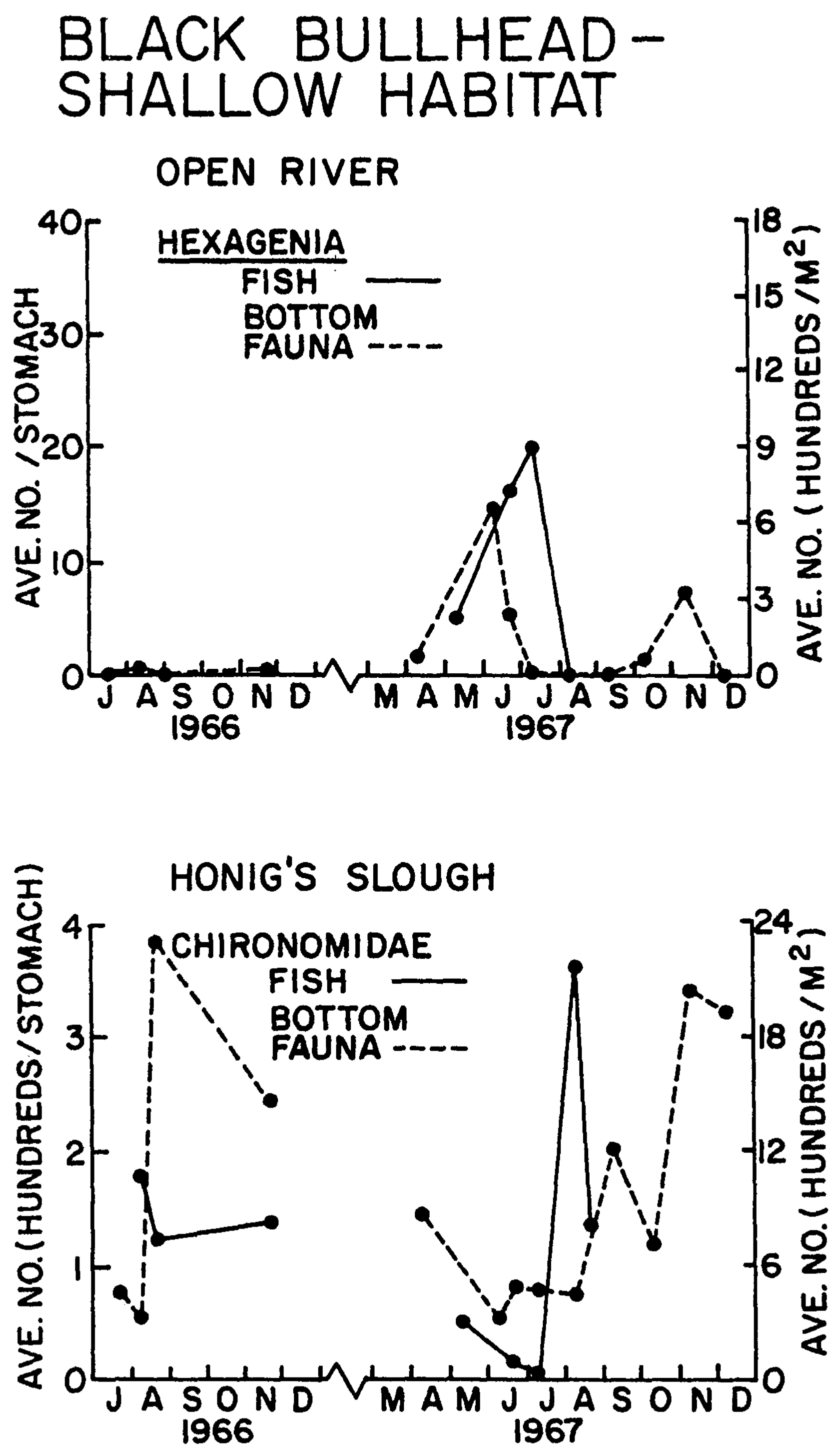

BLACK BULLHEAD - HONIG'S SLOUGH
AUG 1-15 1966 (10 FISH)
AUG 15-31 1966 (14 FISH)
NOV 15-30 1966 (2 FISH)
MAY 1-15 1967 (10 FISH)
JUN 15-30 1967 (8 FISH)
JUL 1-15 1967 (4 FISH)
AUG 1-15 1967 (6 FISH)
AUG 15-31 1967 (1 FISH)
100
0
Hn Oe Ch Fi Ot Un
Hn - HEXAGENIA
Oe - OECETIS
Ch - CHIRONOMIDAE
Fi - FISH
Ot - OTHER
Un - UNIDENTIFIABLE

slough although they are a very important part of the diet of fish taken in the shallow habitat of the open river. Bottom fauna samples in July and August revealed the presence of moderate numbers of sphaeriids and oligochaetes in Honig's Slough, Apparently these benthic organisms were unavailable for fish or the bullheads preferred eating other foods. Fish appear to be eaten at a slightly higher rate in Honig's Slough, which might be expected on the basis of decreasing turbidity and possible availability of more forage fish. In Honig's Slough, 16% of all fish had preyed upon other fishes while only 5% of those from the shallow habitat of the river had done so. Bullheads from Honig's Slough were also eating lesser amounts of food than bullheads captured in river habitat. The major difference in food habits between the bullheads from these two areas was the increased utilization of chironomids by bullheads in Honig's Slough, whereas, fish from the open river had eaten large amounts of Hexagenia, oligochaetes, and fingernail clams during the year.

Bottom fauna utilization

Forney (1955) in his life history study on black bullheads of Clear Lake indicated that the predominance of chironomids as a major food item in the diet probably reflected the abundance of these organisms in the bottom fauna. He did not plot the numbers found in the bottom fauna with numbers found in stomachs during the same period, as was done in this investigation (Figure 25). For bullheads from the open river, Hexagenia were selected to demonstrate this correlation. Numbers of naiads were eaten in approximate proportion to their abundance in the bottom during March and part of July. Peak numbers appeared in stomachs of bullheads during latter June and July,

Figure 25. Utilization of two benthos groups, *Hexagenia* in the open river, and Chironomidae in Honig's Slough, by black bullheads during 1966-67 in Pool 19, Mississippi River


BLACK BULLHEAD-
SHALLOW HABITAT
OPEN RIVER
HEXAGENIA
FISH
BOTTOM
FAUNA
AVE. NO. / STOMACH
AVE. NO. (HUNDREDS / M²)
J A S O N D
1966
M A M J J A S O N D
1967
HONIG'S SLOUGH
CHIRONOMIDAE
FISH
BOTTOM
FAUNA
AVE. NO. (HUNDREDS / STOMACH)
AVE. NO. (HUNDREDS / M²)
J A S O N D
1966
M A M J J A S O N D
1967

when faunal numbers of Hexagenia are minimal in shallow habitat. However Hexagenia naiads in the bottom of flats habitat were still numerous. Therefore, Hexagenia eaten during June and July, which were mainly composed of subimagos and pharate adults, are probably derived from mayflies present on the flats. Bullheads may have captured subimagos which drifted into shallow areas or ingested pharate adults during short excursions to the flats.

Numbers of fingernail clams in the bottom fauna (Table 7A, 7B, 7C) of the shallow habitat (transect 3 station 1) were lowest in June during 1967, increased and maintained their numbers through September, and then generally increased to maximum numbers in November and December. It has been noted that bullheads were eating quantities of large sphaeriids during the latter part of August and September, just before numbers in the bottom began to increase. Bullheads appeared to be utilizing these large sphaeriids when they were at maximum size and numbers.

The consumption of chironomids by bullheads in Honig's Slough appeared to follow the general trend in numbers found in the bottom sediments of shallow habitat, whose numbers were used for correlation. The decline in June and July in the faunal numbers, followed by a similar decline in numbers of chironomids eaten, would seem to indicate that bullheads were bottom type feeders sifting through the sediments and eating chironomids in proportion to their abundance. Other fish, such as the mooneye, which might be more dependent on sight for food gathering, were eating maximum numbers of chironomids as pupae during May and June when numbers in the fauna were minimal, presumably because of emergences.

Carp

Carp were not present in the Mississippi River before 1880 (Carlander, 1954). By 1894, one-half million pounds of carp were reported in the commercial catch, and the catch for 1899 had increased six-fold from 1894 values. The commercial carp harvest continues to far exceed that of any other species in the Mississippi River. Though price per pound is low, quantity brings the monetary value to around one-quarter of a million dollars annually to fishermen (Nord, 1967). In Pool 19, the commercial catch of carp was 277,861 pounds in 1965, which was fourth highest among the 26 pools of the Upper Mississippi. It has remained around this figure for the last 10 years (UMRCC, 1967). Carp ranked sixth in the sport catch over the entire 1957 season.

General observations and high catches in gill nets suggested that carp were one of the more abundant species in Pool 19. Carp were not important as a forage fish (Ranthum, 1968), but may exert considerable influence on other fish through competition for food and the increased turbidity that is sometimes caused by their food gathering activities. Most fish captured were from water less than 3 feet in depth, and like catfish, barbed spines which carp possess made them more susceptible to gill nets than they might have been without spines.

In 1966, 105 carp selected for stomach analysis ranged from 6.5 to 23.4 inches. Of these 78% of the fish from which stomachs were removed were between 10 and 17 inches, 10% were less than 10 inches and 12% were greater than 17 inches. Size range of carp in 1967 was from 6.9 to 25.5 inches.

Distribution

The number of carp captured per 24 hours attained a seasonal maximum during August, 1966 and June, 1967 (Figure 26). During 1967 the catch-per-effort values for shallow habitat were somewhat lower than equivalent values for 1966. Trends in temperature were generally followed in all habitat types though most fish were taken in shallow habitat, suggesting a preference for this type of environment. However, many were captured on the flats, indicating that they also utilize this habitat type to a certain degree, at least in shallow water. Activity of carp appeared to be minimal after September, 1967, as reflected in catch-per-effort data. The 1966 catch data were not indicative of actual conditions, since fish were not collected during September and October. However, the number of fish captured per day in the channel and flats habitat were lowest during September and October.

The distribution of carp by three depth categories, as shown by the average number captured per gill net over 24 hours, indicated that carp were associated with water less than 3 feet deep (Table 14). Most fish captured on the flats (3-8 feet deep) were taken from shallow water stations with vegetation near by (eg., transect 4 station 1). The high catch-per-effort in the channel during August, 1966, was due mostly to contributions from transect 8 station 2 on the "Nauvoo flats." Nets at this station were set mostly in deep water near the channel, but part of the net was set in shallow water, resulting in carp and other fish characteristic of shallow water being taken. Since the station was best described as being located in channel habitat, fish appeared in the catch which were not usually recorded from channel waters. During the entire study only two carp were

Figure 26. Water temperature and mean catch of carp per 24 hours in experimental gill nets averaged over 15-day intervals. Catch-per-effort for the shallow, flats and channel habitat is shown

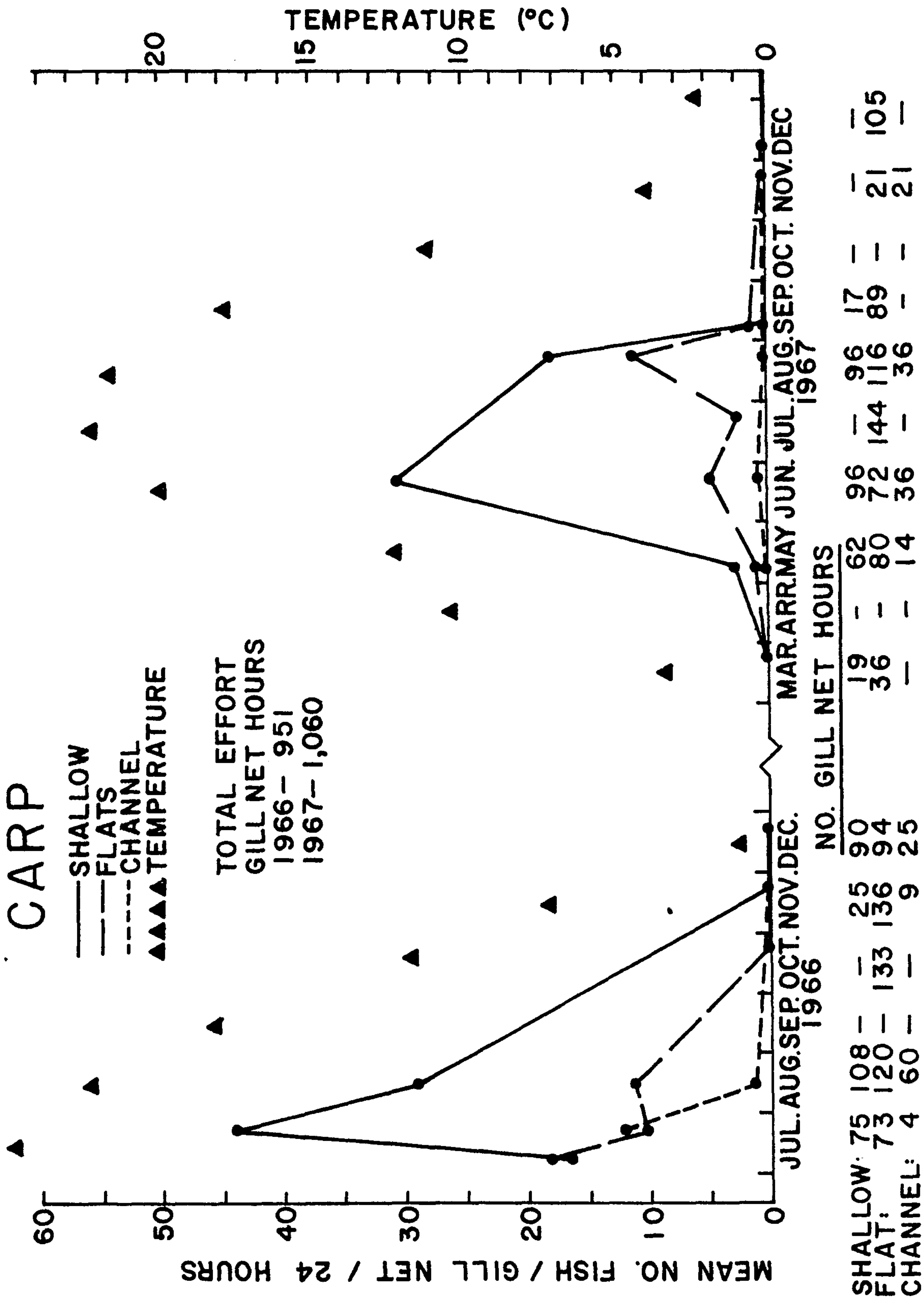
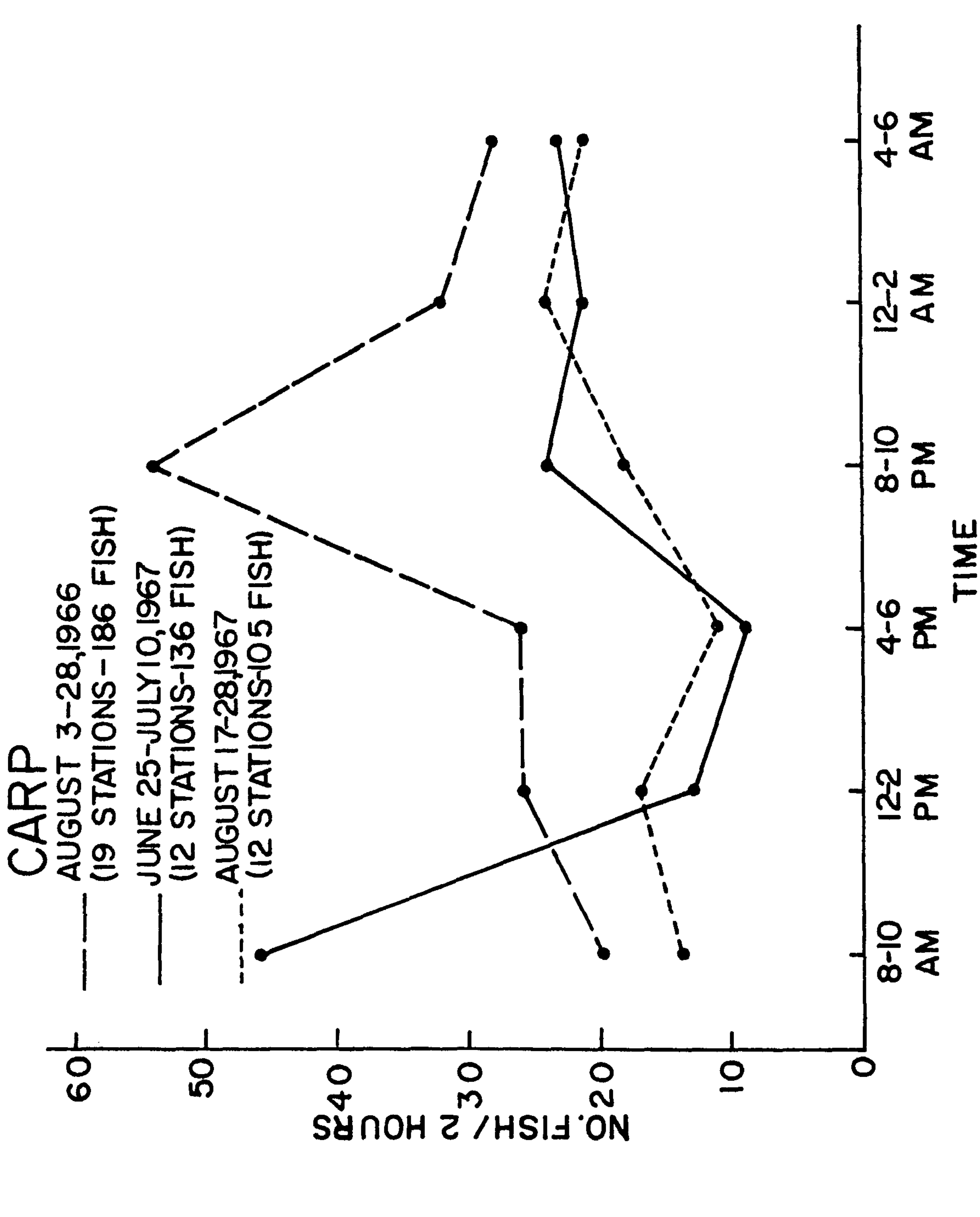

CARP
SHALLOW
FLATS
CHANNEL
TEMPERATURE
TOTAL EFFORT
GILL NET HOURS
1966– 951
1967– 1,060
TEMPERATURE (°C)
MEAN NO. FISH / GILL NET / 24 HOURS
JUL. AUG. SEP. OCT. NOV. DEC.
1966
MAR. APR. MAY JUN. JUL. AUG. SEP. OCT. NOV. DEC.
1967
NO. GILL NET HOURS
SHALLOW: 75 108 – – 25 90 19 – 62 96 – 96 17 – – –
FLAT: 73 120 – 133 136 94 36 – 80 72 144 116 89 – 21 105
CHANNEL: 4 60 – – 9 25 – – 14 36 – 36 – – 21 –

Table 14. The average catch of carp per experimental gill net per 24 hours for three depth categories and three 24-hour sampling programs in Pool 19, Mississippi River. The average number of fish caught per station (12 hours of actual netting) was multiplied by two to give the data in terms of catch per 24 hours

Date	No. Fish	Number Stations	Depth Category	Average catch per experimental gill per 24 hours
1966				
August 3-28	186	10	<3 ft.	32.4
		9	3-8 ft.	4.6
		5	>8 ft.	1.2
1967				
June 25-July 10	136	8	<3 ft.	31.8
		6	3-8 ft.	2.6
		3	>8 ft.	0.6
August 17-28	105	8	<3 ft.	22.5
		6	3-8 ft.	5.0
		3	>8 ft.	0

captured in nets set in the navigational channel, one at transect 7 station 3 during August, 1966 and one at transect 3 station 5 during June, 1967. Carlander (1953) found the carp of Clear Lake, Iowa showed no marked peaks in daily activity. Carp in the present study exhibited a higher degree of activity during the night, particularly at 8-10 PM for all three 24-hour sampling programs (Figure 27). The catch at 8-10 PM during August, 1966, demonstrated that in 1966 carp were distinctly more active than they were during any other 2-hour period. Trends in 1967 were less pronounced, but slight increases in numbers captured during the night periods were evident. The peak in catch encountered at 8-10 AM during June, 1967, was believed to have resulted from spawning activities observed at that time. Catch at two vegetated stations (transect 5, station 1 and transect 4 station 1) accounted

Figure 27. Daily activity pattern for the carp as reflected in the total catch of fish from gill nets set for 2 hours during three 24-hour sampling programs in 1966-67, Pool 19, Mississippi River


CARP
AUGUST 3-28,1966
(19 STATIONS-186 FISH)
JUNE 25-JULY 10,1967
(12 STATIONS-136 FISH)
AUGUST 17-28,1967
(12 STATIONS-105 FISH)
NO. FISH / 2 HOURS
0
10
20
30
40
50
60
8-10 AM
12-2 PM
4-6 PM
8-10 PM
12-2 AM
4-6 AM
TIME

for 32 of the 46 carp captured during the 8-10 AM period in June, 1967. Three gill nets set for 24-hours each parallel and perpendicular to the shore indicated that an outward migration for this species may occur.

Food habits

The average volumes eaten by carp attained seasonal peaks in spring (Table 15A, 15B). The amount of food eaten by carp in Honig's Slough (1.54 cc) was less than amounts found in carp from the open river during the same period (2.76 cc), and throughout 1966-1967 which may mean carp in Honig's Slough had less food available.

The diurnal peaks in the amount of food eaten at 12-2 AM and 4-6 AM (Figure 28) were preceded by the maximum amount of activity exhibited by carp at 8-10 PM. It would appear, as with most other fish investigated, that activity of carp was closely related to food gathering.

Food habit studies of carp summarized by Moen (1953) indicated that in general carp were omnivorous and food eaten consisted mainly of animal matter, though plant material and unidentified detritus were predominant in some fish. The animal material in stomachs consisted of insect larvae, small crustaceans and snails. Plant matter was composed of debris, plant seeds and fragments. Stomachs from carp captured during winter contained about equal amounts of small crustaceans and midge larvae.

Vaas and Vaas (1959) who worked in Indonesia presented an extensive review of the literature particularly from pond studies. A wide variety of natural foods were utilized by carp, apparently according to their relative availability in the bottom fauna. Wide differences were often observed between gut contents of fish from the same pond. Bottom fauna, particularly

Table 15A. Number, volume (cc) and occurrence of the material ingested by carp in the open river habitat, July, 1966 to December, 1967. (t=trace, p=present)

Date	No. Stations	No. Stomachs w/food		Sphaeriidae	*Hexagenia*	Chironomidae	Vegetation	*Oecetis* sp.	*Hyalella*	Unidentifiable	Total Volume per Fish
1966											
July 15-21	9	16	No.	6	0	1	0	p	0	-	
			Vol.	1.49	0	t	0	t	0	.16	1.65
			Occur.	16	0	4	0	2	0	3	
Aug. 1-15	12	19	No.	3	0	2	0	2	0	-	
			Vol.	.59	0	t	0	.01	0	.10	.70
			Occur.	18	0	7	0	7	0	10	
Aug. 15-31	11	24	No.	14	0	1	-	p	p	-	
			Vol.	.53	0	t	.02	t	t	.07	.62
			Occur.	19	0	13	3	1	1	7	
Nov. 15-31	1	1	No.	1	0	5	0	0	0	0	
			Vol.	.44	0	t	0	0	0	0	.44
			Occur.	1	0	1	0	0	0	0	
Dec. 15-31	1	1	No.	9	0	41	0	2	1	0	
			Vol.	.39	0	.01	0	t	t	0	.40
			Occur.	1	0	1	0	1	1	0	
1967											
May 1-15	2	4	No.	2	1	7	-	6	p	-	
			Vol.	.24	.01	.02	.35	.08	t	2.06	2.76
			Occur.	2	1	2	2	2	1	3	
June 15-30	8	17	No.	8	3	1	-	1	p	-	
			Vol.	.81	.20	t	.01	t	t	.30	1.32
			Occur.	12	6	4	3	1	1	11	
July 1-15	7	16	No.	3	3	2	-	p	0	-	
			Vol.	.35	.79	t	.02	t	0	.50	1.66
			Occur.	6	7	4	2	2	0	11	
Aug. 1-15	1	2	No.	6	0	9	0	2	0	-	
			Vol.	.55	0	t	0	.01	0	.37	.93
			Occur.	2	0	2	0	1	0	2	

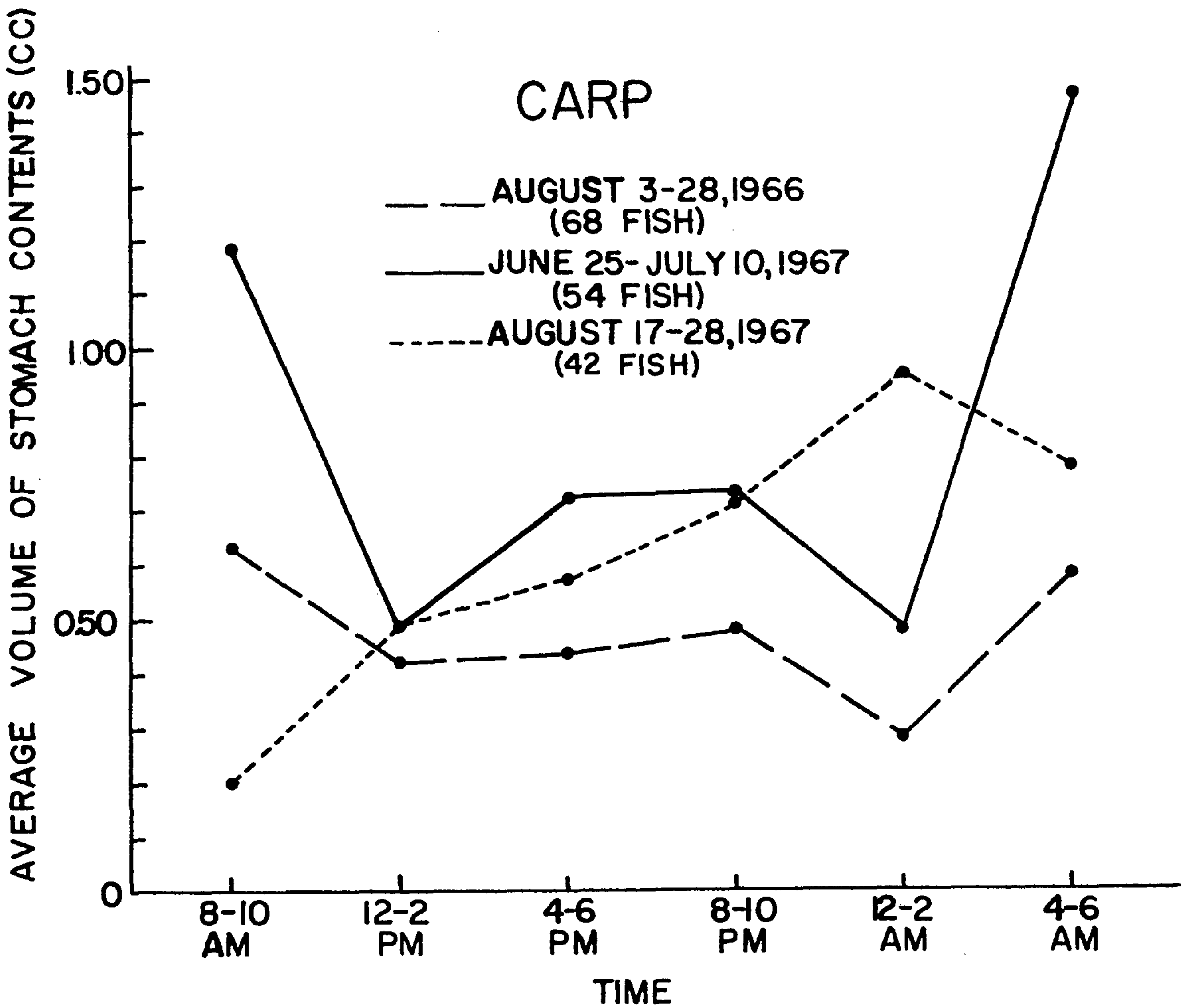
Table 15A. Continued

Date	No. Stations	No. Stomachs w/food		Sphaeriidae	*Hexagenia*	Chironomidae	Vegetation	*Oecetis* sp.	*Hyalella*	Unidentifiable	Total Volume per Fish
Aug. 15-31	9	22	No.	4	0	2	-	3	0	-	
			Vol.	.64	0	t	.08	.02	0	.22	.96
			Occur.	17	0	8	2	13	0	18	
Nov. 15-30	1	1	No.	0	0	6	0	0	0	0	
			Vol.	0	0	t	0	0	0	0	t
			Occur.	0	0	1	0	0	0	0	
Dec. 1-15	1	1	No.	0	0	1	0	0	38	0	
			Vol.	0	0	t	0	0	.03	0	.03
			Occur.	0	0	1	0	0	1	0	

Table 15B. Number, volume (cc) and occurrence of the material ingested by carp in the backwater area of Honig's Slough, August, 1966 to August, 1967. (t=trace, p=present)

Date	No. Stations	No. Stomachs w/food		Sphaeriidae	Chironomidae	Ostracoda	Cladocera	Unidentifiable	Total Volume per Fish
1966									
Aug. 15-31	2	2	No.	0	3	362	387	-	.81
			Vol.	0	.01	.12	.13	.55	
			Occur.	0	2	1	1	2	
1967									
May 1-15	1	2	No.	0	30	5	0	-	1.54
			Vol.	0	1.49	t	0	.05	
			Occur.	0	2	1	0	1	
June 15-30	2	9	No.	0	22	41	0	-	.72
			Vol.	0	.16	t	0	.56	
			Occur.	0	8	2	0	8	
July 1-15	2	6	No.	p	11	1	0	-	.44
			Vol.	t	.11	t	0	.33	
			Occur.	1	6	1	0	6	
Aug. 1-15	1	3	No.	0	5	27	0	-	.16
			Vol.	0	t	t	0	.16	
			Occur.	0	1	2	0	3	
Aug. 15-31	2	3	No.	33	4	41	0	-	.21
			Vol.	.01	t	t	0	.20	
			Occur.	1	3	2	0	3	

Figure 28. Average volume of stomach contents over a 24-hour period for carp taken in Pool 19, Mississippi River during August 3-28, 1966, June 25-July 10 and August 17-28, 1967


CARP
AUGUST 3-28, 1966 (68 FISH)
JUNE 25- JULY 10, 1967 (54 FISH)
AUGUST 17-28, 1967 (42 FISH)
AVERAGE VOLUME OF STOMACH CONTENTS (CC)
1.50
1.00
0.50
0
8-10 AM
12-2 PM
4-6 PM
8-10 PM
12-2 AM
4-6 AM
TIME

midge larvae, were nearly always important food items. Vegetation was utilized in the absence of animal food.

Recent studies by Walburg and Nelson (1966) of carp feeding habits in Lewis and Clark Lake, Missouri River found the following composition of items in the diet: organic detritus (61%), insects (19%), microcrustaceans (10%), and phytoplankton (9%). During the summer of 1958 carp from the Des Moines River fed mostly on seeds (22.3%), other plant material (54.8%), and insects (10.3%), mostly chironomids (Rehder, 1959). Earthworms and terrestrial insects were important during floods. Coker (1930) noted carp aggregated in the tailwaters of Pool 19, Mississippi River were in the process of eating floating bodies of an accumulated mass of *Hexagenia*. Seven stomachs examined from these fish revealed the remains of adult mayflies. Wenke (1965) examined the stomachs of 36 carp from Pool 19, 30 of which contained food. Approximately 24% of the food eaten was unidentifiable. During June, carp had eaten caddisfly larvae, high percentages of mollusks, plant remains, and *Hexagenia*. Stomachs of fish collected during July contained plant remains, gastropods, *Hexagenia*, and one fish collected near Fort Madison had ingested fingernail clams in large amounts. In August, fingernail clams predominated carp diets. Mills, Starrett, and Bellrose (1966) noted that Sphaeriidae were an important part of the food of carp from the Illinois River

In the present study, 46 stomachs of 113 examined from the 1966 collections were empty, while 26 of 112 carp taken in 1967 contained no food. The pharyngeal teeth possessed by carp reduced most food eaten, especially fingernail clams, to a mass of finely ground pieces. Since only whole fingernail clams and chironomids could be readily counted, the number of these organisms was underestimated. Recorded volumes were more accurate because both broken and whole organisms were measured.

As food organisms eaten by fish of different lengths from a given area were not found to be different, no separation as to size of fish was attempted. However, carp from the lake-like environment of Honig's Slough and those from the open river exhibited qualitative differences in food ingested. As a result, the food habit analyses of fish from these two locations were treated individually.

Material classified as unidentifiable was composed of detritus, mostly of plant origin. Unidentifiable stomach contents from most carp were examined microscopically for algae. No additional identifications of zooplankton were made, but diatoms were found in six fish.

The diet of carp from shallow habitat of the open river was largely composed of fingernail clams (Table 15A). The only two carp captured in the navigational channel (transect 7 station 3 in 1967 and transect 3 station 5 in 1966) had also eaten fingernail clams although most of the food in one stomach was classified unidentifiable. The naiads and exuviae of Hexagenia constituted a significant portion of the diet of carp during June and July. Chironomids were found in fish from the open river during every period of the investigation but were never important volumetrically. Vegetation in the form of aquatic plant fragments occurred in 12 of 124 carp taken and only attained importance during May, 1967. Oecetis sp. were found in stomachs fairly consistently, but were unimportant as a major food item. Hyalella comprised the entirety of food consumed by a single carp captured in December, 1967.

Contents classified as unidentifiable comprised about 10% of the volume of food eaten by carp during 1966 but a much greater part of the total diet during 1967, especially during May when almost three-fourths of the food eaten had to be classified as unidentifiable. This might indicate that appropriate food during May was scarce, thus forcing the fish to consume more bottom detritus to maintain themselves.

The percentage composition by volume of the material ingested by open river carp pointed out the major importance of Sphaeriidae in their diet (Figure 29). The only other important items were Hexagenia which were eaten during June and July, and unidentifiable matter which comprised a large part of the diet in June.

Chironomidae along with detritus were the mainstays of carp collected in Honig's Slough (Table 15B). Chironomids comprised the greatest volume in the diet during May and June, when these larvae were also important for other species studied. Negligible amounts of midge larvae were found in the diet during August. Unidentifiable material comprised a large portion of the food eaten by carp in Honig's Slough during all periods except May, 1967. Ostracods and cladocerans were numerically abundant in the food eaten by the carp throughout the summer but they comprised only a minimal part of the amount consumed. Oecetis sp. was apparently utilized only in the river since none were eaten by fish in Honig's Slough. The absence of Hyalella in the diet is strange, since these organisms were shown to be very abundant in bottom samples taken in July and August in Honig's Slough. Perhaps the bottom feeding habits of the carp prevents it from catching this amphipod while vegetation is present, where these mobile organisms usually reside. The occurrence of large numbers of Hyalella in the digestive tract of a single carp captured during December may be a reflection of

Figure 29. Percentage composition by volume of the material ingested by carp captured in the open river from July, 1966 to December, 1967 in Pool 19, Mississippi River

CARP - OPEN RIVER

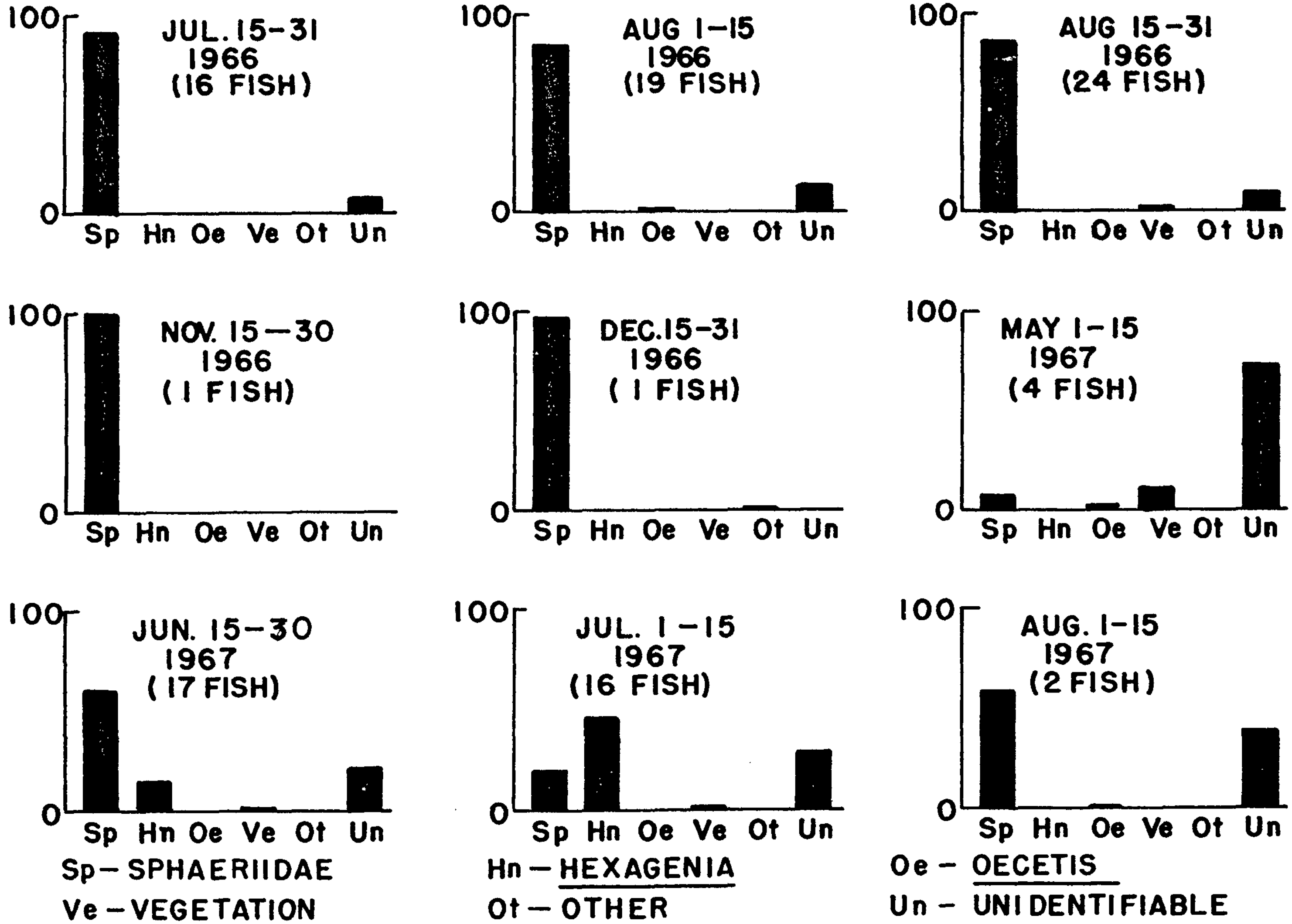
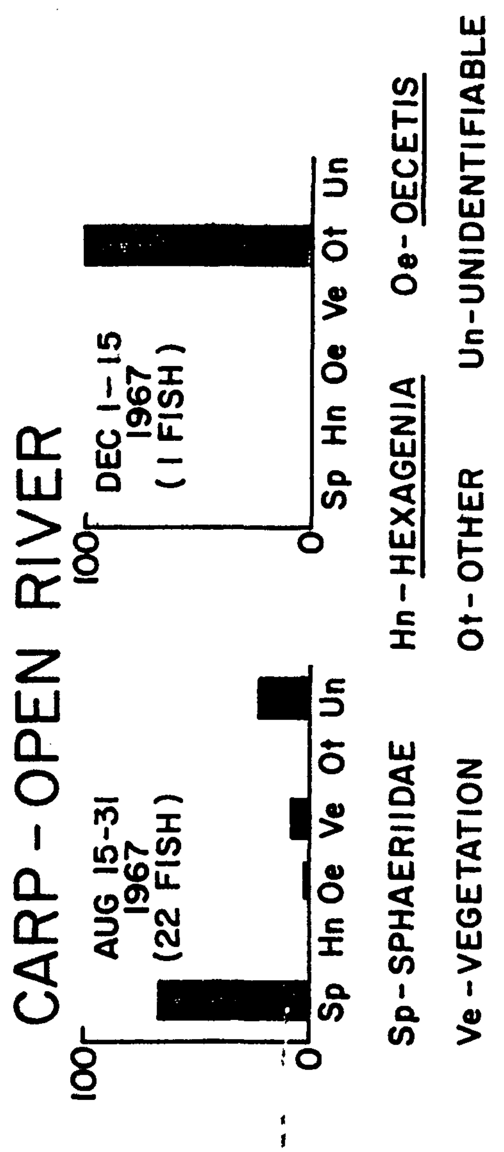


Figure 29. Continued



CARP - OPEN RIVER
AUG 15-31
1967
(22 FISH)
DEC 1 – 15
1967
(I FISH)
100
0
Sp Hn Oe Ve Ot Un
Sp - SPHAERIIDAE
Hn - HEXAGENIA
Oe - OECETIS
Ve - VEGETATION
Ot - OTHER
Un - UNIDENTIFIABLE

of increased abundance or availability of Hyalella in the benthos (Table 7A), when vegetation dies and falls to the bottom.

Calculating the percentage composition by volume of the material eaten by carp in Honig's Slough points out that chironomids and unidentified material were the dominant foods found in carp stomachs (Figure 30). Chironomids were most important in May while material classified as unidentifiable comprised the greatest percentage of the diet in all other periods during which carp were captured.

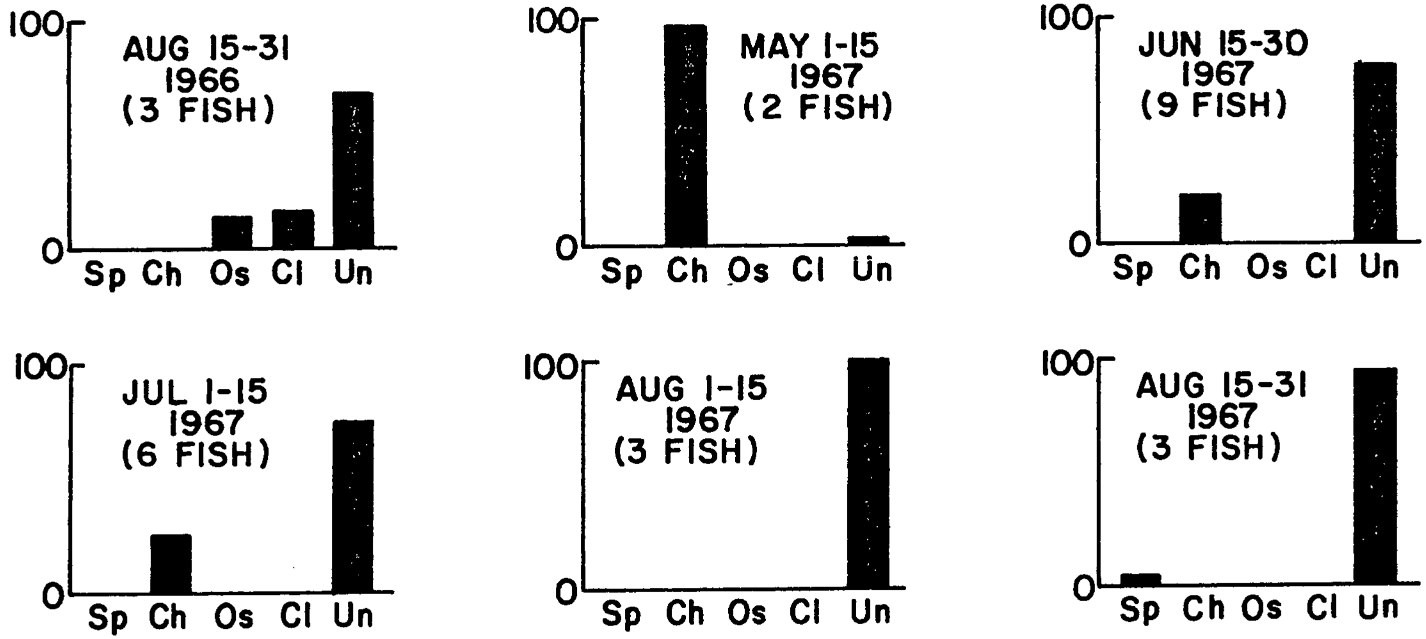
Contrasting the food of carp from the two habitats demonstrated that fish in the open river were most dependent on fingernail clams although Hexagenia were important during June and July. Chironomids appeared in large amounts in stomachs collected during May from carp in the open river as well as fish from Honig's Slough. Carp from the backwater area, however, had eaten midge larvae over a greater length of time. Unidentifiable material was the major constituent of the diet of fish from Honig's Slough otherwise

Bottom fauna utilization

To show the degree of bottom fauna utilization for sphaeriids in the open river the average volume of fingernail clams found in fish stomachs was plotted against the number of clams per square meter in the bottom (Figure 31). Numbers of chironomids in stomachs were similarly plotted against numbers of midge larvae in the bottom fauna of shallow habitat, in hopes that numerical trends in the fauna of the river would be similar to trends in Honig's Slough. Trends in abundance of fingernail clams in the fauna seemed to be generally related to the amount eaten by carp in 1967.

Figure 30. Percentage composition by volume of the material ingested by carp captured in Honig's Slough from August, 1966 to August, 1967 in Pool 19, Mississippi River

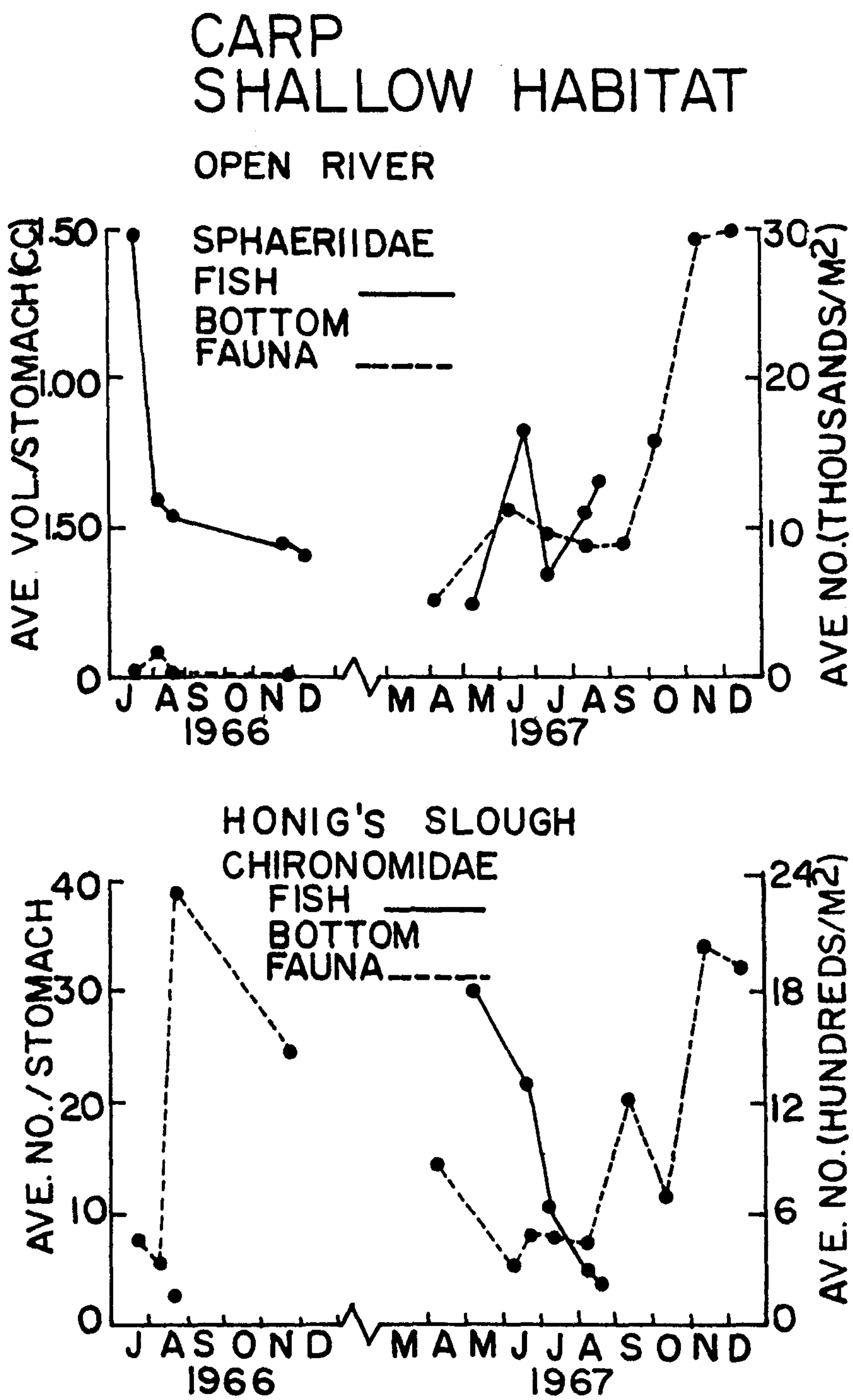
CARP - HONIG'S SLOUGH



Sp - SPHAERIIDAE   Ch - CHIRONOMIDAE   Os - OSTRACODA

Cl - CLADOCERA   Un - UNIDENTIFIABLE

Figure 31. Utilization of two benthos groups, Sphaeriidae in the open river, and Chironomidae in Honig's Slough, by carp during 1966-67 in Pool 19, Mississippi River


CARP
SHALLOW HABITAT
OPEN RIVER
SPHAERIIDAE
FISH
BOTTOM
FAUNA
AVE. VOL./STOMACH (CC)
AVE. NO. (THOUSANDS/M2)
0
.50
1.00
1.50
10
20
30
J A S O N D
1966
M A M J J A S O N D
1967
HONIG'S SLOUGH
CHIRONOMIDAE
FISH
BOTTOM
FAUNA
AVE. NO./STOMACH
AVE. NO. (HUNDREDS/M2)
0
10
20
30
40
6
12
18
24
J A S O N D
1966
M A M J J A S O N D
1967

If the same decrease as observed in 1966 was indicative of conditions during the fall and winter of 1967, either the preference for clams was lost, or lowered temperatures were responsible for the decreased amounts of sphaeriids eaten.

Populations of chironomids in the shallow habitat of the open river appeared to be directly related to the number eaten by carp. Apparently carp are bottom sifters, eating certain organisms proportional to their abundance in the sediments.

Gizzard Shad

Gizzard shad are present in all pools of the Upper Mississippi River. They held a rather unique position among the fishes studied and were undoubtedly the most numerous fish found in Pool 19 as attested by the 1,368 individuals taken in gill nets ranking it first among species captured. Gizzard shad appeared in virtually every net set and the numbers selected for food analysis were the second highest. Shad furnish a direct route in the food chain between the primary producers and the other predaceous fish of the river, found by Ranthum (1968) to prey heavily upon this species. Young shad soon grow past the 6-inch upper limit, beyond which few are preyed upon and no commercial use of these large fish has been developed. Thus their importance as a forage fish may be balanced by their more detrimental role as competitors for food and space, displacing more commercially important species. Since the two most important commercial fish, catfish and carp, fed upon negligible quantities of gizzard shad, their importance even as forage fish is doubtful. Sauger, a fish of limited value for sport fishermen in Pool 19, depended heavily upon gizzard shad for food (Ranthum, 1968).

Distribution

Gizzard shad were taken at all 41 permanent stations sampled during 1966-1968. Shad were captured at transect 2 in 1966 prior to the 24-hour sampling program in August, but none were captured with the 24 hours of gill netting expended there during August. Dissolved oxygen values were recorded at 4.4 ppm for the bottom at 11 AM on July 22 during the time the shad were present in the slough. Oxygen values probably were greatly reduced during the night and later in August, so that shad, which are susceptible to reduced dissolved oxygen (Trautman, 1957), may have been eliminated In 1967, however, shad were taken during both sampling periods in June and August, which may be related to the fact that Lemna which had covered the slough in 1966 was much reduced in quantity in 1967. During sampling activities in March, 1967 about 5,000 dead gizzard shad were noted along 200 yards of shoreline near transect 4 station 1. Other species were also noted. Fishermen stated that it was a common occurrence in this section of the river to find gizzard shad of all sizes dead along the shore in spring. Bodola (1964) reported similar occurrences for Lake Erie gizzard shad.

Gizzard shad captured in gill nets during 1966 (647) and 1967 (721) were separated into three size groups to better portray the trends in seasonal catch-per-effort values. During 1966, 21 shad captured were less than 6 inches long, 394 were between 6 and 10 inches, and 234 were greater than 10 inches. They ranged from 4.4 to 17.4 inches in total length. In 1967 the range was from 4.3 to 16.9 inches, with 216 being less than 6 inches, 188 between 6 and 10 inches, and 316 greater than 10 inches.

The catch-per-effort values for all sizes of gizzard shad showed that catch followed the trends in temperature fairly well. The peak in 1960 was recorded in latter July, whereas, the largest catch-per-effort values in 1967 were found during September, when young-of-the-year gizzard shad were predominate in the catch Catch-per-effort values segregated by habitat types demonstrated that gizzard shad were about equally catchable in all three habitats, however some differences were apparent. In 1967 catch-per-effort in the channel was lowest, lower than 1966 values. Highest catches were obtained in shallow water, while catch-per-day on the flats was between shallow and channel catch-per-effort values.

Differences between catches of the three sizes of gizzard shad in shallow and flats habitat are pronounced (Figure 32A, 32B, 33). Fish less than 6 inches, mostly young-of-the-year, became prevalent in gill net catches during August and September, when they grew to a size recruitable to the smallest mesh in the gill nets. Most of these fish were around 4 inches long. The large increase in catch of shad less than 6 inches to an average of 80 fish per net per 24 hours in shallow habitat, 1967, was somewhat biased, as were catch-per-effort values for the other sizes of gizzard shad captured in September. The catch was larger than average during September because data gathered came mostly from transect 4 station 1 where the highest catch-per-effort for almost all species was found. The difference between numbers of young-of-the-year captured during 1966 and 1967 indicated a larger population of young in 1967. Fish between 6 and 10 inches followed fairly closely the trends in catch-per-effort shown for larger fish. Gizzard shad greater than 10 inches were found in largest numbers in the early spring and fall in shallow habitat. During summer they exhibited an outward movement from shallow habitat (shown by lower catch per day during the summer in shallow habitat) where they were found in greatest numbers in flats and channel habitat. These latter relationships were not as well shown in 1967. Bodola (1964) in his Lake Erie study noted that as gizzard shad grew larger they tended to move offshore into deeper water. The only time he was able to capture large age-group VI shad was during the spawning season (June-July) when they were found in shallow waters.

Catch-per-effort values for large shad in shallow habitat demonstrated

Figure 32A. Water temperature and mean catch per gill net of three size groups of gizzard shad in the shallow habitat of Pool 19, Mississippi River

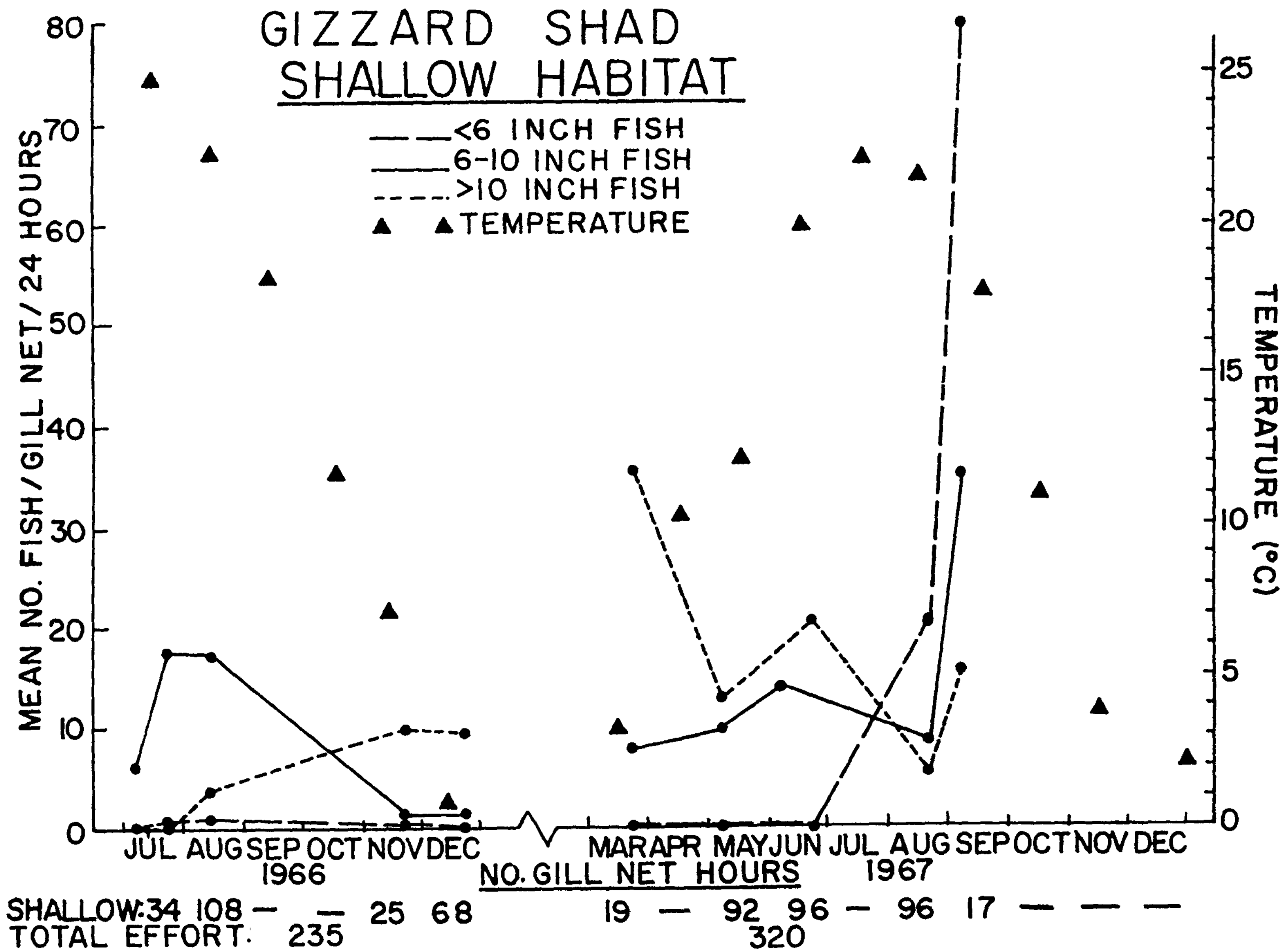

GIZZARD SHAD
SHALLOW HABITAT
<6 INCH FISH
6-10 INCH FISH
>10 INCH FISH
TEMPERATURE
MEAN NO. FISH / GILL NET / 24 HOURS
0
10
20
30
40
50
60
70
80
TEMPERATURE (°C)
0
5
10
15
20
25
JUL AUG SEP OCT NOV DEC
1966
MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1967
NO. GILL NET HOURS
SHALLOW: 34 108 — — 25 68 19 — 92 96 — 96 17 — — —
TOTAL EFFORT: 235 320

Figure 32B. Water temperature and mean catch per gill net of three size groups fo gizzard shad in the flats habitat of Pool 19, Mississippi River

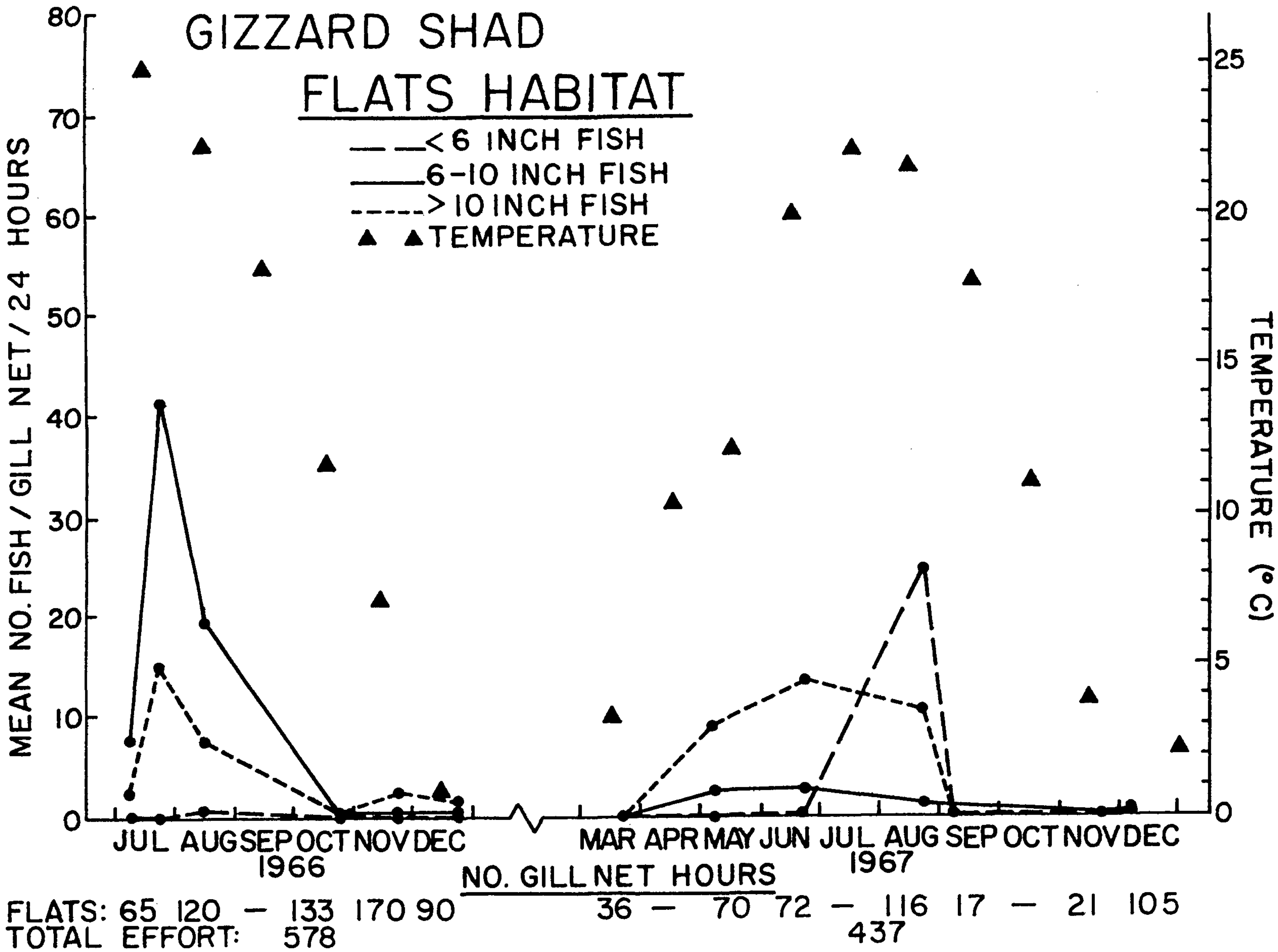
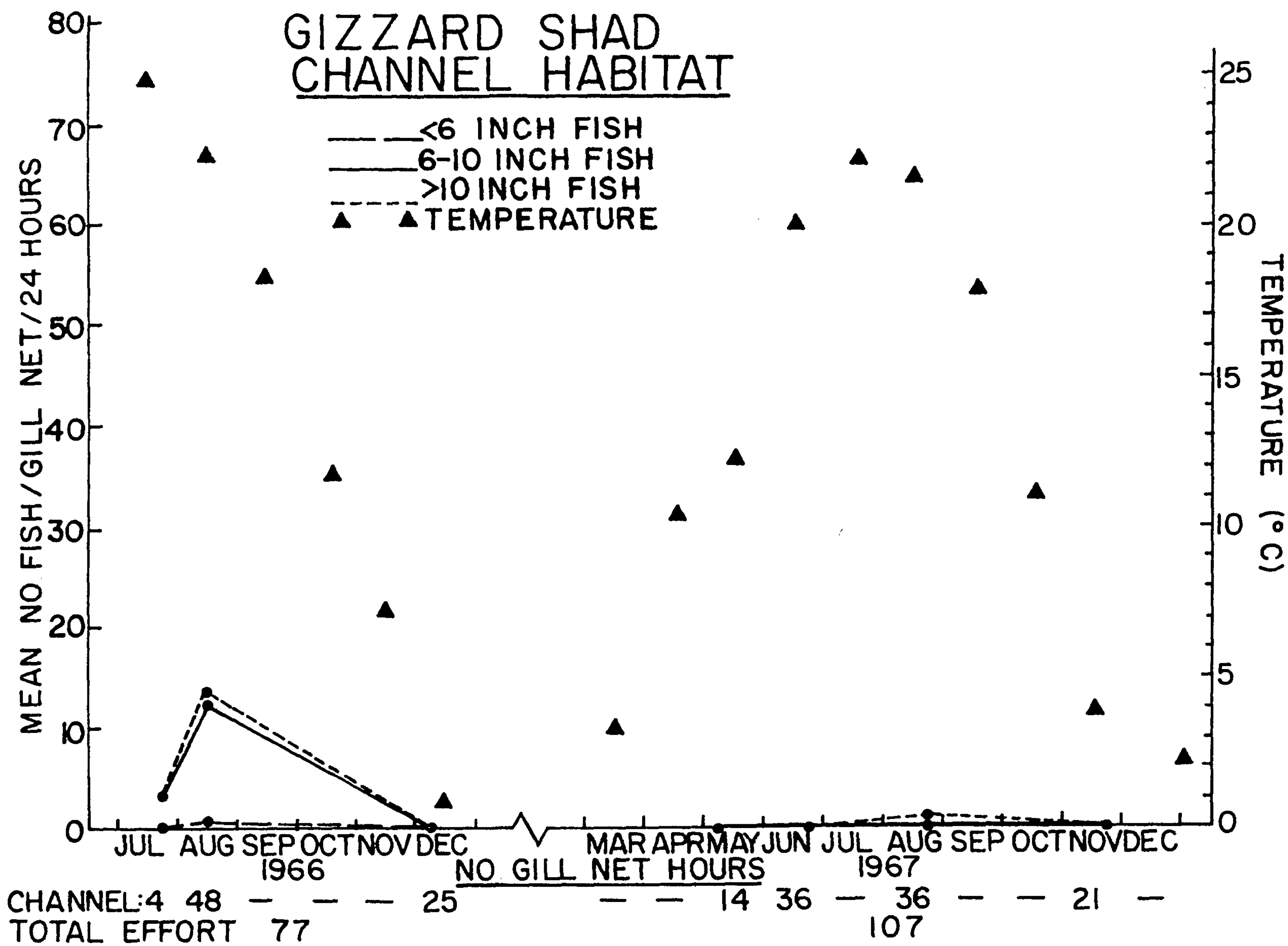

GIZZARD SHAD
FLATS HABITAT
<6 INCH FISH
6-10 INCH FISH
>10 INCH FISH
TEMPERATURE
MEAN NO. FISH / GILL NET / 24 HOURS
TEMPERATURE (° C)
0
10
20
30
40
50
60
70
80
5
15
25
JUL AUG SEP OCT NOV DEC
1966
MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1967
NO. GILL NET HOURS
FLATS: 65 120 — 133 170 90
TOTAL EFFORT: 578
36 — 70 72 — 116 17 — 21 105
437

Figure 33. Water temperature and mean catch per gill net of three size groups of gizzard shad in the channel habitat of Pool 19, Mississippi River


GIZZARD SHAD
CHANNEL HABITAT
<6 INCH FISH
6-10 INCH FISH
>10 INCH FISH
TEMPERATURE
MEAN NO FISH/GILL NET/24 HOURS
TEMPERATURE (°C)
JUL AUG SEP OCT NOV DEC
1966
NO GILL NET HOURS
MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1967
CHANNEL:4 48 — — — 25 — — 14 36 — 36 — — 21 —
TOTAL EFFORT 77 107

two peaks of higher catch which were much lower than the values exhibited for the 6-10 inch fish. During March, April, May, and June, particularly March, the catch was much higher for these large-sized individuals in shallow habitat. This relatively high catch was undoubtedly associated with spawning activities. Harlan and Speaker (1956) reported that gizzard shad spawned during April or May in Iowa. In Lake Erie, gizzard shad spawning occurred around June and July when inshore movements of shad were recorded (Bodola, 1964).

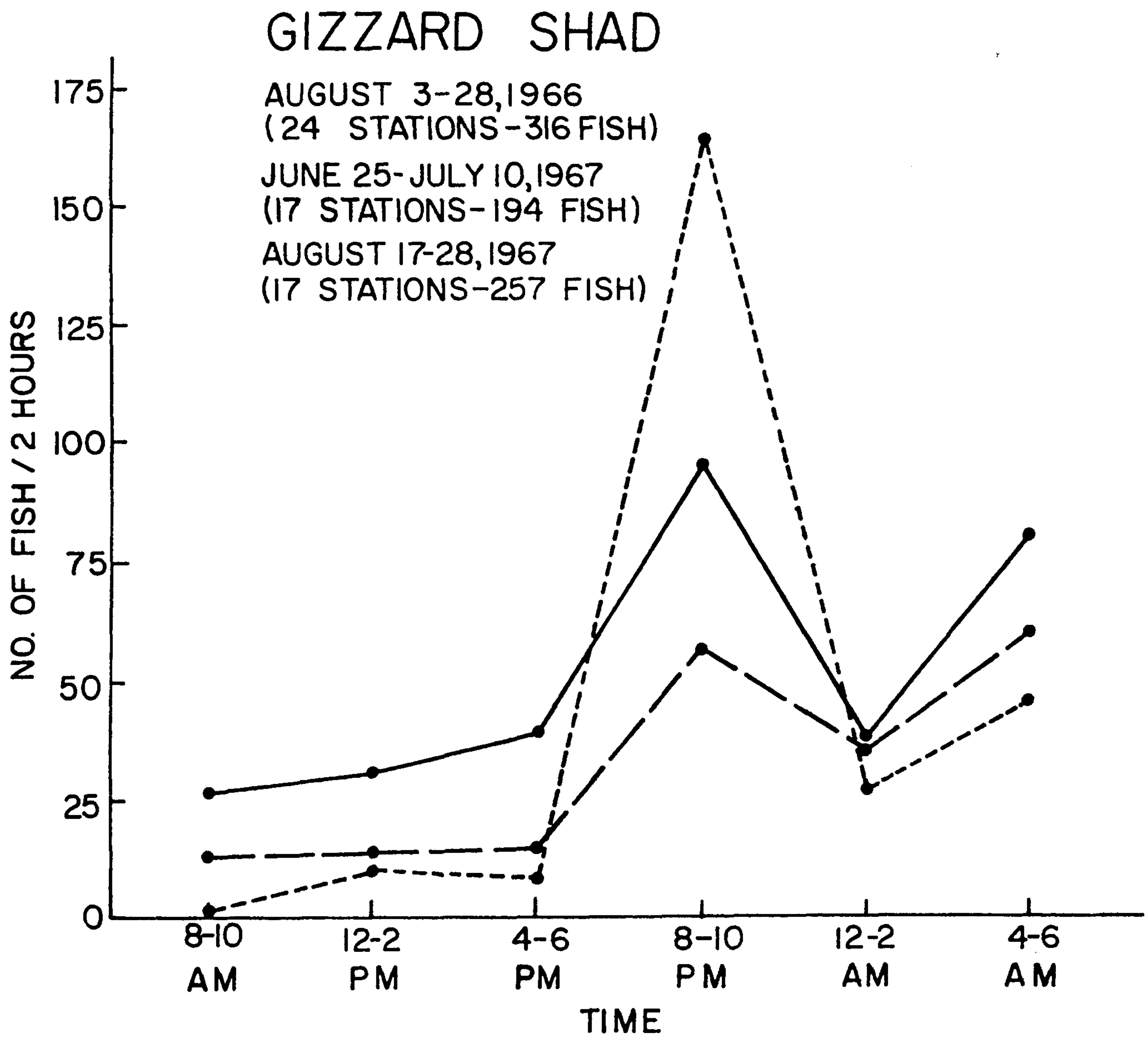
The other difference between the catch of gizzard shad 6-10 inches and those greater than 10 inches was the increase in catch of fish greater than 10 inches during the winter months which was clearly shown in the 1966 data. Activity for fish less than 10 inches as reflected in catch-per-effort values was at a minimum during these winter months. The increased movement by these large gizzard shad was not associated with food gathering activities since of 44 fish stomachs examined during this period, only 10 contained minimal amounts of unidentifiable material. Swanson (1932) recorded a mid-winter migration of gizzard shad in the Minnesota River near Shakopee, Minnesota. Great numbers of shad appeared in the river around the first of December and were present until January. The mild weather in the first part of the winter was cited as a possible reason for the unusual movements

Catch-per-effort in channel habitat demonstrated that few gizzard shad less than 6 inches were found there during 1966-1967. Catches per day of the 6-10 inch shad, and those greater than 10 inches were similar in 1966, apparently indicating equal abundance of these two size groups in the channel. In 1967 catch-per-effort was considerably lower which was due to station differences. The larger gizzard shad (greater than 10 inches) exhibited the highest catch-per-effort during August, as in 1966.

The depth distribution of the gizzard shad for the August, 1966 24-hour sampling program indicated equal preference for the three depth categories (Table 16). During August, 1967, catch was greatest at flats stations (66.6 fish per net per 24 hours), and least (1.4 fish per net per 24 hours) for channel habitat. The reason for the high catch at stations from the flats compared to results found in 1966 was the contribution by young-of-the-year shad caught at transect 4 station 1, classified by depth as flats (3-8 feet). Differences between the two programs in 1967 indicated that gizzard shad might have been materially affected by the current velocities at this time (Table 3B) since none were captured in the channel, though not many more (1.4 per net per 24 hours) were captured during August. This tendency for most gizzard shad to be found in shallow water during June may be associated with spawning. It also appeared that there was a movement from shallow water after the June flood. The catch per day in shallow water (0-3 feet) during June was 34 fish, whereas only 13.8 fish were taken in shallow habitat in August. For flats habitat catch per day was 19.4 in June and 66.6 in August.

The diurnal activity of gizzard shad followed an exact pattern for all three 24-hour samples (Figure 34). Numbers captured showed bimodal peaks during two of the nightly four-hour periods. Maximum numbers were recorded at 8-10 PM with a lesser peak shown for the 4-6 AM period. Results of the continuous 24-hour sampling during 1967 (Figure 35) during which three gill nets were set at transect 4 station 3, demonstrated the bimodal peak of activity shown for gizzard shad in the major sampling programs.

Figure 34. Daily activity pattern for the gizzard shad, as reflected in the total catch of fish from gill nets set for 2 hours during three 24-hour sampling programs in 1966-67, Pool 19, Mississippi River



GIZZARD SHAD
AUGUST 3-28,1966
(24 STATIONS-316 FISH)
JUNE 25-JULY 10,1967
(17 STATIONS-194 FISH)
AUGUST 17-28,1967
(17 STATIONS-257 FISH)
NO. OF FISH / 2 HOURS
175
150
125
100
75
50
25
0
8-10 AM
12-2 PM
4-6 PM
8-10 PM
12-2 AM
4-6 AM
TIME

Figure 35. Daily activity pattern for the gizzard shad as reflected in catch per 2 hours at transect 4 station 3 during July 13-14, 18-19 and September 4-5, 1967 in Pool 19, Mississippi River

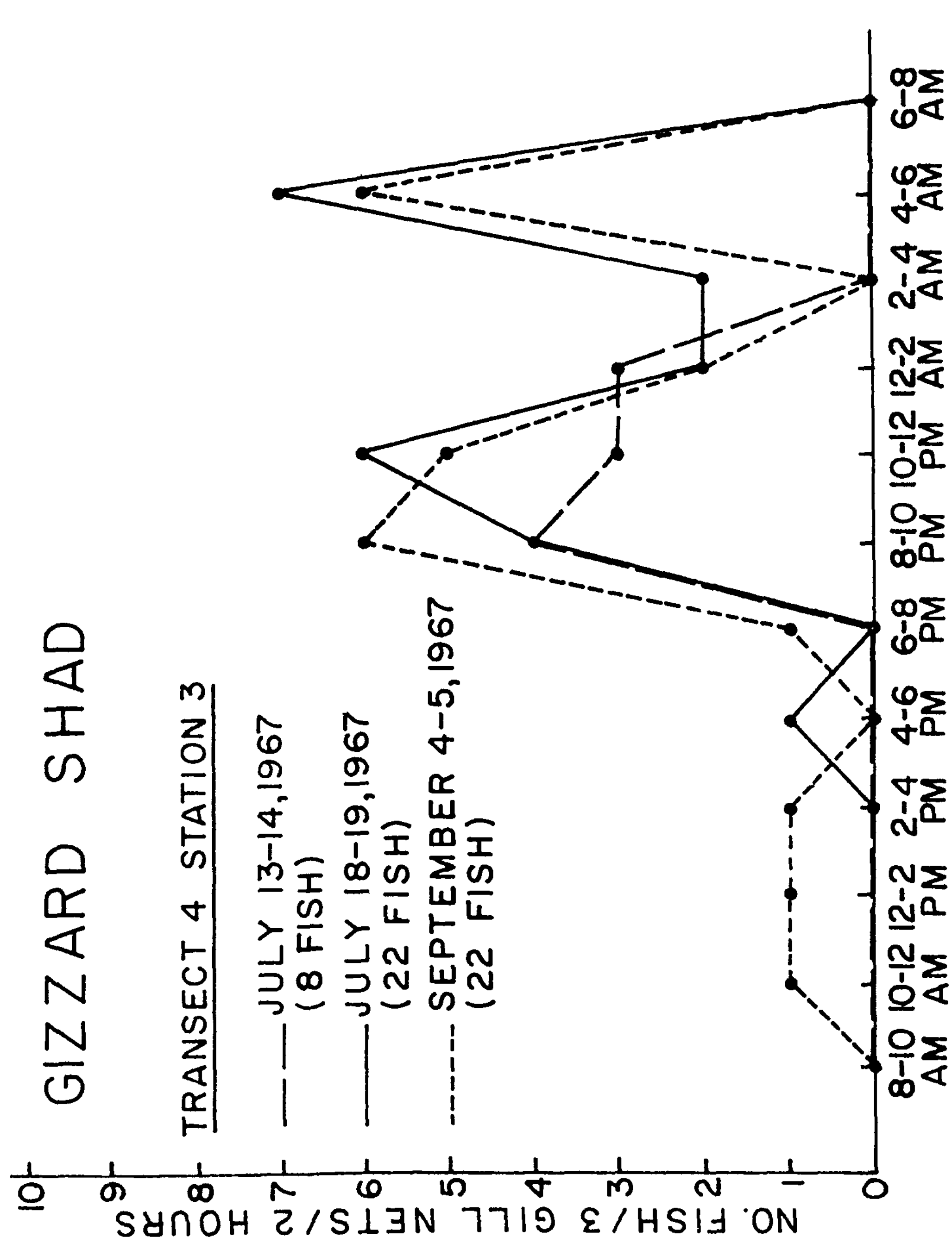

GIZZARD SHAD
TRANSECT 4 STATION 3
JULY 13-14,1967 (8 FISH)
JULY 18-19,1967 (22 FISH)
SEPTEMBER 4-5,1967 (22 FISH)
NO. FISH/3 GILL NETS/2 HOURS
0
1
2
3
4
5
6
7
8
9
10
8-10 AM
10-12 AM
12-2 PM
2-4 PM
4-6 PM
6-8 PM
8-10 PM
10-12 PM
12-2 AM
2-4 AM
4-6 AM
6-8 AM
TIME

Table 16. The average catch of gizzard shad per experimental gill net per 24 hours for three depth categories and three 24-hour sampling programs in Pool 19, Mississippi River. The average number of fish caught per station (12 hours of actual netting) was multiplied by two to give the data in terms of catch per 24 hours

Date	No. Fish	No. of Stations	Depth Category	Average Catch per Gill Net per 24 hours
1966				
August 3-28	316	10	<3 ft.	24.6
		9	3-8 ft.	27.4
		5	>8 ft	28.0
1967				
June 25-July 10	194	8	<3 ft.	34.0
		6	3-8 ft.	19.4
		3	>8 ft	0
August 17-28	257	8	<3 ft	13.8
		6	3-8 ft.	66.6
		3	>8 ft.	1.4

Food habits

An attempt was made to examine the stomach (esophagus plus gizzard) from at least one gizzard shad from each net in which they appeared. More were not sampled because these fish were very abundant and stomach analyses proved difficult. Previous studies had shown that gizzard shad of various lengths from a given area had eaten the same type of food, which was generally found to be true in the present endeavor. However, larger fish (greater than 10 inches) tended to feed more on fingernail clams than smaller individuals. In 1966, 65% of the fish examined for stomach analyses were between 8 and 12 inches, while 51% of those sampled in 1967 were in this range. Of the 347 stomachs examined, 54 were empty during 1966, and 55 were considered empty during 1967. Most of these gizzard shad were captured during the spring and fall when they had ceased feeding although many captured during the summer were also empty. Fish captured during March contained no food, while almost all taken in the first part of May contained ingested material, therefore, indicating that the initiation of feeding activities occurred sometime during April. During fall and winter, feeding seemed to cease during the first part of September. All stomachs collected from September to December were essentially empty. Some however, contained small amounts of unidentifiable material. Bodola (1964) noted that shad in Lake Erie consumed little food in winter and early spring. He stated that fish subsisted largely on energy stored in body tissues. Metabolic rates were found to be low in winter so the decrease in weight was slight.

The seasonal trend in the average amount of food eaten by gizzard shad in the present study may be somewhat biased by the presence of large gizzard shad, particularly in channel samples taken during the summer. The number of each of the three size groups (less than 6 inches, 6-10 inches, and greater than 10 inches) showed that most fish selected for stomach analyses were greater than 6 inches long (Table 17A, 17B, 17C). The tendency for gizzard shad to eat fingernail clams more occurred at 8 inches or longer, so that bias introduced was mainly in quantity of food, not quality eaten. However these differences in sizes should be born in mind when observing the data. The volume of food determined for gizzard shad captured in shallow habitat (Table 17A) was consistently lower than the volumes eaten by fish from the flats (Table 17B). The amount of food found in the stomachs of shad captured in the channel was consistently higher than volumes eaten at the other habitat types. As previously stated,

Table 17A. Number, volume (cc) and occurrence of the material ingested by gizzard shad from July, 1966 to August, 1967 in the shallow habitat of Pool 19, Mississippi River. (t=trace, p=present)

Date	No. Stations	>6 inches	6-10 inches	>10 inches		Sphaeriidae	Sand	Unidentifiable & Algae	Fontigens	Cladocera	Ostracoda	Chironomidae	Total Volume per Fish
1966													
July	3	0	6	1	No.	3	-	-	2	0	0	1	
15-31					Vol.	.02	.02	.03	.01	0	0	t	.08
					Occ.	5	5	5	3	0	0	3	
Aug.	7	1	9	6	No.	1	-	-	p	8	p	1	
1-15					Vol.	.02	.01	.08	t	t	t	t	.11
					Occ.	3	4	16	1	7	3	6	
Aug.	6	3	7	4	No.	1	-	-	0	4	10	1	
15-31					Vol.	.01	.01	.12	0	t	t	t	.14
					Occ.	3	4	13	0	6	4	2	
1967													
March	1	0	0	1	No.	0	0	0	0	0	56	0	
15-31					Vol.	0	0	0	0	0	t	0	t
					Occ.	0	0	0	0	0	1	0	
May	4	0	2	5	No.	0	-	-	0	242	80	0	
1-15					Vol.	0	.03	.20	0	.01	t	0	.24
					Occ.	0	4	6	0	4	5	0	
June	4	0	6	3	No.	p	-	-	0	122	27	p	
15-30					Vol.	t	.02	.09	0	t	t	t	.11
					Occ.	1	4	9	0	3	5	1	
July	7	0	3	10	No.	p	-	-	0	2	0	p	
1-15					Vol.	t	.02	.03	0	t	0	t	.05
					Occ.	1	6	10	0	3	0	1	
Aug.	2	1	0	1	No.	0	-	-	0	0	0	p	
1-15					Vol.	0	t	.02	0	0	0	t	.02
					Occ.	0	1	2	0	0	0	1	
Aug.	5	3	5	9	No.	0	-	-	0	7	3	1	
15-31					Vol.	0	.02	.07	0	t	t	t	.09
					Occ.	0	5	9	0	4	4	4	

Table 17B. Number, volume (cc) and occurrence of the material ingested by gizzard shad from July, 1966 to August, 1967 in the flats habitat of Pool 19, Mississippi River. (t=trace, p=present)

Date	No. Stations	No. Fish with Food >6 inches	No. Fish with Food 6-10 inches	No. Fish with Food >10 inches		Sphaeriidae	Sand	Unidentifiable & Algae	Fontigens	Cladocera	Ostracoda	Chironomidae	Total Volume per Fish
1966													
July 15-31	10	1	2	3	No.	6	-	-	7	p	p	1	
					Vol.	.07	.04	.06	.03	t	t	t	.20
					Occ.	17	20	21	21	1	1	8	
Aug. 1-15	9	0	11	9	No.	1	-	-	1	40	p	p	
					Vol.	.01	.03	.04	t	.01	0	t	.09
					Occ.	5	5	15	2	9	1	5	
Oct. 1-15	2	0	0	2	No.	0	-	-	0	p	0	1	
					Vol.	0	t	.03	0	t	0	t	.03
					Occ.	0	1	2	0	1	0	1	
Nov. 15-30	4	0	4	4	No.	0	0	-	0	3	0	0	
					Vol.	0	0	.02	0	t	0	0	.02
					Occ.	0	0	4	0	3	0	0	
1967													
May 1-15	1	0	1	10	No.	6	-	-	0	60	1	1	
					Vol.	.01	.07	.28	0	.01	t	t	.37
					Occ.	5	10	11	0	10	3	2	
June 15-30	2	0	2	8	No.	26	-	-	1	p	0	0	
					Vol.	.16	.10	.04	t	t	0	0	.30
					Occ.	10	10	6	5	2	0	0	
July 1-15	3	0	1	5	No.	6	-	-	p	0	p	p	
					Vol.	.07	.07	.21	t	0	t	t	.35
					Occ.	4	6	6	1	0	1	2	
Aug. 15-31	6	1	3	4	No.	3	-	-	p	0	0	1	
					Vol.	.03	.14	.06	t	0	0	t	.23
					Occ.	4	6	8	1	0	0	3	

Table 17C. Number, volume (cc) and occurrence of the material ingested by gizzard shad from July, 1966 to August, 1967 in the channel habitat of Pool 19, Mississippi River. (t=trace, p=present)

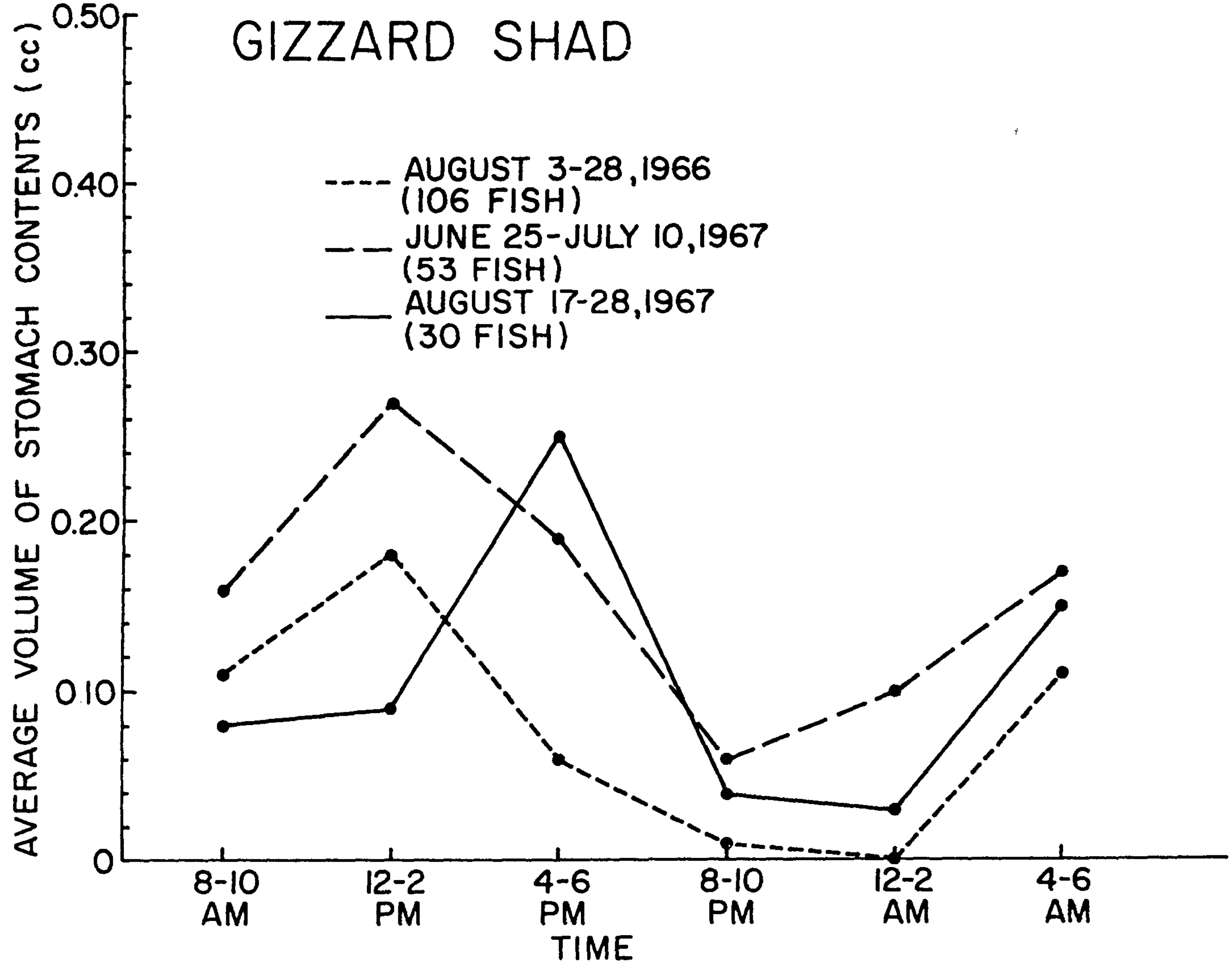
Date	No. Stations	No. Fish with Food <6 inches	6-10 inches	>10 inches		Sphaeriidae	Sand	Unidentifiagle & Algae	Fontigens	Cladocera	Ostracoda	Chironomidae	Total Volume per Fish
1966													
July 15-31	3	0	4	7	No.	10	-	-	7	0	0	p	
					Vol.	.19	t	.04	.04	0	0	t	.27
					Occ.	11	1	7	9	0	0	3	
Aug. 1-15	3	0	3	6	No.	20	-	-	1	4	0	4	
					Vol.	.26	.04	.06	.01	t	0	t	.37
					Occ.	8	4	8	2	6	0	2	
Aug. 15-30	5	0	1	12	No.	12	-	-	1	05	0	1	
					Vol.	.17	.02	.06	.01	.01	0	t	.27
					Occ.	11	5	7	5	7	0	4	
1967													
Aug. 15-31	2	0	0	2	No.	3	-	-	0	p	0	0	
					Vol.	.06	.19	.08	0	t	0	0	.33
					Occ.	1	2	2	0	1	0	0	

the reason for the higher volumes eaten by fish from the channel could be due to the larger fish captured there. Volumes of food ingested seasonally were highest in May when the first feeding activity was recorded and generally decreased to negligible quantities in October, November, and December.

The diurnal peaks in the amount of food eaten by gizzard shad were found during 4-6 AM and around 12-2 PM (Figure 36). Fish captured during June, 1967, exhibited a shifting of the second period of maximal amount eaten from what was found in the other two programs (12-2 PM) to a later time (4-6 PM). Good agreement was found between the August programs in 1966 and 1967. The peak activity periods (Figure 34, 35) were found to be at 8-10 PM and 4-6 AM. No apparent relationship was evident between the time of peak activity and the time when the peaks in food consumption were reached.

The material ingested by gizzard shad was generally similar for all habitat types, though differences in the amount eaten were apparent (Table 17A, 17B, 17C). Sphaeriids, sand, and material classified as unidentifiable comprised the major portion of the food eaten, while Fontigens nickliniana (Lea) and Cladocera were important only during certain times. Fontigens, a member of the Gastropoda, was identified by William Gale from verified specimens he collected in bottom fauna samples. Unidentified material presented problems since it was composed of varying amounts of algae which was not measured. Slides examined from almost every shad stomach contained many forms and genera of algae, especially diatoms. A greater portion of the material however, was comprised of detrital matter and finely divided mud. The detritus appeared to be fragments of plant material undoubtedly

Figure 36. Average volume of stomach contents over a 24-hour period for gizzard shad taken in Pool 19, Mississippi River during August 3-28, June 25-July 10, and August 17-28, 1967


GIZZARD SHAD
AUGUST 3-28, 1966 (106 FISH)
JUNE 25-JULY 10, 1967 (53 FISH)
AUGUST 17-28, 1967 (30 FISH)
AVERAGE VOLUME OF STOMACH CONTENTS (cc)
0
0.10
0.20
0.30
0.40
0.50
8-10 AM
12-2 PM
4-6 PM
8-10 PM
12-2 AM
4-6 AM
TIME

derived from the bottom or close to it. Therefore, the importance of the stomach contents placed in the unidentifiable category depended on the percentage of it which was algae.

Measureable fingernail clams eaten by gizzard shad were usually less than 5 mm in length. They occurred whole in the esophagus, but in a crushed condition in the gizzard, although very small sphaeriids sometimes were not crushed in gizzard contents. Fingernail clams were particularly predominant in the diet of shad greater than 10 inches in length.

In shallow habitat, gizzard shad diets were mainly composed of unidentifiable material which reached maximum amounts during May, 1967. Cladocera (Diaptomous, Daphnia, and Leptodora), were important in the diet during July, 1966 and May, 1967. Minor amounts of sphaeriids were ingested in shallow habitat during 1966, but none were eaten during 1967.

Fish captured from shallow habitat were utilizing unidentifiable material and algae to a considerable extent; whereas, sphaeriids were more important in the diet of gizzard shad caught in flats habitat. Seasonal trends in the consumption of fingernail clams eaten in flats habitat, indicated a major dependence early in the year, with declining amounts eaten until lows were reached during August. One 13.4 inch gizzard shad captured at transect 1 station 1 on August 25, 1966, had eaten .19 cc of oligochaetes. Transect 1 station 1 was also the only station where channel catfish had eaten these aquatic worms.

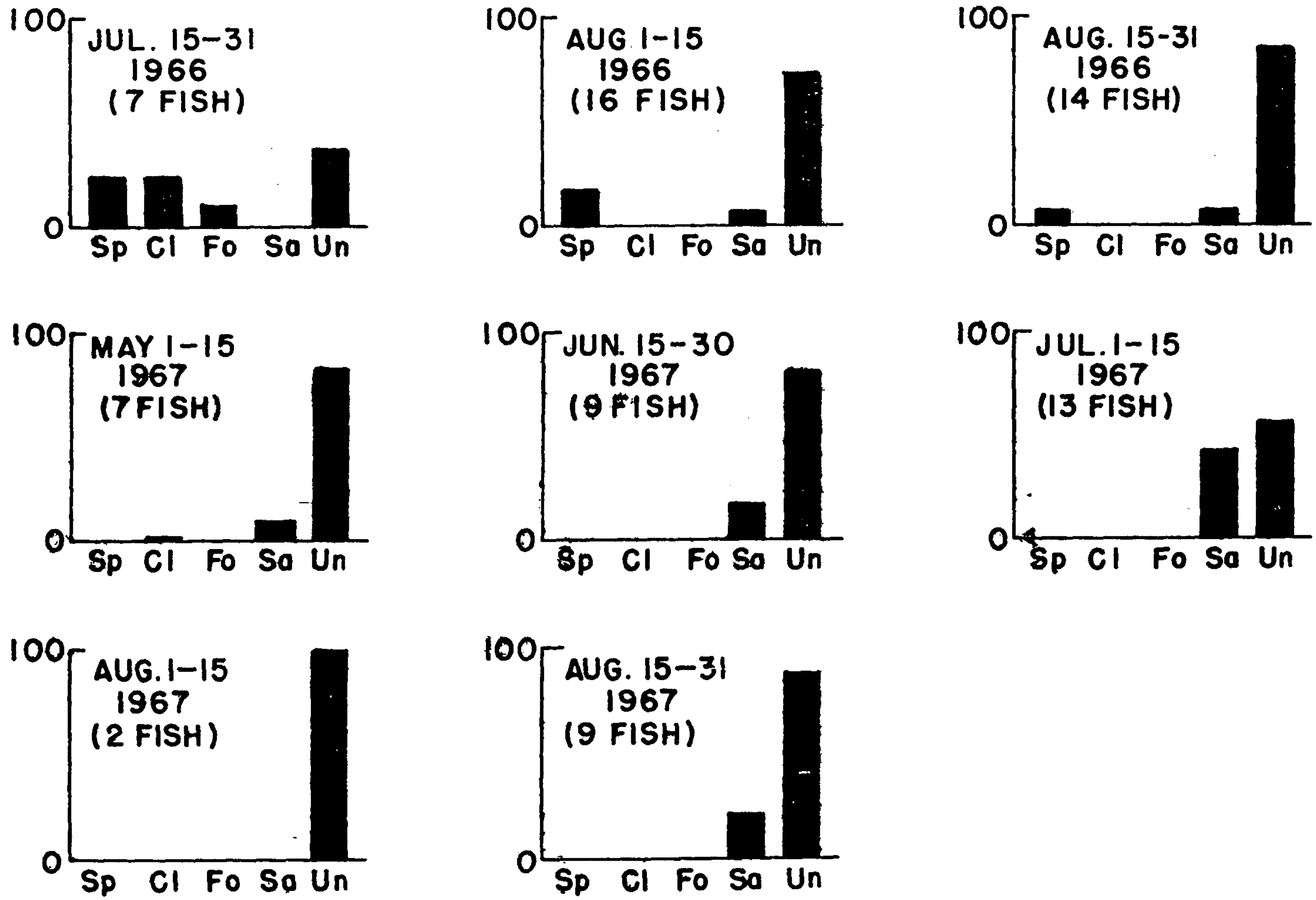
The importance of fingernail clams to gizzard shad from channel habitat may be related to fish size, since most captured there were large individuals. Sphaeriids comprised the major amount of food eaten during the four months in which stomachs were examined. Sand and Fontigens occurred in larger amounts in stomachs examined from the channel than for other habitats.

The percentage composition of the major material ingested by gizzard shad in shallow habitat showed that unidentifiable material and algae were the major foods consumed with various contributions at certain times from sphaeriids and cladocerans (Figure 37A). Sand in some quantities was found in stomachs from gizzard shad in 6 out of the 8 periods. In flats habitat the relative amount of each type of food consumed appeared to be half-way between that eaten in shallow and that in channel habitat (Figure 37B, 37C). Sphaeriids and unidentifiable material contributed about equally to the diet of gizzard shad during 1966, while unidentifiable material was the major part of the diet in 1967. Sand was present in stomachs examined in 7 out of the 9 periods on the flats, sometimes comprising a large proportion of the material ingested In channel habitat, the importance of fingernail clams to shad diets was shown (Figure 37C)

From these results, it appeared the manner of food acquisition by the gizzard shad was divided between two methods. They appear to filter suspended material, a portion of which is algae, from the water during their normal swimming activities, and must also perform some type of bottom probing activities when they ingest the fingernail clams, Fontigens, and sand observed in stomachs. This bottom feeding activity appears to be quite characteristic of large gizzard captured from channel habitat, since 20-30 small clams were commonly found in the esophagus of these gizzard shad, and 71 were counted in one individual 15 inches long.

Figure 37A. Percentage composition by volume of the material ingested in shallow habitat by gizzard shad for selected periods from July, 1966 to August, 1967 in Pool 19, Mississippi River

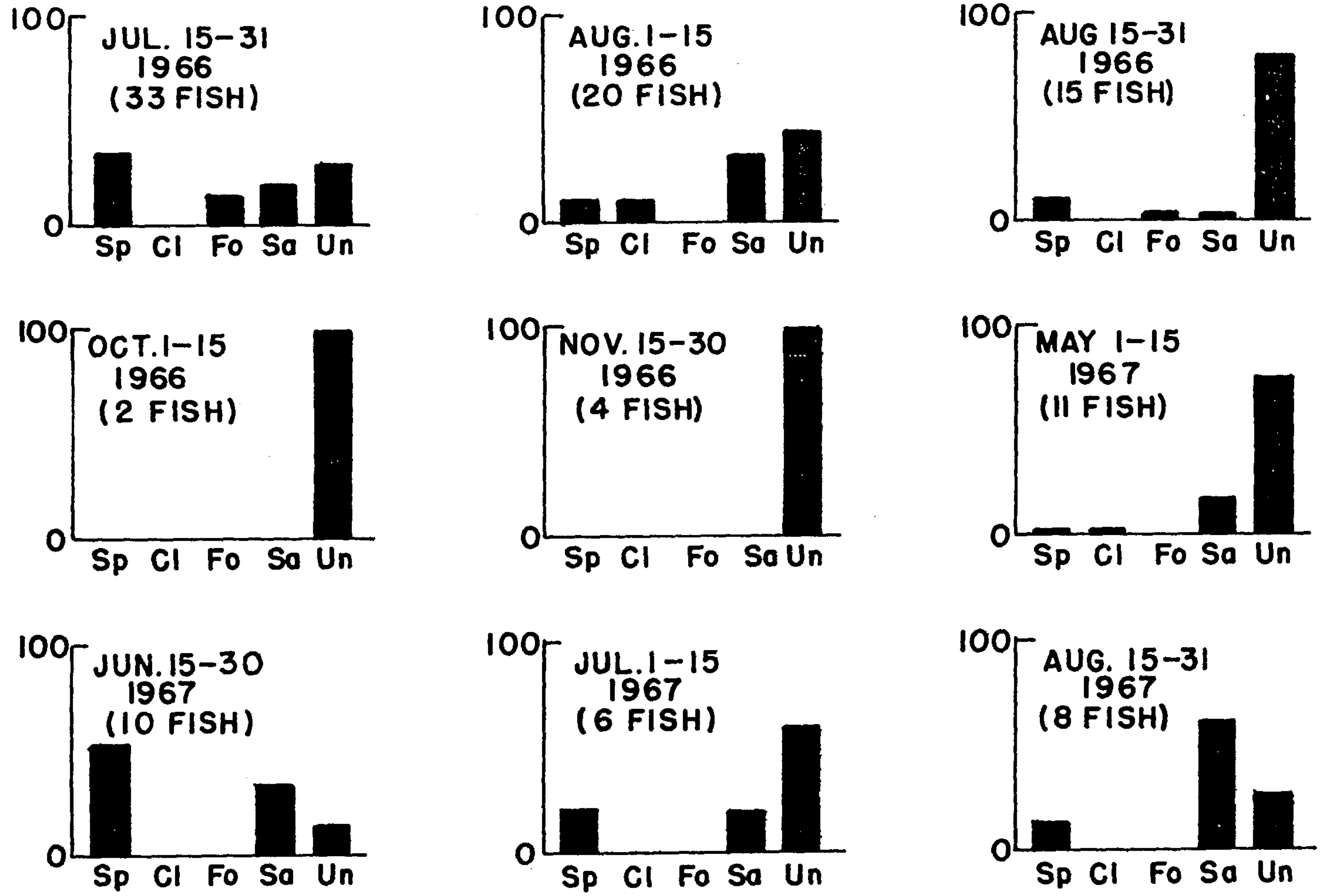
GIZZARD SHAD – SHALLOW HABITAT



Sp – SPHAERIIDAE
Sa – SAND
Cl – CLADOCERA
Un – UNIDENTIFIABLE AND ALGAE
Fo – FONTIGENS

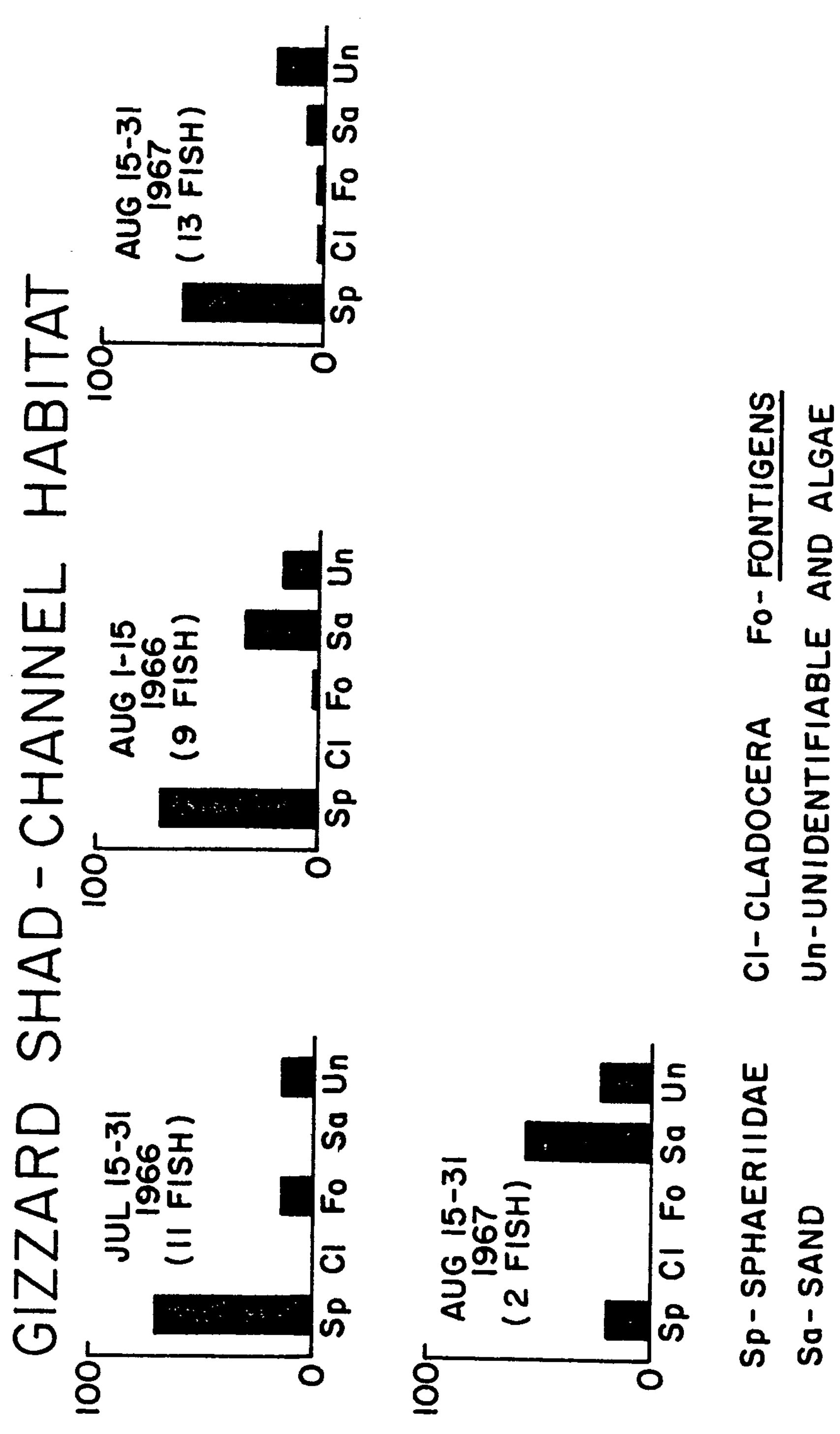
Figure 37B. Percentage composition by volume of the material ingested in flats habitat by gizzard shad for selected periods from July, 1966 to August, 1967 in Pool 19, Mississippi River

GIZZARD SHAD — FLATS HABITAT



Sp – SPHAERIIDAE
Sa – SAND
Cl – CLADOCERA
Un – UNIDENTIFIABLE AND ALGAE
FO – <u>FONTIGENS</u>

Figure 37C. Percentage composition by volume of the material ingested in channel habitat by gizzard shad for selected periods from July, 1966 to August, 1967 in Pool 19, Mississippi River


GIZZARD SHAD - CHANNEL HABITAT
JUL 15-31
1966
(11 FISH)
AUG 1-15
1966
(9 FISH)
AUG 15-31
1967
(13 FISH)
AUG 15-31
1967
(2 FISH)
100
0
Sp Cl Fo Sa Un
Sp - SPHAERIIDAE
Cl - CLADOCERA
Fo - FONTIGENS
Sa - SAND
Un - UNIDENTIFIABLE AND ALGAE

Bottom fauna utilization

Since fingernail clams were the major faunal element contributing to gizzard shad diets, some of the relationships between the faunal distributions and amounts of this organism eaten indicated certain trends in feeding Benthos data (Table 7A) showed fingernail clam populations to be low in shallow vegetated areas, most abundant on the flats, and channel habitat numbers ranked between the other two habitats. Numbers of fingernail clams in the bottom fauna of the channel as previously noted, were derived from samples taken near and not in the channel, where, because of a more sandy environment greater numbers might be expected. The incidence of clams in the gizzard shad diet corresponded well with numbers of spaeriids found in the bottom fauna The least amount of clams eaten was in shallow habitat, where numbers in the fauna were lowest. The predation by carp on fingernail clams may be a factor in the reduced amount of fingernail clams found in shallow habitat, since carp are quite prevalent there. Carp predation on sphaeriids may be part of the reason why more clams are not eaten by gizzard shad in shallow habitat. The other is the shift to or possibly increased availability of unidentifiable material and algae which was found to be the major constituent of shad diets in shallow habitat. Maximum amounts of clams found in fish from channel habitat were not correlated directly with the location of maximum numbers of clams which occurred in flats habitat.

The seasonal trends in the number of sphaeriids in the benthos from flats and channel habitat generally exhibited an increase in numbers from values around 11,000 per square meter during March on the flats to 60,000 per square meter in the winter months. Similar trends although less consistent occurred in channel habitat, however, numbers were much lower. The volume of clams eaten by shad in flats habitat generally decreased from maximum values in June to lows during August. Therefore it appears that gizzard shad predation on fingernail clams is unrelated to numbers present since the amount eaten on the flats generally decreased over the season while numbers of sphaeriids in the bottom exhibited a continual increase These relationships may be changed if only the numbers of small clams (less than 5 mm) were plotted, since these were the size gizzard shad had preyed upon In channel habitat little can be said regarding utilization trends since only July and August are represented and amounts of sphaeriids eaten are generally high for all periods.

Availability of algae to gizzard shad would be expected to be highest in the littoral zone, where in fact the largest quantities of unidentifiable material and algae were found Limited samples of plankton taken by William Gale indicated that algae were also quite abundant in water taken over flats habitat, where unidentifiable material was of less importance to gizzard shad diets than it was in the diet of fish from shallow areas.

Infrequently Captured Species

Goldeye

Apparently goldeye, Hiodon alosoides is scarce in Pool 19 since very few were captured during the present investigation as well as in studies by Hoopes (1959) and Wenke (1965). The goldeye, often confused with the more abundant mooneye, is also unimportant in the commercial fishery of Pool 19. However large quantities of goldeyes are taken in commercial operations from the Red Lakes, Minnesota and sold as smoked fish (Grosslein and Smith, 1959).

Thirty-five goldeyes were captured during 1966-68. In 1966 fish ranged from 8.7 - 13.6 inches and averaged 11.0 inches. Goldeyes captured during 1967 averaged 11.4 inches, with a range from 6.4 to 13.3 inches. Goldeyes were apparently most abundant in shallow water, since 21 were captured in shallow habitat, 10 on the flats, and 3 in the channel. Three of the fish captured in flats habitat were taken at transect 1 station 1 (around 1 foot deep) and all of those captured in the channel habitat were from transect 8 station 2, where nets were set partially in shallow water. In 1966, 15 goldeyes were taken during the 24-hour sampling program. Since between two and four fish were captured during every 2-hour period except 4-6 AM peak activity was not evident.

The food of the goldeye was reported by Harlan and Speaker (1956) to consist of insects, small crustacea and minute plant life. Bajkov (1930, 1932a) noted goldeye (Hiodon chrysopsis) in Lake Winnepeg was entirely a surface feeder, subsisting by feeding on plankton at night. Hexagenia and other mayflies were also found in the diet. Thirty-four goldeyes examined from Red Lakes, Minnesota contained mostly larvae and adults of aquatic insects (Grosslein and Smith, 1959). In Pool 19, near Keokuk, Coker (1930) reported the food to be mostly insects. Hoopes (1959) examined 44 goldeye stomachs from Pool 19 and found the food to be similar to that of the mooneye. Hexagenia comprised most of the diet during spring and fall, but Potamyia flava, most abundant in stomachs examined during summer, was also present in spring and fall samples.

In the present study the seasonal maximum in the average amount of food eaten occurred in the spring, and generally decreasing amounts were eaten during the rest of the year (Table 18). Hexagenia naiads were eaten during the spring and fall with adults predominating in the diet during June and July. The percentage composition by volume of the food eaten by goldeyes demonstrated the importance of Hexagenia in the diet (Figure 38). Potamyia flava and Corixidae became the important forms eaten during August. Odonata and fish were found in minor amounts with no seasonal trends noted.

As noted for the mooneye, goldeye predation on Hexagenia followed the numerical trends of these mayflies in the bottom fauna. Adults were eaten during the major emergences recorded during June and July. Chironomids, characteristically found in goldeye stomachs examined during May were eaten in the form of pupae probably because of increased susceptibility to predation. Faunal numbers were minimal at this time, indicating that emergences apparently had taken place.

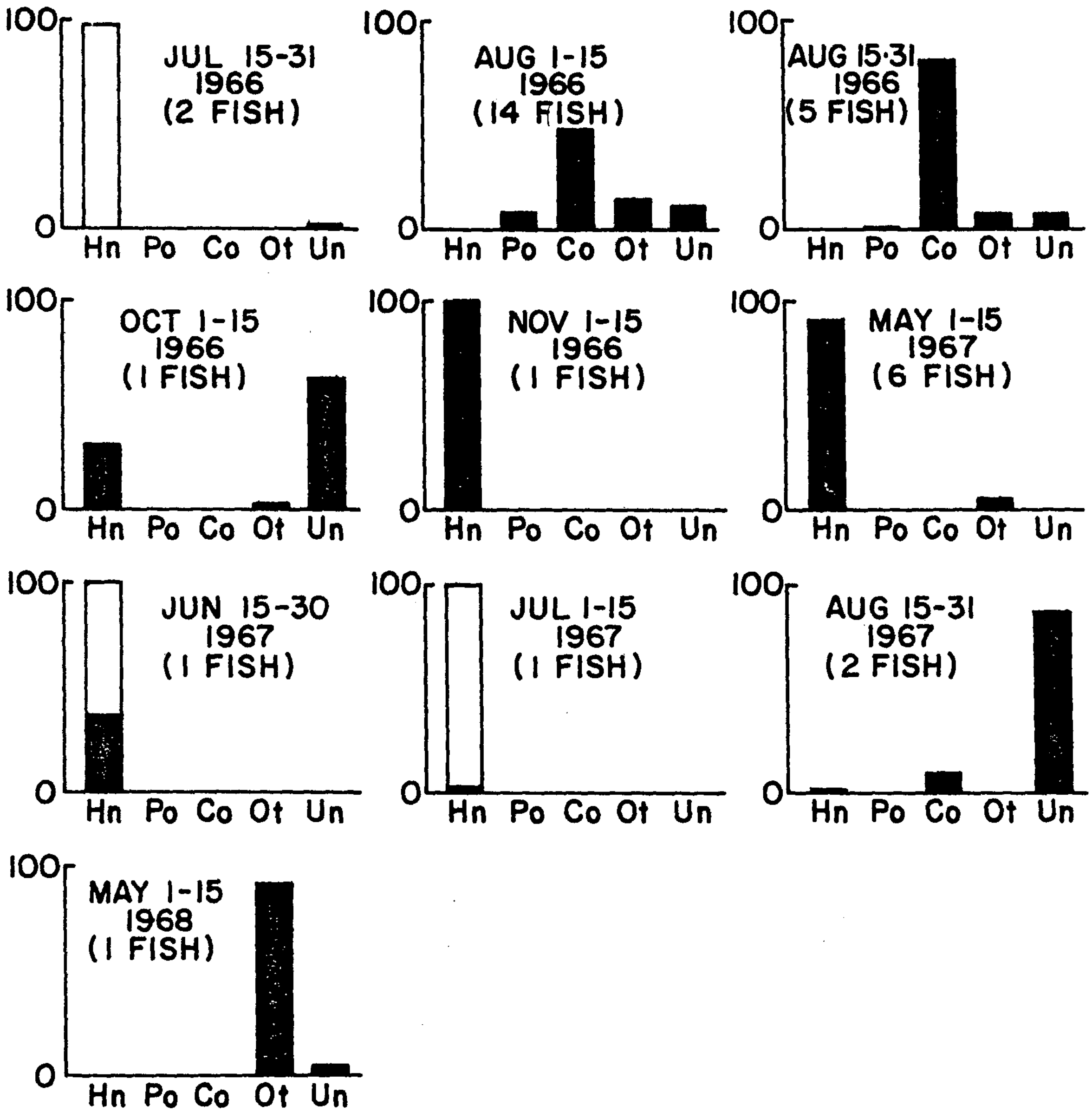
Skipjack herring

The skipjack herring, Alosa chrysochloris (Rafinesque), was once a common fish in the Mississippi River (Carlander, 1954) where it was the

Table 18. Number, volume (cc) and occurrence of the material ingested by goldeye from July, 1966 to May, 1968. (t=trace, p=present)

Date	No. Stations	No. Stomachs w/food		*Hexagenia* naiads	*Hexagenia* adults	*Potamyia flava*	Corixidae	Odonata	Hirudinea	Chironomidae	Fish	Other	Unidentified	Total Volume per Fish
1966														
July 15-31	2	2	No.	0	19	p	0	0	0	p	0	2	-	
			Vol.	0	1.00	.02	0	0	0	t	0	t	.02	1.04
			Occ.	0	1	1	0	0	0	1	0	1	1	
Aug. 1-15	6	14	No.	p	p	24	96	p	p	p	0	2	-	
			Vol.	t	t	.09	.70	.04	.01	t	0	.11	.13	1.08
			Occ.	5	1	8	11	3	1	3	0	4	5	
Aug. 15-31	5	5	No.	0	0	1	155	0	0	5	-	p	-	
			Vol.	0	0	.01	.65	0	0	t	.02	.05	.07	.80
			Occ.	0	0	1	5	0	0	1	1	1	1	
Oct. 1-15	1	1	No.	8	0	0	0	0	0	0	0	1	-	
			Vol.	.14	0	0	0	0	0	0	0	.02	.29	.45
			Occ.	1	0	0	0	0	0	0	0	1	1	
Nov. 1-15	1	1	No.	11	0	0	2	0	0	0	0	1	0	
			Vol.	.94	0	0	t	0	0	0	0	t	0	.94
			Occ.	1	0	0	1	0	0	0	0	1	0	
1967														
May 1-15	2	6	No.	25	0	0	1	p	0	24	0	2	p	
			Vol.	1.65	0	0	t	.06	0	.05	0	t	t	1.76
			Occ.	3	0	0	3	1	0	3	0	1	1	
June 15-30	1	1	No.	9	14	0	2	0	0	0	0	0	0	
			Vol.	.82	1.38	0	t	0	0	0	0	0	0	2.20
			Occ.	1	1	0	1	0	0	0	0	0	0	
July 1-15	1	1	No.	3	10	0	0	0	0	0	0	0	0	
			Vol.	.06	2.01	0	0	0	0	0	0	0	0	2.07
			Occ.	1	1	0	0	0	0	0	0	0	0	
Aug. 15-31	2	2	No.	1	0	0	20	0	0	0	0	1	-	
			Vol.	.01	0	0	.08	0	0	0	0	t	.07	.79
			Occ.	1	0	0	1	0	0	0	0	1	2	
1968														
May 1-15	1	1	No.	0	0	1	1	0	73	35	0	3	-	
			Vol.	0	0	t	t	0	6.82	.01	0	.02	.37	7.22
			Occ.	0	0	1	1	0	1	1	0	1	1	

Figure 38. Percentage composition by volume of the material ingested by goldeye for selected periods from July, 1966 to May, 1968. (For Hexagenia shaded portion of graph represents percentage of naiads, while open spacing indicates adults or last instar naiads)



Hn - HEXAGENIA   Co - CORIXIDAE   Un - UNIDENTIFIABLE
Po - POTAMYIA FLAVA   Ot - OTHER

host for the larval form of a commercially important clam, the "niggerhead" mussel. With installation of dams, the skipjack's spawning activities were detrimentally affected. Carlander (1954) also stated that there probably were no skipjacks above the Keokuk dam. Harlan and Speaker (1956) reported that if it exists at all in Iowa, it was in small numbers. Nord (1967) lists this species as rare in the impounded Mississippi and absent in collections from Pool 19.

On July 14, 1966 one 10-inch skipjack herring was captured in an experimental gill net which was set overnight on the flats at transect 1 station 1. Unfortunately the fish was too badly decomposed when the net was checked so that nothing can be said regarding food habits.

Yellow bullhead

Yellow bullheads, like black bullheads, were all captured at shallow water stations. Only 1 fish of the 27 captured was found in nets at stations where there was no vegetation present. In 1966 they were captured at five stations and the size range of fish sampled was 7.8 - 11.0 inches, averaging 9.6 inches. The average length of yellow bullheads at six stations in 1967 was 10.2 inches, with a range from 9.0 - 12.3 inches.

Catches of yellow bullheads during 24-hour sampling activities indicated that this species was distinctly nocturnal. Fourteen of the 18 fish captured during the three sampling programs were taken at 8-10 PM and the rest at 12-2 AM.

Food eaten by yellow bullheads was composed of many different groups (Table 19). Hexagenia were only present in large amounts during November. The absence of naiads and adults from the diet during June and

Table 19. Number, volume (cc) and occurrence of the material ingested by the yellow bullhead from August, 1966 to July, 1967 in shallow habitat of Pool 19, Mississippi River. (t=trace, p=present)

Date	No. Stations	No. stomachs with food		*Hexagenia*	Chironomid larvae	Dipteran pupae	Fish	Hirudinea	*Oecetis* sp.	Odonata	Mollusca	Algae	Crayfish	Unidentifiable	Other	Total volume per fish
1966																
August 1-15	3	10	No.	0	45	3	1	p	0	16	p	p	0	0	10	
			Vol.	0	.08	t	.15	t	0	.28	.09	t	0	0	.04	.64
			Occur.	0	8	4	3	1	0	9	1	1	0	0	10	
November 15-30	1	1	No.	8	2	0	1	0	0	0	0	0	0	0	0	
			Vol.	.37	t	0	1.15	0	0	0	0	0	0	0	0	1.52
			Occur.	1	1	0	1	0	0	0	0	0	0	0	0	
1967																
May 1-15	4	6	No.	1	14	7	1	2	5	p	0	0	p	0	9	
			Vol.	.01	.09	.06	1.29	.76	.17	.01	0	0	.24	0	.03	2.66
			Occur.	2	5	4	2	4	2	3	0	0	2	0	5	
June 15-30	1	1	No.	0	7	3	1	0	0	0	0	0	0	-	1	
			Vol.	0	.21	t	.51	0	0	0	0	0	0	.04	t	.76
			Occur.	0	1	1	1	0	0	0	0	0	0	1	1	
July 1-15	2	2	No.	0	1	2	3	0	0	2	-	0	0	-	4	
			Vol.	0	t	t	.18	0	0	.03	4.15	0	0	.05	.06	4.47
			Occur.	0	1	1	1	0	0	1	1	0	0	1	1	

July was strange. Chironomids were important during May and June, and were present in stomachs in the other periods. Fish constituted a large part of the food eaten in almost every period, especially during May and November. Leeches, Oecetis sp. (Trichoptera), Odonata and Mollusca were important to yellow bullheads in various periods, but showed no seasonal trends in amount eaten. Results found by other investigators were similar. One yellow bullhead sampled by Wenke (1965) during July contained plant material, fish, and insects. In an earlier study, Forbes (1888) found food of "yellow cats" to consist of fish, remnants of a dead animal, and Hexagenia. Food of yellow bullheads from Reelfoot Lake, Tennessee, was comprised of 80% chironomid larvae, 10% caddisfly, and 10% fish during the summer months (Rice, 1941).

Flathead catfish

Flathead catfish proved to be one of the most difficult species to capture during the study. None were taken in experimental gill nets or trammel nets. Of the 9 individuals examined, all less than 12 inches, 1 was taken from a trot line, 2 were shocked in Ortho outlet, 5 came from baskets and 1 was taken from a hoop net. All of the stomachs were empty except the flathead captured with a trot line on July 31, 1967. This fish contained one Hexagenia pharate adult. In an attempt to gather more data on feeding habits, flatheads from Haigh's Fish Market, Niota, Illinois were sampled during June, 1967. Most fish examined were from 6 to 12 pounds, and the stomachs of all but five were empty, probably because of the method of capture (baskets). These five fish had fed upon crayfish, Hexagenia, and scales, leaves, bark and other detritus were also noted. One 50 pound flathead caught the day before contained a 4 pound drum in its stomach. Flatheads examined by Forbes (1888) contained mostly fish. Specimens sampled by Hoopes (1959) contained *Hexagenia* naiads and a single *Cheumatopsyche campyla* larva. Wenke (1965) reported that three flatheads (1.7 - 5.0 inches) captured in Pool 19 during June had eaten mayflies and caddisflies. *Hexagenia* and fish comprised the greater part of the diet of the six larger flatheads examined.

Bigmouth buffalo

The bigmouth buffalo, is one of the buffalos contributing significant poundage to the commercial catch each year. In 1965 the catch in Pool 19, (128,013 pounds) ranked third behind catfish and carp (UMRCC, 1967). Fifty-three bigmouth buffalo captured in 1966 averaged 11.6 inches in size (range 8.7 - 19.2 inches). In 1967, bigmouth buffalos averaged 12.6 inches and ranged from 9.2 - 16.6 inches. Bigmouth buffalo occurred in nets set at 7 of the 24 stations in 1966 and 7 of the 17 stations in 1967. Only five were caught in flats habitat. The remaining bigmouth buffalo were all from nets set at shallow water stations with vegetation present indicating a preference for this type of habitat.

The 14 fish captured during the 24-hour sampling program were equally distributed in each 2-hour period, and thus exhibited no pronounced peaks in activity.

The food habits of bigmouth buffalo have been investigated by Walburg and Nelson (1966) who found the diet of young-of-the-year to be composed of 100% zooplankton. In the adults 53% of food eaten was copepods and cladocerans while fragments of these organisms comprised the remainder.

Moen (1954) found the food of bigmouth buffalo to be mainly crustaceans. Forbes (1888) found the food of bigmouth buffalo consisted of algae, zooplankton, vegetation, chironomids, and Hexagenia. Wenke (1965) in his study found unidentifiable material, gastropod mollusks (some Physa), and a few Oecetis larvae in the stomachs of bigmouth buffalo.

Cladocera and Ostracoda comprised the major portion of the material ingested by bigmouth buffalo from the Fort Madison section of the river (Table 20). Stomach contents classified as unidentifiable was the next largest item found in bigmouth buffalo. Cladocera made up a large part of the food eaten from May through August, although Ostracoda occurred in the diet in large numbers during May and June. The unidentified portion of contents examined was high in almost every period during which bigmouth buffalo were captured, and was particularly predominate during April and May.

Smallmouth buffalo

Numbers of smallmouth buffalo captured (55) were similar to the number of bigmouth captured. The range in size of smallmouth buffalos was 6.7 - 13.4 inches (average 10.1 inches) in 1966. In 1967 the mean length was 12.0 inches with a range from 5.5 - 18.2 inches. The smallmouth buffalo is also the object of considerable effort exerted by commercial fishermen in capturing fish in Pool 19. This species appeared to prefer flats habitat more than the bigmouth and was captured at a larger number of stations (10 in 1966, 7 in 1967). Of the 55 smallmouth buffalo captured, 19 were captured at shallow stations, 31 at flats stations, and 1 was captured at transect 3 station 6, near the navigational channel. Results of the 24-hour

Table 20. Number, volume (cc) and occurrence of the material ingested by the bigmouth buffalo from July, 1966 to August, 1967. (t=trace, p=present)

Date	No. Stations	No. Stomachs w/food		Cladocera	Chironomidae	Oecetis sp.	Ostracoda	Sphaeriidae	Zygoptera	Caenis sp.	Corixidae	Plea striola	Unidentifiable	Total Volume per Fish
1966														
July	1	1	No.	0	1	0	0	0	0	0	0	0	-	
15-31			Vol.	0	t	0	0	0	0	0	0	0	.05	.05
			Occ.	0	1	0	0	0	0	0	0	0	1	
Aug.	2	2	No.	2,103	2	0	11	0	1	0	0	0	0	
1-15			Vol.	.13	t	0	t	0	t	0	0	0	0	.13
			Occ.	2	2	0	1	0	1	0	0	0	0	
Aug.	2	2	No.	265	0	0	0	0	0	0	0	0	-	
15-31			Vol.	.02	0	0	0	0	0	0	0	0	.01	.03
			Occ.	2	0	0	0	0	0	0	0	0	1	
1967														
Apr.	1	1	No.	0	0	0	0	0	0	0	0	0	-	
15-30			Vol.	0	0	0	0	0	0	0	0	0	.16	.16
			Occ.	0	0	0	0	0	0	0	0	0	1	
May	4	5	No.	190	0	6	6,790	0	0	3	0	0	-	
1-15			Vol.	.07	0	.03	.38	0	0	.01	0	0	.14	.63
			Occ.	5	0	1	5	0	0	1	0	0	4	
June	2	5	No.	2,542	p	0	147	0	0	0	p	0	-	
15-30			Vol.	.20	t	0	.01	0	0	0	t	0	.03	.24
			Occ.	5	1	0	4	0	0	0	1	0	4	
July	3	4	No.	2,782	4	0	2	0	0	0	0	1	-	
1-15			Vol.	.36	.01	0	t	0	0	0	0	.01	.02	.40
			Occ.	4	3	0	1	0	0	0	0	1	2	
Aug.	2	2	No.	3	0	3	7	-	0	0	0	0	-	
1-15			Vol.	t	0	.01	t	.06	0	0	0	0	.52	.59
			Occ.	1	0	1	1	1	0	0	0	0	2	

sampling, although from limited numbers, indicated that the species may be nocturnal in activity.

Food habit investigations of smallmouth buffalo have shown that diets were primarily composed of zooplankton and algae with some contribution by insects and mollusks (Walburg and Nelson, 1966; Forbes, 1888). Sand was also found in stomachs. Wenke (1965) reported that smallmouth buffalo examined from Pool 19 had eaten cladocerans, ostracods, and some algae. Unidentified material comprised 73% of the contents of all stomachs examined. Hexagenia and Oecetis were important in individual fish.

The results of Wenke (1965) as regards unidentifiable material, were similarly a problem in the present study, since a major part of the food eaten by smallmouth buffalo could not be identified (Table 21). Examination of the material microscopically revealed the presence of small numbers of diatoms and filamentous algae which were not a major percentage of the material present. Sphaeriids were found to comprise a large part of the food eaten during August and were also found in lesser amounts during May and June. Chironomid larvae, although sometimes numerous, contributed negligible volumes to the diet. Cladocerans and ostracods occurred in the stomachs in large numbers during May and June. Oecetis sp. were eaten in August, 1967 The unidentifiable material was present in every period, except August, 1966 and comprised the major portion of the diet during certain periods.

River carpsucker

The average length of 20 river carpsuckers captured in 1966 was 13.8 inches, and these fish ranged from 7.9 - 17.1 inches. During 1967 the mean

Table 21. Number, volume (cc) and occurrence of the material ingested by the smallmouth buffalo from August, 1966 to August, 1967 in Pool 19, Mississippi River. (t=trace, p=present)

Date	No. of Stations	No. stomachs with food		Sphaeriidae	Chironomid larvae	Chironomid pupae	*Oecetis* sp.	Corixidae	Cladocera	Ostracoda	Unidentifiable	Total volume per fish
1966												
August 16-31	1	1	No.	10	31	1	0	1	0	0	0	
			Vol.	.45	t	t	0	t	0	0	0	.45
			Occur.	1	1	1	0	1	0	0	0	
November 16-30	1	1	No.	p	4	0	0	0	0	0	-	
			Vol.	.04	t	0	0	0	0	0	.03	.07
			Occur.	1	1	0	0	0	0	0	1	
1967												
March 1-15	1	1	No.	0	0	0	0	0	32	7	-	
			Vol.	0	0	0	0	0	.01	t	.13	.14
			Occur.	0	0	0	0	0	1	1	1	
May 1-15	2	3	No.	1	0	0	0	0	27	226	-	
			Vol.	0.03	0	0	0	0	.01	.04	.31	.39
			Occur.	1	6	0	0	0	1	2	3	
June 16-30	2	2	No.	p	5	0	0	2	64	1,680	-	
			Vol.	.10	t	0	0	t	.01	.13	.09	.33
			Occur.	1	2	0	0	1	1	1	2	
July 16-31	1	1	No.	0	0	0	0	0	0	0	-	
			Vol.	0	0	0	0	0	0	0	.07	.07
			Occur.	0	0	0	0	0	0	0	1	
August 16-31	2	2	No.	p	0	0	11	0	0	0	-	
			Vol.	.57	0	0	.05	0	0	0	.17	.79
			Occur.	1	0	0	2	0	0	0	2	

of 12 river carpsuckers taken was 14 inches with a range from 7.9 - 17.7 inches. This species appeared to be equally distributed in shallow and flats habitat, since 14 carpsuckers were taken from nets set at stations with shallow habitat, 16 were in flats habitat, and 2 were taken in channel sets. River carpsuckers were taken at six stations in 1966, and eight stations in 1967. Activity of the carpsucker as reflected in the number captured during the 2-hour periods of the 24-hour sampling program was highest at 8-10 PM, but data were limited (only 14 fish).

The food eaten by river carpsuckers agreed generally with other studies. Walburg and Nelson (1966) in Lewis and Clark Lake found this species to be eating largely organic detritus (69%), zooplankton (14%), with minor contributions by phytoplankton and insects. Harlan and Speaker (1956) reported the food of river carpsuckers from the Des Moines River to consist of 86% unidentifiable material, 12% plant, and 2% insects. Buchholz (1957) found similar results in his study of Des Moines River carpsuckers. Forbes (1888) examined the food of 19 fish collected in various lakes and the Illinois River. Sphaerium comprised one-fourth of the food, insects (mostly chironomids) another one-third; Entomostraca another one-fourth, and mud and detritus the rest. Wenke (1965) and Brezner (1958) found unidentifiable material to be a predominate constituent of river carpsuckers studied. Plant remains, entomostracans and some insects were also found.

Only 15 carpsuckers of those examined during this investigation had food present in the stomach. Material classified as unidentifiable was present in every fish examined and comprised the major amount of the food eaten during most periods (Table 22). Cladocera were found to be important in the two fish captured during October, while chironomids were heavily fed

Table 22. Number, volume (cc) and occurrence of the material ingested by the river carpsucker in selected periods from August, 1966 to August, 1967 in Pool 19, Mississippi River. (t=trace, p=present)

Date	No. of Stations	No. Stomachs with food		Cladocera	Chironomid larvae	Dipteran pupae	Sphaeriidae	Ostracoda	*Oecetis* sp.	Sand	Unidentifiable	Total volume per fish
1966												
August 1-15	1	2	No.	0	0	0	0	0	0	0	-	
			Vol.	0	0	0	0	0	0	0	.02	.02
			Occur.	0	0	0	0	0	0	0	2	
August 15-31	2	4	No.	p	1	0	2	0	0	0	-	
			Vol.	t	t	0	t	0	0	0	.06	.06
			Occur.	1	1	0	1	0	0	0	4	
October 1-15	1	2	No.	466	41	0	0	0	12	0	-	
			Vol.	.12	t	0	0	0	.04	0	.01	.17
			Occur.	2	2	0	0	0	2	0	2	
1967												
March 1-15	1	1	No.	0	4	0	0	0	0	0	-	
			Vol.	0	t	0	0	0	0	0	.01	.01
			Occur.	0	1	0	0	0	0	0	1	
August 1-15	1	1	No.	0	74	3	0	0	0	0	-	
			Vol.	0	.44	.01	0	0	0	0	.19	.64
			Occur.	0	1	1	0	0	0	0	1	
August 15-31	5	5	No.	20	1	0	0	p	4	-	-	
			Vol.	t	t	0	0	t	.01	t	.05	.06
			Occur.	1	2	0	0	1	2	1	5	

upon during August, 1967. *Oecetis* sp. appeared in the diet of river carpsuckers taken during October and August. Sand was recorded in one fish as were fingernail clams.

White sucker

The white sucker is cited as uncommon in the Upper Mississippi, but it is recorded as present in Pool 19 (Nord, 1967). The single specimen encountered during this study was captured August 18, 1966 in the deep water portion of transect 8 station 2 on the "Nauvoo Flats". This fish was 11.5 inches long and weighed 375 grams. It had eaten .11 cc of food composed mostly of crushed fingernail clams. This corresponded to what Forbes (1888) stated for the food habits of the white suckers.

Northern redhorse

On August 20, 1967 one northern redhorse was captured in a gill net set at transect 4 station 4. This fish was 15.4 inches long and weighed 707 grams. Its stomach contents were comprised mainly of fingernail clams (.44 cc) although unidentified material (.05 cc) was also found. The findings of Wenke (1965) as regards the food of four northern redhorse were somewhat different from those found in the present study. Trichopterans, chironomids, *Caenis*, and *Sphaerium traversum* were found in minor amounts. One other specimen, too decomposed to attempt stomach analysis, was observed lying along the shore during March, 1967.

DISCUSSION

The Fort Madison section of the Mississippi River is similar to most areas of the Upper Mississippi River with its navigation channel flanked on both sides by large reaches of shallow flats. Areas, especially backwater sloughs where the river's current is not quite as severe, contain vascular aquatic vegetation.

Most species of fish were common to abundant in shallow habitat throughout the year. The scarcity of channel catfish in shallow habitat during fall and winter was a result of reduced activity of these fish. Species most abundant in flats habitat throughout the year were channel catfish, gizzard shad, mooneye, smallmouth buffalo and river carpsucker, while only gizzard shad and channel catfish were abundant in channel habitat. The greatest number of species occurred in shallow habitat during the spring, when many fishes were spawning. Flood conditions at this time with strong currents in the channel may also be a factor. In the summer many more species were caught in greater numbers in flats and channel habitat. Few species occurred regularly in gill net catches during the fall and winter; however, reduced fish activity may be a major cause

The catch of various species of fish during the three 24-hour sampling programs at selected stations gave an indication of the variability to be expected at individual stations and a picture of the species complex commonly present in the different habitat types. Catches in August, 1966, compared to 1967 catches at the same station, showed that total numbers and species captured were generally higher in 1966. Certain species, such as bullhead and bigmouth buffalo were very prevalent in catches from Honig's

Slough, indicating a greater abundance of these fish in this habitat. Carp and gizzard shad were also numerous in catches from the slough, the gizzard shad being the most widely distributed of all fishes studied. Typical flats habitat stations exhibited lower catches than most shallow water stations, with the characteristic species being mooneye, channel catfish and gizzard shad.

Catches at transect 4 station 1 in shallow habitat consistently contained the most species and numbers of fish. The appearance of channel catfish, more mooneyes, black bullheads and gizzard shad in 1967 catches was probably the result of moving the station into deeper water in 1967.

In 1966 nets set at transect 5 station 1 were in open water with little vegetation near vast beds of *Lotus*. In 1967 the net was placed in the *Lotus*, resulting in a decreased number of species being caught. Mooneye, goldeye, channel catfish and yellow bullhead were never captured in nets after they were set in the *Lotus*; whereas, black bullheads, carp and gizzard shad were the most common species caught in this vegetation.

Ivlev (1961) in discussing the feeding of fishes states that the phenomenon of electivity (selectivity) is a function of several factors operating simultaneously. There are a combination of features characteristic to the predator and to the prey. Size and concentration of the food was a basic factor in determining whether a fish will exhibit selection for a particular food eaten from others present. The preference of the predator and the degree of accessibility of the food were also important in this choice. Undoubtedly many of these factors are controlling the consumption of particular faunal groups at certain times in Pool 19. Some particular behavioral characteristic exhibited by the food (movement in drift or prior to emergence) make it particularly susceptible to fish which feed in a characteristic way. To see if any of these factors were operating the monthly percentage compositions by volume for four benthos elements were compared for each of 10 species of fish.

The consumption of Hexagenia in the open river was high during spring for all species except gizzard shad, smallmouth and bigmouth buffalo and river carpsucker. These mayflies were fed upon most heavily during May, June and July prior to and during emergences with increased utilization again toward the fall. Some of the laboratory work by Ivlev (1961) pointed out that fish given an unlimited food supply ate a certain amount, which was not increased with increased abundance of the food. During mayfly hatches the maximum amounts of food were found to occur for mooneyes, goldeyes, channel catfish and carp.

Chironomids were susceptible to predation by many of the species of fish at one time during the year. Consumption by fishes of larvae and pupae of Chironomidae was stated by Ivlev (1961) to occur on a large scale in nature. During May, midge larvae and pupae comprised from 5-97% of the diet of five species of fish. Some behavioral activity of this insect preparatory to emergence was probably responsible for the increased utilization, particularly of pupae, during May by these fish. Carp and black bullhead were able to consume large quantities of chironomids at times when fish such as the mooneye and channel catfish were not ingesting them. Preference by mooneye and catfish may be the reason that these fish are not eating chironomids. However, since mooneye and catfish fed on food that should require some aid of sight during the times carp were ingesting large numbers of midge larvae, lends credence to the conclusion that carp and black bullheads are not dependent upon sight feeding.

Potamyia flava, like chironomids, appeared to be susceptible only during a given period in the latter part of July and August. Catfish, mooneye and goldeye all preyed on this caddisfly which was thought to become more vulnerable because of natural drift.

The importance of fingernail clams was demonstrated for carp, gizzard shad and smallmouth buffalo which fed on sphaeriids over most of the growing season. Black bullheads ingested large amounts during August and September.

On the basis of food habits, the goldeye and mooneye probably do not compete since their main foods, Hexagenia, Potamyia flava and corixids, were undoubtedly not limiting at the times fish were feeding on these insects. Yellow bullheads appeared to be more active sight feeders than the black bullhead whose food was mostly derived from the bottom by some kind of sifting process. Yellow bullheads preyed much more heavily upon fish, damselflies and dragonflies which required more than just passive sifting activity.

Little can be said regarding competition between smallmouth buffalo, bigmouth buffalo and carpsuckers because of the amounts of unidentifiable materials ingested and low numbers caught. The distribution of the buffalos was sufficiently different so that any competitive effect would be reduced. Smallmouth buffalo subsisted largely on unidentifiable material, sphaeriids and chironomids, whereas, bigmouth buffalo had eaten cladocerans and ostracods with unidentifiable material the next highest amount found in the diet. The carpsucker was mainly dependent on unidentified material, cladocerans and chironomids.

SUMMARY

Data regarding distribution, food habits, and bottom fauna utilization were collected in the Fort Madison section of Pool 19, Mississippi River during 1966-1968. The mooneye was one of the more commonly captured fish in gill nets. Of 636 mooneye, 366 were selected for stomach analyses. The mooneye was little utilized as a prey fish, so its impact on the ecology of other fish in the pool may be the effect it exerts through competition. The flats appeared to be the preferred habitat of the mooneye. Catch-per-effort values for the mooneye generally followed the average monthly water temperatures. Activity curves for the mooneye as reflected in gill net catches, indicated peak period of movement at 8-10 PM, a decline around 12-2 AM, and another increase at 4-6 AM.

The mean amount of food eaten per mooneye attained a maximum (5.9 cc) during June and July on the flats when the large Hexagenia (Ephemeroptera) hatches occurred. Amount of food eaten decreased progressively to values around 0.9 cc in August and then to zero in December The lowest consumption of food during 24 hours occurred at 4-6 PM, with an increase at 8-10 PM and a maximum at 12-2 AM. The activity of fish was therefore closely associated with feeding, since fish were most active at 8-10 PM followed by the maximum amount of food found in stomachs at 12-2 AM and later.

Hexagenia were eaten by mooneye in all habitat types during June, July and part of August. Potamyia flava (Trichoptera) were eaten during latter July, August, and September. Feeding resumed on Hexagenia during the fall and winter. During August and September Corixidae (water boatmen) were eaten in large numbers in shallow habitat, and Chironomidae were important

in the diet of fish captured from shallow areas in May. Unidentifiable material attained highest volumes in stomachs during August when a diverse number of insects were eaten.

Associating the numbers of a given organism found in the bottom fauna with the numbers found in fish stomachs indicated the degree of utilization for four selected groups: Hexagenia, Trichoptera, Corixidae, and Chironomidae. Numbers of Hexagenia, Trichoptera and Corixidae found in mooneye stomachs followed the numerical trends in the bottom fauna. Chironomidae were eaten in maximum numbers when the minimum number were present in the bottom fauna on the flats and in shallow habitat.

Channel catfish were captured in all three habitat types. A high catch-per-effort was found for the shallow habitat in the spring and an increased preference for the flats during August. Despite the inefficiency of nets in the channel, large catches were recorded. Activity curves suggested that channel catfish were nocturnal with highest catches at 8-10 PM and 4-6 AM. Average volume of the stomach contents for channel catfish less than 16 inches long was highest during the spring months (April, May, and June) and gradually declined to lows during the winter. The peak diurnal activity at 8-10 PM was followed by the maximum amount of food in stomachs at 4-6 AM, demonstrating that activity was closely related to feeding movements. Catfish consumed a variety of foods during the year. Hexagenia naiads were found in the stomach contents during April, May, June and July while Hexagenia adults were consumed during June and July. Of the three Trichoptera found in the stomachs collected, only Oecetis sp. larvae comprised a large percentage volume of the food found in individual catfish from July to September. Most Mollusca eaten were comprised of large pieces of unionid clams which were probably dead when ingested, and the inner parts of snails (Viviparidae). Hexagenia were eaten in proportion to their abundance in the bottom fauna in all three habitat types, but little relationship between abundance of Trichoptera in the bottom fauna and the amount utilized as food of channel catfish.

Bullheads were generally captured in shallow weedy areas of the river particularly in Honig's Slough. Diurnal peaks in activity were recorded at 4-6 AM and 8-10 AM. The stomach contents from 177 bullheads were examined and of these 48 were empty probably from regurgitation. The average volume of food eaten by black bullheads attained a diurnal maximum around 4-6 AM. Bullheads from the open river consumed a large variety of different foods, but Hexagenia and oligochaetes were the principal items eaten from May to July, while large numbers of fingernail clams were found in stomachs during August and September. Black bullheads from Honig's Slough depended mainly on chironomids for food, although Hexagenia was dominant in the diet during July. Black bullheads appeared to be ineffective as fish predators.

Seasonal maximum in catch-per-effort of carp was attained during August. The depth distribution of carp indicated that they were associated with water less than 3 feet deep. A tendency toward nocturnal activity was noted from the daily activity pattern. Peak volume of food eaten seasonally occurred during spring. Most pronounced activity at 8-10 PM was followed by peak amounts of food eaten at 12-2 AM and 4-6 AM indicating activity was associated with feeding. Food habits of carp from the open river stations were found to be different from those of Honig's Slough. The diet of open river carp was largely composed of fingernail clams. Hexagenia were important during June and July. Chironomids and unidentified material comprised the major portion of food eaten by carp from Honig's Slough. Populations of fingernail clams and chironomids in the bottom fauna generally followed amounts and numbers eaten by carp.

Gizzard shad taken at all 41 permanent sampling stations were probably the most numerous fish found in the Fort Madison section of the river. Seasonal catch-per-effort values for three sizes of gizzard shad (less than 6 inches, 6-10 inches, and greater than 10 inches) showed that smallest shad became predominant in the catch in shallow water during latter August and September. Largest gizzard shad were more numerous than any of the other size groups in shallow water during spring and fall and appeared to migrate to flats and channel habitat during the summer. High catches of these largest gizzard in shallow water during spring were attributed to spawning. Depth distribution of all sizes of gizzard shad showed an equal distribution in all three habitats in August, 1966. Feeding by gizzard shad started in May and appeared to discontinue in September. The highest volume of food eaten attained peaks at 4-6 AM and 12-2 PM. Peak activity occurred at 8-10 PM and 4-6 AM. Stomachs from 238 gizzard shad examined containing food indicated sphaeriids, sand, and unidentified material (including algae) were the major constituents of the diet.

Only 35 goldeyes were captured during the study and were apparently most abundant in shallow water. Food habits were similar to those of mooneyes, with Hexagenia comprising most of the contents during spring and fall. Potamyia flava and Corixidae were eaten during August and chironomids were important during May.

Yellow bullheads were found generally in shallow habitat and showed nocturnal activity. Food eaten was diverse with Hexagenia present in large amounts in November, chironomids important during May and June, and fish present in stomachs sampled from almost every period.

Bigmouth buffalo food contents were composed mainly of cladocerans, ostracods and unidentifiable material. Bigmouth buffalo were most common in nets set in shallow water.

Smallmouth buffalo appeared more prevalent in flats habitat. Unidentified material was the major item found in stomachs of smallmouth buffalo with contributions at different times from sphaeriids, chironomids, cladocerans, and ostracods.

River carpsuckers were found in shallow and flats habitat. The diet was comprised of unidentifiable material, cladocerans, and chironomids.

One white sucker and one northern redhorse examined for food content were found to be eating mainly fingernail clams. One skipjack herring, thought to be rare in Pool 19, was captured.

Fish considered collectively were most prevalent in shallow habitat throughout the year. Hexagenia was important in the diets of 6 of the 10 species of fish during May, June and July. Naiads became increasingly abundant in the diets of four species during the fall. Chironomids were common to the diet of six species of fishes during April and May. Two other species, carp and black bullheads, fed on chironomids throughout the warmer growing season. Potamyia flava appeared in the diet of mooneyes, goldeyes, and catfish during July. Fingernail clams were important to three species of fish over most of the year, and to black bullheads during August and September.

The relationships between closely related species were discussed with little evidence of competition found.

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