FOOD SELECTIVITY OF THE SHOVELNOSE STURGEON, *SCAPHIRHYNCHUS PLATORYNCHUS*, IN THE MISSOURI RIVER

by

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INTRODUCTION

Sturgeon (O. Acipenseriformes, F. Acipenseridae) represent descendents of an ancient taxon of Paleoniscoid fishes which remain little changed morphologically from their Cretaceous ancestors. Paleoniscoid fishes were the dominant bony fishes during the late Paleozoic Era but only the sturgeon and the paddlefish have survived to modern times. The shovelnose sturgeon, Scaphirhynchus platorynchus, is the smallest North American sturgeon. The life cycle of the shovelnose, its generic counterpart the pallid sturgeon, Scaphirhynchus albus, and the lake sturgeon, Acipenser fulvescens, takes place entirely in freshwater. Most other species of sturgeon are anadromous.

The shovelnose, which is also called the sand or flathead sturgeon, hackleback or switchtail, generally ranges between 45 and 100 centimeters in fork length when sexually mature and weighs between 0.4 and 2.3 kilograms (one to five pounds). Earlier reports record shovelnose weights exceeding 4.5 kilograms, however, it is likely that most if not all of these weights were actually recorded from pallid sturgeon which have been observed to attain a weight of 21.3 kilograms (Brown, 1955).

The elongated body of the shovelnose varies from a pale olive to yellowish brown dorsally to white ventrally. The anterior portion of the shovelnose head is compressed dorso-ventrally producing a shovel-like rostrum. The shovelnose does not exhibit sexual dimorphism and is without a distinctive color pattern (Zweiacker, 1967). Five rows of bony spiny scutes extend along the body from the head to the caudal fin. Between the cuspidate rows of bony scutes lie small, irregularly shaped scale-like plates. The ventral surface of the body is protected with subrhombic scales which are smaller anteriorly. The upper lobe of the caudal fin is produced into a long slender caudal filament which is more pronounced in younger fish. As one of the most primitive teleosts, the sturgeon retains a notochord and possesses a cartilaginous endoskeleton.

Being a suctorial feeder, the mouth of the shovelnose is located ventrally. Anterior to the mouth are four evenly spaced, fringed barbels; the position and length of these barbels are either in line or slightly anterior of the inward pair in the shovelnose, whereas in the pallid the outer barbels are much longer and situated posteriorly to the inner pair. The lips of the sturgeon are plicate (having folds) or papillose, i.e. having small tufts of skin (Lagler et al., 1962). End organs for the gustatory senses which are concentrated on the barbels and lips are used to locate benthic organisms upon which they feed (Mellon, 1927).

The shovelnose is found almost exclusively in lotic environments within the Mississippi-Missouri-Ohio River Drainage System. In the late 19th Century, the shovelnose range extended as far west as New Mexico and Colorado, eastward to Pittsburg, Pa., north to North Dakota and south to Louisiana (Bailey and Cross, 1954). During this period the shovelnose sustained a large fishery in the Mississippi and Illinois Rivers (Forbes and Richardson, 1920). The range and population density of the shovelnose have been substantially reduced since the beginning of the 20th Century, presumably because of habitat destruction by man's activities (Trautman, 1957). Bailey and Cross (1954) suggested that the impoundment of rivers, commercial fishing and pollution were the principal factors contributing to the decline of the species.

In recent years the shovelnose has been harvested commercially only in the Mississippi River Drainage where they are captured in the tailwater areas of dams during the late spring with stationary trammel nets. Although the commercial supply of shovelnose is limited, it is among the highest priced commercial food fish in the Mississippi River Fishery (Helms, 1972). The meat is usually smoked or steaked while the roe is sold as caviar (Eddy and Surber, 1947).

The shovelnose is a bottom dweller and occurs in greatest abundance within swift channels of large rivers, usually preferring sand or gravel substrates. In the unchannelized portion of the Missouri River, shovelnose are usually found behind sand bars located adjacent to the main channels. Seasonal movements have been observed in the Missouri River shovelnose population. During the late fall and early spring they appear to concentrate behind sand bars in the unchannelized river, but in the summer they either disperse or migrate from the region.[1]

The shovelnose spawns in the spring, reportedly traveling

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[1]Schmulbach, James C. Personal correspondence, Department of Biology, University of South Dakota, Vermillion, South Dakota.

upstream until suitable spawning sites are located over gravel beds (Eddy, 1957). There is little evidence to suggest that the shovelnose is successfully reproducing in the Missouri River. Although extenisve efforts have been made by the personnel at the University of South Dakota to locate the young-of-the-year, only one has ever been captured.[2] If the shovelnose does travel upriver to traditional spawning sites in the spring, the six major dams located along the Missouri River would certainly halt upstream movement. Moreover, the reservoirs behind the dams have substantially reduced sturgeon habitat thus further limiting suitable spawning sites above the dams.

Food habit studies on the shovelnose have indicated that this species feeds predominately on aquatic insect larvae (Eddy and Surber, 1947; Forbes and Richardson, 1920; Hoopes, 1960; Held, 1966). The importance of aquatic insect larvae in the diet of several species of sturgeon in Russia has also been observed (Zadhin and Berg, 1961; Nikolsky, 1963). Nikolsky (1963) described the importance of the caddisfly larvae to sturgeon in rivers with fast currents and shifting sandy substrates. In these environments the benthic biomass was small and could not fully satisfy the food requirements of the fish. The Family Chironomidae was reported to be a major food source for the smaller species of sturgeon, especially those in newly impounded reservoirs where larger populations of other aquatic

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[2]Moos, Richard Personal correspondence, Department of Biology, St. Marys College, Winona, Minnesota.

insect larvae had not become well established (Zadkin and Berg, 1961).

Held (1966) examined the stomach contents of Missouri River shovelnose during a two-week period in the summer and found the bulk of the stomach contents consisted of dipteran larvae, almost exclusively of the Families Chironomidae and Ceratopogonidae. A greater diversity of organisms was observed at the site with the highest current velocity. The author suggested that the substrate in an area swept by fast current would have less silt, making benthic organisms more available to the feeding sturgeon.

A recent study of the food habits of the shovelnose from the tailwaters of the Gavins Point Dam on the Missouri River compared stomach contents (ration) with the availability of benthos and drift organisms (Walburg et al., 1971). In general, the tailwater sturgeon were opportunistic feeders utilizing available food organisms in proportion to their seasonal availability. Midges (F. Chironomidae) were present in large numbers throughout the spring, summer and fall collecting periods. Caddisfly larvae constituted a major portion of the diet only during the early spring and summer months, whereas the burrowing mayfly naiads, Hexagenia spp., were important during both the spring and late fall.

The food habits of the shovelnose from the Mississippi River immediately below the lock and dam at Keokuk, Iowa, were described by Hoopes (1960). Caddisfly larvae and burrowing mayfly naiads composed 75% and 17% respectively of the annual diet. Immature specimens from the Orders Diptera, Plecoptera, Odonata and other miscellaneous aquatic taxa constituted the remaining 8%. This study covered the period from early spring until early fall and contained no information as to the availability of the food organisms present at the collecting sites.

Previous workers on shovelnose food habits have indicated that this species feeds on a wide variety of macrobenthos, microcrustaceans and terrestrial insects depending on their availability as dictated by seasonal and other environmental conditions. Only Walburg et al. (1971) provided data on the concurrent availability of food organisms, yet this report gives no quantitative values of preference. The previous studies (Hoopes, 1960; Held, 1966) were more concerned with the taxonomic diversity of the ration rather than the feeding behavior of the sturgeon. Moreover, to the author's knowledge data on the food habits of the shovelnose on a year-around basis including the winter, have not been previously reported.

The aspect of selectivity (preference for certain food organisms) is not treated extensively in the literature. Because of the difficulty in obtaining valid preference data, some workers have conducted studies under laboratory conditions in an effort to control variables such as vulnerability (Lewis et al., 1961; Ivlev, 1961). Methods of determining the relative importance of food organisms in the environment were introduced by Hess and Swartz (1939) and Ivlev (1961). Hess and Swartz proposed the term "forage ratio" to interpret the food grade values of a stream. In this context, the forage ratio was defined as the percentage comprised by a given organism in the ration divided by the percentage of this same organism in the environment of the predator. This method is valuable in interpreting the important food items within the environment, but is somewhat deficient in providing a standard value to express either an affinity (selectivity) or avoidance.

Ivlev introduced the electivity index to determine the degree of food selection. Ivlev's electivity index is affected by the accessibility of the food items just as is the forage ratio of Hess and Swartz. Although a particular food organism may be available (i.e. present), and desirable (i.e. palatable), to a predator, unless the prey is vulnerable it will be poorly represented in the ration. The advantage of the electivity index over the forage ratio is that it provides both positive and negative values which denote either an affinity or avoidance for any particular food group. In this manner not only preference but selective elimination (avoidance) may be recorded.

This study was an attempt to determine the seasonal food habits and food selectivity of the shovelnose in the Missouri River. Stomachs were examined so as to evaluate the relative importance and preference of the food items in the ration. Collections were made throughout the year in an effort to determine seasonal differences in the feeding habits of the shovelnose. The availability of organisms was compared to the ration to determine electivity and selectivity by the sturgeon. Environmental changes, particularly water releases from the upstream dam and water temperatures, were examined to determine their effects upon shovelnose feeding behavior and food availability.

METHODS AND MATERIALS

Description of Study Area

The study area encompassed a 16.1 kilometer (10 miles) section of the Missouri River between Vermillion and approximately 6.4 kilometers (4 miles) west of Meckling in Clay County, South Dakota. This area is located within the 83.2 kilometer portion of the unchannelized river between Yankton, South Dakota and Ponca, Nebraska. The river width averages 720.7 meters and has a mean depth of 2 meters with maximum depths rarely exceeding 7 meters (Morris et al., 1968).[1] Vertical temperature profiles have shown that the river is homeothermic and the bottom substrate is composed of sand or sandy loam (Volesky, 1969). Fallen trees and aquatic vegetation occur along the banks and are also present on sand bars located within the river. Shallow subsidiary channels (chutes) are commonly found adjacent to the main channel producing backwater marshes which are dominated by cattails. Although the river environment is relatively unaltered directly by man's activities, the water levels are controlled by the timing and rates of discharge at the Gavins Point Dam located approximately 48 kilometers (30 miles) upriver from the principal study area.

Although there were no permanent stations, the fish sampled were taken from four general collecting sites. Area

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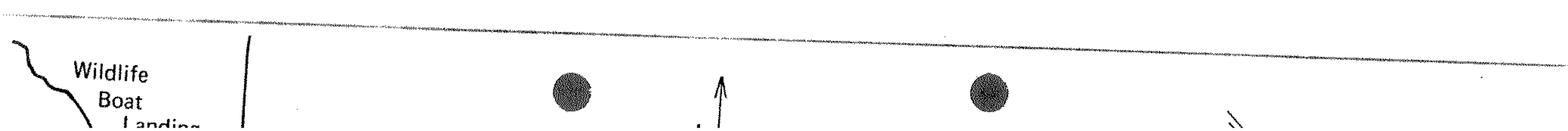
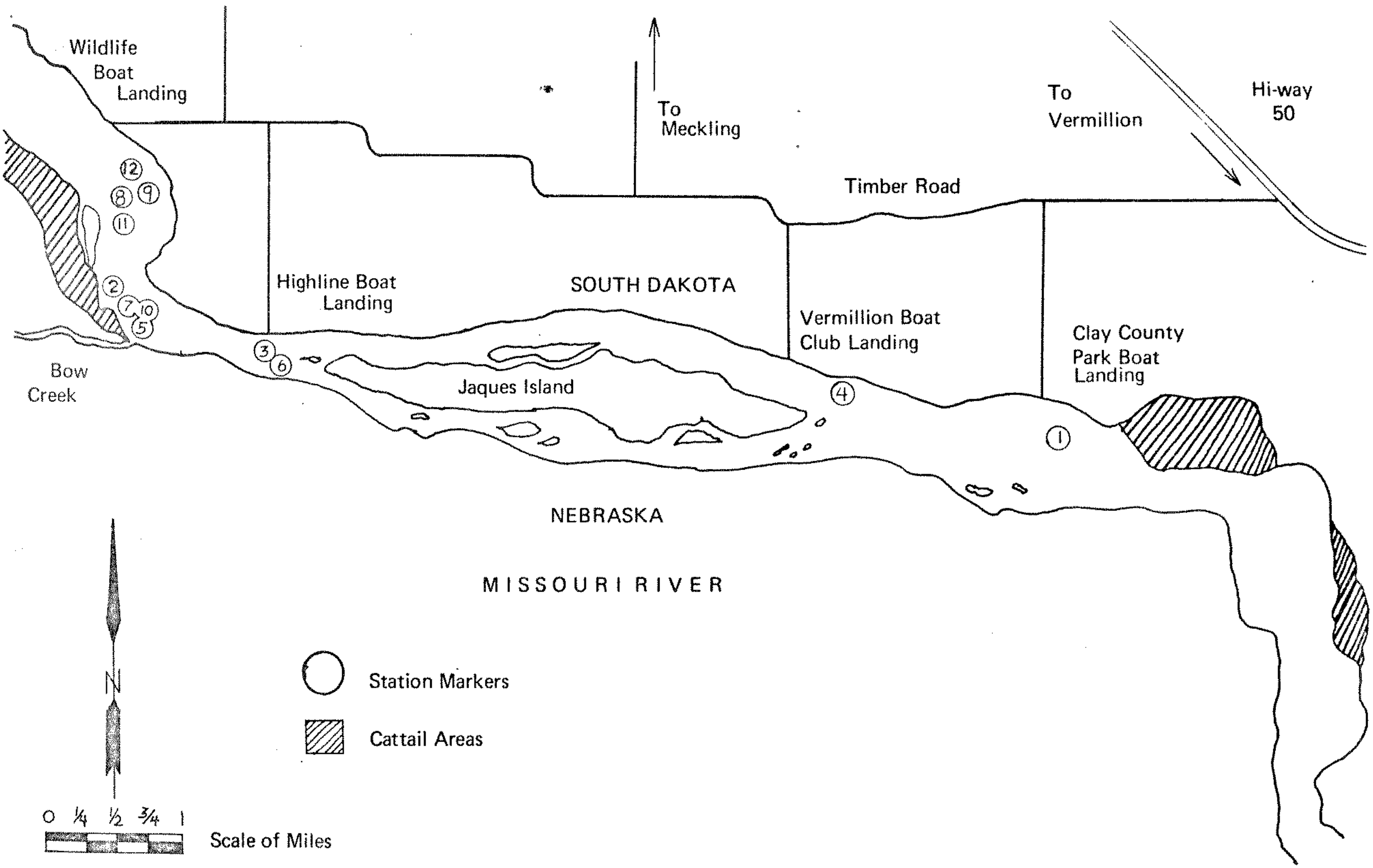
[1]Moos, Richard Personal correspondence, Department of Biology St. Marys College, Winona, Minnesota.

Figure 1. Map of the study area in the Missouri River. Sampling sites are marked numerically. Cattail habitats are indicated by cross-hatching.




Wildlife Boat Landing
To Meckling
To Vermillion
Hi-way 50
Timber Road
Highline Boat Landing
SOUTH DAKOTA
Vermillion Boat Club Landing
Clay County Park Boat Landing
Bow Creek
Jaques Island
NEBRASKA
MISSOURI RIVER
N
Station Markers
Cattail Areas
0 ¼ ½ ¾ 1
Scale of Miles

I was located near Wildlife Landing (R53W, T92N, Sec. 17) and was situated in the widest and shallowest portion of the river within the study area. Most fish were taken from Area II located near Bow Creek (R53W, T92N, Sec. 20) on the Nebraska side of the river which is characterized by a heavily vegetated shoreline consisting primarily of cattails. The two remaining sampling sites, Area III and Area IV, each included only one monthly sample. Area III was situated near the Vermillion Boat Club (R53W, T92N, Sec. 24) and Area IV near Clay County Park (R52W, T92N, Sec. 20). More emphasis was placed upon obtaining seasonal samples rather than equalizing the samples between study areas since the environmental conditions were similar at all sites.

Sampling Procedure

A total of 130 shovelnose sturgeon was collected during monthly intervals from October 1971 through September 1972 (Table I).

Table I. Dates and number of fish collected between October 1971 and September 1972.

Date	Oct 15	Nov 18	Dec 15	Jan 19	Feb 28	Mar 17	Apr 14	May 19	Jun 22	Jul 17	Aug 15	Sept 15
No. of Fish	15	17	16	4	13	13	13	9	10	10	4	6

The fish were all taken with nylon or monofilament gill nets with a mesh size of 3.81 centimeters (1.5 inches) bar measure 1.8 meters deep and ranging in length from 12.2 to 91.5 meters. Nets were behind sand bars in water which varied in depth between 2 and 5 meters. This type of net set was described by Dumont and Sundstrom (1961) as an "anchored" set. Nets were secured to a steel rod driven into the downstream edge of a sand bar and were extended parallel to the direction of the current. Sets were made as close to dusk as possible and retrieved the following morning. According to Moos, the shovelnose are most active during the evening hours and again at dawn.[2]

During the month of April, 5 of the 13 fish utilized were taken with a drifting trammel net set in the afternoon. In this type of set the trammel net is extended so it floats perpendicular to the current in such a way as to drift downstream. A complete description of this technique is provided by Helms (1972).

Macroscopic drift and benthos organisms were sampled each month from the same sites at which the fish were taken. Drift organisms were captured with a 000 mesh nylon fry net (grid aperture 0.93mm in diameter) with the orifice diameter measuring one half meter. Drift organisms were sampled only at the surface of the river during the dusk hours since the species composition and total numbers of drift organisms are greatest during this period (Namminga, 1967). The collecting time for drift samples, due to seasonal changes in the density of drift organisms, varied from one hour during the winter to

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[2]Moos, Richard Personal correspondence, Department of Biology, St. Marys College, Winona, Minnesota.

ten and fifteen minutes in the summer months.

The nylon fry net used to sample drift organisms was fastened directly to the boat and fished for between 15 minutes and one hour. After the fry net was removed from the water the contents were immediately emptied into jars containing 10% formalin. During the cold weather sampling period, the contents of the nets were not removed until after returning to the laboratory.

Monthly benthos collections consisted of three samples from the ponar dredge. Due to adverse weather conditions, benthos samples could not be taken during the months of January and February. For similar reasons (i.e. floating ice) a representative drift sample could not be obtained in the month of December.

A portable boom was attached directly to a flat-bottomed John boat, and functioned as a means of lowering and raising the dredge from the bottom. Since much sand was included in the benthos sample, the organisms could not be washed from the substrate samples until some of the sand was removed from the samples in the laboratory. Therefore, the substrate samples were placed in plastic garbage pails and returned to the laboratory for analysis.

A Gurley current meter, model #622, was utilized to determine the stream velocity at each collecting site. The volume of water sampled could then be estimated by knowing the time "fished" and the velocity of the current moving through the known aperture size of the fry net. Both atmospheric and water temperatures were recorded with a hand thermometer.

Laboratory Methods

The sturgeon were immediately transported to the laboratory after being removed from the nets. Specimens were measured for fork and total length to the nearest millimeter and weighed to the nearest one half ounce on a commercial scale. All fish sampled in this study measured between 45 and 60 centimeters in fork length. A longitudinal incision was then made on the ventral surface from the anus to the region of the pectoral girdle at which time the sex was recorded and the digestive tract removed.

The alimentary tract was removed beginning with the esophogus in the region of the pectoral girdle and extending to the intestine in the region of the spiral valve. The alimentary tract was immediately injected with 10% formalin and stored in vials containing 10% formalin. Since not all of the identifiable food contents were found in the morphologically distinguishable stomach, the term "stomach" will hereafter include the other portions of the digestive tract which were removed.

Stomachs were later opened and the food organisms grossly separated into taxonomic categories. These categories of organisms were then stored in a 10% formalin solution until further identification could be completed.

In the laboratory the contents of the drift samples were placed in a white enamel pan containing a concentrated salt solution and were also grossly separated into taxonomic categories. There they were placed into vials containing a fresh solution of 10% formalin. The salt solution increased the specific gravity of the medium and caused the drift organisms to float above the sand and heavier organic material, enhancing the removal of the organisms. Vials containing the drift organisms were then set aside until a later date, at which time they were identified, counted, dried and weighed.

Benthic organisms were separated from the substrate samples by decanting a portion of the sample five times in a plastic pail (Williams, 1971). The decanted water containing the organisms was strained through a #100 U.S. Standard Testing Sieve (grid aperture 0.149mm in diameter) and the remaining organic matter placed into vials containing 10% formalin until the organisms could be picked from the samples. The salt floatation method previously described was also used to facilitate the extraction of benthic organisms from the decanted samples. When time permitted, benthic organisms were picked immediately after the samples were decanted as less time and effort was needed to detect the live organisms, because of their movement.

Organisms found in the ration and in the drift and benthos samples were counted and identified to the lowest taxa possible. A binocular microscope with a magnification range of 7 to 50 diameters and a 2X auxillary lens was used to help identify organisms. Slide preparations of the various midge larvae were prepared in order to identify these larvae to the generic level. The following works were used as keys in identifying organisms: Borror and Delong (1954), Mason (1968), Usinger (1956), Ross (1944), Johannsen (1934), Boving and Craighead (1953), Peterson (1959) and Pennak (1953).

Not all of the stomach contents could be identified. That portion of the ration composing fragments of exoskeletons, unidentifiable organic material and inorganic particles were combined into a miscellaneous category. Microcrustaceans were not enumerated and identified but instead were considered miscellaneous matter.

Identifiable organisms were dried at 65°C for 24 hours in a drying oven and then weighed on an analytical balance (Mettler, Type H6) to the nearest 0.1 milligram. Miscellaneous matter was dried and weighed in the same manner as the identifiable organisms, but was then combusted at 550°C for 45 minutes. In this manner, both the organic and inorganic fraction of the miscellaneous category could be determined.

Mean monthly discharge rates from the Gavins Point Dam were obtained from the U.S. Army Corps of Engineers, at Yankton, South Dakota. Daily means and ranges in air temperatures were provided by the South Dakota State Geological Survey. Statistical analysis was accomplished through use of the IBM 1620 Computer provided by the University of South Dakota Computer Center.

Lagler (1956) lists and discusses the following methods of analyzing the food ingested by fish: (1) numerical, (2) frequency of occurrence, (3) estimating percentage by bulk, (4) gravimetric, (5) volumetric, and (6) the restoration of original properties of food items. Because of the limited information that can be obtained from any single procedure, a combination of the techniques is usually employed to project a valid conclusion. By combining a series of different measurements, the investigator acquires a more accurate appraisal of the food items comprising any ration. Numerical, frequency of occurrence and volumetric (or gravimetric) methods are the most frequently used combinations employed by investigators. In this study, the gravimetric method was utilized with the numerical and frequency of occurrence methods.

In the numerical method, food organisms are identified, counted and expressed as a percentage of the total number of food items present in the stomach. The obvious handicap of this method is the fact that although an organism may constitute a numerical majority it may not necessarily be the most important contributor to the sample biomass. This condition was witnessed in the present study when large numbers of relatively small midge larvae were found in the stomachs but these midges constituted a minor portion of the ration biomass. The numerical method does, however, aid in evaluating the importance of any food item and is especially meaningful when contrasting a series of samples which are used to monitor seasonal changes.

The frequency of occurrence method records the number of stomachs, expressed as a percentage, in which a food item is present. The frequency of occurrence also has its weaknesses and limitations and the interpretation of its meaning is subject to a certain degree of bias. Digestive activity proceeds more slowly upon larger food items and produces an accumulating effect, yielding a higher frequency than those smaller items which are digested at a faster rate. Another limitation of this method is its failure to illustrate the biomass relationships of the different food groups.

The most representative means of measuring the importance of the different food items is the gravimetric method. This method involves obtaining either wet or dry weights of each of the food items. In this study, the dry weights were utilized. Although the gravimetric is the most representative gauge, it also contains a certain amount of bias. As previously mentioned, larger items require longer periods to completely digest than do equal weights of smaller items. Another source of bias is the presence of an occasional large food item which could cause one to misinterpret the true importance of this food item in the ration. Under most conditions, however, the gravimetric method presents the most unbiased information regarding the food ingested by a species and was the principal method used in interpreting the data from the samples.

RESULTS AND DISCUSSION

Stomach Contents

Identifiable food items were found in 129 of the 130 stomachs examined. Arthropods, primarily aquatic insect larvae, were the most important food item observed throughout the 12 month sampling period. Insects constituted 12 of the 16 orders and 66 of the 73 families which were identified in the sturgeon's ration. Aquatic organisms comprised 98.4% of the total dry weight, 99.4% of the total numbers, and were present in 99.2% of the stomachs (annual frequency of occurrence). Terrestrial organisms, although present in 53.7% of the stomachs, made up only 1.6% of the total dry weight and 0.6% of the numbers (Table II).

Throughout the year, the ration of the shovelnose consisted mainly of immature insects from one, or a combination of the following three insect orders: Diptera, primarily the Family Chironomidae; Trichoptera; and Ephemeroptera. Together the chironomid and caddisfly larvae, especially Genus *Hydropsyche* spp. (mostly *H. orris*), comprised 81.2% of the annual weight and 96.3% of the total numbers. The burrowing mayfly naiads, *Hexagenia* spp. (primarily *H. limbata*), constituted 8.2% of the total weight while making up only 0.2% of the numbers. The only other food item constituting over one percent of the annual total dry weight was the aquatic Isopod, *Asellus* spp., with 1.8% of the weight and 0.2% of the total numbers.

Table II. Annual percentage of weight, numbers and frequency of occurrence if the major food items comprising the ration of the shovelnose sturgeon between October 1971 and September 1972.

FOOD ITEM	WEIGHT	NUMBERS	FREQUENCY OF OCCURRENCE
AQUATIC ORGANISMS			
Diptera	26.0	84.2	98.7
Chironomidae	24.8	82.6	98.7
Misc. Diptera	1.2	1.6	78.9
Trichoptera	57.0	13.9	78.8
Hydropsyche	56.4	13.7	77.0
Neureclipsis	.5	.2	36.6
Ephemeroptera	9.9	.7	62.1
Hexagenia	8.2	.2	23.7
Odonata	.6	.1	26.7
Coleoptera	.2	.1	13.4
Isopoda			
Asellus	1.8	.2	44.0
TERRESTRIAL ORGANISMS			
Coleoptera	.9	.1	24.8

Trichopterans constituted the largest percentage of the annual biomass of any food item and was represented in the ration by the larvae of two Families, Hydropsychidae and Psychomyiidae. The majority of the Psychomyiids belonged to the Genus Neureclipsis, which composed 0.5% of the total annual weight and was found in 36.6% of all stomachs and by the Genus Polycentropus which constituted only a trace (≤0.1%) of both the total weight and the numbers (Table I, Appendix). Most caddisfly larvae in the ration belonged to the Family Hydropsychidae which comprised 56.4% of the weight, 13.9% of the numbers and occurred in 77.0% of the stomachs. No serious attempts were made to identify trichopteran larvae to the species level, however, previous studies upon the drift and aufwuchs within the study area mentioned Hydropsyche orris as the most frequently occurring species in the Hydropsychidae (Namminga, 1969; Nord, 1971).

The Family Chironomidae was the second most important taxon in the ration and constituted 24.8% of the total annual dry weight, 84.2% of the total numbers and was found in 98.7% of the stomachs. Chironomids in the ration were primarily species of the Subfamily Chironominae, although there were seasonal occurrences of the Subfamilies Orthocladinae and Tanypodinae. The most frequently occurring midge larvae within the ration was the Genus n. nr. Demicryptochironomus A and B. Other chironomid genera and species represented in the ration were: Paratendipes, Harnischia curtilamellola, Phaenopsectra, Thienemanniella, Xenochironomus, Cryptochironomus, Paracladopelma tethys, Genus n. nr. Omisus, Trissocladius, Orthocladius, Ablasbesmyia and Procladius (Hudson, 1972).

Larvae belonging to the Family Ceratopogonidae, the second most important dipteran family, constituted only 0.9% of the total dry weight and were present in 50.2% of the sturgeon stomachs. The most abundant ceratopogonid larvae belonged to the Genus Palpomyia.

Burrowing mayfly naiads, Hexagenia spp., comprise the bulk of the Order Ephemeroptera in the ration. Of minor importance were species of the Family Ephemeridae, Pentagenia spp. and Ephemera spp. Other mayfly genera present in the ration included Caenis, Ameletus, and Heptagenia. The remaining aquatic insect larvae were represented by the Orders Odonata (nymphs of Gomphidae, Libelluidae, Coenagrionidae, and Lestidae), Coleoptera, Plecoptera, Collembola and Hemiptera (Corixidae).

Aquatic macrocrustaceans were represented in the ration by the Orders Isopoda and Amphipoda. Asellus spp. was the only Isopod encountered during the study; it occurred in 44.0% of the stomachs and composed approximately 2.0% of the total dry weight. The only Amphipod in the stomachs belonged to the Family Gammaridae (primarily Hyalella azteca) but it was poorly represented and comprised only a trace of the annual total dry weight and total numbers. Microcrustaceans were present in abundance in the stomachs of some shovelnose. However, because of their small size they were difficult to enumerate and these organisms were not separately identified in the analysis of the food contents. All microcrustaceans were included in the biomass determinations under miscellaneous organic matter.

The only other aquatic organisms in the ration belonged to the Classes Nematoda and Oligochaeta. The oligochaetes constituted 0.4% of the total dry weight but this percentage was primarily due to a single large earthworm, which was present in one stomach. Its importance in the ration is best illustrated by the annual frequency of occurrence which amounted to only 3.7%. Also of minor importance in the ration were the nematodes, which were found in 31.1% of the stomachs and comprised only a trace (0.1%) of both the total annual dry weight and numbers.

The terrestrial organisms were represented by eight orders but the bulk of the dry weight was composed of terrestrial beetles. The Order Coleoptera was principally represented by both adults and larvae of ground beetles from the Families Carabidae, Curculioidea and Scarabaeidae. The remaining terrestrial organisms consisted mainly of adults from the Orders Hymenoptera, Homoptera, Diptera, Hemiptera, Orthoptera and Araneae (Class Arachnida).

Fish fry were found in three stomachs but were not included in the total weight, numbers, or frequency of occurrence. It is doubtful whether the shovelnose actively feeds upon young fish and in the opinion of the author including such data would only obscure the importance of those organisms regularly occurring in the diet.

Other workers have also found that the shovelnose sturgeon feeds primarily on aquatic macrobenthic larvae. The food of the shovelnose from the Mississippi River below the Keokuk, Iowa, lock and dam consisted primarily of caddisfly larvae (Hoopes, 1960). Hydropsychid larvae were the dominant trichopterans comprising 75.0% of the annual biomass volumetrically. However, unlike the present study, species of *Hydropsyche* were not considered to be important. Burrowing mayflies, *Hexagenia* spp., made up 17.0% of the total food biomass and the dipteran larvae constituted an insignificant portion of the ration. The tailwater environment at Keokuk has a large benthic population of burrowing mayflies and caddisflies (Fremling, 1960) and this may explain the reliance of shovelnose sturgeon upon caddisflies and burrowing mayflies in Hoopes' study.

In the previous study of Missouri River sturgeon food habitats chironomid and trichopteran larvae and *Hexagenia* naiads were the most important items observed in the ration of shovelnose from the Gavins Point Dam tailwaters (Walburg et al., 1971). In this study, chironomid larvae appeared in the ration of the shovelnose throughout the sampling period, which extended from early spring to late fall, whereas the abundance of trichopteran larvae and *Hexagenia* naiads displayed marked seasonal variation. The remainder of the diet was composed of other insect larvae, Isopods (*Asellus* spp.) and fingernail clams (Musculium spp.) which were endemic to the area.

In a prior study of the food habits of the shovelnose in the Missouri River apart from the tailwaters, Held (1966) observed that the dipteran Families Chironomidae and Ceratopogonidae constituted the major portion of the ration on both a numerical and volumetric basis. Chironomids composed 29.2% and the ceratopogonids 20.5% of the volume while mayflys made up 8.8% of the biomass. Small Baetidae maiads constituted 5.6% of the biomass while other mayfly families (Heptagenidae and Ephemeridae) comprised only 3.2% of the stomachs in his study. The dissimilarities between Held's study and those of the present study were probably caused by both seasonal differences in the sturgeon ration and by the habitat differences between the collecting sites. All fish utilized in Held's study were collected within a two-week period during the month of June and only 20% of the fish were taken from the unchannelized portion of the Missouri River. The remainder of the sturgeon in Held's study were taken from the upper confines of the Lewis and Clark Reservoir. However, in the authors opinion seasonal differences in the sturgeon's ration may be the most important variable which contributed to the observed differences. This aspect will be discussed in detail later.

Seasonal Variation of the Ration

Inspection of the monthly ration means suggested that these data could be grouped into three seasonal time periods (Figures 2 and 3). Within these periods the shovelnose were consuming similar food organisms. Although these intervals are somewhat similar to the lunar seasons, the grouping of

Figure 2. Monthly gravimetric percentages of the stomach contents for shovelnose sturgeon between October 1971 and September 1972.

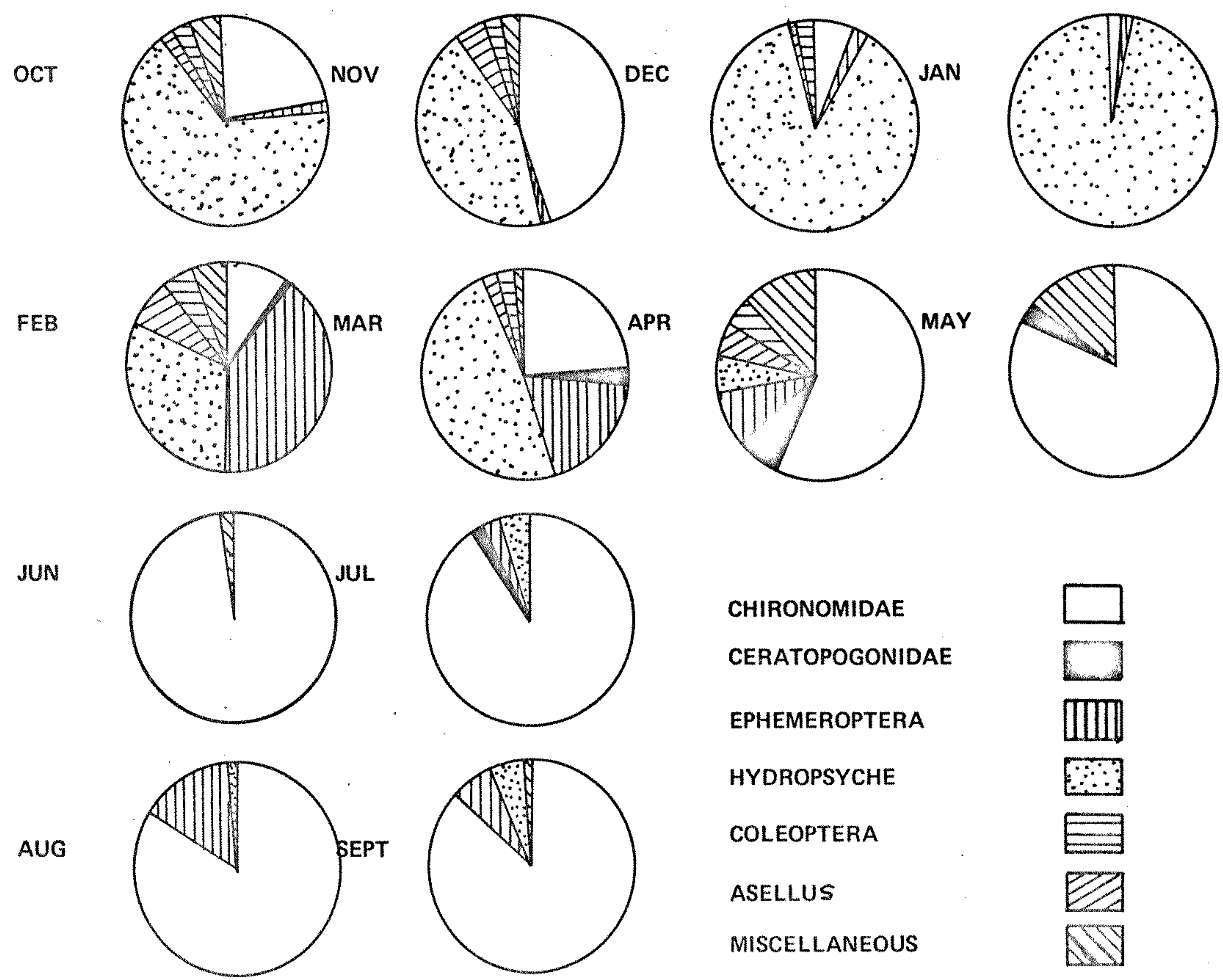
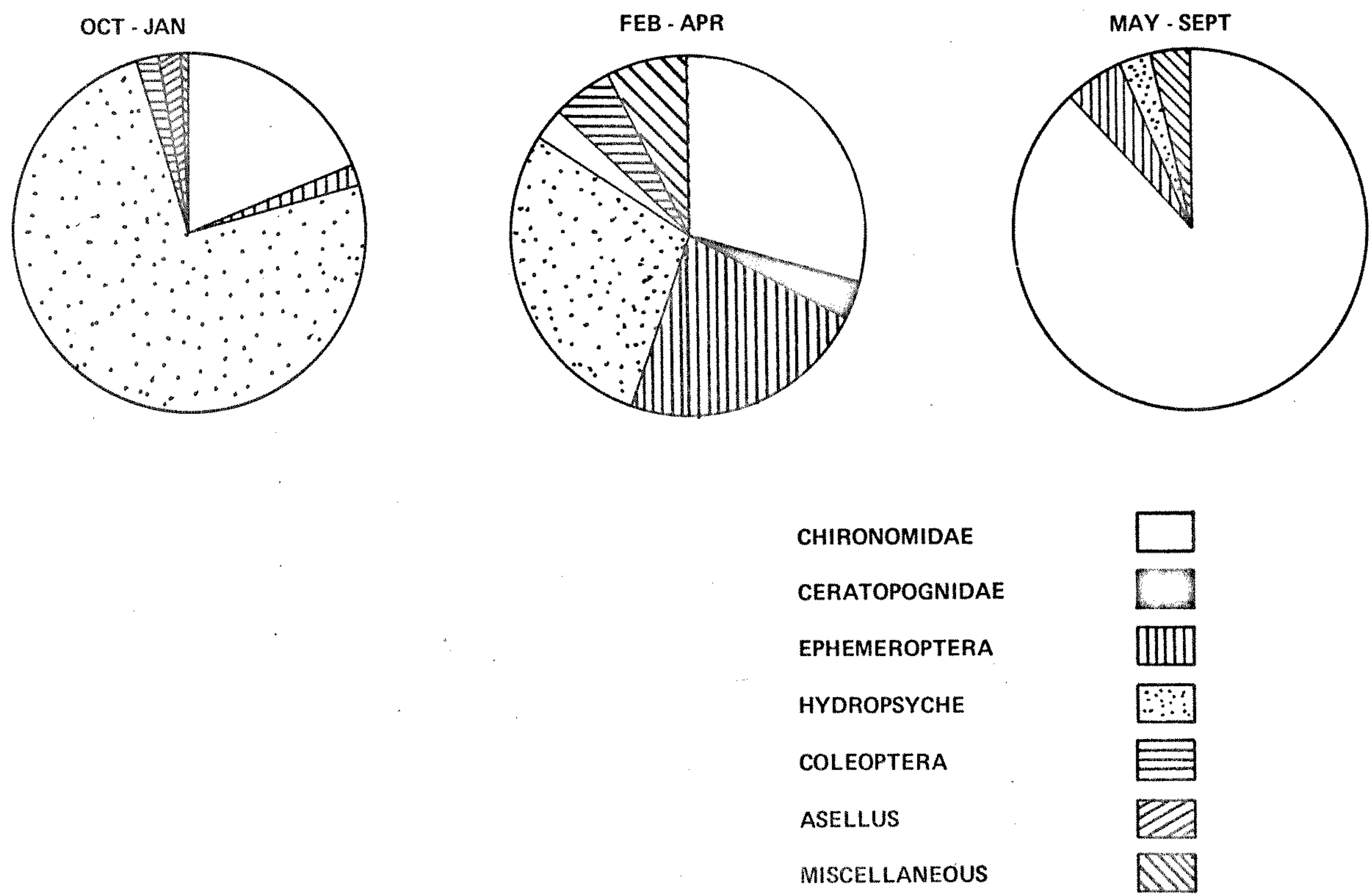

OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEPT
CHIRONOMIDAE
CERATOPOGONIDAE
EPHEMEROPTERA
HYDROPSYCHE
COLEOPTERA
ASELLUS
MISCELLANEOUS

Figure 3. Seasonal gravimetric percentages of the stomach contents for 130 shovelnose sturgeon taken between October 1971 and September 1972.

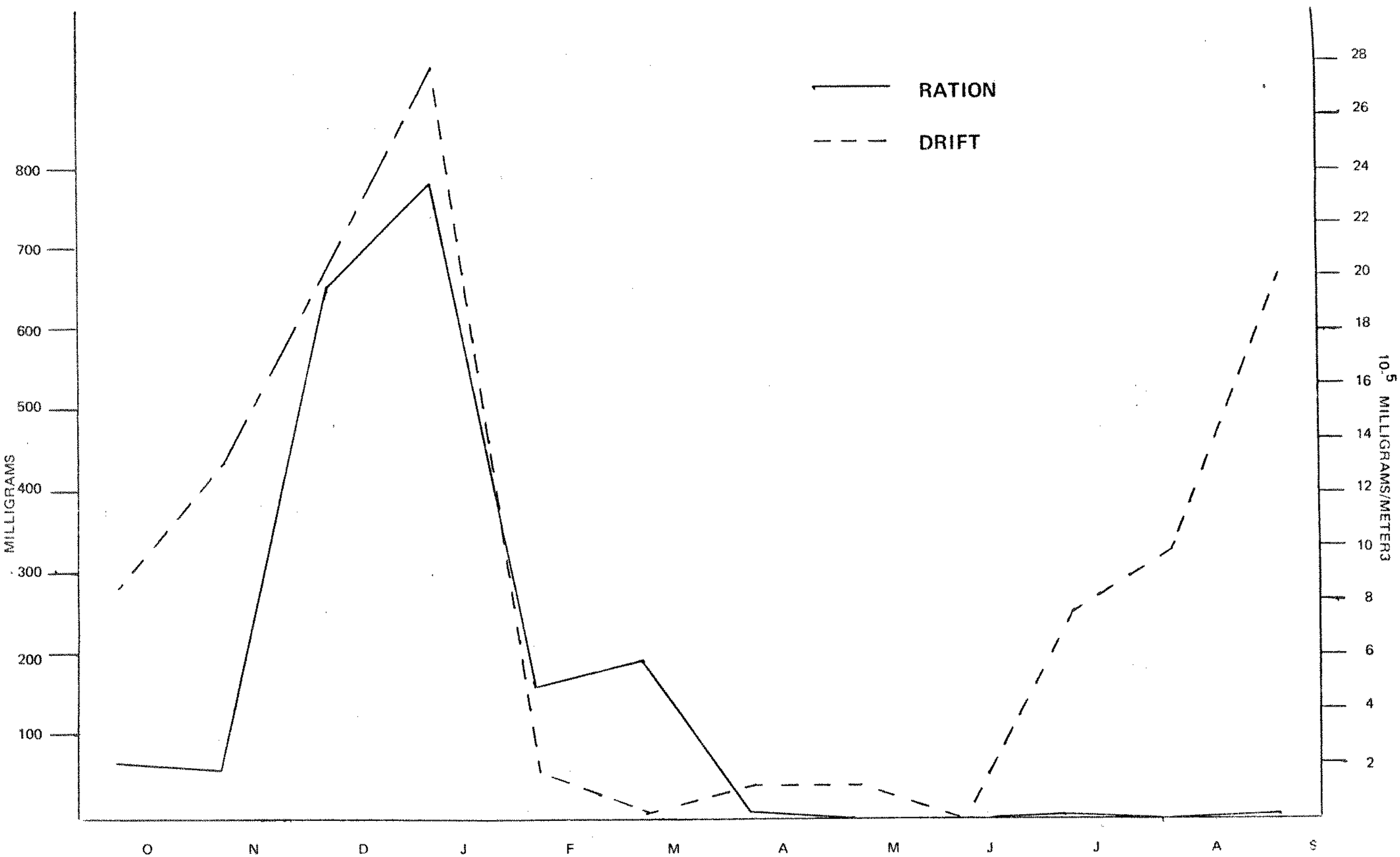

OCT - JAN
FEB - APR
MAY - SEPT
CHIRONOMIDAE
CERATOPOGNIDAE
EPHEMEROPTERA
HYDROPSYCHE
COLEOPTERA
ASELLUS
MISCELLANEOUS

the 12 monthly samples was based solely on the relative taxonomic composition of the ration.

The period between October and January was characterized by the dominance of trichopteran larvae in the stomachs. Caddisfly larvae were primarily represented by Hydropsyche spp. (F. Hydropsychidae) while Neureclipsis spp. (F. Psychomyiidae) was poorly represented. The only other taxon of any importance during this period was the Family Chironomidae which comprised a small but consistent percentage of the biomass. The November mean chironomid biomass percentage was uncommonly large because one stomach contained 51% of all chironomids recovered from the 17 sturgeon stomachs taken that month. This large percentage of chironomids from one stomach may have biased the November sample so that their relative importance during that month was inflated. However, on a seasonal basis chironomids comprised only 13% of the October-January ration biomass.

During the fall and early winter months when Hydropsyche spp. composed the bulk of the ration, they also comprised the bulk of the drift biomass (Figure 4) while their abundance in the benthos was relatively low (Table V, Appendix). Excluding the December sample, when ice prevented taking a valid drift sample, Hydropsyche, larvae constituted 66.3% of the total drift biomass (Table III and IV, Appendix). The dominance of caddisfly larvae in both the drift and the ration between October and January illustrated that not only was Hydropsyche available, but also that they were vulnerable to shovelnose predation. In the late spring and early summer

Figure 4. Monthly weights of *Hydropsyche* larvae in the ration and the drift.


RATION
DRIFT
MILLIGRAMS
800
700
600
500
400
300
200
100
10^{-5} MILLIGRAMS/METER3
28
26
24
22
20
18
16
14
12
10
8
6
4
2
O
N
D
J
F
M
A
M
J
J
A
S

few caddisfly larvae were found in the either the drift or the ration. However, in the late summer and early fall between the months of July and September when the concentration of Hydropsyche in the drift was increasing few were found in the ration. In fact, during September caddisfly larvae in the drift were nearly as abundant as that observed in the fall and early winter months but the ration biomass of Hydropsyche was at its annual minimum. An explanation for this seemingly anomalous situation will be hypothesized later.

Between February and the end of April the quantity of Hydropsyche larvae in the ration decreased while the biomass of the chironomids increased. During this period burrowing mayfly naiads, Hexagenia spp., constituted approximately 30% of the ration biomass and the greatest seasonal taxonomic diversity of food organisms also was observed. Moreover, the largest ration biomass of terrestrial organisms observed during the 12 month study was encountered between February and April. Since terrestrial insects are not active during the winter months this observation was completely unexpected. Most of the biomass during this period, however, was made up of chironomids, Hydropsyche larvae and Hexagenia naiads. Also, many aquatic organisms characteristic of more lentic environments were observed in relative abundance in the ration during this period. For example, dipteran larvae (other than the sand dwelling chironomids) and insects from the Orders Collembola, Hemiptera, and Odonata were well represented in the stomach samples. Increased numbers of Amphipods were also observed, and the isopod *Asellus* spp. was particularly abundant during February and March (Figure 4).

The large taxonomic diversity of both aquatic and terrestrial organisms in the ration during the February-April period is difficult to explain. Although the terrestrial and small aquatic organisms did not individually constitute a major item in the winter ration biomass, their total percentage did represent a significant contribution (Figure 3). Because these organisms are not typically either a major constituent of the drift or benthos, it was difficult to determine availability even though it was obvious, from their presence in the ration, they were available and vulnerable to sturgeon predation.

Other workers have observed that some of the taxa infrequently found in the summer and fall samples of the aufwuchs and drift do become more abundant in the winter period. Nord (1971) observed that the colonization of artificial substrate samplers by *Asellus* spp. increased sharply in February in comparison to their abundance in the fall. In the present study a corresponding increase in the number of *Asellus* spp. in the ration was observed during the winter period.

The months of February and March were the only months throughout the year in which burrowing mayflies, *Hexagenia* spp., constituted a significant portion of the ration (Figure 2). *Hexagenia*, in this study, were present in the drift samples only in March. Swanson (1967) reported a migration of *Hexagenia* spp. through the Gavins Point Dam during March.

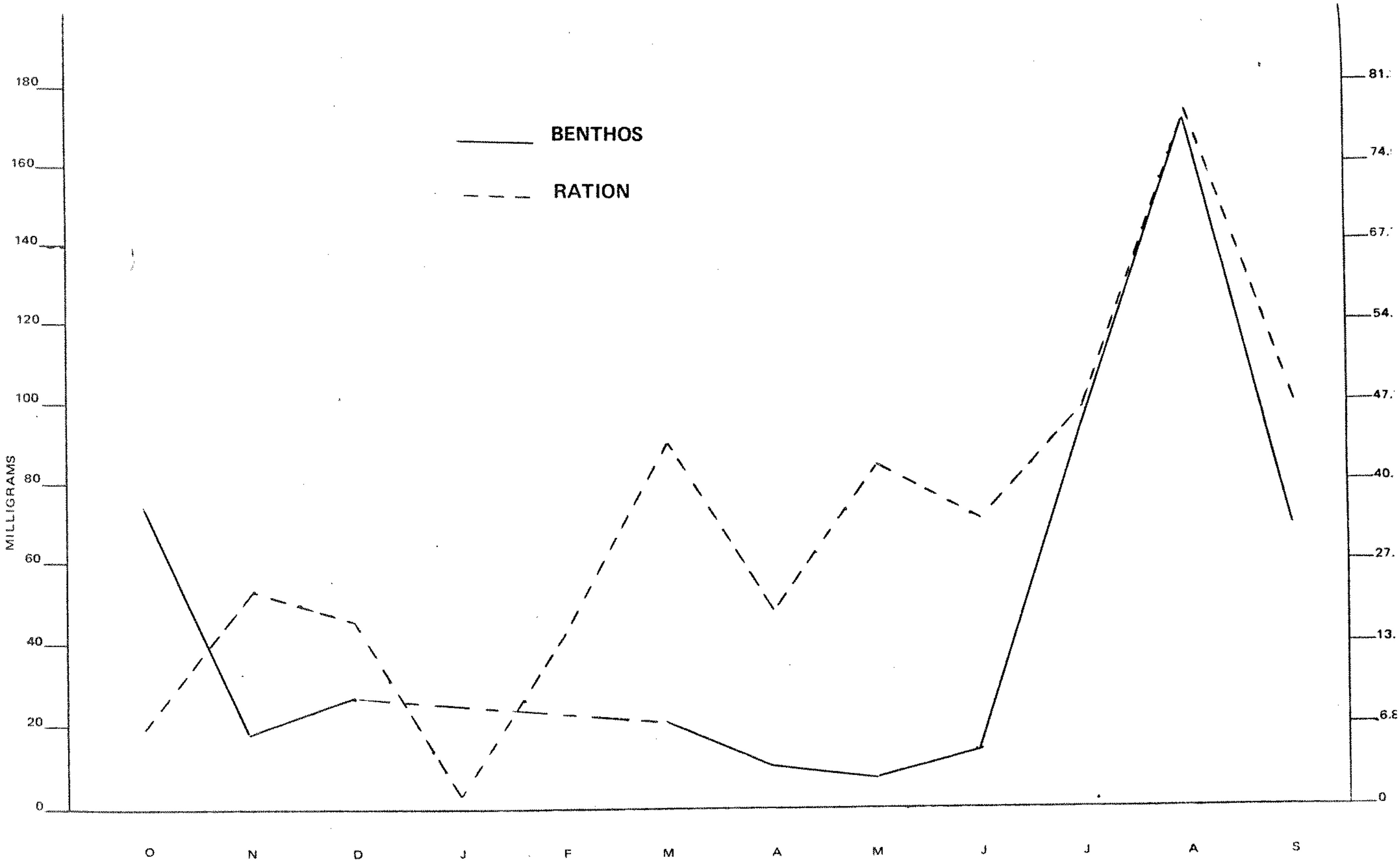
This migration was strongly correlated with the spring break-up of ice which occurred on Lewis and Clark Reservoir on March 21, 1972 and post dated the time in which Hexagenia naiads were found in the stomachs (Table I). The earlier occurrence of Hexagenia in the ration during 1972 may suggest either an earlier movement through the reservoir, or more probable, that the naiads in the ration actually came from local back-water areas adjacent to the main channel. It is possible that drift samples in this study were either taken too infrequently or at the improper hour of the day to accurately determine the period of maximum appearance of Hexagenia naiads in the water mass.

Although chironomid larvae had a high frequency of occurrence (98%) they were particularly abundant in the ration during the late spring and summer months composing 87% of the total weight of the identifiable food organisms. This taxon was almost exclusively composed of larvae from the Subfamily Chironominae, although some pupae and adults of this taxon also were present. The Subfamilies Orthocladinae and Tanypodinae were also represented but were common only in the late winter and spring months. Ephemeropterans, particularly Ameletus spp. were common in the ration during August and September and occurred in 91.7% of the stomachs during those months.

The increased percentage of midge larvae in the ration during the summer was more a function of declining numbers and weights of other organisms which were previously important rather than a marked increase in the ration biomass by chironomids (Figure 8). The change in the ration composition during the summer was accompanied by an increase in the diversity and total biomass present in the drift (Table IV, Appendix). It appeared, therefore, that the decrease in the number of typical drift taxa in the ration was not a function of availability. Conversely an increase in the benthic biomass and numbers was observed between the months of July and September (Figure 5 and 6). This increase was accompanied by an increase in the ration of those taxa normally associated with the benthos. The increased abundance of chironomid larvae in the drift during this period can be attributed to the recruitment of early instars into the population. The most frequent chironomids in the benthos throughout the study were the Genus n. nr. Demicryptochironomus A and B. Other genera identified within the benthos were Harnischia, Cryptochironomus, Polypedilum and Genus n. nr. Omisus (Hudson, 1972).

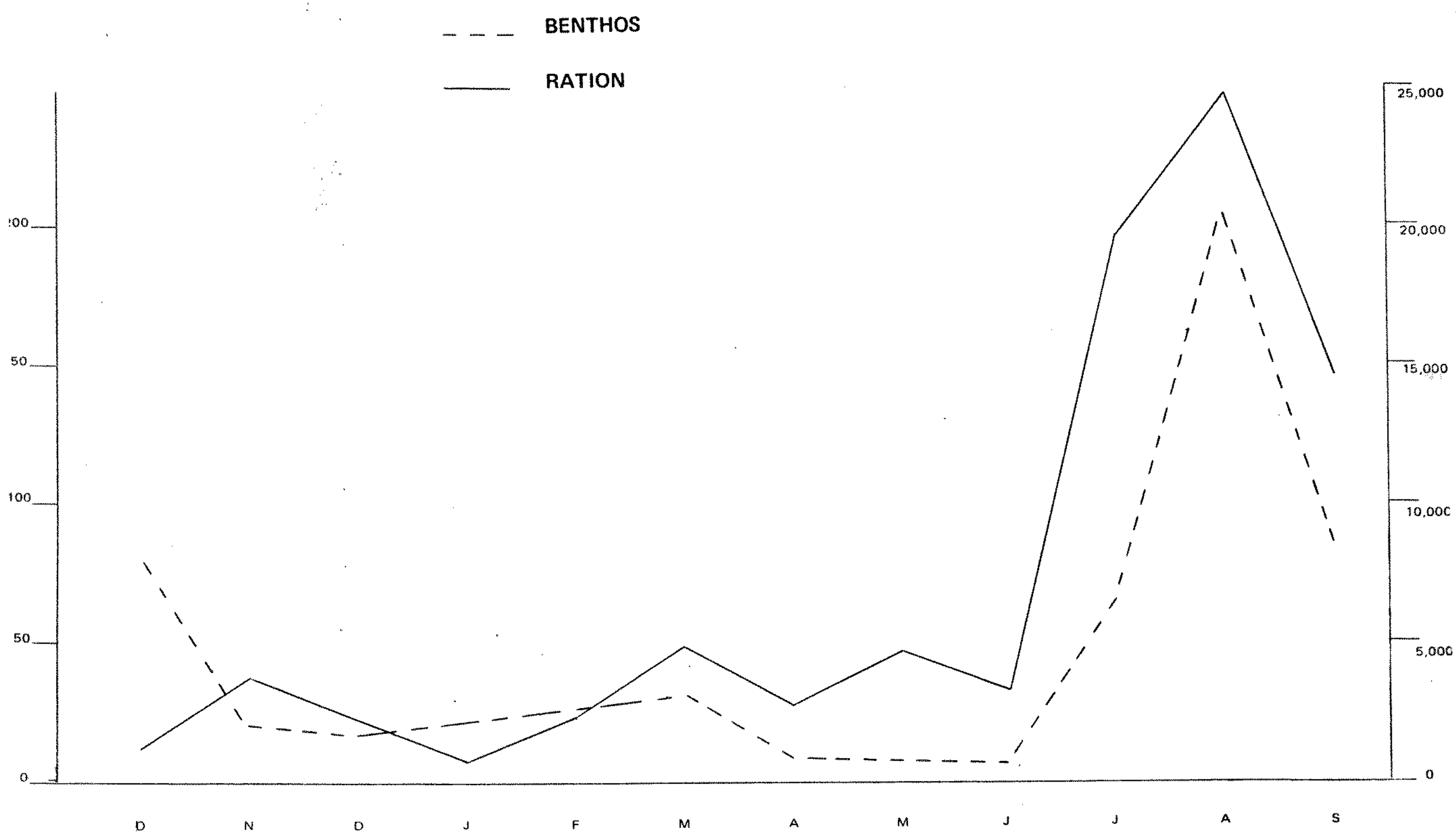
The ration between May and July was similar to that reported for the shovelnose in the Missouri River by Held (1966). Chironomids, however, constituted a greater majority of the ration and the Family Ceratopogonidae was not as significant in the present study. Held (1966) reported an average of 18.5 families per sturgeon stomach in fish sampled during the summer from the unchannelized portion of the Missouri River, as compared to 14.7 families per stomach for the months of May, June and July in the present study. However, Held reported that terrestrial taxa occurred in 90.9% of the

Figure 5. Monthly weights of the Family Chironomidae present in the ration and the benthos.



BENTHOS
RATION
MILLIGRAMS
180
160
140
120
100
80
60
40
20
0
81.
74.
67.
54.
47.
40.
27.
13.
6.8
0
O
N
D
J
F
M
A
M
J
J
A
S

Figure 6. Monthly numbers of the Family Chironomidae present in the ration and the benthos.



BENTHOS
RATION
:00
50
100
50
0
25,000
20,000
15,000
10,000
5,000
0
D
N
D
J
F
M
A
M
J
J
A
S

stomachs as compared with a 17.3% frequency of occurrence in this study.

Hoopes (1960) reported that the ration of the shovelnose in the Mississippi River consisted primarily of trichopteran larvae, but a significant portion of the ration was also composed of burrowing mayfly naiads. It was interesting to note that the sampling period of Hoopes' study (i.e. April, June, July and October) corresponded to the season in which chironomids composed the bulk of the diet for the shovelnose in the Missouri River. In the present work, caddisfly larvae were infrequent and the Hexagenia naiads are almost nonexistent within the ration from spring to early fall. It was not surprising, however, that chironomid larvae were not an important food item in Hoopes' study because of the large concentrations of Hexagenia naiads and trichopteran larvae within the study area (i.e. the tailwaters of Keokuk Dam).

Electivity

Electivity values, as proposed by Ivlev (1961), were used to express the preference by the shovelnose for particular food items which occurred in the Missouri River. These values are simply ratios of the percentage on a dry weight basis of any food organism in the ration to the dry weight percentage of that organism in the environment. Electivity values for food items were determined by the following formula:

$$\text{Electivity} = (r_i - p_i)/(r_i + p_i)$$

where: r_i = percentage of the item in the ration

p_i = percentage of the item in the environment

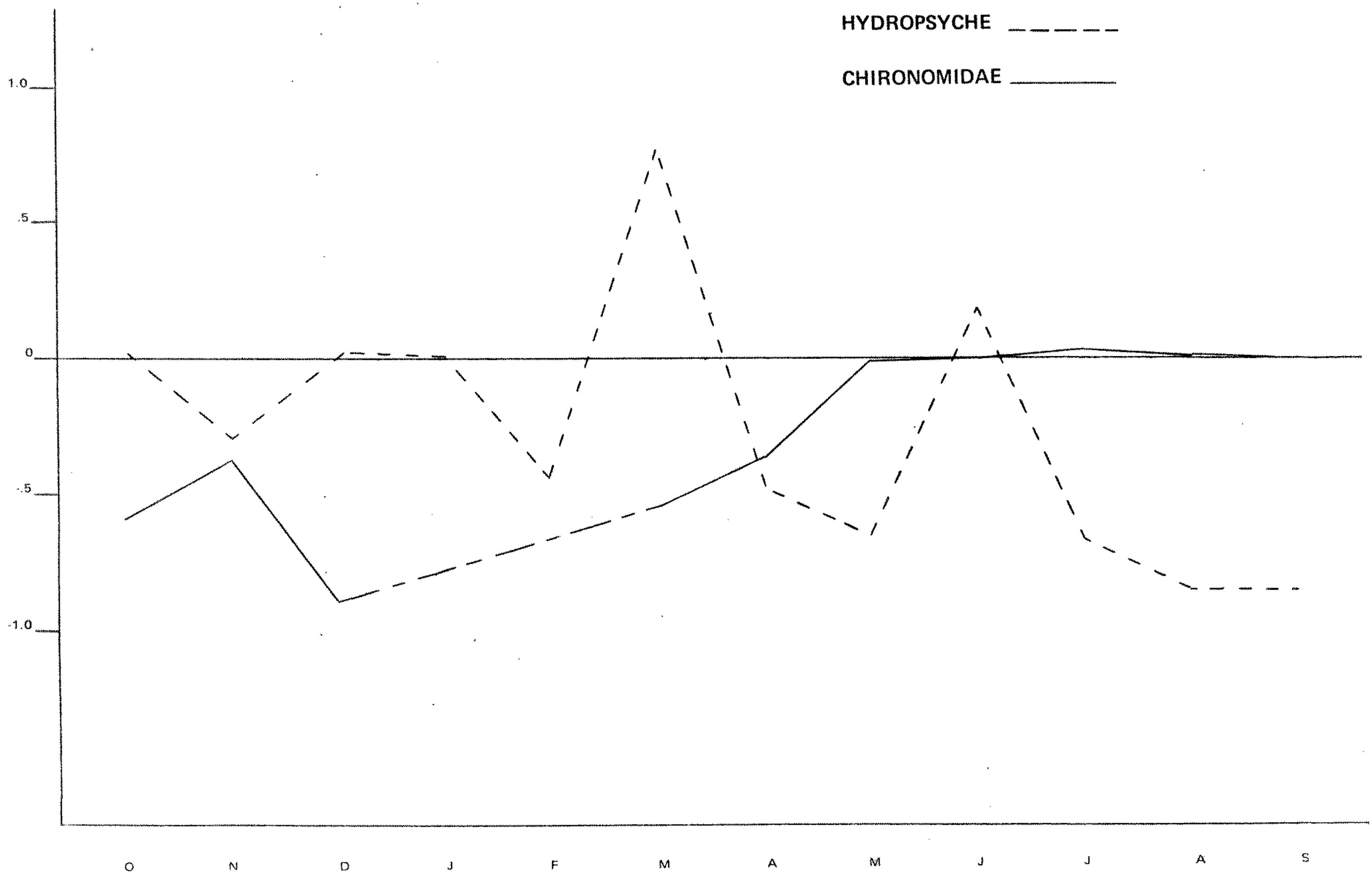
In this measure, maximum preference or selectivity is characterized by a plus one and maximum avoidance is indicated by a minus one value.

Electivity values are dependent not only upon the food preference of the predator, but also the availability and vulnerability of the prey. Although a predator may exhibit a preference for a particular food organism, unless that organism is available and vulnerable it will display a poor electivity value.

Since most shovelnose food organisms comprised only a small percentage of the total ration or were only seasonally important in the ration, drift and benthos only the electivity values for Hydropsyche in the drift and the Subfamily Chironominae from the benthos were considered to be based on sufficient data. These two food items constituted the major quantity of the ration throughout the year and were the principal constituents of the drift and benthic communities.

Neutral electivity values for both Hydropsyche and Chironominae were exhibited during the periods in which these organisms composed the bulk of the ration (Figure 7). Hydropsyche composed the bulk of the ration from October to January and chironomids were the dominant taxa in the May through September stomach samples (Figure 3). In the author's opinion the slightly negative electivity value of Hydropsyche in November was due to a sampling artifact because one of the 17 stomachs taken that month had a large biomass of chironomid larvae which biased the monthly samples. In both instances

Figure 7. Electivity values for *Hydropsyche* in the drift and Chironomidae from the benthos.



HYDROPSYCHE
CHIRONOMIDAE
1.0
.5
0
-.5
-1.0
O
N
D
J
F
M
A
M
J
J
A
S

the neutral electivity values of the principal food items corresponded to the periods when the items were abundant within the environment.

Between February and April both Hydropsyche and Chironominae exhibited negative electivity values which were due to the presence of Hexagenia naiads and other food items, such as the isopod Asellus. Evidently when the food items, such as Hexagenia, other littoral zone aquatic taxa and terrestrial organisms, became concentrated and vulnerable during the winter they were quickly selected by the shovelnose. Further interpretation of this condition will be discussed later in this paper.

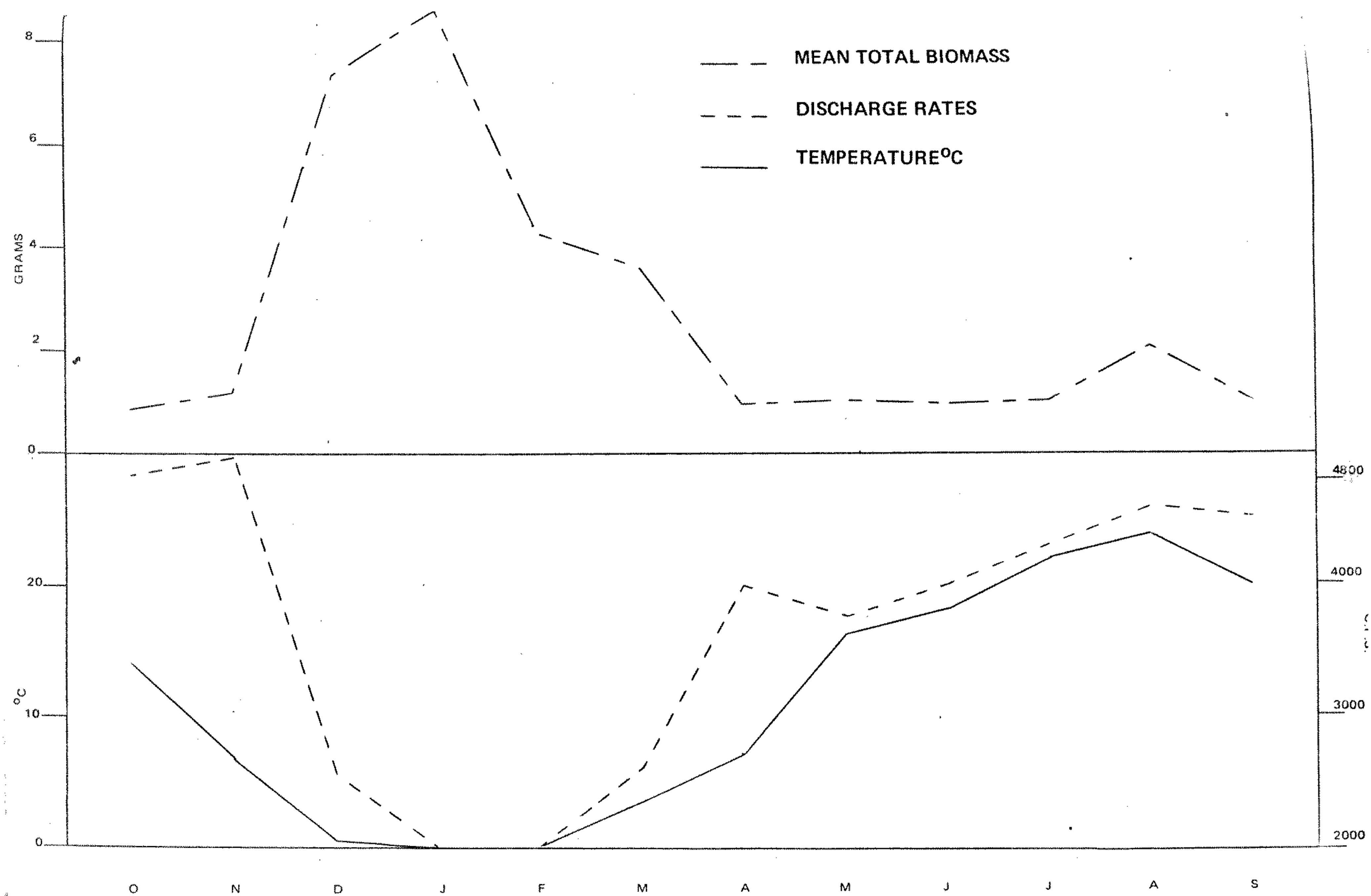
The neutral and negative electivity trends exhibited by Hydropsyche and Chironominae larvae were probably the result of both the changing conditions of availability and vulnerability rather than a palatability preference for any food item. The data suggested that between October and July the variety and types of food organisms present in the ration were closely correlated with the total available food supply. The presence of the food organisms in the environment was influenced by a wide variety of abiotic and biotic factors including changes in water elevation produced by the fluctuations in the discharge rates at the Gavins Point Dam, and by the life cycles and behavior of the organisms themselves. It appeared that when any food organism was abundant and concentrated, they immediately became more vulnerable to shovelnose predation. Sturgeon are opportunistic and take advantage of organisms when they become more available and vulnerable. Neutral electivity rather than positive values for the two main food groups, at the time when they dominated the ration, seems to support this assumption.

The shovelnose is known as a suctorial feeder on benthos (Lagler et al., 1962; Mellon, 1927; Henshall, 1891) and the mouth, as in all sturgeon, is protrusible and modified for bottom feeding. However, the results of this study suggested that for at least six months (October through March) of the year the shovelnose fed in a grazing type manner upon drift organisms which have settled near the bottom. The occurrence of large numbers of microcrustaceans in the ration may suggest that feeding activity is not always directed solely toward suctorial feeding on the benthos. The presence of microcrustaceans in the alimenatary tract was also reported by Held (1966) who also suggested that the shovelnose grazed on available food organisms.

Influence of Water Discharge Rates

The data from this year-long study indicated that discharge rates from the Gavins Point Dam were negatively correlated with the total biomass present in the ration (r=-.85061). This relationship was particularly evident during the low water period on the Missouri River between December and April when the stomachs contained the greatest amount of biomass throughout the year (Figure 8). The amount of water discharged from the Gavins Point Dam affected both stream velocities and water levels in the study area which consequently altered

Figure 8. Comparison of water temperature and discharge rates to the monthly mean total biomass present in the stomachs.


MEAN TOTAL BIOMASS
DISCHARGE RATES
TEMPERATURE°C
GRAMS
8
6
4
2
0
°C
20
10
0
4800
4000
3000
2000
O
N
D
J
F
M
A
M
J
J
A
S

the concentration and vulnerability of food organisms to the shovelnose.

In order to provide flood control during the 1972 spring thaw, the water level of the main-stem reservoirs was lowered during the fall of 1971, especially between October and mid-December. In fact the discharge rates through the Gavins Point Dam were at their seasonal highest during this time. After the water elevation in the reservoir was reduced to a level capable of retaining the expected flood water, the discharge rates were lowered. At this point the spillways were shut, and the total discharge was composed of that water passing through the turbines. This condition produced the lowest seasonal water elevation along the unchannelized river averaging approximately two meters below the mid-fall high water level.

Between the months of October and January, Hydropsyche larvae dominated the ration biomass. During this period caddisfly larvae were also relatively abundant in the drift (Figure 4). Conversely the benthos at this time averaged only 7 mg/m^2 which was somewhat lower than the standing crop during the previous summer months (Namminga 1967; Morris et al., 1968). Thus, with a low benthic biomass and a moderately plentiful supply of food organisms in the drift, it appeared that the shovelnose fed primarily upon drift organisms. After the discharge rates were lowered to their minimum output (December 14, 1971), the river elevation also dropped to its seasonal low. The reduction in the water level probably caused many Hydropsyche larvae, which are normally aufwuchs organisms, to enter the drift and perhaps more importantly to become concentrated in the remaining suitable habitats. This low water condition produced the highest concentration of caddisfly larvae observed in the drift samples during the 12 month study (Figure 4). A large increase in biomass present in the ration during December and January show that not only were caddisfly larvae available but also vulnerable to the shovelnose.

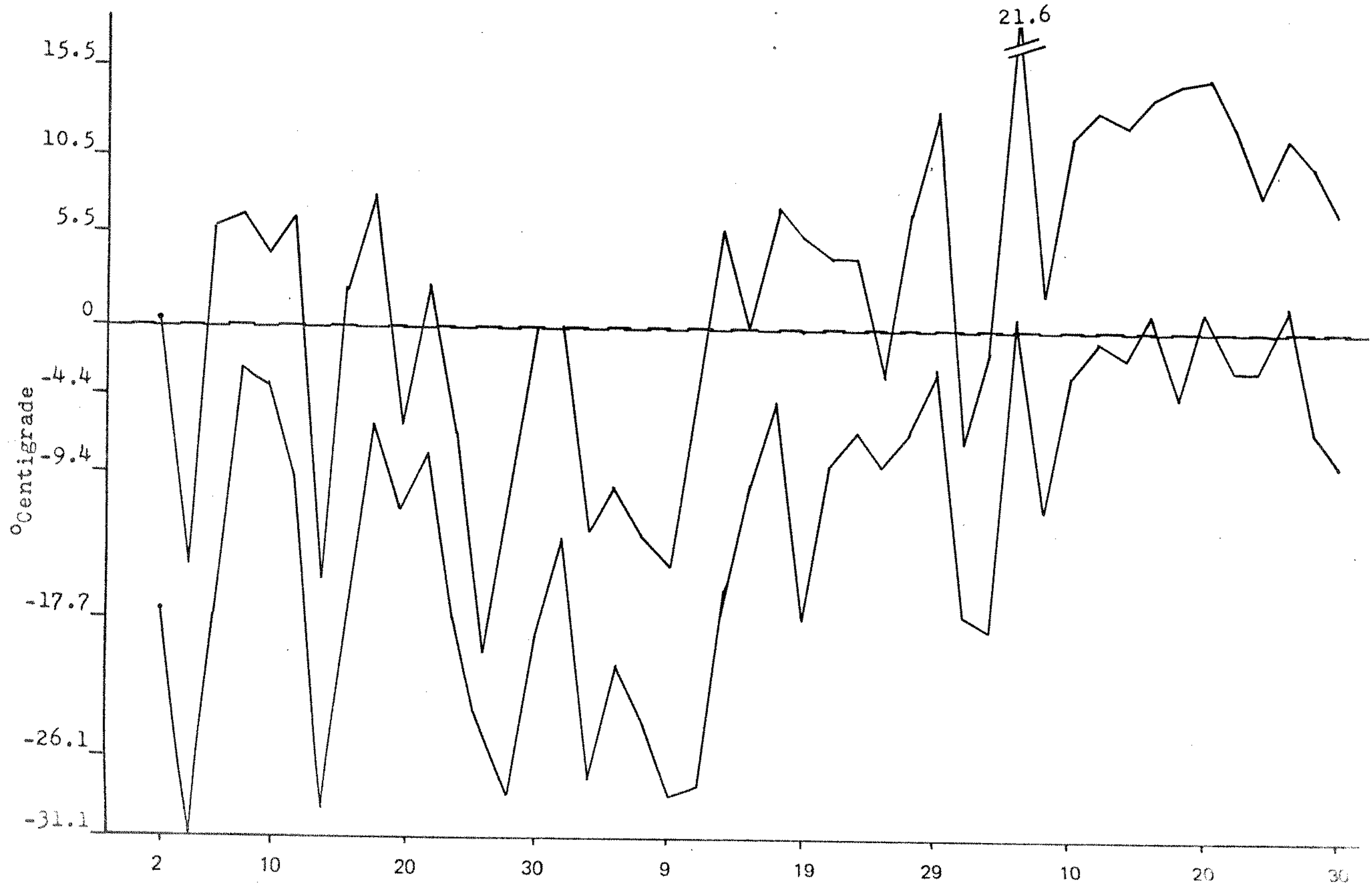
The lowering of the water levels in early winter may also be responsible for the sudden appearance in the ration of Hexagenia and other littoral aquatic and terrestrial organisms. This was especially noticeable in February. Throughout the winter the water elevation of the Missouri River was kept at approximately two meters below the summer operating levels. Certainly this substantial drop in the water level exposed much of the backwater areas to the atmosphere. Benthic and aufwuch organisms in the backwaters would have either perished, burrowed into the substrate or escaped as drift organisms. This would have had the affect of concentrating such typical littoral benthic taxa as Amphipods, Corixids, Dytiscids, Ceratopogonids, the Subfamilies Orthocladinae and Tanypodinae and the Genus Xenochironomus in the shallow substrate adjacent to the main channel. These taxa were previously observed in the shallow littoral zone of Missouri River habitats (Sandholm, 1969; Volesky, 1969; Hudson, 1971).

Previous workers have ascribed the term "catastrophic" drift to those invertebrate organisms which occur in abundance in the water mass following a severe change in the physical environment (Waters, 1965). Although flooding has been suggested as the major factor in producing catastrophic drift (Waters, 1965; Beauchamp, 1932), it is also possible that the opposite effect of lowering the water level may cause organisms to concentrate in backwater pools or in subsidiary channels. Some of these organisms may be either flushed or they may swim into the main channel where they are vulnerable to sturgeon predation. The migration of macrobenthic taxa as a result of acute changes in the environment and their subsequent aggregation in protected areas downstream from the initial colonization site has been reported earlier by Pennak (1953) and Allee (1929). In all probability once the organisms were concentrated they were located by foraging sturgeon.

The range of daily air temperatures provided by the South Dakota State Geological Survey clearly indicated that insufficient solar radiation was absorbed by the water mass in the winter of 1971-72 to produce a mid-winter thaw of any consequence (Figure 9). This fact removed the possibility that the terrestrial organisms, represented by the orders Coleoptera, Hymenoptera, Orthoptera, Homoptera, Diptera and Araneae could have occurred naturally within this period. Evidently the terrestrial taxa also were concentrated in the remaining water mass by the drawdown.

Ivlev (1961) stated that when the concentration of a

Figure 9. Atmospheric temperature ranges between January and March.


21.6
15.5
10.5
5.5
0
-4.4
-9.4
-17.7
-26.1
-31.1
°Centigrade
2
10
20
30
9
19
29
10
20
30

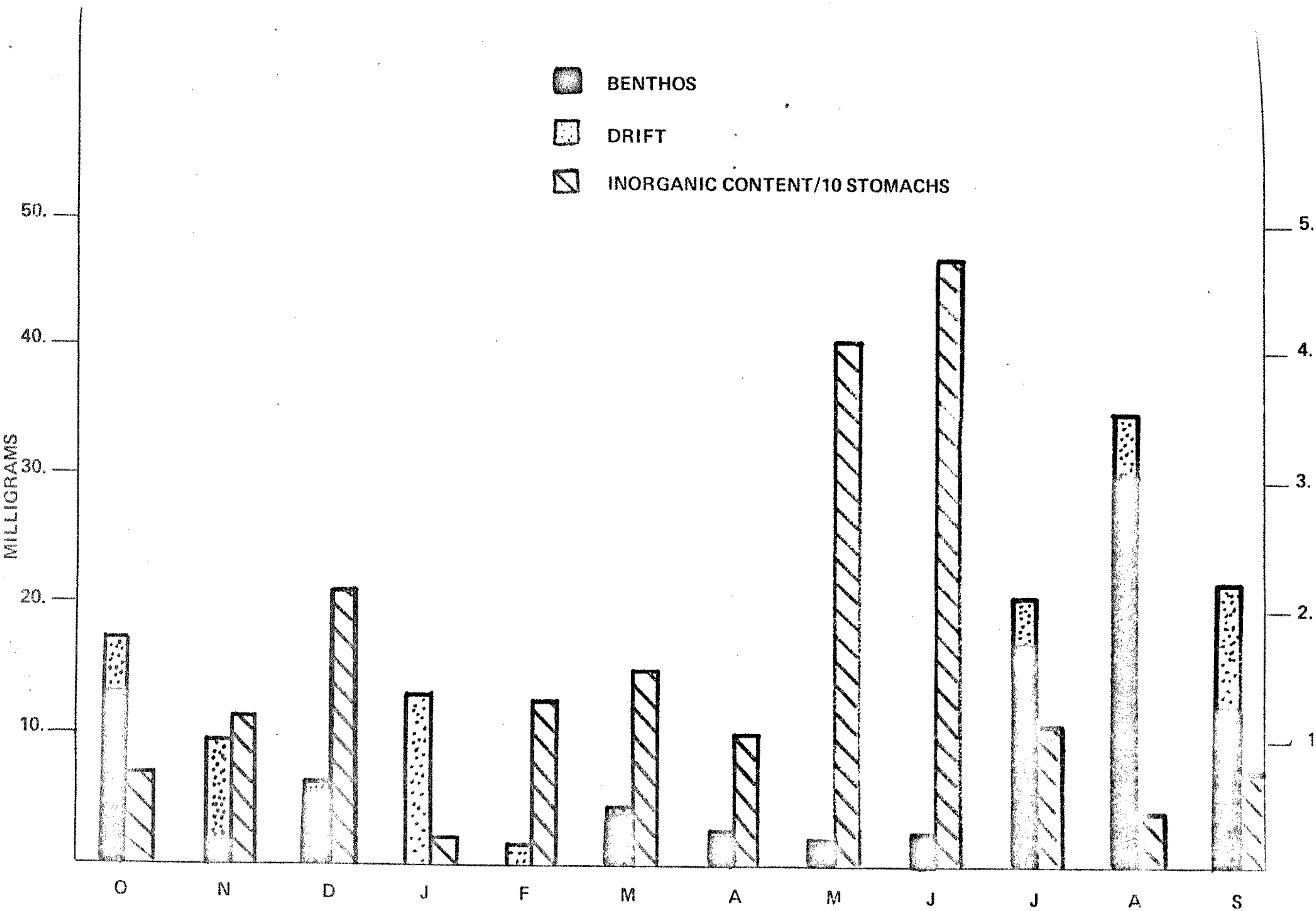
favorite food item is noticeably reduced, as was the case with Hydropsyche larvae from the drift in February, the normal predator-prey relationship is disrupted. Organisms which were previously consumed with less selectivity exhibit an increased "preference" in the ration as the concentration of the preferred group diminishes. Ivlev (1961) quoted Shorygin who stated that 'after the biomass of a preferred organism drops below a certain limit, its selectivity indices are sharply reduced and instead the selectivity of other organisms grow just as sharply -- the fish declines to feed on its favorite object and goes over to feeding on substitute organisms.' Thus the characteristic feeding behavior of fish may offer an explanation to the observed reduction of Hydropsyche in the shovelnose ration and the increased diversity of the organisms composing the ration between February and April.

If Hexagenia and other littoral benthic and terrestrial organisms migrate from the backwater areas during the low water levels in late fall and winter and subsequently concentrate in protected areas along the main channel, they probably are distributed in a patchy fashion with large aggregations in certain areas. In his studies on the feeding of fishes, Ivlev (1961) reported that non-uniform and patchy distribution of food items results in more food being consumed than when the items are situated in a more random distribution, such as one would expect to find in the drift. This factor, in addition to the decline of Hydropsyche in the drift, further supports the assumption that the shovelnose were actively seeking aggregations of littoral benthic organisms which were present in the ration between February and April.

A substantial reduction in the Hydropsyche larvae in the drift was witnessed in the late spring. At this time the average benthic biomass consisted of only 1.9 mg/m^2 (Table V, Appendix). In spite of the depauperate benthos the shovelnose ration in late spring was composed primarily of benthic organisms, specifically chironomid larvae. Accompanying the low diversity in the ration were large amounts of sand which indicated that the shovelnose was concentrating its feeding upon benthos (Figure 11).

It appears that with the reduction of Hydropsyche biomass in the drift, resulting from a greater dilution produced by the increase of the discharge rates at the Gavins Point Dam, the shovelnose was forced to maintain themselves on what may amount to a subsistence diet composed of sand dwelling chironomids. Large amounts of sand were present in the alimentary tracts sampled during the months of May and June and suggest that the chironomids were neither available nor vulnerable to the shovelnose (Figure 10). Thus, it appeared as if the inorganic material (i.e. sand) was simultaneously injested with the midge larvae as the sturgeon fed upon the meager benthic community. When the numbers and biomass of the benthos increased during the months of July through September, and therefore became more available, the amounts of sand observed in the alimentary tract was markedly reduced

Figure 10. Comparison of the biomass present in the drift and benthos with the inorganic content in the stomachs.



BENTHOS
DRIFT
INORGANIC CONTENT/10 STOMACHS
MILLIGRAMS
50.
40.
30.
20.
10.
5.
4.
3.
2.
1
O
N
D
J
F
M
A
M
J
J
A
S

and the mean stomach biomass increased (Figure 5 and 6, Table V, Appendix).

The drift biomass between July and September exhibited a different situation. Although the drift biomass of *Hydropsyche* larvae during July through September was only slightly less than that which existed between October and January on mg/m^3 basis, the biomass of *Hydropsyche* which passed through a square meter per hour was considerably greater in the summer than in the winter (Table III and IV, Appendix). This increase in larval caddisfly biomass was probably caused by normal seasonal recruitment of new larvae into the population. It appeared therefore, that although a greater biomass was present in the water mass during the late summer, the concentration and thus the availability and subsequent vulnerability of caddisfly larvae were greatest in the winter period. The increased amounts of water and the increased velocity of the water mass during the summer were responsible for the changes in the ration composition and the biomass in the ration.

Although the concentration of the caddisfly larvae per m^3 was nearly as high in late summer as those concentrations observed when the ration of shovelnose was dominated by *Hydropsyche* in the winter, a very low biomass of these larvae was found within the stomachs during the summer. The food items comprising the ration within this period remained predominately benthic, composed primarily of chironomids. This occurred in spite of the fact that the taxonomic diversity of the drift during the summer was reasonably large. Obviously one or several environmental factors were influencing the vulnerability of the drift organisms.

Previous workers have suggested that the shovelnose is an opportunistic feeder which exploits whatever food source is available (Hoopes, 1960; Held, 1966; Walburg et al., 1971). The absence of a strong preference for most major food items, as expressed by neutral electivity values, was observed in this study. It was also shown by comparing the ration with the drift and benthos standing crops that more than just increased concentration (availability) was involved in determining whether a food item was ingested by the shovelnose sturgeon.

Ivlev (1961) proposed an equation to determine accessibility, which the author considered the best estimator of vulnerability.

$$A = ((r_i - p_i)/(r_i + p_i)) - ((_i r_p + p_i)/(_i r_p - p_i))$$

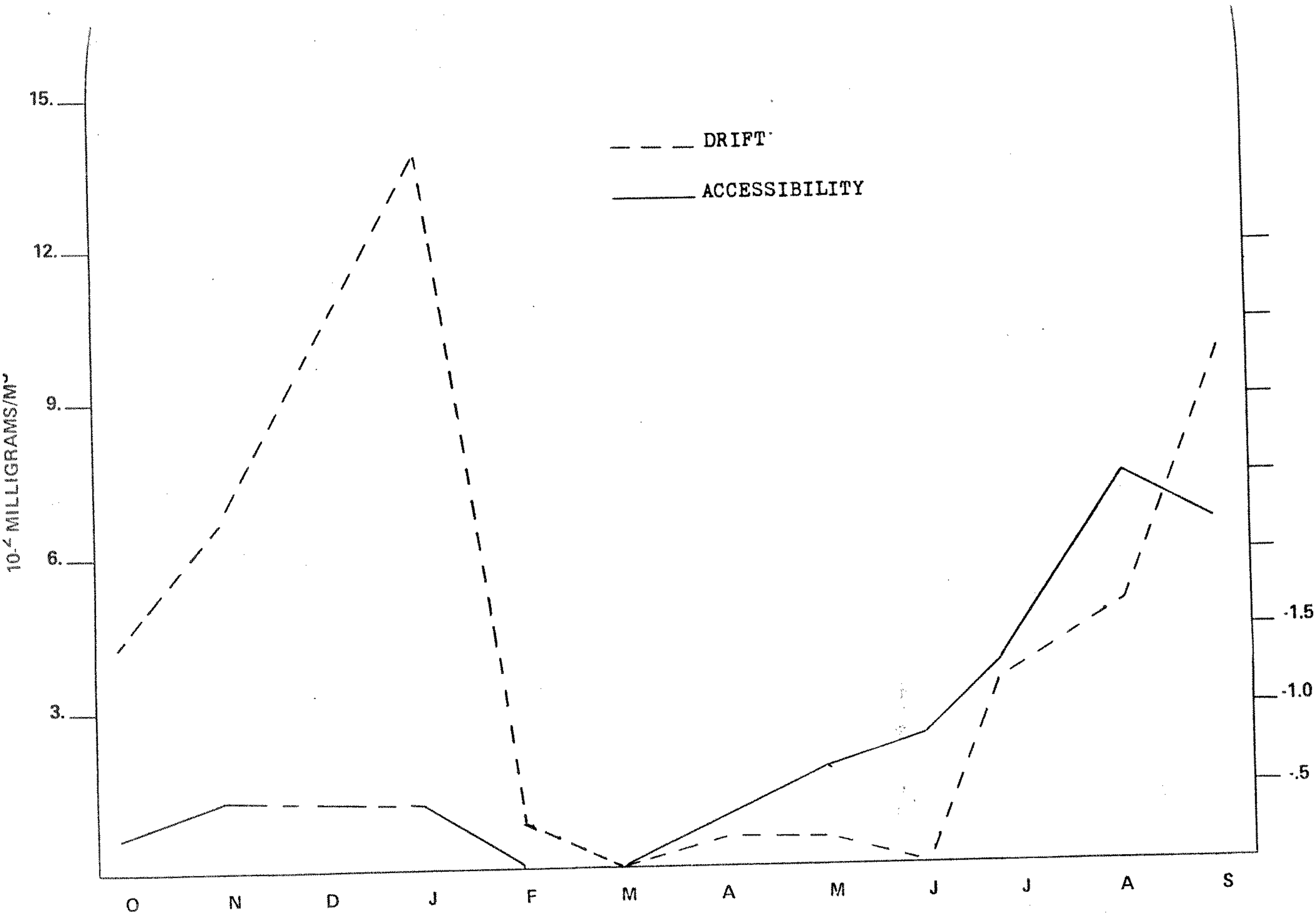
where: r_i = relative value of food item in the ration

$_i r_p$ = relative value of food item with absolute accessibility

p_i = relative value of food item in food complex

If we assume that the preference value for Hydropsyche was zero, the accessibility of the Hydropsyche larvae in the drift can be computed (Figure 11). As expected, the accessibility was a smaller negative value during those months of the year in which the caddisfly larvae constituted the bulk of the ration (i.e. November-January). Higher negative values of accessibility were witnessed between July and September even

Figure 11. Comparison of the Hydropsyche biomass in the drift with assessibility.



DRIFT
ACCESSIBILITY
10-2 MILLIGRAMS/M2
15.
12.
9.
6.
3.
-1.5
-1.0
-.5
O
N
D
J
F
M
A
M
J
J
A
S

though the larvae were fairly abundant during this period. The factors contributing to decreased accessibility of *Hydropsyche* larvae to the shovelnose probably included the increased velocity of the water mass produced by the increased discharge rates at the Gavins Point Dam.

Increased mobility of the food source was discussed by Ivlev (1961) as a factor contributing to the decreased selectivity of any food item. Since the velocity of the water mass was high in July through October, the mobility of all drift organisms present would have increased in relation to their vulnerability to the shovelnose. This factor probably reduced the accessibility of the drift organisms to the shovelnose which may find difficulty in capturing these organisms with its suctorial method of feeding.

SUMMARY AND CONCLUSIONS

Between October 1971 and September 1972, 130 shovelnose sturgeon were collected at monthly intervals from the unchannelized portion of the Missouri River. Stomach contents were removed and the seasonal food habits recorded. Surface drift and benthos samples were taken at the same time and site as the fish stomachs in an effort to determine the environmental availability of the food items. The food contents were separated into identifiable taxa, miscellaneous matter and inorganic material. The identifiable organisms within the ration were then contrasted with those available in the environment in order to determine selectivity. The findings of this investigation may be summarized as follows:

1. Identifiable food items were found in 129 of 130 stomachs. The ration was represented by 19 orders and 73 families over the 12 month study period. Aquatic organisms comprised 98.4% of the annual dry weight, 99.4% of the numbers and were represented by a 99.2% frequency of occurrence. Terrestrial organisms, although present in 53.7% of the stomachs, made up only 1.6% of the total dry weight and 0.6% of the numbers. The Family Chironomidae, (primarily the Subfamily Chironominae) and the Genus *Hydropsyche* constituted 24.8% and 56.4% of the annual weight and 82.6% and 13.7% of the total numbers, respectively. *Hexagenia* (burrowing mayfly) and *Asellus* (aquatic isopod) comprised 9.9% and 1.8% of the weight but only 0.7% and 0.2% of the total numbers, respectively.

2. The shovelnose ration demonstrated pronounced seasonal variation. The ration during the October through January period was characterized by the dominance of *Hydropsyche* larvae and a minor but consistent quantity of the Family Chironomidae. Between the months of February and April the numbers of *Hydropsyche* larvae in the diet decreased while the abundance of the chironomids increased. During this period burrowing mayfly naiads, *Hexagenia* spp., also constituted a large portion of the ration. The greatest diversity of organisms in the ration, including terrestrial taxa, was observed in the February-April interval. The ration during the spring and summer months was composed primarily on chironomids, almost exclusively of the Subfamily Chironominae. The most frequently occurring larvae were from the Genus n. nr. *Demicryptochironomus* A and B.

3. Electivity values, as proposed by Ivlev, were used to express preference or selectivity. Representative availability values were computed only for the Genus *Hydropsyche* in the drift and the Subfamily Chironominae in the benthos. Neutral electivity values of both *Hydropsyche* and the chironomids were observed during those periods in which they composed the bulk of the ration. These periods of relative abundance in the ration corresponded to their relative abundance in the environment. Negative electivity values for both organisms were observed between the months of March and April which

corresponded to the time when Hexagenia and a great diversity of other food items were found in the ration.

4. A negative correlation between the total ration biomass and the discharge rates at the Gavins Point Dam existed throughout the 12 month study. This relationship was particularly noticeable between the months of November and March. The reduced water level, produced by the low discharge rates at the Gavins Point Dam, concentrated the drift organisms, composed primarily of caddisfly larvae, and increased the availability and vulnerability of these organisms to the shovelnose. The data suggested that the reduced water levels caused some macrobenthos to migrate from the shallow backwater areas into the river proper. After the density of the Hydropsyche larvae declined in the drift in February, these shallow water aquatic organisms were then selected by the shovelnose until May.

5. The period between May and September was characterized by an increase in the river elevation and subsequent reduction in the biomass of food organisms present in the ration. The stomach contents at this time were dominated by chironomid larvae, particularly Genus n. nr. Demicryptochironomus A and B, which constituted 87.0% of the ration weight. Large amounts of sand were present in the stomachs during May and June. During these months the benthos standing crop was very low. An increase in the biomass of the benthos

was observed from July through September due to recruitment by early instars. At this point the amount of inorganic material in the stomach was reduced.

6. The biomass present in the drift increased greatly in the mid-summer months. The greatest drift diversity and biomass during the 12 month period was observed in the summer while the ration diversity and biomass was low. Accessibility values according to Ivlev, suggested that during this period these organisms were relatively invulnerable to predation by the shovelnose. Increased water velocity was suspected as a primary factor regarding the decreased vulnerability.

7. The feeding behavior of the shovelnose, as most fish, was opportunistic. The seasonal changes in the ration abundance of all food items were related to their availability and vulnerability within the environment. The accessibility of food organisms to the shovelnose appeared to depend largely upon the river elevation, as controlled by the Gavins Point Dam, but were also influenced by the migration patterns and reproductive recruitment of the insect larvae and other organisms.

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