

Temporal variation in diet and food selection of shovelnose sturgeon in the Missouri River above Fort Peck Reservoir, Montana
by Douglas J Megargle

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University
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Abstract:
Seasonal variation in discharge affects aquatic invertebrate distribution and production in rivers and may influence the foraging efficiencies of insectivores. I investigated the temporal variation in diet and food selection of shovelnose sturgeon (Scaphirhynchus platorynchus) inhabiting the Missouri River above Fort Peck Reservoir, Montana where discharge pattern is unaltered. I examined significant relations between changes in river discharge and changes in shovelnose sturgeon forage biomass, changes in sturgeon use of important prey, and changes in relative abundance and biomass of important prey in the benthos and water column. Results were compared to those of similar studies conducted in the flow-altered Missouri River below Gavins Point Dam, South Dakota. I sampled prey availability and sturgeon food habits monthly during ice-free periods. Ninety nine sturgeon stomachs and 105 forage availability samples were collected in 1994. Attempts to non-lethally remove sturgeon gut contents were unsuccessful. Shovelnose sturgeon consumed invertebrates from 12 aquatic invertebrate orders and small quantities of terrestrial invertebrates and larval fish. Representatives of Ephemeroptera, Diptera, Trichoptera, and Plecoptera made up most of the sturgeon diet. Trichoptera composed 54.4% of the annual average ration biomass, but their relative importance was less than that of Ephemeroptera. The relative composition of shovelnose sturgeon diet and the availability of important prey significantly varied between months; Electivity index indicated shovelnose sturgeon generally consumed prey in proportion to availability. I found little evidence that discharge influenced either shovelnose sturgeon forage availability or food selection. A significant positive relation was found among the average monthly sturgeon ration biomass and the average monthly discharge. Sturgeon from Montana and South Dakota had similar diets, but different relative diet composition. Shovelnose sturgeon in South Dakota fed predominantly on Chironomidae and Ephemeroptera, and foraged upon Chironomidae at rates not in proportion to their availability. In South Dakota, a significant negative relation was found among monthly discharge and average monthly ration biomass. Average sturgeon ration biomass trends were similar in Montana and South Dakota, but river flow patterns differed, suggesting discharge was not the major factor influencing sturgeon ration biomass.

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ABSTRACT

Seasonal variation in discharge affects aquatic invertebrate distribution and production in rivers and may influence the foraging efficiencies of insectivores. I investigated the temporal variation in diet and food selection of shovelnose sturgeon (*Scaphirhynchus platorynchus*) inhabiting the Missouri River above Fort Peck Reservoir, Montana where discharge pattern is unaltered. I examined significant relations between changes in river discharge and changes in shovelnose sturgeon forage biomass, changes in sturgeon use of important prey, and changes in relative abundance and biomass of important prey in the benthos and water column. Results were compared to those of similar studies conducted in the flow-altered Missouri River below Gavins Point Dam, South Dakota. I sampled prey availability and sturgeon food habits monthly during ice-free periods. Ninety nine sturgeon stomachs and 105 forage availability samples were collected in 1994. Attempts to non-lethally remove sturgeon gut contents were unsuccessful. Shovelnose sturgeon consumed invertebrates from 12 aquatic invertebrate orders and small quantities of terrestrial invertebrates and larval fish. Representatives of Ephemeroptera, Diptera, Trichoptera, and Plecoptera made up most of the sturgeon diet. Trichoptera composed 54.4% of the annual average ration biomass, but their relative importance was less than that of Ephemeroptera. The relative composition of shovelnose sturgeon diet and the availability of important prey significantly varied between months. Electivity index indicated shovelnose sturgeon generally consumed prey in proportion to availability. I found little evidence that discharge influenced either shovelnose sturgeon forage availability or food selection. A significant positive relation was found among the average monthly sturgeon ration biomass and the average monthly discharge. Sturgeon from Montana and South Dakota had similar diets, but different relative diet composition. Shovelnose sturgeon in South Dakota fed predominantly on Chironomidae and Ephemeroptera, and foraged upon Chironomidae at rates not in proportion to their availability. In South Dakota, a significant negative relation was found among monthly discharge and average monthly ration biomass. Average sturgeon ration biomass trends were similar in Montana and South Dakota, but river flow patterns differed, suggesting discharge was not the major factor influencing sturgeon ration biomass.

INTRODUCTION

Shovelnose sturgeon (*Scaphirhynchus platorynchus*) evolved from the ancient bony fishes of the subclass Paleopterygii which was dominant during the Paleozoic Era and flourished during the late Paleozoic and early Mesozoic Era (U.S. Fish and Wildlife Service 1993). Including the shovelnose sturgeon, eight North American sturgeon species (Acipenseridae) now exist (U.S. Fish and Wildlife Service 1993). Other species include the pallid sturgeon (*Scaphirhynchus albus*), white sturgeon (*Acipenser transmontanus* Richardson), green sturgeon (*Acipenser medirostris* Ayres), Atlantic sturgeon (*Acipenser oxyrhynchus* Mitchilli), shortnose sturgeon (*Acipenser brevirostrum* LeSueur), lake sturgeon (*Acipenser fulvescens* Rafinesque), and a recently described Alabama sturgeon (*Scaphirhynchus suttkus* Williams) (U.S. Fish and Wildlife Service 1993).

Of the above species, only *Scaphirhynchus* spp. complete their life cycles in freshwater lotic systems. Pallid and shovelnose sturgeon are endemic to large rivers of the central United States of America, primarily in the Mississippi River Basin (Bailey and Cross 1954) and its major tributaries (Rochard et al. 1990). Shovelnose sturgeon are often found in sympatry with pallid sturgeon in the lower and middle Mississippi River and in the Missouri and Yellowstone Rivers (Carlson et al. 1985). Shovelnose are also reported from the Tombigbee River in Alabama, the Wichita River in Texas, and the Ohio River in Ohio (U.S. Fish and Wildlife Service 1994) and occur from the Hudson Bay drainage in Canada south to Kentucky, Arkansas, and New Mexico. Its historical range has been reduced by anthropogenic river modifications, commercial harvest, and pollution (Bailey and Cross 1954; Hurley et al. 1987; Rochard et al. 1990). Shovelnose sturgeon do

not appear to sustain populations in reservoirs (Coker 1930; U.S. Fish and Wildlife Service 1994).

The shovelnose sturgeon is the smallest of the North American sturgeons (Bond 1979). Sexually mature adults range from 40-100 cm in fork length and from 0.4-2.3 kg in weight (Modde 1971). The congeneric pallid sturgeon can reach weights of 30.8 kg and lengths exceeding 1.2 m (Kallemeyn 1977).

The shovelnose is characterized by a tapered, compressed, and shovel-like snout. Typical of many bottom dwellers, the eyes are small (1/24 of total head length) and must be unimportant in detecting food (Weisel 1979). The shovelnose sturgeon has a ventrally-located protractile mouth. The fully-extended mouth of a mature shovelnose can project 15 mm beyond the ventral surface of the head (Weisel 1979). Shovelnose lips are papillose and plicate (Lagler et al. 1962). A transverse row of four similar lengthed ventral-barbels is located half the distance between the protractile mouth and the tip of the rostrum. Taste buds are copious on the papillose barbels and lips (Weisel 1979). The head is protected by bony plates joined by sutures. The endoskeleton is cartilaginous with a persistent notochord (Weisel 1979).

The body of the shovelnose sturgeon is long and sub-cylindrical with a flat, white ventral surface protected by small and numerous rhomboidal denticles (Weisel 1979). The dorsal and lateral surfaces are dark olive green to brown and armored with five longitudinal rows of large bony scutes. These carinate scutes are strongly spined in juveniles and dull with age. Minute dermal plates cover the body between the scutes. The shovelnose sturgeon is an ancient fish with posterior-positioned anal and dorsal fins, and a

heterocercal caudal fin. The pectoral fins are large and situated near the ventro-lateral border of the anterior trunk (Moos 1978). Shovelnose sturgeon are morphometrically distinct and genotypically similar to the pallid sturgeon (Phelps and Allendorf 1979, 1983). Hybridization occurs among shovelnose and pallid sturgeon (Phelps and Allendorf 1979, 1983; Carlson and Pflieger 1981; Carlson et al. 1985).

The shovelnose sturgeon is a bottom dwelling species. Shovelnose sturgeon occur in greatest abundance in the swift channels of large rivers and usually prefer gravel or sand substrates (Bailey and Cross 1954; Moos 1978; Modde 1971). Shovelnose sturgeon abundance in the Missouri River was highest in substantial currents within main channel and sand bar habitats (Schmulbach et al. 1975; Kalleymeyn and Novotny 1977; Bramblett 1996). Commercial fishermen seek shovelnose sturgeon in habitats adjacent to the main channel, whereas sportsman concentrate in areas behind sandbars or adjacent to shoreline eddies. Shovelnose in the unchannelized Missouri River preferred deep water behind sand bars in spring and fall but dispersed widely during the warm summer months (Schmulbach et al. 1975). Shovelnose sturgeon preferred a current velocity of 0.5-0.8 m/sec in the Missouri River (U.S. Fish and Wildlife Service 1979). Shovelnose preferred a depth of 0.4-0.9 m in spring and early summer in the Tongue River, Montana (Elser et al. 1977).

Spawning habitat of the shovelnose sturgeon is not well documented. It has been suggested that this species ascended small streams to spawn (Forbes and Richardson 1920). Capture of adults in breeding condition has been used as circumstantial evidence of spawning in the Chippewa River, Wisconsin (Christianson 1976), the Tongue River, Montana (Elser et al. 1977), the Missouri River, South Dakota (June 1976; Moos 1978),

and the Mississippi River, Iowa (Coker 1930; Helms 1974). Shovelnose sturgeon spawning occurs in the main channels of the Missouri and Mississippi Rivers and their smaller tributaries. Shovelnose sturgeon are thought to spawn in areas of rapid current (Eddy and Surber 1943) and on rocky bottoms (Coker 1930; June 1976).

The shovelnose sturgeon spawns in spring. They spawned from April to June in the Mississippi River bordering Illinois (Forbes and Richardson 1920) and Iowa (Helms 1972, 1973). Shovelnose sturgeon spawn from May to June in Minnesota and Wisconsin (Eddy and Surber 1943; Christenson 1975).

The age and length of shovelnose sturgeon at sexual maturity differ between sexes. Most shovelnose sturgeon females did not mature until they reached a fork length > 63.5 cm, but age of sexual maturity was difficult to determine (Monson and Greenbank 1947, Christenson 1975). Sexual maturity of male and female individuals occurs at lengths of about 55.9 and 63.5 cm, respectively (Helms 1972, 1973). Males mature earlier than females. About 40% of age IV males were mature or maturing, whereas females first spawned at age VII or older (Helms 1972). The shovelnose sturgeon mature at smaller sizes (i.e. 43.2-48.3 cm) in areas in the Missouri River where sturgeon grow more slowly (Zweiacker 1967).

Shovelnose sturgeon appear to be opportunistic feeders (Walburg 1971). Sturgeon forage benthically using sensory organs on the snout, barbels, and mouth to distinguish prey items from debris (Weisel 1979). They often consume non-benthic food items which settle in river deposition zones. Sturgeon often consume terrestrial insects (Modde and Schmulbach 1977), crustaceans (Held 1969), and isopods (Walburg 1971;

Moos 1978). Aquatic insect larvae and naiads dominated diets of shovelnose sturgeon from the Mississippi River (Eddy and Surber 1947; Barnickol and Starrett 1951; Hoopes 1960; Held 1969; Modde and Schmulbach 1977). Naiads (*Hexagenia* spp.) were included in the diets of shovelnose sturgeon from the Mississippi River at Andalusia, Illinois (Barnickol and Starrett 1951). Immature aquatic insects were present in over 97% of 75 stomach samples of shovelnose sturgeon collected from the Missouri River (Held 1969). Baetidae naiads, Tendipedidae larvae, and Heleidae larvae were the dominant food items (Held 1969). Shovelnose sturgeon also consume Odonata naiads (Eddy and Surber 1947).

The diet of shovelnose sturgeon from the Missouri River below Gavins Points Dam, South Dakota was made up largely of immature Trichoptera, Diptera, and Ephemeroptera (Modde and Schmulbach 1977). Shovelnose sturgeon diets were made up largely of drifting Tricoptera larvae (69%) when discharge decreased from October to January (Modde and Schmulbach 1977). Odonata naiads, crustaceans, and terrestrial insects were consumed by shovelnose sturgeon when discharges were consistently low from January to April (Modde and Schmulbach 1977). During high discharge in late spring and summer (May-September), shovelnose foraged predominantly on benthic Chironomidae (Modde and Schmulbach 1977). Shovelnose sturgeon prey availability and feeding patterns were related to upstream variations in discharge from Gavins Point Dam (Modde and Schmulbach 1977). Shifts in feeding behavior of shovelnose sturgeon were strongly influenced by the timing and magnitude of discharge from Gavins Point Dam (Modde and Schmulbach 1977).

My study evaluated temporal variation in food selection of shovelnose sturgeon in a non-impounded reach of the Missouri River. I examined the relation among river discharge and the diet of shovelnose sturgeon in the Missouri River. In my study area the hydrograph is less influenced by mainstem dam releases and closely resembled the natural river hydrograph. I examined the relation among seasonal discharge and the available shovelnose sturgeon prey in six river habitats. The habitats included the mainchannel (deepest point in river cross-section), midchannel (half the depth of the mainchannel), shoreline (near shore at a depth > 0.15 m and < 1 m), side-channel (flows separate from main river), and the water column (drift) habitats. I examined the relation among river discharge and shovelnose sturgeon diets.

A similar study was conducted concurrently by the South Dakota Cooperative Fish and Wildlife Research Unit in the flow-altered Missouri River below Gavins Point Dam, South Dakota (Berry 1996). This study repeated an earlier study (Modde 1971). My data were compared with data from Berry (1996), Modde (1971), and Modde and Schmulbach (1977).

The objectives of my study were to:

1. Quantify and compare food selection of shovelnose sturgeon across discharge levels and seasons.

2. Determine the relation among discharge level and invertebrate drift and benthic abundance in main channel, midchannel, shoreline, side-channel, and water column habitats.

3. Compare patterns of invertebrate resource abundance and use by shovelnose sturgeon among studies.

4. Evaluate the feasibility of a non-lethal means of extracting stomach contents from shovelnose sturgeon.

STUDY SITE DESCRIPTION

The Missouri River originates at the confluence of the Gallatin, Madison, and the Jefferson rivers in southwestern Montana. It flows easterly and southeasterly for about 4000 km and joins the Mississippi River just north of St. Louis, Missouri. Ten dams impound the Missouri River in Montana.

The Missouri River is not impounded in a 336-km reach from Morony Dam near Great Falls, Montana to the headwaters of Fort Peck Reservoir, Montana. The land adjacent to the river in this area has retained most of its primitive characteristics (Gardner and Berg 1980). The 240-km section of the Missouri River from Fort Benton, Montana, to Robinson Bridge, Montana was designated "Wild and Scenic" in 1976 (U.S. Congress 1975a). This designation affords considerable river protection in that no dams can be built on it and specific protective regulation is imposed on any new commercial development within adjacent designated areas (U.S. Congress 1975b). The law does allow minor diversions and pumping of water for agricultural uses. Private landowners in the area engage in traditional farming, grazing, residential, and recreational uses.

Fifty-three fish species from 14 families are known to occur in the Missouri River between Morony Dam and Fort Peck Dam (Berg 1981). The transition zone between cold water and warm water fish assemblages occurs in the Missouri River from Morony Dam, Montana to the confluence of the Marias River, Montana. Sauger (*Stizostedion canadense*) are the predominant game fish species, and significant numbers of trout, mountain whitefish (*Prosopium williamsoni*), sculpins, longnose dace (*Rhinichthys*

cataractae) and suckers (Catostomidae) also occur (Gardner and Berg 1982). My study area was in the warm water zone between the Marias River confluence and the headwater of Fort Peck Reservoir, Montana. Shovelnose sturgeon, sauger, paddlefish (*Polyodon spathula*), channel catfish (*Ictalurus punctatus*), and a variety of cyprinids (Cyprinidae) and suckers are the predominant fish species of this reach (Gardner and Berg 1982).

My study area consisted of a 24.1-km reach of the Missouri River from river mile 1197 to 1182 (km 1926 to 1902) (Figure 1). The Judith Landing boat ramp and the Slaughter River campground are the only public access sites on the Missouri River near my study area. Judith Landing is located at T 23 N; R 16 E approximately 762 m above sea level. Average monthly flow ranged from about 170 m^3/s in October to 510 m^3/s in June (United States Geological Survey 1995). The gross seasonal timing of flow is not greatly altered by dams upstream from my study area (Scott et al. 1993). However, annual peak flows have decreased and annual low flows have increased since dam construction (Scott et al. 1993). The Missouri River in my study area has gradients ranging from 0.38 to 0.76 m/km (Gardner and Berg 1982). Water temperature ranged from <0 ^{0}C in winter, to 20-25 ^{0}C in late summer and early fall.

River channel characteristics in my study area include slight meandering profile, sloping sandy banks, islands, chutes (or side channels), rapids, and a river bed of rubble and cobble with limited sand patches. The upper section of the study site is confined by steep and narrow canyons with very few islands (Gardner and Berg 1982). The lower section is characterized by low-sloping sandy banks. There are nine islands during low flows within my study site, of which three have permanent vegetation (e.g. plains

cottonwood, *Populus deltoides*). Other islands support young willows (*Salix* sp.), grasses, and shrubs.

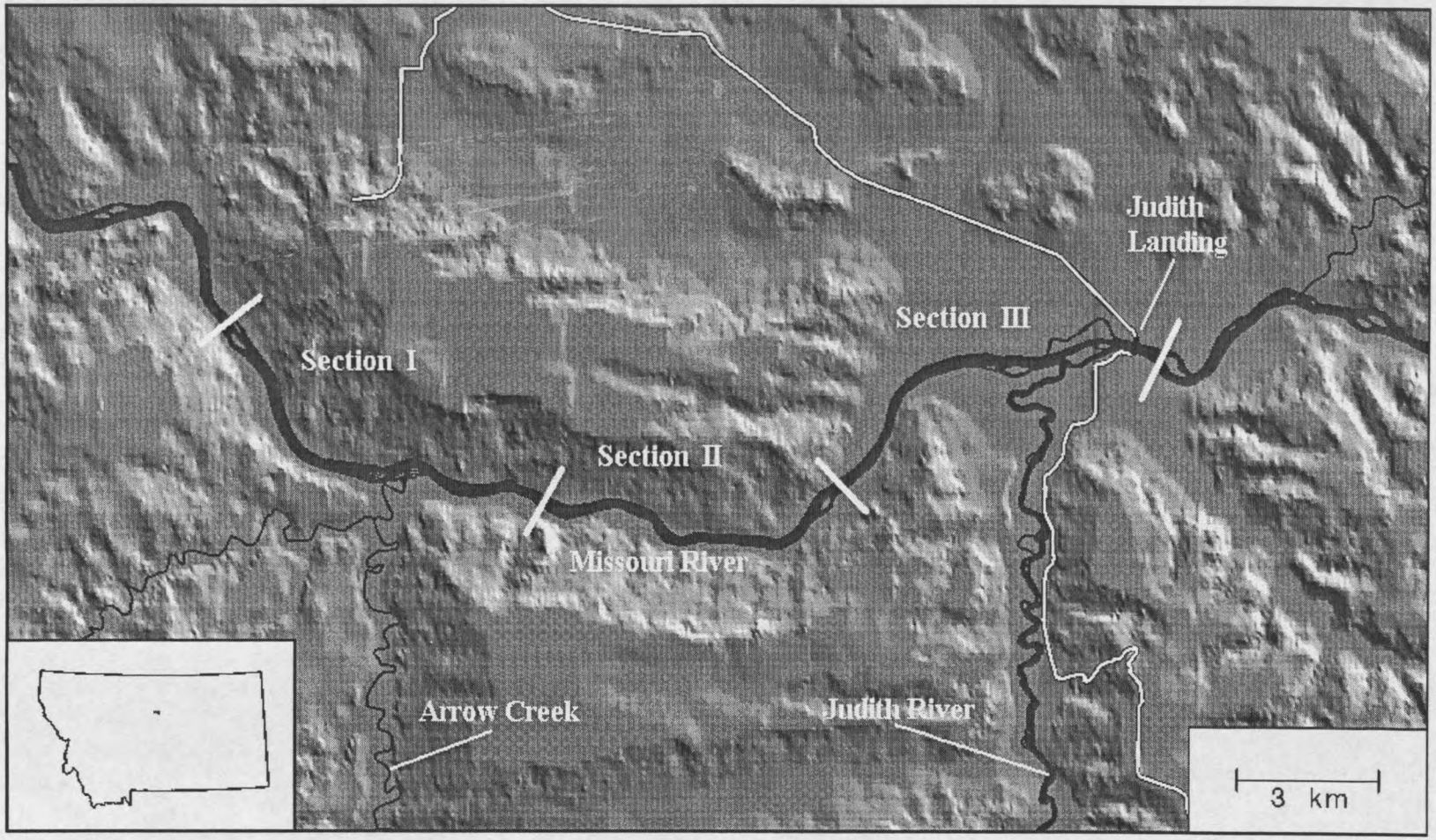


Figure 1. Map of the study area. Included are the three, 8.1 sampling sections. The top of the map is North.

METHODS

Sampling Procedures

I sampled the Missouri River study area monthly during ice-free periods between July 1993 and October 1994 (excluding December 1993 to May 1994). Logistic and mechanical problems prevented sampling of prey availability during 1993. Both prey availability and shovelnose sturgeon forage data were collected from April to October 1994. Seasons were defined as spring (March to May), summer (June to August), fall (September to November), and winter (December to February) when discussing shovelnose sturgeon forage availability and use.

Shovelnose Sturgeon

I assumed that shovelnose sturgeon had full access to my entire study site and that they did not feed only where they were collected. These assumptions were based on a study of movement and habitat use of shovelnose and pallid sturgeon (Bramblett 1996). Shovelnose sturgeon can travel great distances in a 24-h period (Bramblett 1996). I collected 15 shovelnose sturgeon monthly throughout the study area. I took stomach samples from shovelnose sturgeon of various lengths.

River depth, width, velocity, substrate composition, and boat maneuverability were considered when selecting sampling sites. Often current seams and scour holes were targeted. Preferred netting sites were sand bar eddies, island eddies, and main channel

habitat which lacked potential snags. I drifted the boat through potential netting sites and detected snags using a depth sounder (model X-15B, Lowrance Electronics, Inc.). Potential snags included large boulders and submerged logs. I did not net in river areas where snags were detected, where current was not sufficient to move the net downstream, or where the river channel was too narrow to maneuver the boat.

I collected shovelnose sturgeon using nylon gill and trammel nets. Trammel nets were 45.8 m long and 1.8 m deep, with a 5.1-cm-bar-mesh inner panel (# 3 twine) and a 25.5-cm-bar-mesh wall panel (# 9 twine). The gill net used was 45.8 m long by 1.8 m deep with five alternating panels of 5.1 and 10.2 cm bar mesh. An experimental gill net was used in shallow and narrow areas of the river. The experimental gill net was 36.6 m long, 0.76 m deep, and had five panels of 1.9, 2.5, 3.8, 5.1, and 5.8 cm bar mesh. All gill nets were constructed with # 4 twine, a foam-core float line, a lead line, and had flotation buoys attached at both ends. Lead weights were added to the lead line during high discharge and removed during low discharge for greater netting efficiency. All netting was conducted from a 7.5-m boat equipped with a 90-horsepower jet outboard motor.

I collected sturgeon using an active netting technique (Helms 1972). I did not use overnight stationary gill nets because that method may produce increased stress, accelerated digestion, and regurgitation in fish (Nielsen and Johnson 1983). I deployed the nets from the bow of the boat and fished the nets perpendicular to the current. The boat was maneuvered downstream from the net after it was deployed and was used to dislodge the net if it of snagged. I recorded wet time and retrieved the net if the snag could not be dislodged.

I recorded wet time, mean velocity, average depth, river mile and location, water temperature (C), time (24 h), and substrate composition of each netting attempt. Wet time was considered the time the net was completely deployed to when the net was completely recovered. I recorded physical characters of the river at the point the net was deployed, the point the net was retrieved, and a point midway between the two after each netting attempt. These three points were relocated using shoreline landmarks (e.g. trees, boulders, coulees, etc.) I identified during the netting attempt. Velocity was recorded using a Marsh-McBirney Model 1500 flow meter (Hamilton and Bergersen 1984). I measured depth using a depth sounder. Substrate composition was determined using a probe technique (Hamilton and Bergersen 1984). I described substrate composition using an index modified from the Brusven index (Bovee 1982) (Table 1). Means of the river characteristics within each sample area were calculated (Hamilton and Bergersen 1984). River characteristic data associated with netting attempts were used to determine sturgeon habitat preference. A successful netting attempt was one where at least one shovelnose sturgeon was captured. Rivers characteristics of successful and unsuccessful netting attempts were compared.

Table 1. Modified Brusven substrate index used to describe river substrate composition.

Index	Substrate	Size (cm)
0	Organic debris	0.1 - 0.4
1	Sand	0.5 - 7.5
2	Gravel	7.6 - 3.0
3	Cobble	3.0 - 11.8
4	Boulder	> 11.8

Sturgeon were placed in a live well briefly until all fish were removed from the net. Non-target fish species were identified and their total lengths (mm) were recorded. I measured the weight (g), fork length (mm), and total length (mm) of all sturgeon captured. I did not collect stomach samples from all shovelnose sturgeon captured. I tried to collect stomach samples from shovelnose sturgeon which offered the greatest range in total length with each netting attempt. Excess sturgeon were released. The portion of the alimentary tract from the esophagus to the anterior portion of the spiral intestine was removed and stored in a ziplock bag containing Kahle's fluid. Kahle's fluid is composed of 11% formalin, 28% ethanol, 2% glacial acetic acid, and 59% water (Pennak 1989).

Available Forage

The invertebrate fauna (availability) was sampled in the main channel, midchannel, shallow zone, side-channels, and the water column. These sampling stratifications were chosen because they were measurable (depth) and represented different micro-habitats available to sturgeon. Each habitat type was sampled once each month at a random location within each of three equal-length sections (sections I, II, and III, Figure 1). I collected 15 available forage samples each month in 1994, except in April when I collected 14 samples. Invertebrates were collected using either a kick net, a biological dredge, or a drift net (Merrit and Cummins 1984). Sampling methods varied in the main channel and midchannel habitats. The dredge was used in water too deep, or where current was too strong, to use the kick net. The drift net was used to collect drifting invertebrates.

I sampled shovelnose sturgeon forage availability using a stratified random procedure. Each section was divided into 10 equal 0.8-km increments with the aid of a map. The 0.8-km increments represented sample points and were assigned a numerical value ranging from zero to nine with zero being the most downstream point. A random number was chosen each month to determine the increment and its associated river location to be sampled in each section.

The main channel, midchannel, shallow, and drift samples were collected at each random location. A coin toss predetermined whether to move upstream or downstream to the next acceptable location if the sampling unit selected could not be sampled in all habitats (i.e. large boulder prevented the use of the dredge in the main channel habitat). Only three side-channels were in the study area and they were sampled monthly.

A cross section profile of river depth was recorded using the depth finder to locate the main channel habitat at the sample site. A coin was flipped to determine whether to proceed to river right or river left from the main channel habitat to sample the midchannel and the shallow habitat.

The main channel was sampled using a custom-built dredge which resembled a biological dredge described by Elliott and Drake (1981a). The sled-like dredge had 15.2-cm substratum disturbance probes on the front and a "D" frame net attached in the rear. The dredge weighed 29.5 kg. Its 500-μm "D" frame net was designed with dimensions of 0.61 X 0.45 X 1.5 m (base, height, depth) and equipped with a detachable plankton catch. The dredge sampled 7.4 m^2 of the river bed. I anchored the boat and lowered the dredge with a brake-winch equipped with 0.9 cm stainless steel aircraft cable.

When the dredge was on the bottom, more cable was released to tow the dredge at a shallow angle which reduced its skipping on the substrate. I propelled the boat upstream and dragged the dredge 12 m using the 30-m anchor line as a measure. The dredge was retrieved and the sample was removed from the plankton catch. The sample was still taken if the dredge snagged and the distance sampled was > 6 m. If the sample effort was > 6 m and < 12 m the actual length of the sample was recorded. The sample was considered incomplete and repeated elsewhere if the dredge snagged before traveling 6 m.

I sampled the midsection using the dredge or the kick net (Hynes 1961; Frost et al. 1970; Elliot and Drake 1981b). The kick net was 0.9 m deep, which was 0.6 m more shallow than the dredge net. A 12-m transect was marked on shore, and the kick net was dragged upstream while I disturbed the substrate with my feet. The kick net sampled 7.4 m^2 of substratum. I sampled all side channels with the kick net.

I sampled drifting invertebrates using a hoop drift net (Modde 1971). The 500-μm mesh drift net was 1.8 m deep with a 0.5-m aperture. Drifting invertebrates within 1 m of the surface were sampled once at the sample point in each section. The drift net was deployed behind the anchored boat using the winch. Sample duration was 20 min and was shortened to 10 min when abundant suspended debris plugged the net. I collected no substrate composition data at drift sites.

Processing of my benthic invertebrate samples was standardized. The samples were decanted five times, with two 37-L buckets, to remove sediment and debris. The sample was stored in a ziplock bag and preserved in Kahle's solution. I recorded the water temperature, average velocity, average or actual depth, and substrate composition at

all benthic invertebrate sample locations. Drift net samples were not decanted before they were stored.

Sampling Technique Comparison

Samples were collected to test the effectiveness of the dredge when compared to the kick-net sampling technique. I sampled at five separate sites which were suitable for both sampling techniques. A 12-m transect was measured and marked on the shore. I completed a transect with the dredge and the kick-net parallel to each other. Invertebrates collected by both sampling techniques were identified and enumerated. I tested for significant difference among the relative abundance of invertebrates collected from the two methods.

Non Lethal Means of Extracting Stomach Contents

Gastric lavage was used on 12 shovelnose sturgeon during fall 1993 to remove stomach contents. A 7.5-L pressurized spray tank with surgical or PVC tubing attached to the nozzle was used. Three separate tube apertures were used. I used surgical tubing with a tapered aperture from 1 cm to 5 mm and tubing with a 1-cm aperture. Additionally, I used a flexible PVC tube with a 6-mm aperture. The end of the tube was inserted through the esophagus and I attempted to insert the tube to the distal stomach. The fish was held at a 45^0 angle over a 500-μm mesh sieve as water was injected into the fish. The resulting outflow of water passed through the sieve and trapped food items. All fish were subsequently dissected and examined for water in the gas bladder. The stomachs

were removed and placed in a ziplock bag containing Kahle's solution. Food items were removed from the sieve and stored in Kahle's solution.

River Discharge and Temperature

Missouri River discharge and temperature data were recorded at a gauging station located at Virgelle, Montana (U.S.G.S 1995). Average monthly discharge of the Missouri River in 1993 and 1994 was used to investigate correlation among river discharge or temperature and shovelnose sturgeon diet.

Laboratory Procedures

Stomach Contents

I dissected the gastro-intestinal samples in the lab. I removed the bulk of the food items with forceps and washed the remaining food items from the stomach into an enamel pan. All food items collected were stored in vials containing 70% alcohol. Food items of individual shovelnose sturgeon were separated to taxonomic family groups. I used invertebrate keys to identify Plecoptera (Stewart et al. 1988, Merrit and Cummins 1984), Ephemeroptera (Edmunds et al. 1976, Merrit and Cummins 1984), Diptera (Merrit and Cummins 1984, Clifford 1991), Trichoptera (Wiggins 1977), and Odonata (Merrit and Cummins 1984) families. Food items were identified, counted, and sorted to taxonomic family groups. Like groups were dried on separate pieces of 500-μm nylon mesh for 24 h at 65 ^{0}C. Taxonomic family groups were weighed (mg) on a digital scale. Partial food

items (with heads present) that were > 2/3 intact were counted as one individual. Invertebrate heads capsules were counted and later used to extrapolate total numbers and dry weight within each stomach sample.

All non-identifiable stomach contents were classified as "miscellaneous". This miscellaneous material was used to determine mass of inorganics ingested by the sturgeon. Miscellaneous matter was made up largely of invertebrate body fragments and sand. The miscellaneous matter was dried, weighed, and then combusted at 550 ^{0}C to determine its ash free dry weight (mg). The difference between the pre-combusted weight and the ash weight (mg) was used to determine the weight of inorganic and organic miscellaneous matter in the stomachs.

Available Forage

Laboratory processing of prey availability samples was standardized. The samples were soaked in the Kahle's solution for at least 48 h before I transferred them to a solution of 70% alcohol and Rose Bengal biological stain. I stored the samples in the stain solution for 24 h which allowed the stain to penetrate the invertebrates. The biological stain made it easier to see and remove the invertebrates from the sample. Invertebrate samples were washed through a series of three sieves with 8-mm, 2.36-mm, and 500-µm mesh. All invertebrates trapped in the 8-mm and 2-36 mm sieves were identified, counted, and sorted to taxonomic family groups. Invertebrates trapped in the 500-µm sieves were subsampled using a 2 L Folsom plankton splitter. The sample was split until it was visually estimated to contain about 100-200 individuals. Invertebrates in the subsample

were identified, counted, and sorted to taxonomic family groups. I tested the subsampling procedure to ensure the subsample would accurately represent the whole sample. Sorting was done with a lighted magnifying lens and a binocular dissecting scope.

Numeric Analysis

Stomach Contents

I determined the relative composition of each taxonomic family group found in shovelnose sturgeon stomachs. The total number of individual food items (T_c) found within each shovelnose sturgeon stomach was determined using the following formulas:

$$T_c = \Sigma(FC_1 + FC_2 + FC_i)$$

$$FC = n + N \quad ,$$

where FC was the total number of individuals within each taxonomic family group, and *i* was the number of invertebrate families present. FC represented the sum of the number of partial yet identifiable invertebrates (n) and the number of whole identifiable invertebrates (N). FC was divided by T_c and multiplied by 100 to determine the relative number of each taxonomic family group within each stomach sample (Crisp et al. 1978; Ikusemiju and Olaniyan 1977). Total dry weight (T_{dw}) was estimated with a similar equation but differed slightly because the partial-insect dry weight was estimated (Klarberg and Benson 1975). This measure is defined as

$$T_{dw} = \Sigma\ (WF_1 + WF_2 + Wf_i)$$

$$WF = W_p + W_h$$

$$W_p = (W_h / N) * n \quad ,$$

where WF was the dry weight of all individuals within a taxonomic family group, and *i* was the number of families represented. WF was the sum of the total estimated dry weight of the partials (W_p) and the total dry weight of the whole invertebrates (W_h). I determined the average weight of each taxonomic family group using the average weight of the whole invertebrate from the same family group (Klarberg and Benson 1975). I used the product of the average weight and the number of partials of each taxonomic family group to estimate the weight of the partial invertebrates (W_h). The relative weight (P_w) of each taxonomic family group was calculated using the following formula:

$$P_w = WF / T_{dw} .$$

Only prey items with average relative numbers or biomass (from April to October) >1% in sturgeon diets were analyzed and discussed. Prey items with relative numbers or biomass < 1% in shovelnose sturgeon stomach were considered to be found in trace amounts.

I used a multiple Kruskal Wallis test (95% confidence) to test for significant difference among months of the relative number and biomass of shovelnose sturgeon prey. The null hypothesis tested was that there was no significant difference of the relative number or biomass of shovelnose sturgeon prey among months.

Available Forage

I determined benthic invertebrate density, biomass, relative weight, and relative number per m^2 of shovelnose sturgeon prey items. I only assessed and reported the availability of shovelnose sturgeon prey items which were consumed at levels higher than

trace amounts. The relative composition (P_w and P_n) of benthic invertebrates was determined using the same methods as the shovelnose sturgeon gut content analysis, but did not include partial invertebrates. Most invertebrates from the benthic samples were not mutilated. Density, biomass, P_w, and P_n of prey items at the taxonomic family level were determined for the area sampled (m^2) for each sampling effort. These values were converted to density, biomass, relative weight and number per m^2. All prey availability data were analyzed and reported as invertebrate densities, biomass (dry weight), relative number (P_n), and relative weight (P_w) per m^2 (benthic samples) and m^3 (drift).

I used a multiple Kruskal Wallis test (95% confidence) to test for significant differences of the relative number and biomass of shovelnose sturgeon prey among months in all habitats. The null hypothesis tested was that there was no significant difference of the relative number or biomass of shovelnose sturgeon prey among months.

Electivity and Importance Indices

Electivity (E) was assessed using the Index of Electivity (Ivlev 1961). This index has been widely used as a means of comparing food habits of fishes and other aquatic organisms with the availability of potential food resources. The index is designed to characterize the electivity, or degree of selection, of particular prey species by predators. The relationship is defined as:

$$E= r_i-p_i / r_i+p_i \quad ,$$

where E is the measure of electivity, r_i is the relative abundance of prey item *i* in the gut, and p_i is the relative abundance of the same prey item in the environment. Relative

abundance is expressed as the percentage of the total number of food items found in the gut contents, and the environment. The index has a possible range of +1 to -1. Negative electivity values indicate avoidance of the prey items, positive values indicate active selection, and zero indicates random selection from the environment. Assumptions and weaknesses of Ivlev's electivity index are discussed extensively in the literature (Straus 1979; Hyslop 1980; Johnson 1980, Kohler and Ney 1982). I used Ivlev's index of electivity to compare results with similar data from Modde (1971) and Berry (1996) who used the same index. Electivity was not determined for prey items which were consumed by shovelnose sturgeon at trace levels. To follow trends in selectivity, I calculated electivity for prey items in each month throughout the study period.

The dietary importance of food items in shovelnose sturgeon diet was determined using the Absolute Importance Index (AI) and the Relative Importance Index (RI) (George and Hadley 1979). These indices are defined as follows:

$$AI = \% \text{ frequency occurrence} + \% \text{ total number} + \% \text{ total weight}$$

$$RI = 100\ (AI / \Sigma AI).$$

I chose these indices because they consider both number and size of prey concurrently. Analysis based entirely on weight may overemphasize the importance of large, single food items (Hellawell and Able 1971; George and Hadley 1979). Numerical analysis alone can overestimate the importance of large numbers of small, nutritionally insignificant food items (Wallace 1981). I examined relative importance and electivity values of food items for sturgeon captured only in 1994.

Condition Factor (K)

Condition factors were calculated for all sturgeon collected during 1993 and 1994. Condition factor (K) was defined as:

$$K=(W/TL^3)*100{,}000\ ,$$

where W is the weight (g) and TL is the total length of the sturgeon.

Subsampling Accuracy

A chi-square test was used to determine if the Folsom plankton splitter accurately divided my samples. The null hypothesis was that there was no significant difference between the estimated numbers of invertebrates from each taxonomic family group and the actual numbers. Significance was tested at a 95 % confidence level.

Correlation

I examined the relation among discharge and temperature and the relative number and weight of shovelnose sturgeon prey in all habitats. I also examined the relation among discharge and temperature and the relative number and weight of shovelnose sturgeon prey in stomach contents. Correlation was examined using Pearson Product Correlation Analysis of 1994 data.

Sampling Techniques Evaluation

I tested the sampling efficiencies of the kick net and the dredge using a chi-square analysis at the 95% confidence level. Invertebrates were identified to taxonomic family

groups, and counted to determine their relative numbers. I tested for significant differences among the relative composition (P_n) of taxa collected by the dredge and kick net.

Shovelnose Sturgeon Habitat Preferences

I used a multiple Kruskal Wallis test to test for significant differences of river characteristics among successful and unsuccessful netting attempts. I tested for significance at a 95% confidence level.

RESULTS

Discharge

Compared to the annual monthly average of 1972-1993, discharge of the Missouri River in 1993 was slightly lower during winter periods and higher in summer and early fall (Figure 2). Peak flow during 1993 was later and more prolonged than in the average

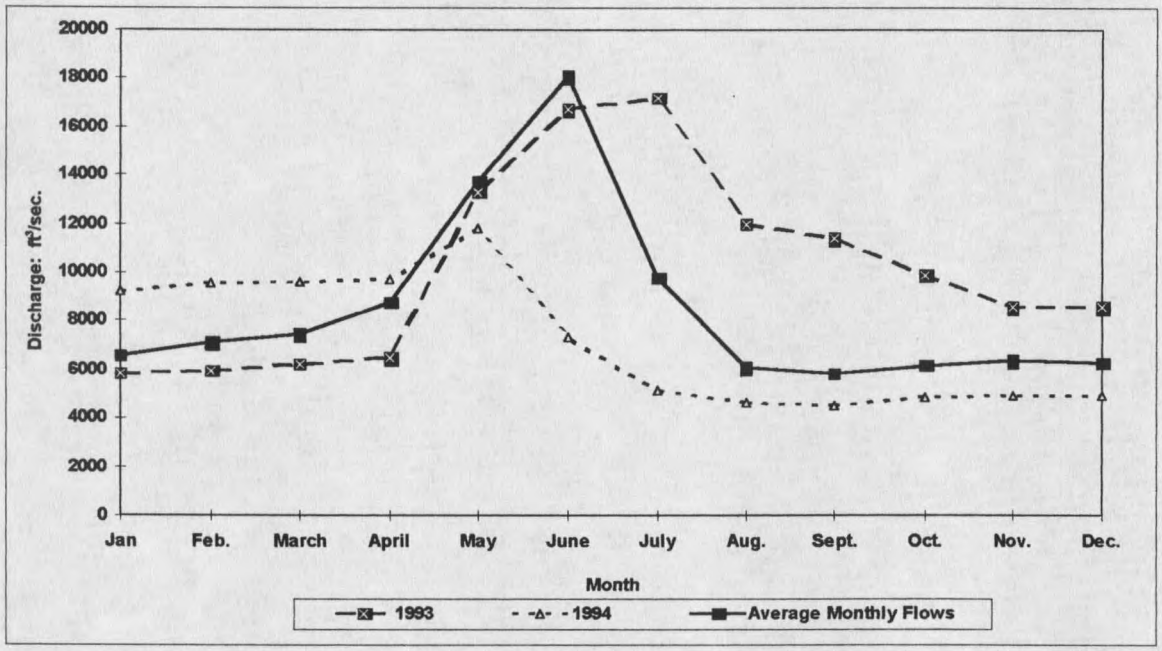


Figure 2. Monthly discharge of the Missouri River at Virgelle, Montana in 1993 and 1994, and the average monthly discharge from 1972-1993 (U.S.G.S 1995).

monthly discharge. In 1994, discharge was higher in winter and early spring, lower from May to December, and peak flow was earlier and lower than the 1972-1993 average. Average annual discharge was higher in 1993 than in 1994 (Table 2). Discharge in 1993

and 1994 was not significantly different from the average discharge for the period of record (P=0.11 and P=0.23, respectively).

Table 2. Discharge of the Missouri River at Virgelle, Montana in 1993 and 1994, and average discharge for 1972 to 1993 (U.S.G.S. 1995).

Year	Average discharge (ft^3/sec)	Standard deviation	Minimum discharge (ft^3/sec)	Maximum discharge (ft^3/sec)
1993	10,174.0	4015.0	5842.0	17,200.0
1994	7181.0	2640.3	4497.0	11,800.0
Average	8513.0	3754.2	5811.0	18,082.0

Sampling

Laboratory Subsampling

The Folsom plankton splitter accurately subsampled the invertebrate samples. Estimated invertebrate numbers determined from the subsamples were not significantly different from the actual invertebrate numbers (Chi-square= 0.51, df=18).

Field Sampling Techniques

I found the kick net and the dredge sampled invertebrate communities similarly in relation to the relative number and weight of invertebrate families collected with each technique (Table 3). I determined that either the dredge or the kick net could be used to sample invertebrate assemblages in the same habitat without bias.

Non-lethal Stomach Contents Extraction

I attempted to extract stomach contents of living sturgeon on 12 occasions using a stomach pump. No attempt produced substantial quantities of food items. I encountered difficulties passing the pump tubing beyond the anterior turn in the intestinal tract.

Table 3. Kruskal Wallis results testing for significant difference between invertebrate sampling efficiency (P_n) of the kick net and the dredge for sampling the invertebrate population in the Missouri River, Montana.

Order	Family	Kruskal Wallis statistic	P- value
Ephemeroptera	Leptophlebiidae	2.22	0.14
	Polymitarcyidae	1.00	0.31
	Ephemerellidae	0.20	0.65
	Heptageniidae	0.27	0.60
	Baetidae	0.10	0.75
Plecoptera	Taeniopterygidae	1.00	0.31
	Perlodidae	0.10	0.74
Trichoptera	Hydropsychidae	0.18	0.67
	Brachycentridae	0.00	1.00
Diptera	Chironomidae	0.18	0.67

The pneumatic duct was located at the first turn in the intestinal tract and made it difficult to pass the tube further toward the stomach without penetrating the gas bladder. The gas bladder was filled with water during 8 of the 12 attempts. I was unable to find tubing flexible enough to curve through the gastro-intestinal tract yet not buckle or bind during insertion. I did not pursue the use of emetics because I was unable to find a method to administer the irritant fluids deep enough into the digestive tract to directly contact the stomach lining.

Available Forage

The invertebrate communities differed slightly among benthic habitats. Relatively few significant differences of the biomass, relative weight, and the number of taxonomic family groups were found between benthic habitats (Table 4). Total numbers of families found in each habitat differed only in October, and total dry weight differed significantly only in August, September, and October (Table 4).

Table 4. Kruskal Wallis tests of family numbers, total dry weight (mg/m^2), and relative biomass of invertebrate families between the main channel, midchannel, shallow, and side channel habitats within each month. Samples were collected from the Missouri River above Fort Peck Reservoir, Montana in 1994. Included in the table is the Kwall statistic and (P value). Significant difference (α=0.05) between habitats is denoted with *.

Variable examined	Kwall statistic (P- value)						
	April	May	June	July	Aug.	Sept.	Oct.
Number of families present	7.11 (0.13)	6.09 (0.19)	4.32 (0.37)	5.31 (0.26)	5.73 (0.22)	0.83 (0.94)	12.09 *(0.02)
Total weight	8.90 (0.06)	4.20 (0.38)	5.23 (0.26)	9.07 (0.06)	10.21 *(0.04)	9.87 *(0.04)	10.77 *(0.03)
Leptophlebiidae	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	3.35 (0.50)	10.1 *(0.04)	0.00 (1.00)	0.00 (1.00)
Polymitarcyidae	0.00 (1.00)	0.00 (1.00)	3.24 (0.52)	8.62 (0.07)	6.13 (0.19)	0.00 (1.00)	0.00 (1.00)
Ephemerellidae	7.08 (0.13)	2.1 (0.72)	4.25 (0.37)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	4.23 (0.38)
Heptageniidae	2.57 (0.63)	2.01 (0.73)	3.26 (0.52)	6.17 (0.19)	6.18 (0.19)	7.38 (0.12)	10.53 *(0.03)
Baetidae	8.70 (0.07)	3.17 (0.53)	6.40 (0.17)	8.03 (0.09)	5.8 (0.21)	2.68 (0.61)	11.93 *(0.02)
Taeniopterygidae	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	4.00 (0.41)	3.24 (0.52)
Perlodidae	3.93 (0.42)	7.19 (0.13)	4.45 (0.35)	4.62 (0.33)	8.57 (0.07)	4.14 (0.39)	7.91 (0.10)
Hydropsychidae	7.78 (0.10)	10.44 *(0.03)	8.29 (0.08)	0.69 (0.95)	2.2 (0.70)	3.23 (0.52)	4.45 (0.35)
Brachycentridae	0.00 (1.00)	0.00 (1.00)	4.48 (0.35)	8.36 (0.08)	5.58 (0.23)	12.07 *(0.02)	8.57 (0.07)
Chironomidae	0.82 (0.94)	8.32 (0.08)	10.48 *(0.03)	7.47 (0.11)	5.33 (0.26)	7.57 (0.11)	7.02 (0.14)

Main Channel

Ephemeroptera, Diptera, Trichoptera and Plecoptera dominated the main channel benthic community (Tables 5 - 7, Appendix A, Figure 8). The annual average relative

Table 5. Average benthic biomass (mg/m^2) (SD) and density ($\#/m^2$) (SD) of four invertebrate orders for mainchannel, midchannel, shallow zone, side channel habitats, and average biomass (mg/m^3) (SD) and density ($\#/m^3$) (SD) for the water column (drift). Samples were collected from April to October 1994, from the Missouri River above Fort Peck Reservoir, Montana. Biomass and density values <0.1 are denoted by <.

Habitat	Invertebrate order	Average biomass (mg/m^2) (SD)	Average P_w (%) (SD)	Average density ($\#/m^2$) (SD)	Average P_n (%) (SD)
Main channel	Ephemeroptera	38.2 (87.8)	45.9 (15.7)	72.4 (101.0)	46.1 (8.1)
	Plecoptera	1.4 (1.2)	7.6 (6.3)	0.6 (0.7)	0.8 (0.9)
	Trichoptera	7.8 (11.7)	28.0 (18.5)	10.7 (7.8)	14.0 (13.2)
	Diptera	4.6 (9.0)	7.3 (6.3)	132.0 (317.2)	16.4 (10.1)
Midchannel	Ephemeroptera	28.3 (14.9)	37.0 (13.9)	113.6 (83.4)	33.1 (15.4)
	Plecoptera	7.5 (14.8)	5.7 (9.5)	4.1 (8.0)	0.6 (0.8)
	Trichoptera	15.6 (13.5)	19.0 (14.7)	36.2 (32.2)	13.0 (15.4)
	Diptera	8.6 (9.3)	13.5 (12.9)	66.5 (58.6)	21.6 (14.5)
Shallow zone	Ephemeroptera	30.5 (30.7)	31.6 (16.2)	91.6 (41.5)	41.1 (11.7)
	Plecoptera	0.7 (4.2)	0.5 (0.6)	5.0 (10.1)	0.6 (4.7)
	Trichoptera	9.6 (5.7)	11.4 (12.1)	55.1 (73.0)	18.4 (11.5)
	Diptera	4.2 (5.5)	20.7 (14.7)	59.8 (64.0)	13.3 (7.7)
Side channel	Ephemeroptera	25.6 (16.8)	35.9 (22.6)	103.3 (86.0)	35.4 (22.5)
	Plecoptera	3.5 (4.5)	3.1 (4.6)	6.4 (14.6)	1.0 (1.3)
	Trichoptera	24.3 (29.8)	18.8 (11.5)	67.2 (88.6)	10.8 (7.0)
	Diptera	6.4 (4.8)	12.3 (9.3)	54.3 (68.0)	18.4 (13.2)
		Average biomass (mg/m^3) (SD)	Average P_w (%) (SD)	Ave.density ($\#/m^3$) (SD)	Ave. P_n (%) (SD)
Drift	Ephemeroptera	<	37.8 (8.6)	0.9 (1.0)	38.7 (11.9)
	Plecoptera	<	1.2 (2.8)	<	1.4 (2.8)
	Trichoptera	<	23.4 (15.8)	0.2 (0.1)	11.4 (8.8)
	Diptera	<	13.1 (9.5)	0.4 (0.3)	25.4 (15.1)

number of Ephemeroptera, Diptera, Trichoptera, and Plecoptera was 46.1%, 16.4%, 14.0%, and 0.8%, respectively. Ephemeroptera comprised the greatest annual average

Table 6. Biomass (mg/m^2) and density (# /m^2)(SD) of available prey in the main channel habitat, whose yearly average comprised greater than one percent (P_n and/or P_w) of shovelnose sturgeon diet from the Missouri River, Montana in 1994. Values <0.1 are denoted with < ; and ----- if no representatives were found.

		April		May		June		July		Aug.		Sept.		Oct.	
Order	Family	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density
Ephemeroptera	Leptophlebiidae	----	----	----	----	----	----	0.5 (0.7)	0.2 (0.2)	0.1 (0.2)	<	----	----	----	----
	Polymitarcyidae	----	----	----	----	<	1.3 (2.3)	0.1 (0.1)	0.1 (0.1)	----	----	----	----	----	----
	Ephemerellidae	1.6	2.3 (0.0)	208.4 (303.6)	141.3 (197.4)	0.2 (0.2)	0.3 (0.3)	----	----	----	----	----	----	0.2 (0.2)	2.7 (1.3)
	Heptageniidae	0.8 (1.0)	4.2 (4.4)	20.2 (34.2)	49.2 (81.5)	1.5 (1.8)	5.0 (4.5)	1.0 (1.4)	2.3 (2.1)	0.3 (0.2)	1.5 (0.9)	3.1 (3.7)	26.4 (33.9)	1.4 (0.9)	7.9 (8.1)
	Baetidae	1.9 (0.9)	4.9 (1.4)	8.7 (15.0)	105.0 (173.2)	1.8 (2.2)	15.0 (15.0)	3.0 (2.7)	18.0 (12.5)	5.1 (1.4)	58.5 (10.7)	4.7 (2.5)	47.0 (31.3)	2.8 (1.3)	13.7 (9.4)
	TOTAL	**4.3**	**11.4**	**237.3**	**295.5**	**3.5**	**21.6**	**4.6**	**20.6**	**5.5**	**60.0**	**7.8**	**73.4**	**4.4**	**24.3**
Plecoptera	Taeniopterygidae	----	----	----	----	----	----	----	----	----	----	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)	0.5 (0.9)
	Perlodidae	2.2 (3.1)	0.3 (0.4)	3.3 (2.9)	1.5 (1.7)	0.1 (0.2)	0.1 (0.2)	1.6 (2.6)	0.2 (0.1)	0.8 (1.3)	0.4 (0.5)	1.6 (2.6)	0.4 (0.5)	---- (0.1)	1.2 (0.9)
	TOTAL	**2.2**	**0.3**	**3.3**	**1.5**	**0.1**	**0.1**	**1.6**	**0.2**	**0.8**	**0.4**	**1.7**	**0.5**	**0.1**	**1.7**
Trichoptera	Hydropsychidae	2.6 (0.7)	2.0 (0.7)	34.0 (48.0)	21.6 (30.1)	4.1 (1.8)	7.3 (2.2)	3.6 (1.9)	9.7 (5.1)	1.1 (0.7)	3.6 (3.1)	4.6 (3.8)	12.6 (6.1)	0.6 (0.8)	2.5 (1.1)
	Brachycentridae	-----	-----	-----	<	1.6 (2.8)	10.3 (17.0)	2.1 (2.4)	4.1 (4.9)	0.4 (0.4)	0.8 (1.2)	----	0.4 (0.4)	----	----
	TOTAL	**2.6**	**2.0**	**34.0**	**21.6**	**5.7**	**17.6**	**5.7**	**13.8**	**1.5**	**4.4**	**4.6**	**13.0**	**0.6**	**2.5**
Diptera	Chironomidae	0.9 (0.3)	7.8 (1.5)	24.8 (42.9)	85.1 (126.3)	----	0.6 (0.5)	0.2 (0.3)	4.9 (3.4)	2.8 (1.7)	25.4 (14.8)	3.5 (4.5)	29.0 (18.5)	0.1 (0.1)	5.4 (4.9)
	TOTAL	**0.9**	**7.8**	**24.8**	**85.1**	**-----**	**0.6**	**0.2**	**4.9**	**2.8**	**25.4**	**3.5**	**29.0**	**0.1**	**5.4**

Table 7. Percent composition (P_n and P_w)(SD) per m^2 of available main channel prey items (whose yearly average comprised greater than one percent by P_n and/or P_w in shovelnose sturgeon diet) from the Missouri River, Montana in 1994. Values < 0.1% are represented with < ; and ---- if none were found. Significant difference between adjacent months (α=0.05) is denoted with *.

		P_n							P_w						
Order	Family	April	May	June	July	Aug.	Sept.	Oct.	April	May	June	July	Aug.	Sept.	Oct.
Ephemeroptera	Leptophlebiidae	----	----	----	0.4 (0.4)	<	----	----	----	----	----	2.9 (3.5)	0.7 (1.2)	----	----
	Polymitarcyidae	----	----	1.3 (2.3)	0.3 (0.4)	----	----	----	----	----	0.2 (0.3)	0.9 (1.0)	----	----	----
	Ephemerellidae	9.7 (2.9)	31.7 (23.4)	*0.7 (0.8)	*----	----	----	*4.1 (1.4)	17.3 (7.6)	54.8 (28.4)	*3.4 (4.4)	*----	----	----	*3.3 (2.8)
	Heptageniidae	15.0 (13.4)	6.5 (4.1)	12.7 (11.6)	4.2 (2.0)	1.5 (1.3)	15.0 (17.7)	9.4 (4.2)	6.5 (6.5)	3.3 (3.2)	11.2 (9.8)	6.3 (7.3)	2.2 (1.9)	13.2 (15.1)	20.1 (8.9)
	Baetidae	21.7 (12.2)	20.9 (17.3)	33.5 (16.9)	38.0 (15.3)	48.5 (12.7)	28.5 (7.0)	18.9 (4.2)	22.7 (18.6)	13.0 (19.8)	16.2 (14.9)	21.5 (11.4)	34.1 (11.8)	27.7 (15.2)	40.0 (7.3)
	TOTAL	**46.4**	**59.1**	**48.2**	**42.9**	**50.0**	**43.5**	**32.4**	**46.5**	**71.1**	**31.0**	**31.6**	**37.0**	**40.9**	**63.4**
Plecoptera	Taeniopterygidae	----	----	<	----	----	0.1 (0.2)	1.1 (1.9)	----	----	<	----	----	1.9 (3.3)	1.7 (2.9)
	Perlodidae	0.9 (1.3)	0.5 (0.6)	0.6 (1.0)	0.5 (0.2)	0.3 (0.4)	0.2 (0.2)	1.7 (1.0)	16.3 (23.0)	1.9 (2.8)	2.4 (4.1)	16.5 (27.0)	6.9 (11.2)	4.9 (7.6)	0.8 (1.4)
	TOTAL	**0.9**	**0.5**	**0.6**	**0.5**	**0.3**	**0.3**	**2.8**	**16.3**	**1.9**	**2.4**	**16.5**	**6.9**	**6.8**	**2.5**
Trichoptera	Hydropsychidae	9.1 (5.7)	6.4 (1.8)	*25.0 (13.6)	22.5 (12.3)	*2.9 (2.1)	*8.9 (4.6)	3.8 (1.6)	26.6 (5.1)	18.5 (10.4)	52.9 (23.0)	32.5 (24.0)	7.6 (5.9)	22.4 (9.2)	11.5 (14.3)
	Brachycentridae	----	<	*11.3 (15.2)	6.9 (5.9)	*1.0 (1.5)	0.2 (0.2)	*----	----	<	7.3 (12.6)	*13.5 (11.2)	3.4 (3.5)	*<	----
	TOTAL	**9.1**	**6.4**	**36.3**	**29.4**	**3.9**	**9.1**	**3.8**	**26.6**	**18.5**	**60.2**	**46.0**	**11.0**	**22.4**	**11.5**
Diptera	Chironomidae	32.1 (3.5)	25.0 (13.5)	*3.0 (2.6)	12.2 (8.7)	18.5 (5.8)	17.2 (2.6)	6.9 (2.3)	8.7 (1.1)	6.1 (5.3)	*<	2.6 (3.7)	*17.3 (9.9)	13.6 (11.1)	*2.4 (2.4)

relative weight (45.9%), followed by Trichoptera (28.0%), Plecoptera (7.6%) and Diptera (7.3%) (Table 5). The relative number and weight of Ephemeroptera, Trichoptera, and Diptera differed significantly among some months (Table 7). The relative weight and numbers of Plecoptera did not significantly differ among months. I found no significant relation among river discharge and invertebrate density, biomass, and relative abundance or biomass of the four invertebrate orders.

Ephemeroptera were collected in all months sampled. Ephemeroptera made up the majority of the benthic community in late spring and early summer. Their relative numbers ranged from about 32.4-59.1% and their relative weight ranged from about 31.0-71.1% during this time (Table 7). The relative numbers of Ephemeroptera generally decreased substantially from late spring to early summer and increased in fall. The densities and biomass of Ephemeroptera peaked in May, with a second smaller peak in October (Table 6; Appendix A, Figure 9). Polymitarcyiidae were found in small numbers in June and July and made up a relatively small portion of the Ephemeroptera community in the main channel (Table 6). The relative numbers and weight of Ephemerellidae were related to discharge ($P=0.01$, $r=0.88$; $P=0.006$, $r=0.90$, respectively). Additionally, the relative numbers of Baetidae were correlated with water temperature ($P=0.02$, $r=0.82$).

Two families of Trichoptera were found in the main channel. The relative numbers of Trichoptera (Hydropsychidae and Brachycentridae) were highest from June to July and peaked in June (Table 7). Their relative numbers ranged from about 3.8-36.3% , and their densities ranged from about $2/m^2$ in April to about $21.6/m^2$ in May (Table 6; Appendix A, Figure 10). The density of Hydropsychidae peaked in May, while that of Brachycentridae

peaked slightly later in June. Although densities of Trichoptera were high in May, their relative numbers were low. The relative weight of Trichoptera ranged from about 11-60.2% (Table 7) and biomass ranged from about 0.6 mg/m^2 in October to about 34.0 mg/m^2 in May (Table 6). No significant relations were found among the relative weight or biomass of Trichoptera and discharge or water temperature.

Plecoptera were collected in low numbers. Plecoptera were found in highest densities in October and greatest biomass in May (Table 6; Appendix A, Figure 12). Both densities and biomass decreased in June and increased slightly from summer into the fall. Densities were always low ranging from about 0.1/m^2 to 1.7/m^2. Biomass ranged from about 0.1 mg/m^2 to 3.3 mg/m^2 (Table 6; Appendix A, Figure 12). Although relative numbers of Perlodidae were quite low (0.3-2.8%), their large size contributed to fairly large relative weights (2.5-16.5%) (Table 7). The relative number of Perlodidae were correlated with water temperature ($P=0.02$, $r=0.17$).

Diptera larvae were collected in great numbers. The density of Chironomidae were highest in early spring and fall. Highest Chironomidae density occurred in May (85.1/m^2) followed by a large decrease to 0.6/m^2 in June (Table 6; Appendix A, Figure 12). The densities increased from summer to early fall and then decreased in October. The relative numbers of Chironomidae were greatest in April and lowest in June. However, their relative weight was lowest in June and highest in August (Table 7). I found no significant relation among river discharge or water temperature and the relative weight or relative numbers of Diptera.

I found significant inter-relations among biomass and densities of Ephemeroptera, Diptera, and Trichoptera within the main channel. The Ephemeroptera densities were strongly correlated with the Diptera densities ($P<0.001$, $r=0.99$). I found significant relations among the biomass of Ephemeroptera and Diptera ($P<0.001$, $r=0.99$) and Ephemeroptera and Trichoptera ($P<0.001$, $r=0.99$). Additionally, there was a positive relationship among the biomass of Trichoptera and Diptera ($P<0.001$, $r=0.97$).

Midchannel

The invertebrate community in the midchannel habitat was generally dominated by Ephemeroptera and Diptera, followed by Trichoptera and Plecoptera (Table 5,8,9; Appendix A, Figure 13). The annual average relative numbers of Ephemeroptera, Diptera, Trichoptera, and Plecoptera were 33.1%, 21.6%, 13.0%, and 0.6%, respectively (Table 5). Ephemeroptera comprised the greatest annual average relative weight (37.0%), followed by Trichoptera (19.0%), Diptera (13.5%) and Plecoptera (5.7%). The relative number and weight of Ephemeroptera, Trichoptera, and the Diptera families differed significantly among months (Table 9). I found no relation among river discharge or temperature and density, biomass, relative weight, or relative numbers of aquatic Ephemeroptera, Diptera, Plecoptera, or Trichoptera.

Ephemeroptera made up a substantial portion of the invertebrate community. The relative numbers of Ephemeroptera ranged from about 12-58% and the relative weight ranged from about 17-51% (Table 9). The relative weight of Ephemeroptera peaked from April to May (50.0%) and again in August (51.4%). Generally, the relative number and

Table 8. Biomass (mg/m^2) and density (#/m^2)(SD) of available prey in the mid channel habitat, whose yearly average comprised greater than one percent (P_n and P_w) of shovelnose sturgeon diet from the Missouri River, Montana in 1994. Values <0.1 are denoted with < ; and ----- if no representatives were found.

		April		May		June		July		Aug.		Sept.		Oct.	
Order	Family	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density
Ephemeroptera	Leptophlebiidae	----	----	----	----	----	----	0.4 (0.7)	<	----	----	----	----	----	----
	Polymitarcyidae	----	----	----	----	<	2.2 (2.5)	0.5 (0.6)	0.3 (0.1)	0.6 (1.1)	0.1 (0.2)	----	----	----	----
	Ephemerellidae	45.1 (56.6)	38.9 (45.5)	24.6 (21.6)	18.4 (15.9)	1.5 (1.4)	3.0 (1.7)	----	----	----	----	----	----	1.7 (0.6)	14.7 (6.0)
	Heptageniidae	4.4 (7.7)	12.5 (21.1)	0.7 (0.6)	2.7 (3.3)	8.3 (8.0)	18.9 (21.7)	4.1 (0.6)	6.3 (4.8)	4.8 (4.1)	18.3 (18.3)	6.3 (3.6)	45.2 (34.7)	28.6 (13.2)	114.9 (42.8)
	Baetidae	4.8 (6.7)	9.3 (11.5)	1.4 (1.6)	23.1 (28.9)	10.2 (6.8)	74.2 (52.3)	1.9 (1.4)	8.7 (7.4)	21.9 (16.8)	227.6 (197.1)	17.7 (9.6)	94.4 (45.2)	8.5 (4.2)	61.4 (67.9)
	TOTAL	**54.3**	**60.7**	**26.7**	**44.2**	**20.0**	**98.3**	**6.9**	**15.3**	**27.3**	**246.0**	**24.0**	**139.6**	**38.8**	**191.0**
Plecoptera	Taeniopterygidae	-----	----	----	----	----	----	----	----	----	----	----	----	0.4 (0.6)	2.9 (5.0)
	Perlodidae	40.2 (66.7)	3.1 (5.2)	<	0.2 (0.2)	0.1 (0.2)	0.4 (0.6)	9.6 (12.6)	2.2 (3.4)	----	----	0.2 (0.2)	0.4 (0.5)	1.7 (1.1)	19.2 (19.4)
	TOTAL	**40.2**	**3.1**	**<**	**0.2**	**0.1**	**0.4**	**9.6**	**2.2**	**----**	**----**	**0.2**	**0.4**	**2.1**	**22.1**
Trichoptera	Hydropsychidae	10.4 (17.9)	9.1 (14.7)	1.2 (1.1)	1.2 (1.0)	21.1 (17.1)	47.5 (22.0)	8.6 (5.4)	23.1 (16.5)	9.0 (12.0)	19.0 (24.2)	11.1 (4.1)	29.6 (10.5)	13.9 (9.8)	89.2 (66.7)
	Brachycentridae	----	----	----	----	22.8 (35.9)	19.8 (10.9)	3.4 (3.4)	5.7 (2.4)	0.6 (0.7)	1.8 (1.2)	2.4 (0.9)	5.7 (5.2)	4.4 (5.2)	1.7 (1.5)
	TOTAL	**10.4**	**9.1**	**1.2**	**1.2**	**43.9**	**67.3**	**12.0**	**28.8**	**9.6**	**20.8**	**13.5**	**35.3**	**18.3**	**90.9**
Diptera	Chironomidae	28.8 (36.0)	144.7 (191.7)	5.7 (4.9)	25.7 (22.8)	3.0 (2.8)	11.8 (6.6)	2.5 (1.5)	23.8 (13.7)	6.2 (1.1)	53.1 (20.3)	3.2 (0.3)	52.5 (12.3)	10.5 (5.2)	154.0 (63.1)
	TOTAL	**28.8**	**144.7**	**5.7**	**25.7**	**3.0**	**11.8**	**2.5**	**23.8**	**6.2**	**53.1**	**3.2**	**52.5**	**10.5**	**154.0**

Table 9. Percent composition (P_n and P_w)(SD) per m^2 of midchannel prey items (whose yearly average comprised greater than one percent by P_n and/or P_w in shovelnose sturgeon diets) from the Missouri River, Montana in 1994. Values < 0.1 % are represented with <; and ---- if none were found. Significant difference between adjacent months (α=0.05) is denoted with *.

		P_n							P_w						
Order	Family	April	May	June	July	Aug.	Sept.	Oct.	April	May	June	July	Aug.	Sept.	Oct.
Ephemeroptera	Leptophlebiidae	----	----	----	0.4 (0.6)	----	----	----	----	----	----	1.1 (2.0)	----	----	----
	Polymitarcyidae	----	----	*0.9 (1.1)	0.3 (0.1)	*0.1 (0.1)	----	----	----	----	<	1.2 (1.3)	2.1 (3.6)	----	----
	Ephemerellidae	29.3 (29.6)	15.6 (15.9)	1.6 (0.4)	*----	----	----	*1.0 (0.4)	46.7 (33.2)	46.1 (41.6)	1.5 (1.3)	*----	----	----	*1.6 (0.6)
	Heptageniidae	2.1 (3.3)	1:8 (1.7)	7.2 (5.8)	7.5 (3.9)	8.5 (12.3)	10.4 (7.2)	7.5 (1.0)	1.2 (2.1)	1.2 (1.1)	7.8 (6.7)	10.2 (0.8)	12.4 (15.6)	7.7 (4.2)	25.2 (11.5)
	Baetidae	3.6 (0.5)	16.1 (13.3)	32.4 (11.9)	*8.6 (4.7)	*49.6 (11.1)	23.8 (14.4)	*3.6 (3.1)	3.0 (1.3)	2.6 (2.8)	*16.0 (4.7)	*4.6 (2.7)	*36.9 (6.4)	22.8 (14.0)	*7.2 (1.2)
	TOTAL	**35.0**	**33.5**	**42.1**	**16.8**	**58.2**	**34.2**	**12.1**	**50.9**	**49.9**	**25.3**	**17.1**	**51.4**	**30.5**	**34.0**
Plecoptera	Taeniopterygidae	----	----	----	----	----	----	0.3 (0.5)	----	----	----	----	----	----	0.4 (0.8)
	Perlodidae	0.5 (0.8)	0.1 (0.1)	0.1 (0.2)	2.0 (2.8)	----	0.1 (0.1)	1.1 (1.0)	13.6 (17.3)	<	0.1 (0.2)	24.1 (32.9)	----	0.3 (0.3)	1.4 (0.9)
	TOTAL	**0.5**	**0.1**	**0.1**	**2.0**	**0.0**	**0.1**	**1.4**	**13.6**	**0.0**	**0.1**	**24.1**	**0.0**	**0.3**	**1.8**
Trichoptera	Hydropsychidae	2.6 (2.0)	1.0 (1.1)	*27.5 (12.9)	22.5 (9.3)	*3.2 (3.0)	7.3 (3.2)	5.4 (3.0)	2.9 (5.0)	2.3 (2.0)	37.7 (22.9)	21.8 (15.5)	11.7 (11.3)	14.2 (6.3)	11.1 (2.9)
	Brachycentridae	----	----	*12.6 (9.1)	7.1 (2.8)	*0.4 (0.3)	1.3 (1.1)	*0.1 (0.1)	----	----	*5.6 (3.2)	6.5 (1.2)	3.6 (2.2)	*11.5 (6.8)	*4.0 (3.3)
	TOTAL	**2.6**	**1.0**	**40.1**	**29.6**	**3.6**	**8.6**	**5.5**	**2.9**	**2.3**	**43.3**	**28.3**	**15.3**	**25.7**	**15.1**
Diptera	Chironomidae	42.5 (26.4)	39.6 (24.7)	*6.4 (2.3)	*25.4 (3.3)	14.7 (4.3)	12.5 (1.6)	10.2 (2.6)	20.1 (17.3)	39.7 (44.6)	3.2 (3.7)	5.9 (4.8)	13.0 (4.8)	4.0 (0.7)	8.9 (2.2)

weight of Ephemeroptera were consistently high. Ephemeroptera densities peaked in August at about 246/m^2 (Table 8) yet biomass was greatest in the spring and late fall (Table 8; Appendix A, Figure 9). Leptophlebiidae and Polymitarcyidae were present in the benthos samples only from June to August and represented a very small portion of the Ephemeroptera community. Densities of Ephemerellidae peaked in April (38.9/m^2) and late fall (115/m^2), when densities of Baetidae began to decrease. Discharge was correlated with the relative number of Ephemerellidae ($P=0.03$, $r=0.80$), and Heptageniidae ($P=0.001$, $r=-0.93$). The relative weight of Ephemerellidae decreased through June but were absent in July, August, and September. Densities of Baetidae were highest in August (227.6/m^2) and September (94.4/m^2). Densities gradually increased from spring to fall and then decreased drastically after September (Table 8). The density and biomass of Heptageniidae were fairly low from April to July. The relative weight and number of Ephemeroptera families were not strongly related to water temperatures.

Diptera were found in great numbers. The highest densities of Diptera occurred in April (144.7/m^2) and October (154.0/m^2) (Table 8; Appendix A, Figure 12). Their biomass was highest in April. However, Diptera made up their greatest relative numbers (39.6-42.5%) and weights (20.1-39.7%) in April and May (Table 8). From late spring through early fall, the relative number of Diptera ranged from about 6.4-25.4% and their relative weight ranged from about 3.2-13.0%. Densities ranged from about 11.8-154.0/m^2 and biomass varied from 3.0-10.5 mg/m^2 during the same period. The relative number and weight of Chironomidae were correlated with discharge ($P=0.04$, $r=0.77$; $P=0.02$, $r=0.84$, respectively).

Trichoptera were found in the midchannel habitat. I found Trichoptera comprised their highest relative numbers and weight in June and July (Table 9) similar to the main channel habitat. At this time their biomass was greatest (43.9 mg/m^2) but their densities peaked in October at 90.9/m^2 (Table 8; Appendix A, Figure 10). In October, Trichoptera densities were relatively high but their biomass was low. I found no correlation among the relative number or weight either Trichoptera family and either discharge or water temperature.

Plecoptera generally comprised a very small portion of the benthic invertebrate community (Table 9; Appendix A, Figure 13). Perlodidae biomass was greatest in April (40.2 mg/m^2) (Table 8) but their greatest relative weight occurred in July (24.1%) (Table 9; Appendix A, Figure 11). Densities ranged between 0-3.1/m^2 from April to September peaking in October (19.2/m^2) (Table 8). No relation was found among the relative weight or number of Plecoptera and discharge or water temperature.

Within the midchannel habitat, I found no inter-relations among the density of any invertebrate orders. However, the biomass of Diptera were related to the biomass of both Plecoptera ($P=0.004$, $r=0.91$) and Ephemeroptera ($P=0.006$, $r=0.90$).

Shallow Zone

The shallow habitat was generally dominated by families of Ephemeroptera (Tables 5,10,11; Appendix A, Figure 16). Ephemeroptera generally made up the greatest relative weight followed by Diptera, Trichoptera, and Plecoptera. The relative number of Ephemeroptera was highest followed by Trichoptera, Diptera, and Plecoptera (Table 10).

Table 10. Biomass (mg/m^2) and density (# /m^2)(SD) of available prey in the shallow habitat, whose yearly average comprised greater than one percent (P_n and P_w) of shovelnose sturgeon diets from the Missouri River, Montana in 1994. Values <0.1 are denoted with <; and ----- if no representatives were found.

		April		May		June		July		Aug.		Sept.		Oct.	
Order	Family	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density
Ephemeroptera	Leptophlebiidae	----	----	----	----	----	----	6.1 (10.5)	0.3 (0.2)	----	----	----	----	----	----
	Polymitarcyidae	----	----	----	----	0.1 (0.2)	8.5 (11.4)	1.5 (1.3)	0.7 (0.5)	----	----	----	----	----	----
	Ephemerellidae	40.1 (46.5)	37.0 (44.0)	83.4 (140.8)	60.2 (94.6)	0.2 (0.4)	5.7 (5.4)	----	----	----	----	<	0.5 (0.9)	0.2 (0.3)	5.6 (2.7)
	Heptageniidae	1.4 (2.2)	6.0 (8.8)	7.4 (11.1)	8.8 (7.0)	1.6 (2.3)	20.9 (28.3)	1.1 (0.7)	5.2 (3.6)	4.9 (5.3)	17.8 (20.2)	6.2 (3.5)	36.6 (16.8)	37.5 (20.4)	112.1 (78.8)
	Baetidae	8.7 (12.7)	16.3 (21.7)	1.4 (0.8)	14.8 (1.0)	6.7 (7.8)	89.6 (100.3)	3.3 (3.1)	23.1 (34.2)	5.8 (3.8)	43.7 (28.9)	11.1 (8.0)	62.7 (55.1)	4.4 (5.1)	32.5 (36.2)
	TOTAL	**50.2**	**59.3**	**92.2**	**83.8**	**8.6**	**124.7**	**12.0**	**29.3**	**10.7**	**61.5**	**17.3**	**99.8**	**42.1**	**150.2**
Plecoptera	Taeniopterygidae	----	----	----	----	----	----	----	----	----	----	<	0.2 (0.3)	----	----
	Perlodidae	11.6 (8.1)	0.8 (0.6)	2.2 (3.9)	1.7 (2.5)	<	0.3 (0.3)	1.0 (1.7)	0.2 (0.3)	----	----	0.1 (0.2)	0.4 (0.7)	0.9 (0.9)	27.4 (30.1)
	TOTAL	**11.6**	**0.8**	**2.2**	**1.7**	**<**	**0.3**	**1.0**	**0.2**	**----**	**----**	**0.1**	**0.6**	**0.9**	**27.4**
Trichoptera	Hydropsychidae	4.7 (5.6)	5.2 (7.5)	10.5 (17.1)	6.7 (9.7)	1.4 (2.2)	27.6 (33.5)	3.7 (3.6)	17.2 (5.5)	0.7 (1.0)	1.4 (1.9)	6.6 (6.7)	18.7 (15.3)	12.9 (14.5)	76.9 (62.2)
	Brachycentridae	----	----	----	----	15.1 (25.7)	175.1 (260.9)	2.2 (3.0)	3.6 (1.4)	0.4 (0.4)	0.5 (0.7)	2.1 (3.6)	1.7 (0.8)	2.9 (5.0)	1.2 (1.3)
	TOTAL	**4.7**	**5.2**	**10.5**	**6.7**	**16.5**	**202.7**	**5.9**	**20.8**	**1.1**	**1.9**	**8.7**	**20.4**	**15.8**	**78.1**
Diptera	Chironomidae	17.2 (6.6)	85.6 (41.3)	3.9 (3.0)	16.0 (9.2)	1.4 (0.7)	22.3 (14.7)	3.2 (0.5)	29.6 (11.0)	3.9 (2.1)	42.3 (15.6)	3.1 (0.9)	49.6 (7.6)	9.4 (4.4)	199.0 (74.0)
	TOTAL	**17.2**	**85.6**	**3.9**	**16.0**	**1.4**	**22.3**	**3.2**	**29.6**	**3.9**	**42.3**	**3.1**	**49.6**	**9.4**	**199.0**

Table 11. Percent composition (P_n and P_w)(SD) per m^2 of the shallow habitat prey items (whose yearly average comprised greater than one percent by P_n and/or P_w in shovelnose sturgeon diets) from the Missouri River, Montana in 1994. Values < 0.1% are represented with < ; and ---- if none were found. Significant difference between adjacent months (α=0.05) is denoted with *.

		P_n							P_w						
Order	Family	April	May	June	July	Aug.	Sept.	Oct.	April	May	June	July	Aug.	Sept.	Oct.
Ephemeroptera	Leptophlebiidae	-----	-----	-----	*0.2 (0.2)	*-----	-----	-----	-----	-----	-----	*11.7 (19.9)	*-----	-----	-----
	Polymitarcyidae	-----	-----	*2.5 (1.9)	*0.5 (0.2)	*-----	-----	-----	-----	-----	0.3 (0.5)	3.3 (3.0)	-----	-----	-----
	Ephemerellidae	16.9 (15.2)	28.2 (33.0)	*1.0 (1.1)	-----	-----	0.1 (0.2)	0.8 (1.0)	35.8 (16.5)	41.2 (31.7)	*0.6 (1.1)	-----	-----	<	0.4 (0.8)
	Heptageniidae	2.6 (3.3)	10.4 (10.4)	4.3 (5.3)	3.5 (1.7)	9.8 (9.8)	11.7 (9.1)	9.0 (3.2)	1.0 (1.2)	11.5 (14.7)	4.3 (6.8)	5.4 (6.9)	18.1 (17.9)	14.0 (9.4)	42.7 (14.9)
	Baetidae	6.9 (8.2)	22.3 (17.7)	23.5 (15.2)	12.2 (15.0)	30.2 (5.9)	17.2 (14.3)	2.0 (2.1)	6.0 (6.9)	7.9 (7.7)	21.9 (19.5)	9.1 (7.4)	29.8 (2.7)	21.2 (10.1)	3.3 (3.2)
	TOTAL	**26.4**	**60.9**	**31.3**	**16.4**	**40.0**	**29.0**	**11.8**	**42.8**	**60.6**	**27.1**	**29.5**	**47.9**	**35.2**	**46.4**
Plecoptera	Taeniopterygidae	-----	-----	-----	-----	-----	0.1 (0.1)	-----	-----	-----	-----	-----	-----	<	-----
	Perlodidae	0.4 (0.2)	0.9 (0.8)	*<	0.1 (0.2)	-----	0.1 (0.2)	*1.7 (1.7)	13.0 (3.9)	0.7 (1.2)	<	1.9 (3.2)	-----	0.2 (0.3)	0.8 (0.7)
	TOTAL	**0.4**	**0.9**	**0.0**	**0.1**	**0.0**	**0.1**	**1.7**	**13.0**	**0.7**	**0.0**	**1.9**	**0.0**	**0.2**	**0.8**
Trichoptera	Hydropsychidae	2.3 (2.8)	4.0 (3.2)	6.1 (5.8)	14.8 (5.8)	1.1 (1.1)	4.8 (3.9)	5.0 (3.0)	3.9 (2.4)	9.2 (9.0)	3.8 (6.2)	15.3 (13.1)	4.2 (4.2)	12.0 (10.2)	10.7 (7.1)
	Brachycentridae	-----	-----	*28.6 (41.4)	3.0 (0.9)	0.4 (0.4)	0.4 (0.1)	0.1 (0.1)	-----	-----	34.0 (48.8)	8.4 (4.7)	4.2 (3.6)	5.3 (2.6)	3.2 (3.2)
	TOTAL	**2.3**	**4.0**	**34.7**	**17.8**	**1.5**	**5.2**	**5.1**	**3.9**	**9.2**	**37.8**	**23.7**	**8.4**	**17.3**	**13.9**
Diptera	Chironomidae	52.5 (25.1)	19.0 (14.3)	10.0 (8.1)	26.7 (15.2)	35.8 (15.7)	13.9 (2.8)	18.9 (8.7)	29.2 (19.3)	16.1 (15.1)	11.9 (14.7)	12.0 (7.5)	21.9 (3.7)	6.8 (3.0)	10.8 (3.9)

The biomass of Ephemeroptera were positively correlated with river discharge (P=0.03, r=0.82). There were no other significant relations among the density, biomass, relative number, or relative weight of Plecoptera, Trichoptera, and Diptera orders and river discharge.

Ephemeroptera were always present in the benthos. The relative numbers (26-61%) and the relative weight (27-61%) comprised the greatest fraction of the benthos in late spring and early summer (Table 11). Ephemeroptera densities were highest in October and June (Table 10) (Appendix A, Figure 9). Density peaks did not coincide with peaks in relative numbers and weight. Their relative weight peaked in May (60.6%), declined in summer, and increased again in fall (35.2-47.9%). Ephemeroptera biomass was greatest in April (50.2 mg/m^2) and May (92.2 mg/m^2), then declined in summer and peaked again (42.1 mg/m^2) in October (Table 10). The relative number of Ephemerellidae was highest in spring (60.9%) but their highest relative weight was highest in early fall (60.6%) (Table 11). Densities of Ephemerellidae peaked in May with densities at $60/m^2$ (Table 10). As in the previously described habitats, Leptophlebiidae and Polymitarcyidae were generally found in the benthos in small numbers from June to August. Of the five Ephemeroptera families investigated, only the relative number (P=0.001, r=0.95) and weight (P=0.001, r=0.94) of Ephemerellidae were correlated with discharge. The relative number Baetidae were related to water temperature (P=0.04, r=0.79). No other relations were found among the relative weight or number of Ephemeroptera families and discharge or water temperature.

Trichoptera were most prominent in the benthos in June and July. Their relative number (34.7%) and weight (37.8%) peaked in June (Table 11). The relative number of Trichoptera ranged from about 1.5-34.7%. Trichoptera density ranged from 1.9/m^2 in August to 202.7/m^2 in June (Table 10; Appendix A, Figure 10). In contrast to the main and mid-channel habitats, Hydropsychidae densities peaked in October (76.9/m^2) while Brachycentridae densities peaked in June at 175.1/m^2 (Table 10). The relative weight of Trichoptera ranged from 3.9-37.8% (Table 11). Biomass ranged from 1.1 mg/m^2 in August to 16.5 mg/m^2 in June. The peak in densities and biomass of Trichoptera coincided with peaks in their relative number and weight. I found no significant relation among the density, biomass, relative number, and relative weight of Trichoptera families and river discharge or temperature.

Representation of Diptera in the benthos was characterized by two peaks, one in April followed by a smaller peak from July to August. Their relative numbers were highest in April (52.5%) and lowest in June (10.0%) (Table 11). Densities were highest in October (199.0/m^2), whereas the greatest biomass occurred in April at 17.2 mg/m^2 (Table 10; Appendix A, Figure 12). Following the April biomass peak, their biomass declined throughout the summer and peaked again October at 9.4 mg/m^2 (Table 10). The relative weight of Chironomidae was greatest in April (29.2%) with a second peak in August. No significant relation was found among the density, biomass, relative weight or number of Diptera and river discharge or temperature.

Plecoptera were found in the shallow habitat. Plecoptera were most dense in October (27.4/m^2) and densities ranged from 0-1.7/m^2 in April to September (Table 10;

Appendix A, Figure 11). Plecoptera numbers were fairly insignificant in the benthos when compared to other invertebrates. Biomass peaked in April at 11.6 mg/m^2 (Table 10). Their biomass peak coincided with the peak in their relative weight (Table 11). Biomass ranged from 0.0-11.6 mg/m^2 (Table 10) and relative weight ranged from 0.0-13.0% (Table 11). I found no significant relationship among the density, biomass, relative number or weight of Perlodidae and river discharge or temperature.

When examining the inter-relations among the four aquatic orders, only one relation was significant. Plecoptera and Diptera were positively related in their densities ($P=0.002$, $r=0.93$) and their biomass ($P=0.006$, $r=0.90$). The positive relation among the biomass of Diptera and Plecoptera was common in most habitats (main channel, midchannel, and side channel).

Side Channel

Average annual density and biomass of the side channel benthic invertebrate community was dominated by Ephemeroptera, followed by Trichoptera, Diptera, and Plecoptera (Table 5, Appendix A, Figure 15). Ephemeroptera average annual densities were higher than the other orders, but the greatest average annual biomass was nearly equal between Ephemeroptera and Trichoptera (Table 5, Appendix A, Figure 15). The relative weight of Trichoptera exceeded that of Diptera by approximately 15% (Table 5). The biomass of Ephemeroptera in the side channel habitat were positively correlated with the river discharge ($P=0.03$, $r=0.82$). Plecoptera were a minor component of the community in this habitat (Tables 12 and 13).

Table 12. Biomass (mg/m^2) and density (# /m^2)(SD) of available invertebrate prey in the side channel, whose yearly average comprised greater than one percent (P_n and/or P_w) of shovelnose sturgeon diets from the Missouri River, Montana in 1994. Values <0.1 are denoted with < ; and ----- if no representatives were found.

		April		May		June		July		Aug.		Sept.		Oct.	
Order	Family	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density
Ephemeroptera	Leptophlebiidae	----	----	----	----	----	----	1.3 (2.3)	0.5 (0.6)	3.1 (3.8)	0.5 (0.7)	----	----	----	----
	Polymitarcyidae	----	----	----	----	<	0.7 (1.0)	2.2 (0.2)	2.1 (0.2)	1.6 (1.8)	0.3 (0.3)	----	----	----	----
	Ephemerellidae	20.4 (30.2)	22.2 (32.2)	50.2 (42.0)	37.9 (33.2)	1.7 (1.5)	2.3 (2.0)	----	----	----	----	<	1.4 (2.5)	0.7 (1.2)	13.2 (19.4)
	Heptageniidae	0.6 (0.5)	2.1 (2.0)	3.1 (3.2)	9.9 (8.3)	3.5 (6.1)	7.8 (12.9)	4.3 (3.1)	9.7 (9.5)	8.9 (6.0)	53.8 (36.2)	6.3 (3.7)	45.4 (29.7)	9.6 (6.4)	69.1 (48.9)
	Baetidae	3.0 (4.9)	8.0 (13.0)	3.6 (3.8)	30.6 (24.5)	5.5 (7.2)	37.9 (53.0)	4.4 (3.0)	20.7 (11.4)	24.7 (9.3)	216.9 (61.0)	17.2 (7.6)	105.4 (54.0)	3.5 (1.8)	24.8 (11.8)
	TOTAL	**24.0**	**32.3**	**56.9**	**78.4**	**10.7**	**48.7**	**12.2**	**33.0**	**38.3**	**271.5**	**23.5**	**152.2**	**13.8**	**107.1**
Plecoptera	Taeniopterygidae	----	----	----	----	----	----	----	----	----	----	----	----	----	----
	Perlodidae	9.1 (13.6)	0.7 (1.1)	10.5 (11.2)	3.1 (2.9)	0.9 (1.4)	0.3 (0.4)	0.1 (0.2)	0.4 (0.5)	<	0.2 (0.4)	0.2 (0.4)	0.6 (1.0)	3.4 (3.6)	39.3 (43.1)
	TOTAL	**9.1**	**0.7**	**10.5**	**3.1**	**0.9**	**0.3**	**0.1**	**0.4**	**<**	**0.2**	**0.2**	**0.6**	**3.4**	**39.3**
Trichoptera	Hydropsychidae	7.4 (9.2)	4.7 (6.1)	8.1 (7.1)	11.3 (6.8)	13.9 (24.1)	13.7 (22.6)	12.1 (15.0)	23.8 (32.6)	5.8 (5.5)	8.0 (8.5)	13.4 (21.4)	62.7 (100.0)	86.7 (69.1)	250.0 (392.0)
	Brachycentridae	----	----	----	----	15.1 (25.7)	88.5 (150.8)	2.2 (3.0)	4.4 (6.0)	0.4 (0.4)	0.7 (0.6)	2.1 (3.6)	1.5 (2.2)	2.9 (5.0)	1.3 (2.1)
	TOTAL	**7.4**	**4.7**	**8.1**	**11.3**	**29.0**	**102.2**	**14.3**	**28.2**	**6.2**	**8.7**	**15.5**	**64.2**	**89.6**	**251.3**
Diptera	Chironomidae	10.0 (10.3)	47.0 (45.0)	4.4 (1.2)	15.4 (17.3)	5.2 (4.0)	18.2 (7.6)	2.2 (1.7)	17.4 (6.5)	5.7 (3.9)	41.1 (22.5)	1.9 (1.8)	35.4 (26.6)	15.3 (10.3)	205.8 (103.5)
	TOTAL	**10.0**	**47.0**	**4.4**	**15.4**	**5.2**	**18.2**	**2.2**	**17.4**	**5.7**	**41.1**	**1.9**	**35.4**	**15.3**	**205.8**

Table 13. Percent composition (P_n and P_w)(SD) per m^2 of the side channel prey items (whose yearly average comprised greater than one percent by either P_n and/or P_w in shovelnose sturgeon diets) from the Missouri River, Montana in 1994. Values < 0.1% are represented with < ; and ---- if none were found. Significant difference between adjacent months (α=0.05) is denoted with *.

		P_n							P_w						
Order	Family	April	May	June	July	Aug.	Sept.	Oct.	April	May	June	July	Aug.	Sept.	Oct.
Ephemeroptera	Leptophlebiidae	-----	-----	-----	*0.8 (1.1)	0.4 (0.4)	*----	----	-----	-----	-----	2.0 (3.5)	*6.9 (9.4)	*----	----
	Polymitarcyidae	-----	-----	*0.5 (0.5)	*2.1 (0.9)	*0.1 (0.1)	*----	----	-----	-----	<	*7.0 (3.1)	*3.3 (4.3)	*----	----
	Ephemerellidae	20.5 (18.2)	30.8 (29.4)	*0.8 (0.3)	*----	-----	0.2 (0.3)	*0.8 (0.8)	25.1 (22.9)	43.6 (30.9)	*1.8 (1.8)	-----	-----	<	0.1 (0.2)
	Heptageniidae	3.5 (4.2)	5.7 (3.3)	2.2 (2.2)	6.9 (3.8)	13.3 (4.9)	15.4 (15.3)	5.7 (2.3)	2.0 (3.0)	3.4 (1.4)	2.6 (4.5)	10.8 (7.2)	15.0 (5.4)	15.1 (15.2)	6.4 (5.4)
	Baetidae	5.4 (7.3)	*17.7 (10.7)	9.1 (9.3)	17.6 (7.5)	*57.8 (5.0)	27.8 (7.2)	*2.5 (0.9)	2.7 (3.8)	6.0 (5.7)	4.8 (5.1)	*11.7 (4.1)	44.1 (10.3)	34.1 (12.9)	*2.8 (2.0)
	TOTAL	**29.4**	**54.2**	**12.6**	**27.4**	**71.6**	**43.4**	**9.0**	**29.8**	**53.0**	**9.2**	**31.5**	**69.3**	**49.2**	**9.3**
Plecoptera	Taeniopterygidae	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
	Perlodidae	0.6 (0.6)	2.2 (1.4)	*0.1 (0.1)	0.3 (0.2)	0.1 (0.1)	0.1 (0.1)	*3.3 (2.1)	11.2 (10.3)	8.2 (7.5)	0.8 (1.0)	0.1 (0.2)	<	0.2 (0.3)	1.5 (0.7)
	TOTAL	**0.6**	**2.2**	**0.1**	**0.3**	**0.1**	**0.1**	**3.3**	**11.2**	**8.2**	**0.8**	**0.1**	**0.0**	**0.2**	**1.5**
Trichoptera	Hydropsychidae	3.7 (2.9)	7.9 (3.9)	3.8 (3.8)	14.4 (15.2)	2.2 (2.7)	9.2 (11.7)	13.2 (15.3)	11.0 (3.4)	6.5 (5.7)	10.4 (18.0)	23.6 (21.6)	10.4 (11.4)	12.8 (15.1)	38.7 (26.6)
	Brachycentridae	-----	-----	*18.0 (29.2)	2.6 (2.7)	*0.2 (0.2)	0.2 (0.3)	0.1 (0.1)	-----	-----	11.4 (19.1)	4.2 (4.2)	0.8 (0.9)	1.6 (2.8)	0.5 (0.9)
	TOTAL	**3.7**	**7.9**	**21.8**	**17.0**	**2.4**	**9.4**	**13.3**	**11.0**	**6.5**	**21.8**	**27.8**	**11.2**	**14.4**	**39.2**
Diptera	Chironomidae	46.6 (40.0)	10.9 (3.7)	16.0 (16.0)	16.1 (8.2)	10.6 (4.2)	7.8 (2.4)	20.5 (7.1)	31.5 (43.0)	8.1 (7.0)	15.7 (12.6)	8.0 (8.2)	10.1 (6.6)	2.6 (2.5)	10.1 (8.3)

Ephemeroptera were collected in fairly large numbers in this habitat. The relative number of Ephemeroptera ranged from 9-71.6% and was highest in August (71.6%) and May (54.2%) (Table 13, Appendix A, Figure 9). Densities were highest in the fall and ranged from 107.1-271.5/m^2. A smaller peak in density occurred in May at 78.4/m^2 (Table 12; Appendix A, Figure 9). The spring peak in relative number of Ephemeroptera was made up largely of Ephemerellidae and the August peak was made up of Heptageniidae and Baetidae. Ephemeroptera biomass was greatest in May (56.9mg/m^2) (Table 12) but their relative weight was greatest in August (69.3%) when biomass was only 38.3 mg/m^2 (Tables 12 and 13). Leptophlebiidae and Polymitarcyidae occurred in the benthos in summer but their densities and biomass were fairly low (Table 12). Discharge was related to the relative number ($P=0.001$, $r=0.94$) and weight ($P=0.0009$, $r=0.95$) of Ephemerellidae. The relative weight of Heptageniidae was also related to discharge ($P=0.04$, $r= -0.77$). The relative number of Baetidae were found to be significantly related to water temperature ($P=0.03$, $r=0.80$).

As in the other habitats, presence of Trichoptera was high. The relative number of Trichoptera ranged from 2.4-21.8% and densities ranged from 4.7/m^2 in April, to 251.3/m^2 in October (Table 12 and 13; Appendix A, Figure 10). The relative number of Trichoptera was highest in June (21.8%), July (17.0%), and in October (13.3%) (Table 13). The largest relative number of Trichoptera did not occur at the same time as their highest density in the benthos (Tables 12 and 13). The relative weight of Trichoptera was highest in October (39.2%) and July (27.8%) (Table 13). The biomass and density of Hydropsychidae was usually greater than that of Brachycentridae, except in June (Table

12). Trichoptera biomass ranged from 6.2-89.6 mg/m^2 and peaked in October when densities were highest (Table 12). Biomass was greatest in October and was preceded by a smaller peak in biomass in June. I found no significant relation among the relative number and weight of either Trichoptera family and river temperature or discharge.

Diptera were most abundant in the benthos of the side channel in the early spring and fall months. Chironomidae comprised their highest relative number in April (46.6%), (Table 13) with densities of 47.0/m^2 (Table 12; Appendix A, Figure 12). Densities decreased (15-17/m^2) through summer then gradually increased in fall when densities peaked at 205.8/m^2 (Table 12). Biomass was greatest in October (15.3 mg/m^2) and April (10.0 mg/m^2) (Table 12). The relative weight of Chironomidae was greatest in April (31.5%) and June (15.7%) (Table 13). I found no significant correlation among the relative number and weight of Chironomidae and river discharge or water temperature.

Except during October, Plecoptera made up a relatively small portion of the benthic invertebrate community. Densities ranged from 0.2-3.1/m^2 from April to September and peaked in October (39.3/m^2) (Table 12; Appendix A, Figure 11). The relative number of Plecoptera also peaked in October (3.3%) (Table 13; Appendix A, Figure 15). Biomass peaked in April (9.1 mg/m^2) and May (10.5 mg/m^2). Biomass declined to low levels from June to September, then increased in October (3.4 mg/m^2) (Table 12). The relative weight of Perlodidae was significantly correlated to river discharge ($P=0.01$, $r=0.87$). No significant relation was found among the relative weight and number of Perlodidae and water temperature.

I found significant relations among densities of invertebrate orders. The density of Plecoptera was positively correlated with those of Trichoptera (P=0.005, r=0.91) and the density of Trichoptera were related to those of Diptera (P=0.01, r=0.87).

Drift

Invertebrate drift was dominated by Ephemeroptera throughout most of the sampling period (average=37.8%) (Tables 5,14,15; Appendix A, Figure 16). Trichoptera comprised nearly twice the relative weight of Diptera. Plecoptera numbers were relatively insignificant. The relative number of Diptera was more than twice that of Trichoptera. I found no significant relations among the relative weight or number of Plecoptera, Diptera, Trichoptera, and Ephemeroptera and river discharge or temperature.

Ephemeroptera were most dense in the drift during August (3.2/m^3) (Table 14) The timing of the highest densities coincided with the timing of the highest relative number of Ephemeroptera (55.1%) (Table 15). Ephemeroptera biomass in the drift was often <0.1 mg/m^3. The relative number and weight of Ephemeroptera were highly variable (Table 15). Heptageniidae and Baetidae were the most common Ephemeroptera in the drift. Ephemerellidae, Polymitarcyidae, and Leptophlebiidae were found only in very low numbers and weight (Tables 14 and 15). The relative number and weight of Ephemerellidae were found to be significantly related to discharge (P=0.03, r =0.79; (P=0.01, r =0.86, respectively).

Trichoptera, all of which were Hydropsychidae, made up a very small fraction of the drift. Their relative numbers peaked in May (20.4%) and June (26.1%). Their relative

Table 14. Biomass (mg/m^3)(SD) and density (# /m^3)(SD) of available invertebrate prey in the water column (drift), whose yearly average comprised greater than one percent (P_n and/or P_w) of shovelnose sturgeon diets from the Missouri River, Montana in 1994. Values <0.1 are denoted with < ; and ----- if no representatives were found.

		April		May		June		July		Aug.		Sept.		Oct.	
Order	Family	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density	Mass (mg)	Density
Ephemeroptera	Leptophlebiidae	----	-----	----	----	----	----	----	----	----	----	<	<	----	----
	Polymitarcyidae	----	----	----	----	<	<	<	<	----	-----	----	----	----	----
	Ephemerellidae	<	<	<	0.1 (0.0)	----	-----	----	-----	----	----	<	<	<	0.1 (0.0)
	Heptageniidae	<	<	<	0.1 (0.0)	<	<	<	0.1 (0.0)	<	0.2 (0.2)	<	0.1 (0.0)	<	0.1 (0.0)
	Baetidae	<	0.3 (0.1)	<	0.2 (0.0)	<	0.5 (0.5)	<	0.4 (0.3)	<	3.0 (1.5)	<	0.6 (0.1)	<	0.3 (0.1)
	TOTAL	**<**	**0.3**	**<**	**0.4**	**<**	**0.5**	**<**	**0.5**	**<**	**3.2**	**<**	**0.7**	**<**	**0.5**
Plecoptera	Taeniopterygidae	----	----	----	----	----	----	----	----	----	-----	----	-----	----	-----
	Perlodidae	----	-----	<	<	<	<	<	<	<	<	<	<	<	0.1 (0.0)
	TOTAL	**----**	**----**	**<**	**<**	**<**	**<**	**<**	**<**	**<**	**<**	**<**	**<**	**<**	**0.1**
Trichoptera	Hydropsychidae	<	<	<	0.1 (0.0)	<	0.3 (0.0)	<	0.2 (0.1)	<	0.2 (0.1)	<	0.2 (0.0)	<	0.1 (0.0
	Brachycentridae	<	<	----	----	<	<	<	<	<	<	<	<	----	-----
	TOTAL	**----**	**----**	**<**	**0.1**	**<**	**0.3**	**<**	**0.2**	**<**	**0.2**	**<**	**0.2**	**<**	**0.1**
Diptera	Chironomidae	<	0.4 (0.3)	<	0.1 (0.0)	<	0.1 (0.0)	<	0.6 (0.6)	<	0.8 (.01)	<	0.7 (0.3)	<	0.3 (0.1)
	TOTAL	**<**	**0.4**	**<**	**0.1**	**<**	**0.1**	**<**	**0.6**	**<**	**0.8**	**<**	**0.7**	**<**	**<**

Table 15. Percent composition (P_n and P_w)(SD) per m^3 of the drifting prey items (whose yearly average comprised greater than one percent P_n and/or P_w in sturgeon diets) from the Missouri River, Montana in 1994. Values < 0.1% are represented with < ; and ----- if none were found. Significant difference between adjacent months (α=0.05) is denoted with *.

		P_n							P_w						
Order	Family	April	May	June	July	Aug.	Sept.	Oct.	April	May	June	July	Aug.	Sept.	Oct.
Ephemeroptera	Leptophlebiidae	----	----	----	----	----	0.1 (0.2)	----	----	----	----	----	----	<	----
	Polymitarcyidae	----	----	*0.6 (0.5)	*0.1 (0.1)	----	----	----	----	----	<	<	----	----	----
	Ephemerellidae	4.2 (3.2)	*10.8 (2.8)	*----	----	----	0.6 (1.1)	*4.4 (1.1)	5.4 (9.4)	*21.5 (11.8)	*----	----	----	<	1.4 (2.4)
	Heptageniidae	2.4 (1.3)	*9.8 (4.6)	*3.1 (1.9)	3.9 (1.4)	3.2 (1.8)	2.7 (1.5)	*8.1 (0.6)	2.8 (3.1)	4.3 (4.8)	1.2 (2.1)	1.0 (1.7)	1.1 (1.2)	0.7 (1.2)	11.6 (2.9)
	Baetidae	34.3 (13.6)	29.5 (7.8)	37.9 (13.0)	26.5 (26.1)	51.9 (9.0)	17.4 (0.6)	19.3 (2.3)	34.6 (20.2)	14.7 (4.8)	25.7 (6.6)	36.4 (34.8)	45.3 (12.5)	24.4 (3.5)	32.2 (10.1)
	TOTAL	**40.9**	**50.1**	**41.6**	**30.5**	**55.1**	**20.8**	**31.8**	**42.8**	**40.5**	**26.9**	**37.4**	**46.4**	**25.1**	**45.2**
Plecoptera	Taeniopterygidae	----	----	----	----	----	----	----	----	----	----	----	----	----	----
	Perlodidae	----	1.6 (2.2)	0.2 (0.3)	0.2 (0.3)	0.2 (0.2)	0.2 (0.3)	7.7 (1.9)	----	1.1 (2.0)	<	<	<	<	*7.6 (1.2)
	TOTAL	**0.0**	**1.6**	**0.2**	**0.2**	**0.2**	**0.2**	**7.7**	**0.0**	**1.1**	**0.0**	**0.0**	**0.0**	**0.0**	**7.6**
Trichoptera	Hydropsychidae	*4.1 (0.7)	20.4 (2.3)	25.4 (11.8)	12.2 (6.8)	*2.8 (1.2)	*6.6 (0.3)	7.1 (1.9)	11.2 (10.7)	56.4 (17.3)	19.1 (5.0)	28.9 (25.8)	12.2 (6.6)	20.9 (2.5)	14.8 (17.0)
	Brachycentridae	----	----	0.7 (0.7)	0.2 (0.4)	0.1 (0.2)	0.1 (0.1)	----	----	----	<	<	<	<	----
	TOTAL	**4.1**	**20.4**	**26.1**	**12.4**	**2.9**	**6.7**	**7.1**	**11.2**	**56.4**	**19.1**	**28.9**	**12.2**	**20.9**	**14.8**
Diptera	Chironomidae	50.8 (11.6)	22.9 (3.0)	*7.9 (4.8)	*41.1 (24.9)	*15.7 (6.4)	19.6 (10.2)	19.6 (1.8)	18.4 (12.5)	*<	<	*22.6 (14.5)	19.0 (7.7)	20.1 (13.5)	11.3 (7.1)

numbers steadily decreased from June to October (Table 15). Densities were relatively constant (0.1-0.3/m^3) and peaked in June (Table 14). The highest relative weight of Trichoptera occurred in May (56.4%), July (28.9%), and September (20.9%) (Table 15). I found no significant relation among the relative number and weight of Trichoptera in the drift and river discharge or temperature.

The relative numbers of Diptera exhibited two major peaks in the drift. Their highest relative number occurred in April (50.8%) and July (41.1%) (Table 15). Densities were only 0.4/m^3 in April and 0.6/m^3 in July (Table 14). The highest densities occurred from July to September when densities ranged between 0.6-0.8/m^3 (Table 14). The highest relative weight of Diptera occurred from July to September (Table 15; Appendix A, Figure 16). With such low numbers present in the drift, biomass values were always <1.0 mg. I found no significant relations among the relative number and weight of Diptera and river discharge or temperature.

Drifting Plecoptera were found in small amounts only in October when their densities were 0.1/m^3 (Table 14). From April to September, densities were <0.1 mg/m^3 (Table 14) and their relative weight ranged from 0-1.6% (Table 15). The relative number and weight of Plecoptera was approximately 8.0% in October. I found no relation among the relative number and weight of Plecoptera in the drift and river discharge or temperature.

Biomass of Ephemeroptera was positively related to biomass of Diptera ($P=0.04$, $r=0.78$) in the drift. The positive relation among Ephemeroptera and Diptera in the drift was common in the benthos of most habitats I examined as well.

Shovelnose Sturgeon

Sturgeon Captured

Shovelnose sturgeon were captured in 38 of 56 netting attempts. I found no significant difference between habitat characteristics (depth, velocity, substrate) associated with successful and unsuccessful sampling efforts (Table 16).

Table 16. Kruskal Wallis tests between habitat characteristics of successful and unsuccessful netting attempts for shovelnose sturgeon in the Missouri River, Montana. Table includes: total netting attempts (unsuccessful / successful), and Kruskal Wallis statistics (P-value) for average depth, average velocity, and substrate composition for April to October 1994.

Month sampled	Netting attempts	Average depth (m)	Average velocity (m/s)	Substrate				
				0	1	2	3	4
April	13	0.38	1.93	0.00	0.10	1.94	2.92	0.14
	4/9	(0.54)	(0.16)	(1.00)	(0.76)	(0.16)	(0.09)	(0.71)
May	4	1.80	1.80	0.330	0.89	0.89	2.0	0.33
	1/3	(0.18)	(0.18)	(0.56)	(0.35)	(0.35)	(0.16)	(0.56)
June	12	1.42	0.46	0.00	4.37	0.35	0.73	1.52
	4/8	(0.23)	(0.50)	(1.00)	(0.04)	(0.55)	(0.39)	(0.22)
July	12	0.42	1.91	0.00	0.03	1.48	0.11	1.54
	5/7	(0.52)	(0.17)	(1.00)	(0.86)	(0.22)	(0.75)	(0.20)
Aug.	4	3.00	2.00	0.00	2.00	2.0	2.00	0.33
	1/3	(0.83)	(0.16)	(1.00)	(0.16)	(0.16)	(0.16)	(0.56)
Sept.	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1/4	(1.0)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
Oct.	6	0.06	0.00	0.00	0.00	0.00	0.00	0.00
	2/4	(0.80)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
All	56	0.38	0.06	0.47	0.20	1.27	0.02	2.56
Months	18/38	(0.54)	(0.80)	(0.49)	(0.66)	(0.26)	(0.90)	(0.11)

Number, Length and Weight of Fish

For the food habits analysis, 142 shovelnose sturgeon were collected; 43 in 1993 and 99 in 1994 (Table 17). The mean total length was 800 mm (SD = 102.6) and ranged

from 495 mm in September 1994 to 980 mm in July 1993 (Figure 3). Mean shovelnose sturgeon weight was 2.0 kg (SD = 0.77), with the smallest (0.26 kg) collected in September 1994 and the largest (3.69 kg) collected in June 1994 (Figure 4). The length-weight regression was linear (r^2= 0.88) and defined as:

$$\text{Length (Ln)} = 4.8430 + 0.24605 * \text{Weight (Ln)},$$

where Ln is the natural log (Figure 5). We collected no young of the year sturgeon,

Table 17. Number, mean total and fork lengths (SD), mean weight (SD) and respective ranges for shovelnose sturgeon collected in the Missouri River, Montana in 1993 and 1994.

Year	Month	Number collected	Total length (mm)	Range (mm)	Fork length (mm)	Range (mm)	Weight (kg)	Range (kg)
1993	July	9	810 (6)	699 - 980	- Na -	- Na -	2.2 (0.6)	1.55 - 3.18
	Aug.	8	791 (63)	695 - 885	739 (53)	665 - 821	1.8 (0.6)	1.12 - 2.95
	Sept.	7	823 (73)	738 - 912	762 (78)	660 - 864	2.1 (0.8)	1.11 - 3.49
	Oct.	15	835 (85)	710 - 968	771 (78)	666 - 897	2.1 (0.7)	1.25 - 3.32
	Nov.	4	810 (41)	751 - 846	752 (35)	711 - 793	2.1 (0.5)	1.67 - 2.66
1994	April	15	782 (80)	596 - 908	718 (80)	520 - 814	1.7 (0.5)	0.51 - 2.47
	May	15	806 (65)	666 - 940	745 (60)	620 - 841	2.1 (0.5)	1.30 - 2.84
	June	15	850 (115)	495 - 955	792 (116)	450 - 897	2.5 (0.9)	0.34 - 3.69
	July	15	801 (91)	570 - 974	738 (91)	521 - 918	1.9 (0.8)	0.51 - 3.46
	Aug.	15	785 (118)	580 - 962	722 (117)	525 - 894	1.7 (0.8)	0.54 - 3.18
	Sept.	15	727 (178)	495 - 695	667 (176)	440 - 906	1.4 (1.0)	0.26 - 2.84
	Oct.	9	809 (48)	745 - 875	749 (53)	676 - 815	1.9 (0.6)	0.88 - 2.49

therefore, the model is weaker for fish smaller than 500 mm. We collected six tagged sturgeon which presented an opportunity to measure their growth during the interval between captures (Table 18). Shovelnose sturgeon fork lengths increased an average of 4.7 mm (SD=8.4) and weights decreased an average of 0.12 kg (SD=0.30) in a year.

Condition factors of individual shovelnose sturgeon ranged from 0.21 in September 1994 to 0.49 in July 1993, October 1993, and May 1994. Mean condition

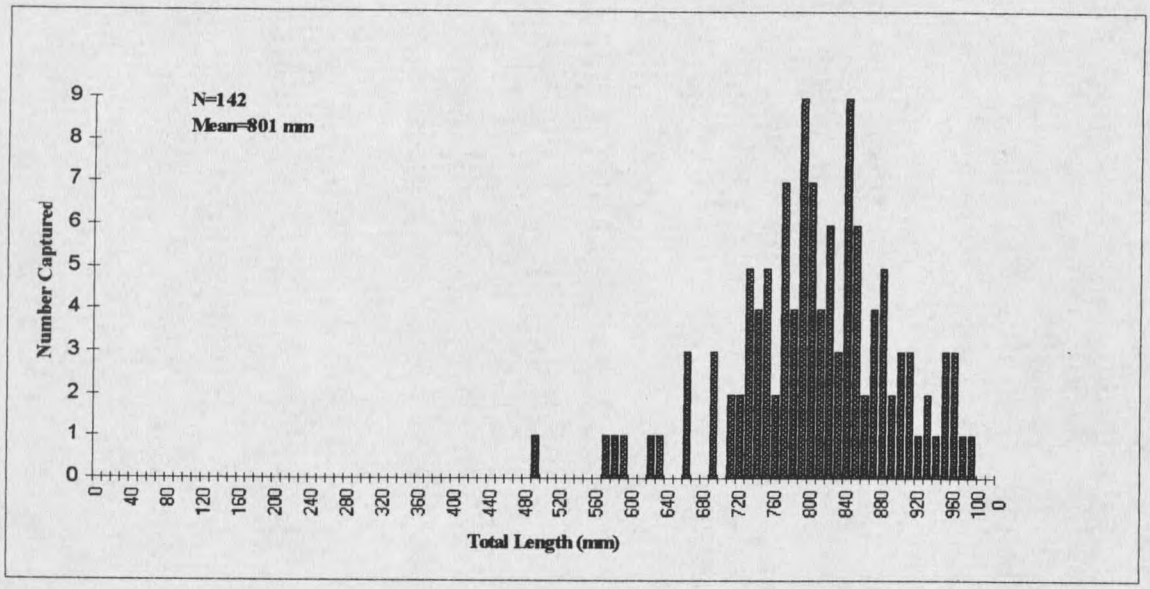


Figure 3. Length frequency of shovelnose sturgeon captured from the Missouri River, Montana in 1993-1994.

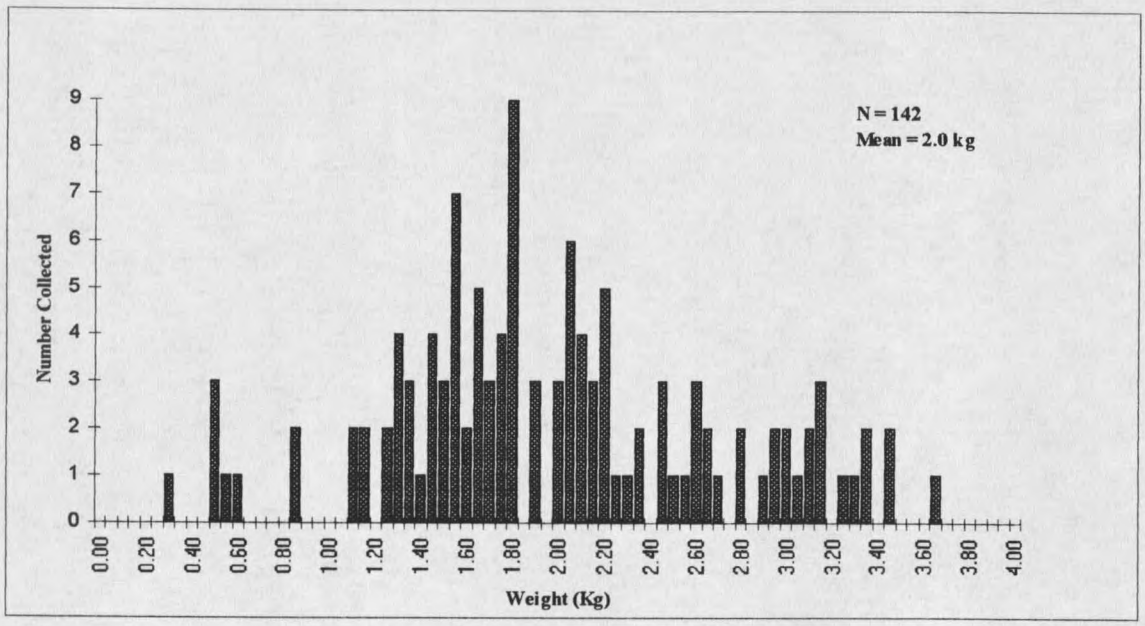


Figure 4. Weight frequency (kg) of shovelnose sturgeon captured from the Missouri River, Montana in 1993-1994.

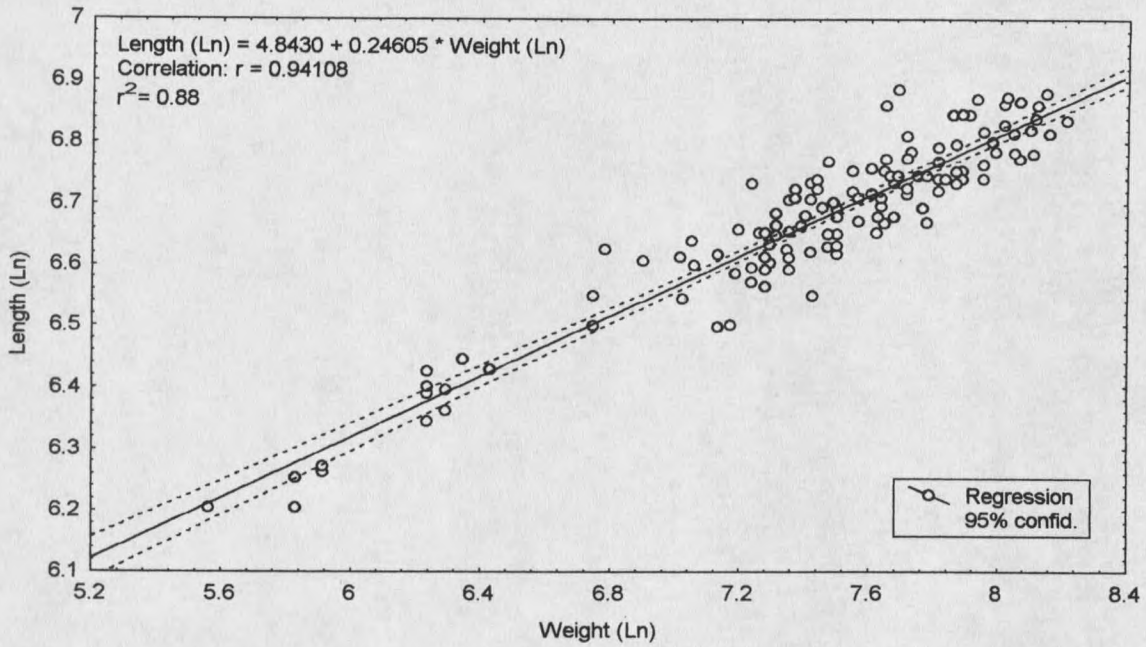


Figure 5. Length weight regression (natural log lengths and weights) for shovelnose sturgeon from the Missouri River, Montana from 1993-1994.

Table 18. Tag number, time between tagging and recovery of tagged fish, fork length (mm), and weight (kg) and changes in fork length and weight of six shovelnose sturgeon recaptured in 1993 and 1994 in the Missouri River above Fort Peck Reservoir, Montana. Fish were tagged by William Gardner (Montana Department of Fish, Wildlife, and Parks biologist).

		Tagged		Recaptured			
Sturgeon tag #	Elapsed time (years)	Fork length (mm)	Total weight (kg)	Fork length (mm)	Total weight (kg)	Fork length change (mm)	Weight change (kg)
G-01382	2.10	818.00	2.45	821.00	2.95	3.00	0.50
S-00148	2.90	775.00	2.36	787.00	2.15	12.00	-0.21
G-02200	1.20	635.00	1.09	660.00	1.11	25.00	0.02
G-03047	1.80	836.00	2.82	834.00	2.58	-2.00	-0.24
G-01785	2.40	912.00	4.36	906.00	2.76	-6.00	-1.60
G-03155	1.10	729.00	1.73	735.00	1.59	6.00	-0.14

factors were 0.37 (SD=0.07) and 0.34 (SD=0.07) for 1993 and 1994, respectively. In 1993 the lowest K (0.23) was recorded in July and the highest K (0.49) in July and

August. In 1994 the low K (0.21) was recorded in September and the high (0.49) in May. Monthly mean condition factors varied from 0.34 (SD=0.06) in August to 0.42 (0.08) in July in 1993 and from 0.29 (SD=0.06) in September to 0.39 (0.06) in May, 1994 (Figure 6).

Stomach Content Biomass

Stomach content (dry weight) of Shovelnose sturgeon ranged from 0.002 g in August, 1993 to 9.647 g in May, 1994 (Table 19). Average shovelnose sturgeon stomach biomass was 1.245 g (SD=1.259) and 1.910 g (SD=2.31) in 1993 and 1994, respectively. In 1993, mean stomach biomass was greatest (3.55 g) in November and

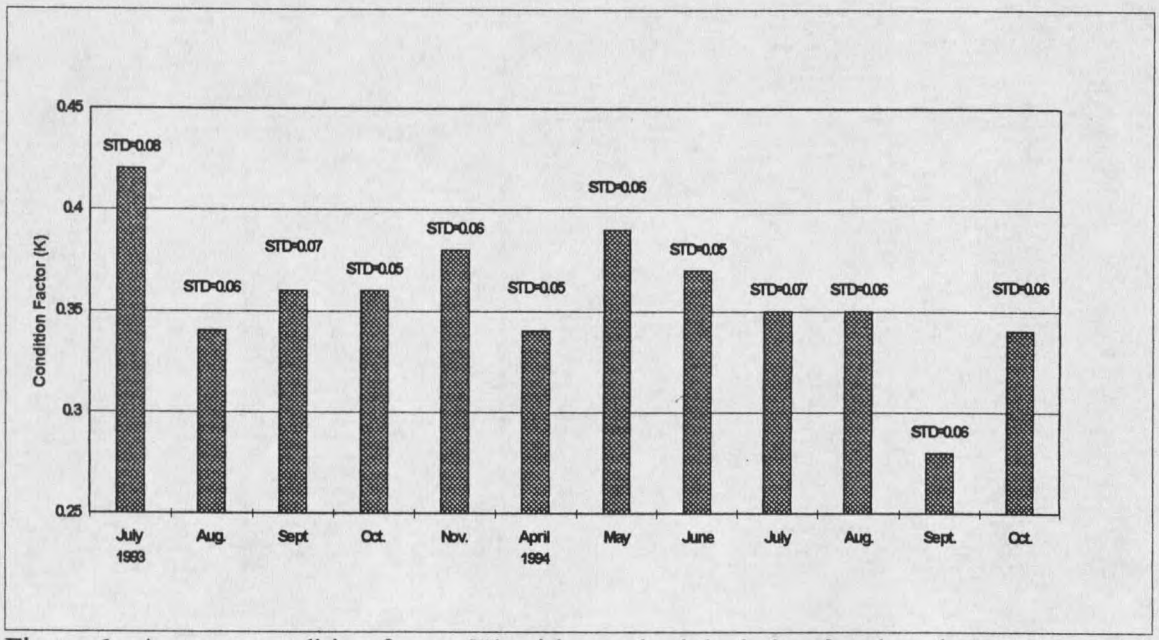


Figure 6. Average condition factor (K) with standard deviation for shovelnose sturgeon from the Missouri River, Montana in 1993-1994.

lowest (0.19 g) in August (Table 20). Maximum mean stomach biomass in 1994 differed from 1993 in that it was greatest in April (5.03 g). In 1993, average monthly stomach biomass differed significantly (α=0.05) between the months of August, September, and November (P=0.001, 0.022, and 0.018, respectively). Average monthly stomach biomass was significantly different from the previous month (P<0.001) in June 1994 (Table 20). Stomach biomass was correlated with discharge (P=0.004, R^2=0.83) but no relation was evident with temperature.

Percent composition by the inorganic, organic miscellaneous and identified food items fraction (dry weight) of stomach contents varied among months but the annual averages were not significantly different between 1993 and 1994 (P= 0.72, 0.22, 0.48, respectively). Inorganic matter comprised from zero to 68 % of the shovelnose sturgeon stomach mass and averaged about 25% (Table 19). In 1993, inorganic matter comprised the greatest portion of the monthly mean stomach content mass in July (42.4 %) and the lowest (1.7 %) in August (Figure 7). In 1994, the greatest monthly mean inorganic fraction was during August and September (33.7, 32.6 %, respectively) with the lowest occurring in October (15.0 %) (Table 21). The inorganic fraction (g) of stomach contents 0.009, respectively) (Figure 7). In 1994, the inorganic fraction was significantly different in June and October (P=0.014, 0.011) (Figure 7). The miscellaneous organic fraction ranged from 0 to 93 % of the stomach biomass (Table 19). The monthly average miscellaneous organic fraction ranged from 18.2 % in May, 1994 to 38.0 % in August and

Table 19. Average (SD), minimum (SD), maximum (SD), dry weight (g) and percent composition (%) by dry weight and month recorded for identified and miscellaneous organic and inorganic portions of shovelnose sturgeon stomach contents taken from the Missouri River, Montana in 1993 and 1994.

Year	Stomach contents	Average (g)	Standard deviation	Minimum dry weight (g)	Month recorded	Maximum dry weight (g)	Month recorded
1993	Identified food items	0.536	0.664	0.002	Aug.	3.136	Nov.
	Misc. organic portion	0.308	0.265	0.000	Aug.	1.242	Nov.
	Misc. inorganic portion	0.401	0.601	0.000	Aug.	3.185	Oct.
	Total weight	1.245	1.259	0.002	Aug.	5.282	Nov.
1994	Identified food items	0.995	1.368	0.000	July	7.696	May
	Misc. organic portion	0.403	0.477	0.000	June, Oct.	2.540	April
	Misc. inorganic portion	0.512	0.654	0.000	June, July, Oct.	2.804	April
	Total weight	1.910	2.31	0.014	July	9.647	May
		Average (%)	Standard deviation	Minimum dry weight (%)	Month recorded	Maximum dry weight (%)	Month recorded
1993	Identified food items	44.6	23.1	16.7	Aug.	100.0	Aug.
	Misc. organic fraction	31.0	18.6	0.0	Aug.	83.3	Aug.
	Misc. inorganic fraction	24.4	19.5	0.0	Aug.	68.2	Oct.
1994	Identified food items	47.2	19.2	0.0	July	100.0	June, Oct.
	Misc. organic fraction	27.2	16.0	0.0	June	92.9	July
	Misc. inorganic fraction	25.5	16.6	0.0	June, July	68.3	Sept.

Table 20. Number of stomachs collected, mean monthly stomach content dry weight (g), identified stomach content dry weight (g), organic and inorganic miscellaneous stomach content dry weight (g) (standard deviation) for shovelnose sturgeon collected from the Missouri River, Montana in 1993 and 1994. Significant difference (α=0.05) between months is denoted with *.

Year	Month	Stomachs collected	Total dry weight (g)	Identified contents (g)	Organic misc. (g)	Inorganic misc. (g)
1993	July	9	1.12 (0.76)	0.31 (0.23)	0.28 (0.12)	0.53 (0.46)
	Aug.	8	* 0.19 (0.38)	* 0.12 (0.27)	* 0.06 (0.09)	* 0.02 (0.04)
	Sept.	7	* 0.78 (0.48)	* 0.34 (0.16)	* 0.27 (0.16)	* 0.17 (0.22)
	Oct.	15	1.49 (1.17)	0.54 (0.33)	0.34 (0.18)	* 0.62 (0.86)
	Nov.	4	* 3.55 (1.59)	* 2.24 (0.84)	* 0.85 (0.40)	0.46 (0.36)
1994	April	15	5.03 (2.32)	2.83 (1.30)	1.13 (0.58)	1.07 (0.69)
	May	15	4.27 (2.30)	2.27 (1.71)	0.74 (0.40)	1.26 (0.88)
	June	15	* 1.04 (1.35)	* 0.57 (0.70)	* 0.21 (0.24)	* 0.25 (0.47)
	July	15	0.67 (0.67)	0.24 (0.25)	0.15 (0.14)	0.28 (0.30)
	Aug.	15	0.54 (0.26)	0.19 (0.12)	0.14 (0.07)	0.21 (0.14)
	Sept.	15	0.63 (0.34)	0.24 (0.15)	0.16 (0.12)	0.23 (0.18)
	Oct.	9	0.56 (0.55)	0.29 (0.32)	0.18 (0.18)	0.10 (0.13)

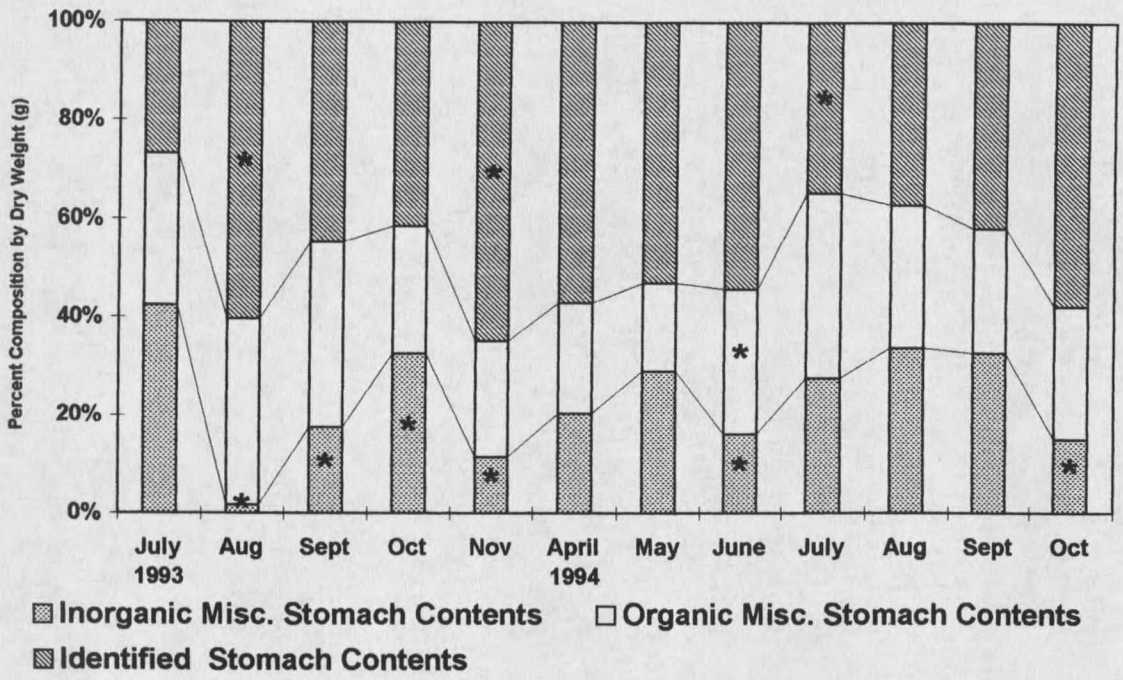


Figure 7. Mean percent composition by dry weight of identified stomach contents, organic miscellaneous stomach contents, and inorganic miscellaneous stomach contents for shovelnose sturgeon collected from the Missouri River, Montana in 1993 and 1994. Significant difference between adjacent months (α=0.05) is denoted with *.

differed in August, September, October, and November, 1993 (P=0.000, 0.003, 0.021, 0.002, respectively). The average monthly miscellaneous organic fraction differed significantly only in June 1994 (P=0.023). The fraction comprised of identified food organisms ranged from 26.8 % in July 1993 to 64.9 % in November 1993 (Table 21, Figure 7). The identified fraction differed significantly in August and November 1993 (P=0.007, P=0.041, respectively) and in July 1994 (P=0.003) (Table 21, Figure 7).

The monthly mean inorganic portion of the stomach contents ranged from 0.02 g in August 1993 to 1.26 g in May 1994 (Table 20). During 1993, the average inorganic portion of the stomach contents was greatest in October (0.62 g) and July (0.53 g). These

2 months also represent the months in which the inorganic portion comprised the greatest relative weight (Table 21, Figure 7). In 1994, April (1.07 g) and May (1.26 g) showed the greatest weight of inorganics in the stomachs (Table 20); however, the greatest relative weight was recorded in July and August (Table 21, Figure 7). The lowest average inorganic weight in 1993 was recorded in August (0.02 g) which coincides with its lowest relative weight. In 1994, the lowest average inorganic weight was recorded in October (0.10 g) (Table 20) which also coincides with its lowest relative weight of the stomach contents (Table 21). Inorganics (g) found in shovelnose sturgeon stomachs differed significantly (α=0.05) in August, September and October 1993 (P=0.000, 0.018, 0.025, respectively) and June 1994 (P=0.000) (Table 20). The inorganics biomass in the sturgeon stomachs was correlated with discharge (P=0.001, r =0.94) but not temperature. The monthly mean miscellaneous organic portion of the stomach contents ranged from

Table 21. Number of stomachs collected, % identified stomach content dry weight (standard deviation), % organic and inorganic miscellaneous stomach content dry weight (standard deviation) for shovelnose sturgeon collected from the Missouri River, Montana in 1993 and 1994. Significant difference (α=0.05) between months is denoted with *.

Year	Month	Stomachs collected	Identified contents (%)	Organic misc. (%)	Inorganic misc. (%)
1993	July	9	26.8 (7.5)	30.8 (13.0)	42.4 (12.6)
	Aug.	8	* 60.4 (36.6)	38.0 (37.0)	* 1.7 (3.8)
	Sept.	7	44.5 (18.2)	38.0 (14.5)	* 17.5 (12.4)
	Oct.	15	41.4 (16.5)	26.1 (8.4)	* 32.5 (18.1)
	Nov.	4	* 64.9 (5.2)	23.7 (2.0)	* 11.4 (4.5)
1994	April	15	57.1 (6.2)	22.6 (4.4)	20.3 (5.9)
	May	15	52.9 (13.9)	18.2 (5.2)	28.9 (12.0)
	June	15	54.3 (18.4)	* 29.7 (19.8)	* 16.0 (11.7)
	July	15	* 34.7 (20.5)	37.9 (27.0)	27.4 (18.7)
	Aug.	15	37.0 (16.8)	29.3 (11.1)	33.7 (18.8)
	Sept.	15	41.8 (19.8)	25.6 (11.9)	32.6 (20.1)
	Oct.	9	57.9 (25.9)	27.2 (15.0)	* 15.0 (18.0)

0.06 g in August 1993 to 1.13 g in April 1994 (Table 20). During 1993, the average miscellaneous organic portion of the stomach contents was greatest in November (0.85 g) and October (0.34 g). In 1994, sturgeon collected in April (1.13 g) and May (0.74 g) had the greatest weight of miscellaneous organics in the stomachs (Table 20); however, the greatest relative weight was recorded in June and July (Table 21, Figure 7). The lowest average miscellaneous organic weight in 1993 was recorded in August (0.06 g) (Table 20); however, the lowest relative weight occurred in November (Table 20). In 1994, the lowest average inorganic weight was recorded in August (0.14 g) (Table 20); however, the lowest relative weight occurred in May (Table 21). Miscellaneous inorganics (g) found in shovelnose sturgeon stomachs differed significantly (α=0.05) in August, September and October during 1993 (P=0.001, 0.004, 0.014, respectively) (Table 20) . Inorganics (g) differed significantly only in June of 1994 (P=0.000) (Table 20).

Identifiable invertebrate components of diet ranged from a monthly average of 0.12 g in August 1993 to 2.83 g in April 1994 (Table 20). In 1993, the greatest weight (2.24 g) occurred in November and the smallest occurred in August (Table 20). During 1994, the greatest weight (2.83 g) occurred in April with the smallest (0.19 g) in August (Table 20). The identifiable portion was significantly different in August (P=0.028), September (P=0.01), and November (P=0.006) of 1993 and in June (P=0.000) of 1994.

Food Habits

Sturgeon consumed invertebrates from 12 aquatic and 6 terrestrial invertebrate orders. Of the 12 aquatic invertebrate orders, only 4 were considered significant (>1%

relative number and weight) in the diet with no terrestrial orders meeting this criterion. Aquatic invertebrate orders which represented the majority of the food items included Ephemeroptera, Plecoptera, Trichoptera, and Diptera (Tables 22 and 23). Representatives of the remaining aquatic orders (Odonata, Hemiptera, Coleoptera, Amphipoda, Decapoda, Gastropoda, Hydracarina, and Class Oligochaeta) were considered trace food items. Fish larvae were the only vertebrates in the diet. Diptera, Aranea, Orthoptera, Hymenoptera, Homoptera, and Coleoptera were the terrestrial invertebrate orders in the diet. I found a significant relation among discharge and the number of invertebrate families found in the diet each month ($P=0.016$, $r=0.84$).

Ephemeroptera were represented by nine families of which five (Leptophlebiidae, Polymitarcyidae, Ephemerellidae, Heptageniidae, and Baetidae) made up a significant fraction of the sturgeon diet. Other mayfly families consumed were Tricorythidae, Caenidae, Isonychiidae, and Ametropodidae. Because of the multitude of families represented by Ephemeroptera and their separate emergent periods, mayflies accounted for a substantial portion of the sturgeon diet throughout the sampling period (Tables 22 and 23, Appendix B, Figures 17 and 18). Of the five prominent families, Heptageniidae and Baetidae were present in the diet in all months sampled. Ephemerellidae were present during late fall and early spring and Leptophlebiidae and Polymitarcyidae were utilized in July and August. Based on their relative numbers in the diet, Heptageniidae were utilized most (9.2-22.4%) in spring and early summer during 1994 and in September and October 1993 (11.3-16.5%) (Table 22). The relative weight of Heptageniidae in the diet (dry weight) was greatest (about 10%) in September and October 1993 but in 1994 the

Table 22. Percent composition by counts (SD) of food items whose yearly average comprised > 1% by either dry weight or count of shovelnose sturgeon from the Missouri River, Montana in 1993 and 1994. Values less than 0.1 percent are represented with < ; and ---- if none were found. Significant difference between adjacent months (α=0.05) is denoted with *.

		1993					1994						
Order	Family	July	Aug.	Sept.	Oct.	Nov.	April	May	June	July	Aug.	Sept.	Oct.
Ephemeroptera	Leptophlebiidae	9.2 (5.6)	*<	---	<	---	0.3 (1.2)	---	---	*1.1 (2.6)	*---	<	---
	Polymitarcyidae	8.5 (9.3)	*---	---	---	---	---	---	---	*1.3 (2.9)	*0.1 (0.2)	*---	---
	Ephemerellidae	---	---	---	<	*0.3 (0.1)	5.9 (3.8)	*21.2 (6.8)	*0.8 (0.8)	*---	---	---	---
	Heptageniidae	9.5 (5.7)	*0.7 (1.9)	*11.3 (9.1)	16.5 (9.3)	*6.3 (3.3)	18.5 (9.6)	22.4 (12.5)	*9.2 (6.7)	17.2 (17.7)	*4.3 (4.7)	6.4 (8.6)	4.3 (3.9)
	Baetidae	1.5 (1.7)	*13.5 (16.6)	13.8 (13.5)	8.0 (3.5)	6.0 (0.9)	15.5 (5.3)	*0.6 (0.5)	4.4 (9.4)	1.7 (2.5)	*34.6 (16.4)	*22.6 (21.1)	* 7.8 (8.7)
	TOTAL	**28.7**	**14.2**	**25.1**	**24.5**	**12.6**	**40.2**	**44.2**	**14.4**	**21.3**	**39.0**	**29.0**	**12.1**
Plecoptera	Taeniopterygidae	<	---	---	*28.1 (15.3)	*65.5 (6.5)	---	---	<	---	---	---	---
	Perlodidae	1.4 (2.4)	5.4 (11.6)	*10.2 (10.4)	*18.2 (9.1)	*6.3 (3.8)	6.7 (7.0)	3.2 (2.7)	*1.4 (2.1)	2.1 (2.9)	0.7 (1.3)	3.6 (5.3)	5.0 (9.9)
	TOTAL	**1.4**	**5.4**	**10.2**	**46.3**	**71.8**	**6.7**	**3.2**	**1.4**	**2.1**	**0.7**	**3.6**	**5.0**
Trichoptera	Hydropsychidae	50.1 (21.3)	*7.9 (12.7)	*54.1 (31.3)	*22.1 (15.7)	*2.6 (0.6)	15.1 (8.8)	*39.6 (10.2)	53.0 (24.5)	50.7 (25.1)	*10.9 (13.6)	21.1 (27.2)	*39.9 (34.0)
	Brachycentridae	0.4 (1.0)	2.1 (12.7)	0.7 (1.0)	0.5 (0.5)	0.9 (1.7)	0.9 (1.2)	0.6 (1.1)	*0.1 (0.2)	0.1 (0.1)	<	*0.4 (0.8)	0.4 (0.8)
	TOTAL	**50.5**	**10.0**	**54.8**	**22.6**	**3.5**	**16.0**	**40.2**	**53.1**	**50.8**	**10.9**	**21.5**	**40.3**
Diptera	Chironomidae	14.2 (10.6)	*61.6 (28.6)	*6.7 (9.6)	4.0 (1.4)	10.3 (9.1)	36.5 (10.2)	*11.8 (4.6)	*30.1 (25.9)	23.4 (20.8)	*48.4 (19.3)	*43.6 (38.9)	38.2 (33.9)
Fish	- Unknown -	0.2 (0.4)	---	0.1 (0.2)	---	---	---	---	---	---	---	---	---
Other	- Trace foods -	5.0	9.0	3.1	2.6	1.8	0.6	0.6	1.0	2.4	1.0	2.3	4.4

Table 23. Percent composition by dry weight (SD) of food items whose yearly average comprised >1% by either dry weight or count of shovelnose sturgeon diet from the Missouri River, Montana in 1993 and 1994. Values < 0.1 % are represented with < ; and ---- if none were found. Significant difference between adjacent months (α=0.05) is denoted with *.

		1993					1994						
Order	Family	July	Aug.	Sept.	Oct.	Nov.	April	May	June	July	Aug.	Sept.	Oct.
Ephemeroptera	Leptophlebiidae	3.4 (3.0)	*<	----	<	----	0.2 (0.7)	----	----	*1.0 (1.5)	*----	<	----
	Polymitarcyidae	3.9 (4.8)	*----	----	----	----	----	----	----	*1.0 (2.3)	*0.6 (1.6)	----	----
	Ephemerellidae	----	----	----	<	*0.1 (0.1)	4.6 (3.1)	*18.2 (8.2)	*0.6 (1.2)	*----	----	----	----
	Heptageniidae	5.5 (4.9)	*0.1 (0.2)	*9.7 (12.5)	8.1 (6.6)	2.0 (1.1)	6.6 (4.2)	9.3 (7.1)	*3.1 (4.3)	*16.7 (16.5)	16.4 (18.2)	12.9 (13.5)	18.0 (16.4)
	Baetidae	0.9 (1.4)	10.1 (28.2)	4.1 (8.7)	*5.3 (5.8)	2.1 (0.8)	5.9 (3.6)	*0.6 (0.5)	*0.4 (1.5)	0.8 (1.1)	*26.9 (14.8)	19.4 (17.2)	*4.9 (3.4)
	TOTAL	**13.7**	**10.2**	**13.8**	**13.4**	**4.2**	**17.3**	**28.1**	**4.1**	**19.5**	**43.9**	**32.3**	**22.9**
Plecoptera	Taeniopterygidae	<	----	----	*6.1 (5.6)	*59.5 (4.5)	----	----	<	----	----	----	----
	Perlodidae	2.1 (4.3)	12.6 (35.3)	8.5 (11.1)	*42.9 (21.2)	23.9 (14.5)	33.6 (18.9)	*14.0 (11.2)	*1.7 (3.0)	0.4 (0.7)	0.8 (1.6)	*5.6 (7.3)	7.0 (14.4)
	TOTAL	**2.1**	**12.6**	**8.5**	**49.0**	**83.4**	**33.6**	**14.0**	**1.7**	**0.4**	**0.8**	**5.6**	**7.0**
Trichoptera	Hydropsychidae	70.4 (16.3)	*23.4 (38.7)	*76.2 (26.6)	*33.8 (23.8)	*4.4 (1.9)	37.1 (19.2)	52.0 (12.1)	*85.2 (23.0)	69.3 (26.5)	*32.4 (28.8)	30.7 (30.9)	*59.4 (34.1)
	Brachycentridae	<	12.5 (35.4)	0.4 (0.9)	1.5 (1.8)	5.7 (10.7)	7.2 (8.6)	2.9 (5.4)	*0.6 (1.1)	0.5 (1.0)	1.2 (4.6)	1.5 (3.3)	1.1 (2.1)
	TOTAL	**70.4**	**35.9**	**76.6**	**35.3**	**10.1**	**44.3**	**54.9**	**85.8**	**69.8**	**33.6**	**32.2**	**60.5**
Diptera	Chironomidae	3.8 (3.0)	*37.0 (51.0)	0.3 (0.3)	0.4 (0.5)	*1.7 (0.6)	3.9 (2.1)	*1.3 (0.7)	7.6 (21.7)	7.0 (19.3)	*20.9 (17.0)	25.6 (36.2)	7.5 (10.2)
Fish	- Unknown -	5.6 (14.0)	----	0.2 (0.4)	----	----	----	----	----	----	----	----	----
Other	- Trace foods -	4.4	4.3	0.6	1.9	0.6	0.9	1.7	0.8	3.3	0.8	4.3	2.1

greatest relative weight (about 12.9-18.0%) occurred from July through October. The relative weight of Heptageniidae in the diet differed significantly between months in 1993 (P=0.002) and in 1994 (P=0.043) (Table 23). Their relative number significantly differed among months in 1993 and 1994 (P=0.00, P=0.00, respectively) (Table 22). The relative importance of Heptageniidae remained relatively constant (RI=9.8-13.3) peaking in October (Table 24). Electivity values indicated that sturgeon generally selected for Heptageniidae in the spring and early summer and against them in late summer and fall months (Table 25) even though they represented a large portion of their diet. The relative number of Heptageniidae in the diet was correlated (P=0.026, r =0.81) with discharge but not temperature. There was no significant relation among the relative weight of Heptageniidae and river discharge or temperature. Baetidae were in the diet predominantly in August and September in 1993 and 1994. During this time in 1993, their relative number ranged from 13.5-13.8% and their relative weight ranged from 4.1-10.1%. Their relative number ranged from 22.6-34.6%, and their relative weight ranged from 19.4-26.9% between August and September 1994 (Tables 22 and 23). The relative weight and numbers of Baetidae in the diet differed significantly among months in 1993 (P=0.011, P=0.014, respectively) and 1994 (P=0.000, P=0.000, respectively). The relative weight and number of Baetidae were not significantly related to river discharge or temperature. Relative importance of Baetidae in the diet peaked (RI=12.1-18.2) during the fall months (highest in August) and ranged from 6.5-9.5 in spring and early summer (Table 24). When RI values for Baetidae were highest, sturgeon generally selected against them (excluding October when electivity values indicated a slight preference). The

Table 24. Frequency of occurrence, absolute importance, and relative importance of food items of shovelnose sturgeon from the Missouri River, Montana in 1994.

Frequency of occurrence

Order	Family	April	May	June	July	Aug.	Sept.	Oct.
Ephemeroptera	Leptophlebiidae	6.7	****	****	57.1	****	06.7	****
	Polymitarcyidae	****	****	****	57.1	40.0	****	****
	Ephemerellidae	93.3	100.0	66.7	****	****	****	****
	Heptageniidae	100.0	100.0	93.3	78.6	93.3	80.0	87.5
	Baetidae	100.0	86.7	66.7	57.1	100.0	100.0	87.5
Plecoptera	Taeniopterygidae	****	****	06.7	****	****	****	****
	Perlodidae	100.0	100.0	60.0	64.3	66.7	73.3	75.0
Trichoptera	Hydropsychidae	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Brachycentridae	93.3	93.3	33.3	35.7	13.3	40.0	37.5
Diptera	Chironomidae	100.0	100.0	100.0	92.9	100.0	93.3	87.5
Fish	- Unknown -	****	****	****	****	****	****	****

Absolute Importance

Order	Family	April	May	June	July	Aug	Sept	Oct
Ephemeroptera	Leptophlebiidae	7.2	****	****	59.2	****	06.7	****
	Ephemerellidae	****	****	****	59.4	40.7	****	****
		103.8	139.3	68.1	****	****	****	****
	Heptageniidae	125.1	131.7	105.6	112.5	114.0	99.3	109.8
	Baetidae	121.4	87.8	71.5	59.7	161.5	142.0	100.2
Plecoptera	Taeniopterygidae	****	****	06.7	****	****	****	****
	Perlodidae	140.3	117.1	63.1	66.7	68.1	82.5	87.0
Trichoptera	Hydropsychidae	152.2	191.6	238.2	220.1	143.2	151.8	199.3
	Brachycentridae	101.5	96.8	34.0	36.2	14.6	41.8	39.0
Diptera	Chironomidae	140.4	113.1	137.7	124.3	169.3	162.6	133.2
Fish	- Unknown -	****	****	****	****	****	****	****

Relative importance

Order	Family	April	May	June	July	Aug	Sept	Oct
Ephemeroptera	Leptophlebiidae	0.6	****	****	6.4	****	0.8	00.0
	Polymitarcyidae	****	****	****	6.4	4.6	00.0	00.0
	Ephemerellidae	8.2	12.1	7.8	****	****	00.0	00.0
	Heptageniidae	9.8	11.4	12.1	12.2	12.9	11.3	13.3
	Baetidae	9.5	7.6	8.2	6.5	18.2	16.1	12.1
	TOTAL	**28.1**	**31.1**	**28.1**	**31.5**	**35.7**	**28.2**	**25.4**
Plecoptera	Taeniopterygidae	****	****	0.8	****	****	00.0	00.0
	Perlodidae	11.0	10.2	7.2	7.2	7.7	9.4	10.5
	TOTAL	**11.0**	**10.2**	**8.0**	**7.2**	**7.7**	**9.4**	**10.5**
Trichoptera	Hydropsychidae	12.0	16.6	27.3	23.9	16.2	17.2	24.2
	Brachycentridae	8.0	8.4	3.9	3.9	1.6	4.8	4.7
	TOTAL	**20.0**	**25.0**	**31.2**	**27.8**	**17.8**	**22.0**	**28.9**
Diptera	Chironomidae	11.0	9.8	15.8	13.5	19.1	18.5	16.1
Fish	- Unknown -	****	****	****	****	****	****	00.0

relative number and weight of Baetidae in the diet differed significantly by month in 1993 (P=0.014, P=0.011, respectively) and 1994 (P=0.000, P=0.000, respectively) (Tables 22 and 23). Consumption of Baetidae by shovelnose sturgeon was not related to discharge or temperature. Ephemerellidae were found in the diet in spring but were not in the diet throughout the summer and fall periods in either 1993 or 1994. Shovelnose sturgeon consumption of Ephemerllidae was highest in May 1994 when they comprised 21.2% of the number and 18.2% of the weight of the ration (Tables 22 and 23). Very few were in the diet during 1993 but no spring samples were taken. The relative number and weight of Ephemerellidae in the diet differed among months in 1993 (P=0.000, P=0.000, respectively) and 1994 (P=0.000, P=0.000, respectively). Relative importance values of Ephemerellidae were greatest (RI=12.1) in May (Table 24) yet sturgeon were selecting against them or feeding neutrally during this period (Table 25). The relative number and weight of Ephemerellidae in sturgeon diets was correlated with discharge (P=0.007, r=0.89; P=0.008, r=0.88, respectively). There was no significant relation to temperature. Leptophlebiidae and Polymitarcyidae appeared in shovelnose sturgeon diets in July, August, and September of both years. They comprised the greatest relative weight and number of shovelnose sturgeon diets in July 1993 (Tables 22 and 23). The relative number and weight of Leptophlebiidae and Polymitarcyidae in the ration differed significantly among months in 1993 and 1994 (P=0.000, in all tests). There was no relation among the relative weight and number of Leptophlebiidae and Polymitarcyidae in sturgeon diets and river discharge or temperature.

Table 25. Electivity of food items whose yearly average comprised >1% (relative weight or number) of shovelnose sturgeon diet from the Missouri River, Montana in 1994.

Order	Family	Habitat	April	May	June	July	Aug.	Sept.	Oct.
Ephemeroptera	Leptophlebiidae	Main	1.00	****	****	0.48	-1.00	1.00	****
		Mid	1.00	****	****	0.48	****	1.00	****
		Shallow	1.00	****	****	0.73	****	1.00	****
		Side	1.00	****	****	0.16	-1.00	1.00	****
		Drift	1.00	****	****	1.00	****	-0.73	****
	Polymitarcyidae	Main	****	****	-1.00	0.61	1.00	****	****
		Mid	****	****	-1.00	0.61	0.14	****	****
		Shallow	****	****	-1.00	0.46	1.00	****	****
		Side	****	****	-1.00	-0.24	-0.06	****	****
		Drift	****	****	-1.00	0.90	1.00	****	****
	Ephemerellidae	Main	-0.24	-0.20	0.07	****	****	****	-1.00
		Mid	-0.66	0.15	-0.32	****	****	****	-1.00
		Shallow	-0.48	-0.14	-0.12	-1.00	****	-1.00	-1.00
		Side	-0.55	-0.19	0.01	****	****	-1.00	-1.00
		Drift	0.17	0.32	1.00	****	****	-1.00	-1.00
	Heptageniidae	Main	0.10	0.55	-0.16	0.61	0.48	-0.40	-0.37
		Mid	0.80	0.85	0.12	0.39	-0.33	-0.24	-0.27
		Shallow	0.76	0.37	0.36	0.66	-0.39	-0.29	-0.35
		Side	0.68	0.60	0.62	0.43	-0.51	-0.41	-0.13
		Drift	0.77	0.39	0.50	0.63	0.15	0.40	-0.30
	Baetidae	Main	-0.17	-0.95	-0.77	-0.91	-0.17	-0.11	-0.41
		Mid	0.62	-0.93	-0.76	-0.66	-0.18	-0.02	0.37
		Shallow	0.38	-0.95	-0.69	-0.75	0.07	0.14	0.59
		Side	0.49	-0.94	-0.35	-0.82	-0.25	-0.10	0.52
		Drift	-0.38	-0.96	-0.79	-0.88	-0.20	0.13	-0.42
Plecoptera	Taeniopterygidae	Main	****	****	1.00	****	****	-1.00	-1.00
		Mid	****	****	1.00	****	****	****	-1.00
		Shallow	****	****	1.00	****	****	-1.00	****
		Side	****	****	1.00	****	****	****	****
		Drift	****	****	1.00	****	****	****	****
	Perlodidae	Main	0.76	0.74	0.40	0.59	0.38	0.91	0.50
		Mid	0.85	0.92	0.83	0.01	1.00	0.95	0.64
		Shallow	0.88	0.56	0.95	0.88	1.00	0.95	0.48
		Side	0.84	0.19	0.91	0.75	0.82	0.95	0.20
		Drift	1.00	0.32	0.72	0.82	0.48	0.91	-0.22
Trichoptera	Hydropsychidae	Main	0.25	0.72	0.36	0.39	0.57	0.40	0.82
		Mid	0.71	0.95	0.32	0.38	0.54	0.48	0.76
		Shallow	0.74	0.82	0.79	0.55	0.82	0.63	0.78
		Side	0.61	0.67	0.87	0.56	0.66	0.39	0.50
		Drift	0.57	0.32	0.35	0.61	0.59	0.52	0.70
	Brachycentridae	Main	1.00	0.89	-0.98	-0.98	-0.93	0.23	1.00
		Mid	1.00	1.00	-0.98	-0.98	-0.86	-0.55	0.63
		Shallow	1.00	1.00	-0.99	-0.95	-0.86	-0.08	0.63
		Side	1.00	1.00	-0.99	-0.94	-0.66	0.30	0.74
		Drift	1.00	1.00	-0.71	-0.50	-0.60	0.70	1.00
Diptera	Chironomidae	Main	0.06	-0.36	0.82	0.31	0.45	0.43	0.70
		Mid	-0.08	-0.54	0.65	-0.04	0.54	0.55	0.58
		Shallow	-0.18	-0.24	0.50	-0.07	0.15	0.52	0.34
		Side	-0.12	0.04	0.30	0.18	0.64	0.70	0.30
		Drift	-0.16	-0.32	0.59	-0.27	0.51	0.38	0.34
Fish	Unknown -	Main	****	-1.00	-1.00	****	****	****	****
		Mid	****	-1.00	-1.00	****	****	****	****
		Shallow	****	-1.00	-1.00	-1.00	****	****	****
		Side	****	-1.00	-1.00	****	****	****	****
		Drift	****	-1.00	-1.00	-1.00	****	****	****

Plecoptera was represented in sturgeon diets by Taeniopterygidae and Perlodidae. Their combined presence in the diet was greatest during the fall and early spring periods (Tables 22 and 23). Representatives of Taeniopteryigidae were found in the diet only in fall 1993 and none were present in 1994. During November 1993, Taeniopterygiidae made up the majority of the relative number and weight of shovelnose sturgeon prey (Tables 22 and 23). Perlodidae were present in shovelnose sturgeon diets throughout 1993 and 1994 (no spring samples were collected in 1993). The fraction of the diet represented by Perlodidae was greatest in October and November 1993 and April and May 1994 suggesting they may be important winter prey for sturgeon. The relative number and weight of Perlodidae in sturgeon diets differed significantly among months (P=0.000, P=0.000, respectively) in 1993 and in 1994 (P=0.000, P=0.000, respectively). The relative number and weight of Perlodidae in shovelnose sturgeon diets were not correlated with discharge but the relative number were correlated with temperature (P=0.021, r=-.83). Electivity values indicate that sturgeon preferred Perlodidae throughout the months we sampled (Table 25).

Trichoptera were represented by six families of which two, Brachycentridae and Hydropsychidae, were found abundantly in sturgeon diets (Tables 22 and 23). Other Trichoptera preyed upon by sturgeon included: Glossosomatidae, Limnephilidae, Leptoceridae, and Hydroptilidae. Hydropsychidae were present in the diet throughout the study. The maximum relative number and weight of Hydropsychidae in sturgeon diets occurred in July and September 1993 and from May to July in 1994 (no spring samples were collected in 1993) (Tables 22 and 23). In both years, there was decreased use of

Hydropsychidae in August and a brief increase in use in September and October. In 1994, relative importance values (ranging from 12.0 to 23.9) exceeded those of other food items from April to July. Electivity values indicated that shovelnose sturgeon selected for Hydropsychidae in all months and habitats (Table 25). High RI values and positive electivity values suggest that Hydropsychidae were a valuable and preferred food source of shovelnose sturgeon in all months sampled. The relative number and weight of Hydropsychidae in sturgeon diets differed significantly among months in 1993 (P=0.000, P=0.000) and 1994 (P=0.000, P=0.000). The relative number and weight of Hydropsychidae in shovelnose sturgeon diet was not correlated with discharge or temperature.

Diptera were represented by four families, of which only one (Chironomidae) was an important prey item. Other Diptera families in the sturgeon diet included: Tipulidae, Simulidae, and Tabanidae. Larvae from the family Ceratopogonidae were probably present but because of the large numbers and difficulty in distinguishing them from Chironomidae, I grouped them with Chironomidae. Chironomidae were found in shovelnose sturgeon diets throughout the study (Tables 22 and 23). In 1993 and 1994, presence of Chironomidae in the diet was greatest from summer to early fall. Relative Importance values in 1994 ranged from 9.8 in May to 19.1 in August. Chironomidae had lower RI values in April and May and relatively higher values from June to September 1994 (Table 24). Electivity values indicated an avoidance of Chironomidae in the spring and a progression from neutral to preferred from June to October (Table 25).

During 1994, I found significant relations among the relative number and weight of prey species in sturgeon diets (Table 26). The relative number of Baetidae in the diet was positively related to those of Chironomidae and negatively related to those of Hydropsychidae. The relative number of Heptageniidae in shovelnose sturgeon diets were negatively related to those of Chironomidae. The relative number of Perlodidae and Brachycentridae in the diet were positively related. The relations among the relative weight of prey in shovelnose sturgeon diets were the similar to those of their relative number, except Heptageniidae were not significantly related to Chironomidae (Table 26).

Table 26. Correlations between invertebrate families present in shovelnose sturgeon diet (% count and % dry weight) in the Missouri River, Montana in 1994.

% Use	Family	Family	r value	r^2 value	P value	N
Count	Heptageniidae	Chironomidae	-0.81	0.66	0.020	7
	Baetidae	Hydropsychidae	-0.87	0.76	0.009	7
	Baetidae	Chironomidae	0.86	0.74	0.012	7
	Perlodidae	Brachycentridae	0.92	0.85	0.002	7
Weight	Baetidae	Hydropsychidae	-0.76	0.57	0.047	7
	Baetidae	Chironomidae	0.87	0.76	0.009	7
	Perlodidae	Brachycentridae	0.98	0.97	0.000	7

DISCUSSION

Shovelnose Sturgeon

Sturgeon gut contents

All shovelnose sturgeon collected had measurable quantities of gut contents. The mass of stomach contents ranged from <1 g to approximately 10 g in dry weight and differed significantly between some months in 1993 and 1994. I did not compensate for variables which may have influenced dry weights of gut contents such as long periods of storage in preservative (Howmiller 1972) and changes in digestion rates due to temperature (Markus 1932; Elliott 1972; Jobling et al. 1977).

The relative mass of miscellaneous inorganics, miscellaneous organics, and identifiable food item fractions varied among months. The mass of inorganic material found in sturgeon stomachs was highest in summer months. Suspended sediment may settle from the water column and deposit on the river bed as the river velocity decreases. The resulting increased benthic sediment may be reflected in the sturgeon gut contents. The relative weight of the miscellaneous organic fraction significantly increased as the relative weight of the identifiable fraction decreased. The significantly lower relative weight of identifiable matter of shovelnose sturgeon ration in summer months is probably due to accelerated digestion rates associated with increased water temperatures (Markus 1932; Elliott 1972; Jobling et al. 1977).

Shovelnose sturgeon forage consisted of aquatic and terrestrial invertebrates with small quantities of fish larvae. The predation on benthic invertebrates by shovelnose sturgeon is extensively reported in the literature (Eddy and Surber 1947; Barnickol and Starret 1951; Hoopes 1960; Held 1969; Helms 1974; Elser et al. 1977; Berg 1981; Gardner and Berg 1982; Gardner and Stewart 1987). Shovelnose sturgeon are known to consume fish (Gardner and Berg 1980,1982; Carlson et al. 1985). I found fish larvae in the diet only in 1993. Lower spring discharge in 1993 may have made fish larvae more accessible to sturgeon. I found terrestrial invertebrates in sturgeon gut contents at trace levels and I suspect their presence in sturgeon diets was incidental.

Shovelnose sturgeon diets were made up largely of larval Ephemeroptera, Trichoptera, Plecoptera, and aquatic Diptera. The dominant food items were different in each season. Shovelnose sturgeon fed on relatively large quantities of small sized Ephemeroptera and Diptera and relatively small quantities of large sized Plecoptera and Trichoptera in spring. Summer forage generally consisted of large sized Trichoptera and small size Diptera, and Ephemeroptera. Plecoptera were present in shovelnose sturgeon summer diets in relatively low numbers and mass. Tricoptera in sturgeon summer diets decreased from July to August, while the relative biomass and number of Diptera and Ephemeroptera increased. Shovelnose sturgeon consumed Diptera, Ephemeroptera, and Trichoptera at somewhat similar levels in fall. Plecoptera presence in sturgeon diets increased in fall from lower summer levels. Gardner and Berg (1980) found shovelnose sturgeon with similar diets.

Shovelnose sturgeon forage at the taxonomic family level varied within each order. Ephemeroptera families consumed by sturgeon included Leptophlebiidae, Polymitarcyidae, Ephemerellidae, Heptageniidae, and Baetidae. Heptageniidae and Baetidae were found in the diet during all months sampled. Baetidae were an important food item in spring and early summer, whereas Heptageniidae were an important food item by numbers in spring and by weight in fall. Trichopteran families in shovelnose sturgeon diets included Brachycentridae and Hydropsychidae. Hydropsychidae were consumed at greater levels than Brachycentridae in all seasons. Plecoptera, including Perlodidae and Taeneopterygidae, were usually found in sturgeon diets in smaller numbers than Ephemeroptera and Trichoptera but their larger size probably offered significant caloric value. Aquatic Diptera larvae were consumed by sturgeon during all months sampled and were found in nearly all sturgeon collected throughout the study period.

Shovelnose sturgeon diets were generally not influenced by discharge or water temperature. I found few significant relations among shovelnose sturgeon diet river discharge and water temperature. Shovelnose sturgeon use (relative number) of Ephemerellidae and Heptageniidae were positively related to river discharge. Only the relative weight of Ephemerellidae in sturgeon diet showed a significant relation to discharge. The relative number of Baetidae in shovelnose sturgeon diets was the only significant relation to river water temperature.

Of the food items used by sturgeon at levels greater than trace amounts, relative importance values indicate that families of Ephemeroptera (RI between 25.4-35.7) and Trichoptera (RI between 17.8-31.2) were most important followed by Diptera (RI

between 9.8-19.1) and Plecoptera (RI between 7.2-11.0). Shovelnose sturgeon from the same area of the Missouri River had similar diets with similar RI trends (Gardner and Berg 1982). Ephemeroptera, Trichoptera, Plecoptera, and Diptera RI values ranged from 28.0-54.0, 16.0-42.2, 9.9-15.8, and 17.0-20.9, respectively (Gardner and Berg 1982). Relative importance of prey at the taxonomic family level were highest for Hydropsychidae followed by Chironomidae, Heptageniidae, and Baetidae. The large size and small amount of non-digestible chitin of Hydropsychidae may have accounted for their importance in sturgeon diets. It is possible the Hydropsychidae were over-represented in sturgeon diets because the head capsules were not digestible and were more easily found in gut contents than those of other invertebrate taxa.

Forage Electivity

Prey avoidance or selection of shovelnose sturgeon is probably related to chemical as opposed to visual perceptions (Weisel 1979). Shovelnose sturgeon vision might not be important for feeding and food probably is recognized and located primarily by gustation, olfaction, textural quality, and possibly by electroreception (Buddington and Christofferson 1985). Sturgeon mouth morphology suggests they use a grazing-like feeding behavior verses a true predatory behavior (Buddington and Christofferson 1985).

Electivity values of important shovelnose sturgeon prey items were variable between habitats and months but general trends were evident. My estimates of shovelnose sturgeon prey availability may be biased due to sampling technique. I may have sampled invertebrates from the benthos which were not truly accessible to shovelnose sturgeon.

This bias may have directly influenced the accuracy of the electivity indices. However, since my sampling was standardized, any sampling bias was consistent throughout the study. Electivity data indicate that shovelnose sturgeon may prey on macroinvertebrates at levels above or below their availability, thus exhibiting "active selection" or "avoidance" of particular prey items (Ivlev 1961). Invertebrate families with high relative importance values were generally used at levels higher than their availability. The exception was Chironomidae which had negative electivity values in spring with a trend toward positive values from summer to fall. Sturgeon seemed to select Leptophlebiidae and Heptageniidae in spring and early summer and avoid Ephemerellidae and Baetidae. Perlodidae were generally consumed at levels higher than their availability throughout the study. Electivity values for either family of Trichoptera were different in that sturgeon selected for Hydropsychidae throughout the study but selected for Brachycentridae only in early spring and avoided them in summer and fall. This spring selection for Brachycentridae may have been related to their large size at this time. Prey item electivity values did not correspond with their relative abundance or mass in the sturgeon ration. During times when electivity values indicated strong selection for particular food items, the food items were not always the dominant in the diet.

Given the general morphology and feeding adaptations of shovelnose sturgeon and the abundance of benthic prey items, I suspect sturgeon relied very little on the invertebrates drifting in the water column as a food source. Although I have no data which directly supports this theory, it seems improbable that feeding from the drift would be energetically productive when compared with benthic feeding (Helfman 1994). Drifting

invertebrates would be more available to sturgeon as a potential food source if they settled in eddies or pools where sturgeon could ingest them more efficiently. If sturgeon did prey upon these transient prey items, I would not be able to distinguish recolonized invertebrates (those which drifted and resettled in the benthos) from those invertebrates which did not drift.

Electivity values were inconsistent among habitat and months. This suggested variable levels of their availability among habitats. The lack of significant difference of available forage among habitats, excluding drift, did not support this hypothesis. Without knowing specifically where shovelnose sturgeon were feeding prior to capture, my electivity values represent the feeding behavior of sturgeon if they were restricted only within each of the five habitats investigated.

Shovelnose sturgeon prey selection is evidently not related to discharge. Electivity values of prey were derived using the relative number of each food item in the environment and the gut samples. Neither variable have showed many significant relations to river discharge. I believe feeding behavior of shovelnose sturgeon is more dependent on prey vulnerability to sturgeon feeding methods than to discharge.

Non-lethal Stomach Contents Extraction

A review of the various methods of securing stomach samples from live fish produced many varieties of three basic techniques. These techniques included gastric lavage, physical removal, and emetics (Robertson 1945; Seaburg 1957; Jernejcic 1969; Baker and Fraser 1976; Meehan and Miller 1978; Giles 1980). Forceps could not be used

because the sturgeon stomach was not reachable and food items could not be grasped. Emetics required reaching the stomach with either gastro-irritants like arsenous acid, tartar emetic, and apomorhpine which stimulates the nervous system to induce vomiting. I did not attempt to use emetics because I was unable to insert tubing deep enough into the shovelnose sturgeon digestive system to place emetics in the stomach where the bulk of the food items resided.

I was unsuccessful in adequately removing stomach contents using the gastric lavage technique. Most examples of successful lavage procedures were used on fish species with simple digestive tracts and well defined stomachs. However, shovelnose sturgeon do not have a well defined stomach. The gastro-intestinal system of the sturgeon contains abrupt curves and the pneumatic duct is attached at the first abrupt curve in the esophagus (Weisel 1979). The shovelnose sturgeon gastrointestinal anatomy was not conducive to the stomach flushing techniques I tested. The location of the pneumatic duct made attempts to insert the evacuation tube difficult because the tube often entered the gas bladder. I could not insert the evacuation tube into the gastrointestinal tract far enough to flush ingested material.

Available Forage

Composition

I did not investigate the vulnerability of the prey to either the sturgeon or the sampling gear. Sturgeon may not forage upon the benthos in the same manner as I

sampled it. Some invertebrates utilize micro-habitats which may not be vulnerable to sturgeon predation but were vulnerable to my benthic sampling gear.

The benthic invertebrate community of my study area was comprised of 10 aquatic orders. Ephemeroptera generally dominated the relative number and weight of of the benthic macro-invertebrate community, followed by Trichoptera, Diptera, and Plecoptera. I found few significant differences of the availability of shovelnose sturgeon forage in the benthos among habitats within each sample month (Table 4). My ability to detect significant differences of sturgeon forage among habitats was probably influenced by the patchy distributions of invertebrate communities in the benthos, my small sample size, and the large variability in biomass and relative weight estimates.

The average weight, density, and relative number and weight of shovelnose sturgeon forage varied among habitats (Table 5). The average biomass, relative weight and number of Ephemeroptera exceeded those of Diptera, Trichoptera, and Plecoptera in all habitats. The average densities of Ephemeroptera were higher than other invertebrates in all habitats except the main channel where Diptera densities were highest. The average density, biomass, relative weight and number of Plecoptera were generally lower than those of Trichoptera and Diptera in all habitats. The average density, biomass, relative weight and number of Trichoptera and Diptera were generally lower than those of Ephemeroptera and higher than those of Plecoptera.

The relative number and weight of sturgeon prey in the benthos varied significantly among some months (Tables 7, 9, 11, 13, 15). I believe the significant difference of the relative number and weight of Diptera, Plecoptera, Trichoptera, and Ephemeroptera

families among months was not biologically relevant. The significant differences between months were probably a reflection of my limited sample size and the weakness of the Kruskal Wallis test to detect significant differences with a small sample size (Daniel Gustafson, Montana State University, Bozeman, Personal Communication).

General trends in Ephemeroptera availability in the benthic habitats were evident. The relative number and weight of Ephemeroptera peaked once in spring and again from late summer to early fall (Appendix A, Figures 8, 13-16). The spring peak was the largest peak in the relative weight and biomass of Ephemeroptera and was made up largely of Ephemerellidae (Tables 7, 9, 11, 13, 15). The spring peak also coincided with the smaller of the two peaks in relative number and density of Ephemeroptera. The large biomass and low densities of Ephemeroptera during the spring peak suggests that individuals were probably large at this time. The spring peak probably reflected the emergence of Ephemerellidae and some Baetidae. Invertebrates often emerge from shelter prior to their migration to the river surface during emergence (Merrit and Cummins 1984) possibly making them more accessible to my sampling. The second fall peak was the largest peak in the relative number and density of Ephemeroptera and was made up largely of Hepetageniidae and Baetidae. This was not true in the main channel habitat where both relative number and density were greatest in the spring. The high density and relative number of Ephemeroptera during the second fall peak were made up largely of Ephemerellidae, Heptageniidae, and Baetidae early instars. The small size of the instars might explain the low biomass and relative weight of Ephemeroptera during this peak. The emergence of Leptophlebiidae and Polymitarcyidae during July and August

contributed to the high density and relative number of Ephemeroptera during the second fall peak. Densities of Ephemeroptera peaked just after peak discharge and again during low discharges in the fall (Tables 6, 8, 10, 12, 14).

Trichoptera presence in the benthos was characterized by two distinct peaks similar to those of Ephemeroptera. The first peak in relative number and weight of Trichoptera occurred in June and the second occurred later in September and October. The first and second peak in relative number and relative weight of Trichoptera occurred slightly later in the season than the first and second peak in relative weight and number of Ephemeroptera. The timing of the peaks in the density and biomass of Trichoptera generally coincided with the timing of the peaks in relative number and weight in most habitats (Tables 6-13). Peaks in biomass of Trichoptera in the midchannel and side channel habitats occurred in June whereas biomass peaked in the main channel and shallow habitats in May and October. I believe the peak in biomass of Trichoptera in the main channel in May might have been the result of patchy benthic invertebrate distributions. The two peaks in biomass of Trichoptera in the shallow habitat were nearly equal and the earlier of the peaks occurred in June. Hydropsychidae comprised over twice the relative number of Brachycentridae and nearly seven times the relative weight during the first peak. Hydropsychidae made up most of the second smaller peak of Trichoptera as well. The highest overall average density (251/m^2) and biomass (89.6 mg/m^2) of Trichoptera was found in the side channel during the second lesser peak in their relative number and weight (Tables 12-13). The density and biomass of Trichoptera increased gradually in most habitats from August to October except in the main channel habitat (Tables 6, 8, 10,

12, 14). The timing of the emergence of Hydropsychidae and Brachycentridae in late May to mid June corresponds with the first relative number and weight peak of Trichoptera. I suspect peaks in densities of Trichoptera were related to the timing of their emergence in spring and the abundance of their early instars in fall.

I found relatively few Plecoptera in the benthos but seasonal trends were evident. Perlodidae were more abundant than Taenioterygidae. Biomass of Plecoptera in the midchannel and shallow habitats were greatest in April. However, biomass of Plecoptera in the main channel and side channel was greatest slightly later in May. A second smaller biomass peak occurred during July in all but the side channel habitat. Similar to peaks in biomass, the relative weight peak occurred in April in all four benthic habitats with a second smaller peak in July. Although densities of Plecoptera were low (usually < 5/ m^2) from April to September, they increased to 20-40/m^2 in October in all habitats except the main channel (<5/m^2) (Tables 6, 8, 10, 12, 14). Relative abundance was generally insignificant when compared to other invertebrate orders. A small peak in relative number of Plecoptera occurred in October when densities were very high. High spring biomass and relative weight of Plecoptera were probably attributed to the large size of the Plecoptera final instars. The high fall density and relative number of Plecoptera might be explained by the reproductive recruitment of Plecoptera to the benthic community.

Benthic Diptera were found in all habitats throughout the study period. Biomass of Diptera peaked from April to May, with a second smaller peak in October. Trends in dipteran relative weight resembled the biomass trend in most habitats (excluding the main channel). Their relative weight peaked from April to May. The second smaller relative

weight peak occurred earlier (August) than the second peak in biomass. This peak resulted in part from the decreased representation of Trichoptera and a simultaneous increase in Diptera. Densities of Diptera were generally high in April followed by a gradual decrease through June. Density increased from June to October. The decrease in Diptera density occurred just after the peak in discharge but then increased as discharge levels declined. This relation suggested a possible negative correlation but it was not found to be significant.

Few invertebrates were found in the drift. I found invertebrate drift densities ranging from zero to about $4/m^3$ (Table 14). Discharge from the boat motor may have altered the drift densities because it often disrupted the natural river flow in front of the net. Changes in relative number and weight were large when densities changed by only a few individuals per m^3. The seasonal trends in relative number and weight of invertebrates in the drift generally reflected trends found in the benthos. The similar seasonal trends in the benthos and drift support my belief that the peaks in relative number and weight of benthic invertebrates occurred during invertebrate emergence periods. The benthic invertebrates may have been collected from the drift while migrating to the water surface prior to emergence. However, increased densities of invertebrates in the drift may be the result of competition between invertebrates for space and food resources (Hart and Resh 1980).

Discharge and Availability

I found few significant relations between among the availability of sturgeon prey in

all habitats and discharge. Most significant relations were found in the shallow or side channel habitats. Weisberg et al. (1990) found when flows were artificially reduced in the Susquehanna River invertebrate densities declined more than three orders of magnitude in shoal areas. In my study site, where decreased river stage often dewatered side channels and receded the shoal areas, declines in densities of invertebrates in such areas might also be expected.

Organisms evolve to contend with regional and local patterns of disturbance (Karr 1994). The few significant relations among densities and biomass of the benthic and drifting aquatic invertebrates and river discharge suggests that the invertebrate community in my study area may be adapted to the stable and predictable river stage cycles. The densities and biomass of benthic invertebrates were significantly related to discharge only in the habitat which dewatered or stagnated as discharge decreased. Decreased density or biomass may be the result of mortality or emigration of the benthic invertebrates in the degraded habitats. Benthic invertebrate densities are negatively influenced by large, drastic, artificial flow perturbations when compared to stable densities in a similar stream without such flow perturbations (Irvine 1985). I found no significant relations among discharge and densities and biomass of benthic invertebrates in the main and mid channel habitats. I believe the resident macro-invertebrate communities within these habitats may not be sensitive to river stage fluctuations. Additionally, the coarse and stable substrate of the study area may provide a favorable habitat for benthic macro-invertebrates which would minimizes the need for insects to drift to seek shelter.

The relative abundance and biomass of sturgeon prey in all habitats do not seem to be related to river discharge and temperature. I found only 16 of 200 potential relations among the relative weight or numbers sturgeon forage and discharge that were significantly related. Thirteen of the 16 significant relations involved relations among the relative number and weight of invertebrates and river discharge. Six of these 13 significant relations with discharge involved invertebrate relative weight and seven involved their relative number. Two of the three significant relations with water temperature involved the relative number. The lack of significant relations may indicate that the relative number and weight of available shovelnose sturgeon forage is not dependent on discharge.

Relations among the relative number and weight of Ephemeroptera and river discharge or water temperature accounted for 13 of the 16 significant relations. Ephemerellidae made up 8 of 13 thirteen significant relations and Heptageniidae or Baetidae were involved in the remaining five. The relative number and weight of Ephemerellidae were positively associated with discharge in four of five habitats examined (not including shallow habitat). The significant correlations involving Baetidae and Heptageniidae were not consistent in all habitats. The inconsistency of significant relations may indicate a more localized relation among the relative number and weight of sturgeon available forage and river discharge or water temperature. Patches of available sturgeon forage may respond differently to discharge or water temperature. My small sample size and lack of sampling duplication may have influenced my ability to detect relationships.

South Dakota and Montana: Study Comparison

My study area on the Missouri River above Fort Peck Reservoir afforded the opportunity to investigate food habits of shovelnose sturgeon in a habitat which may closely resemble the Missouri River in its natural state. The river in this area is naturally channeled and possesses no anthropogenic restrictions to lateral movement. Hesse and Mestl (1993) compared the historic and present hydrographs of the Missouri River in the Dakotas and described the natural river stage as peaking in May and again in June. The discharge at my study site followed this pattern. Major dams upstream from my study site operate primarily as run-of-the-river facilities minimally influencing the hydrograph. Many unregulated tributaries contribute to the annual discharge cycle.

River disturbance is any discrete occurrence that kills, displaces, or damages organisms or populations (Sousa 1984) and it is an occurrence that disrupts the structure or function of a biological system (White and Pickett 1985; Sparks et al. 1990). Recurring events with ecological effects and varied attributes of intensity, frequency, predictability, and duration are considered river disturbance (Poff 1992). Artificial fluctuations in stream flow and regulated hydrological regimes are disturbances since modified stream flows can alter stream communities (Petts 1984; Cushman 1985; Irvine 1985). Food habit studies of shovelnose sturgeon from the Missouri River below Gavins Point Dam were conducted in a controlled river reach (Modde 1971; Modde and Schmulbach 1973; Berry 1996) and thus were conducted in a disturbed environment.

My study area appears to have an abundance of preferred habitat, when compared to the South Dakota study, suggesting that conditions are more optimal for shovelnose sturgeon. High gradients combined with the gravel and cobble substrates produce swift currents and intermittent riffles in my study area (Gardner and Berg 1980, 1982). Higher benthic production is found in gravel and cobble substrates, when compared to shifting, sandy substrates (Hynes 1970; Junk et al. 1989; Allan 1995). Shovelnose sturgeon significantly prefer gravel and cobble substrates and avoid sand (Bramblett 1996) and smaller pallid sturgeon use areas with larger substrates (Erickson 1992). Riffles and swift currents are important to sturgeon which feed on invertebrates occupying these habitats (Gardner and Berg 1980, 1982). The river bed in my study area was comprised primarily of cobble (58%), and gravel (24%), followed by boulders (9%), and sand (6%) (Gardner 1994). The South Dakota study area (Modde 1971; Berry 1996) was characterized with shifting sand and silt substrates and was probably less productive in terms of shovelnose sturgeon prey.

The Missouri River in my study area may provide more suitable environmental conditions for shovelnose sturgeon than the conditions found in South Dakota. Shovelnose sturgeon were larger in my study area (Figure 3) than sturgeon from South Dakota. Shovelnose sturgeon total lengths ranged from 445 mm to 657 mm in South Dakota (Berry 1996). Shovelnose sturgeon in the Missouri River near Virgelle, Montana (approximately 96 km upstream from my study site) were found at densities of 6.9/ha and biomass of 17.2 kg/ha (Gardner 1996). Shovelnose sturgeon were found at densities of 5.67/ha and biomass of 2.6 kg/ha at Yankton, South Dakota (Schmulbach 1974).

Shovelnose sturgeon in South Dakota are slow growing (Schuckman 1982; Berry 1996). Tagged fish in the South Dakota study area grew about 12 mm in length and one fish lost 11 mm over a 13-year period (Berry 1996). Shovelnose sturgeon had growth rates of about 0.9 mm/year (ranging between 0-22 mm) in an earlier study (Schuckman 1982). Tag returns from six fish in my study site showed average annual fork length increase of 4.7 mm/year (SD=8.5). This growth was nearly four times the annual growth found in South Dakota.

Available Sturgeon Forage

I considered the different sampling techniques involved when I compared the invertebrate fauna in my study area with that described by Modde (1971), Modde and Schmulbach (1977), and Berry (1996). My benthic sampling techniques included methods which generally targeted the larger invertebrates. My sampling was based upon substrate disturbance followed by capture of subsequent drifting insects. My sampling transects were large and may have captured invertebrates which were found at low densities. Both Modde (1971) and Berry (1996) sampled the benthos using a petite ponar dredge which is a point sampling technique. This technique would most likely capture more burrowing invertebrates such as Diptera and certain Ephemeroptera than either the kick net or the dredge I used in this study. The use of the ponar dredge may have missed rare or sparsely populated insects (Merrit and Cummins 1984). The study site below Gavins Point Dam, South Dakota has sandy substrate vulnerable to the ponar sampling device (Patric Braaten,

South Dakota Cooperative Fishery Research Unit, Pers. Comm.). This difference in substrate was considered when comparing the benthic invertebrate fauna of the two sites.

Before this research began, I expected different invertebrate species composition between studies. I conducted my study in a reach of the Missouri River which possesses a discharge hydrograph closely resembling a natural one and Modde (1971) and Berry (1996) conducted similar studies in an aquatic environment controlled by Gavins Point Dam, South Dakota. The presence of major dams and hydroelectric facilities has been shown to alter natural river water temperature, turbidity, and affect biological communities within the dammed river (Morris et al. 1968; Fraser 1972; Ward and Stanford 1983a, 1983b; Cushman 1985; Gilason 1985; Irvine 1985; Pflieger and Grace 1987; Mundahl and Kraft 1988; Bain and Boltz 1989; Poff and Ward 1989; Weisburg et al. 1990; Kingsolving and Bain 1993). In addition, the degree of longitudinal and geographical separation between my study area and the study sites below Gavins Point Dam would suggest a transition in the invertebrate community composition and relative abundance (Vannote et al. 1980; Minshall et al. 1985; Sedelle et al. 1989). The river substrates were very different between sites and would be expected to support different invertebrate communities.

The composition of invertebrate families of my undisturbed habitat was different from that described by Modde (1971) and Berry (1996). Berry (1996) reported that Diptera made up 60-90% of the benthic invertebrate community and Ephemeroptera and Trichoptera made up 5-10%. The benthic invertebrate composition reported by Berry (1996) were similar to those of Modde (1971) who reported that Dipteran made up 88%

of the biomass and 98% of the numbers of the benthic community in the same area. In my study, Diptera only comprised from 7.3-20.7% of the weight and 13.3-21.6% of the number of the benthic invertebrate community. Additionally, I found the invertebrate fauna was dominated numerically and in biomass by representatives of Ephemeroptera and Trichoptera. The dominance of Diptera in the South Dakota study site was not unusual given the substrate characteristics (Daniel Gustafson, Montana State University, Personal Communication). I suspected that Diptera, especially Chironomidae, were less vulnerable to my sampling technique than those used by Modde (1971) or Berry (1996) possibly accounting for their smaller representation in my study. Modde (1971) and Berry (1996) reported significant negative relations among the benthic biomass and the river discharge among years. I had no data to compare with this relation in that I did not have data to compare among years. I found nearly all positive significant relations among benthic biomass and discharge among months. The conflicting negative relations between studies may suggest factors other than river discharge are influencing benthic biomass in the Missouri River. I found no relation among the benthic biomass and changes in water temperature among months. I did not examine changes in the combined total benthic biomass and their relation with discharge but examined specific invertebrate orders (including only important food items) and their relation to river discharge.

Discharge and Available Prey

Both studies (Modde 1971; Berry 1996) conducted in the disturbed habitats suggested a relationship between changes in discharge and changes in quantity and quality

of shovelnose sturgeon diet. Modde and Schmulbach (1977) suggested shovelnose sturgeon exhibited multiple feeding strategies dictated by changing accessibility of prey organisms. It was inferred that shovelnose sturgeon follow an optimum feeding strategy (Berry 1996). Modde and Schmulbach (1977) suggested that the dominant factors which affected accessibility of prey to shovelnose sturgeon in the unchannelized Missouri River were environmental changes caused by fluctuations in river velocity and elevation. More specifically, factors affecting sturgeon prey availability include water temperature, seasonal recruitment, and changes in density influenced by timing and discharges from Gavins Point Dam. Modde and Schmulbach (1977) suggested that decreased discharges might induce a catastrophic drift or migration from backwaters and side channels to the main channel increasing densities and biomass of available prey. Compounding the contributions of this mass migration to main channel biomass and density, the decreased river bed surface area may force invertebrate communities to crowd into the remaining suitable habitat. Berry (1996) examined benthic biomass during 3 years with different flow regimes and suggested a trend toward higher benthic biomass and densities during low flows which supported this hypothesis.

Although my analysis evaluated changes in availability of benthic macroinvertebrate within one year, my study did not support Berry's (1996) theory. I did not evaluate multiple years of "high", "medium", and "low" discharge levels and their respective invertebrate densities and biomass but I examined discharge relations within 1 year. Within the annual discharge cycle, few correlations among the densities, biomass, the relative weight number of available sturgeon forage and discharge were found. Berry

(1996) also reported a negative relation among discharge and the benthic biomass was not apparent when monthly discharges within the individual year was examined.

Drifting invertebrates were believed to be a substantial resource for shovelnose sturgeon in the Missouri River below Gavins Point Dam (Modde and Schmulbach 1977; Berry 1996). Berry (1996) found sturgeon selected for drifting caddisflies in March and against them at other times possibly due to their inability to capture the drifting caddisflies. Modde and Schmulbach (1977) implied sturgeon feeding behavior changed with seasonal changes in prey availability and that sturgeon used drifting invertebrates when they were abundant.

Drifting invertebrates in the undisturbed habitat (this study) were always found at low densities and biomass. Relative abundance and biomass in the water column generally reflected those found in the benthos. The lack of large settling eddies and backwaters in my study site , regardless of discharge, suggests that invertebrate density and migratory behavior as described for the unproductive South Dakota habitats may not be similar to my study area. I suggest that the increased invertebrate drift associated with the dewatering of backwater in South Dakota study area was either negligible or not found in my study area. Given the lack of significant relations among discharge and the available sturgeon forage, the relatively high productive benthic invertebrate population, and the low drifting invertebrate biomass it may be suggested the shovelnose sturgeon in my study area may not use drifting or resettling invertebrates as a major food resource.

Sturgeon Dietary Weight

The average dry weight of shovelnose sturgeon stomach contents was generally higher in my study than in Modde (1971) and Berry (1996). Average ration weight was generally less that 1 g in South Dakota (Modde 1971; Berry 1996). Berry (1996) reported dietary weight was greatest in early spring (March) and Modde (1971) reported greatest biomass from December to February. Niether this study or Berry (1996) sampled during the winter months. In the disturbed habitat there was no significant difference in diet weight among years of low, medium, and high flow (Berry 1996) but there was significant diet weight differences among some months. In my study, average dry weight of stomach contents was 1.245 g (July to November) and 1.910 g (April to October) in 1993 and 1994, respectively. Stomach content dry weight for individual sturgeon ranged from 0.002 g to 9.647 g. The fact that estimated dry weights of partial food items were included in dietary weight in my study and that sturgeon were generally larger may explain some of the difference between my findings and those of the South Dakota studies. Most importantly, I found a significant positive relation among the average dietary weight and river discharge.

The positive relation among the diet biomass and river discharge does not support the hypothesis (Berry 1996) that increased discharge reduces the quantity and quality of shovelnose sturgeon food items. The discharge cycle; however, differed between study areas. The undisturbed habitat (this study) exhibited relatively natural discharge cycles which peaked in spring months following snow melt and spring rains and decreased gradually into winter months. In the disturbed habitat, discharge releases from Gavins

Point Dam generally increased steadily from March to November (Berry 1996). The different cycle of discharge between studies may explain the conflicting relation. Disregarding different discharge rates, all three studies show greatest stomach biomass in early spring (or late winter in Modde (1971)) followed by a gradual decrease. This implies consistency in sturgeon seasonal feeding patterns regardless of geographic location. The contrast between the relation of discharge and ration biomass between studies may suggest that sturgeon ration biomass is dependent upon some other variable other than river discharge. Additionally, when investigating stomach content biomass between high, medium, and low discharge years, Berry (1996) reported low shovelnose sturgeon stomach biomass at low discharges did not support his working hypothesis that low discharges concentrate invertebrates and allow sturgeon to feed more effectively.

Sturgeon Diet

Studies in both the disturbed and undisturbed habitats support the importance of benthic aquatic macro-invertebrates in shovelnose sturgeon diets. In 1971, benthic invertebrates comprised 98.4% of the total dry weight, 99.4% of the total numbers, and were found in 99.2% of the shovelnose sturgeon stomachs in the disturbed habitat below Gavins Point Dam, South Dakota (Modde 1971). Modde and Schmulbach (1977) reported that Trichoptera larvae (*Hydopsyche sp.*) constituted the largest percentage of the annual biomass followed by Chironomidae larvae. Species of *Hydropsyche* and *Chironominae* constituted approximately 81.2% (Chironomidae represented 24.8%) of the ration throughout the year and were the principal constituents of the drift and benthic

communities (Modde and Schmulbach 1977). Berry (1996) reported about 80% of the stomach biomass was composed of midge larvae (Family Chironomidae) with an additional 3.4% of other aquatic dipterans. Berry (1996) supported Modde's findings that Chironomidae were more abundant in the shovelnose sturgeon diet from May to September. In my study, I found sturgeon diets included Ephemeroptera, Diptera, Trichoptera, and Plecoptera. In 1994, I found Hydropsychidae larvae comprised the greatest relative weight (ave=54.4%) of stomach contents and represented the highest RI (19.6) values of important food items. From July to November 1993, I found Trichoptera constituted the greatest annual relative weight (45.7%) as well. In 1993, the relative weight of Ephemeroptera exceeded Diptera and Plecoptera in shovelnose sturgeon gut contents. However, Plecoptera exceeded Diptera and Ephemeroptera in 1994. This contrast between years may be explained by the small sample size in 1993 as well as different sample seasons between years. Diptera constituted about 10.5% of shovelnose sturgeon gut biomass in 1994 and 8.6% in 1993. However, in 1994 average RI values indicate Ephemeroptera were most important followed by Trichoptera, Diptera, and Plecoptera, respectively. Given the large variation in available prey items between study sites, the difference in sturgeon diets is not unexpected. The fact that composition of shovelnose sturgeon diet differed among studies suggests they are flexible in their diets and feed upon the aquatic invertebrates found in their habitat.

Studies from both the unproductive and productive habitats support the hypothesis that sturgeon exhibit temporal variation in gut content composition. I found the relative weight of prey items varied significantly among some months as did Modde (1971) and

Berry (1996). The sporadic significant differences among the relative abundance and biomass of food items in sturgeon diet in my study does not seem to be biologically related. There were no clear patterns to the significant changes among months and statistical significant differences may have resulted from my small sample size. Modde (1971) suggested that changes in gut content composition could be stratified into three seasonal trends: October to January, February to April, and May to September. It was unclear how this stratification was devised but I suspect he used changes in the dominant fraction of the gut contents in the diet. Collection efforts in both my study and Berry (1996) occurred during the third seasonal trend described by Modde (1971). Berry (1996) reports food habits which supported those of Modde (1971) but my study did not.

Sturgeon Forage Electivity

Both my study and Berry (1996) seem to indicate that shovelnose sturgeon use prey items at rates which exceed or fall short of their relative availability, whereas Modde (1971) reports an opportunistic feeding strategy (Ivelev 1961). Modde (1971) found positive correlations (though not tested statistically) among the use of *Hydropsyche sp.* and Chironomidae and their availability. Electivity values in Modde (1971) reflected these positive correlations in that they generally suggested nonselective feeding strategies (Ivelev 1961). Berry (1996) reported electivity values which suggest shovelnose sturgeon exhibit an avoidance or selective behavior. More specifically, he reports electivity values for midges, particularly in the genus *Chernoviskiia*, were usually negative before June but usually positive after June. This indicates that midges appeared in the diet in greater

proportions than in the benthic community. My data showed similar trends in electivity values for aqautic Diptera (Chironomidae). Berry (1996) found sturgeon generally avoided Ephemeroptera in the benthos, whereas I found sturgeon feeding strategies were different for each family of Ephemeroptera. This avoidance of Ephemeroptera in South Dakota may have actually been more related to their accessibility and low densities.

Disturbed and Undisturbed Habitats: Summary

Availability of shovelnose sturgeon prey items in the disturbed habitat may be influenced by rapid de-watering of backwaters and side channels. I suggest that disrupted annual discharge cycles, varying annual discharges, distorted thermal dynamics, and dynamic river substrates all contribute to an unstable and relatively unproductive prey base for the shovelnose sturgeon in the Missouri River below Gavins Point Reservoir. The relatively small size and poor growth of shovelnose sturgeon in the disturbed habitat suggest that condition were less than optimal for the sturgeon population. Relatively high shovelnose sturgeon populations, good growth, and relatively stable and diverse food resources in the undisturbed habitat of my study suggest this is a more suitable environment for sturgeon. I found little evidence that river dishcharge was related to the food availability or the shovelnose sturgeon diet or feeding behavior in the undisturbed habitat. Most importantly, I suggest relations among shovelnose sturgeon diet biomass and discharge (Modde 1971, Modde and Schmulbach 1977, and Berry 1996) may not represent a causative correlation.

Management recommendations

On a long range basis, I suggest the need to establish a program which would monitor the environment (specifically the Yellowstone and the Missouri Rivers) occupied by shovelnose sturgeon. This analysis has at least raised the question as to the suitability of the environment for shovelnose sturgeon below Gavins Point Dam in South Dakota. The available population data and the general size and growth differentiation between shovelnose sturgeon in this study and those in South Dakota suggest that sturgeon are less stressed in the undisturbed habitat than in the disturbed. I found evidence that discharge may not play a major role in shovelnose sturgeon diet and feeding behaviors. The complex nature of large rivers creates a highly variable, site-specific complex of biological and biophysical relationships (e.g. Carpenter 1988). Bioenergetic studies or models should be investigated as a means of isolating major limiting factors which affect sturgeon populations in different sites (Hewett and Kraft 1993; Ney 1993).

My investigation of such complex biophysiological and biological relationships may have been conducted at too small a scale (Brandt and Mason 1994). Local density-dependent (biological) and density-independent (physical) processes, occurring at lesser spatial scales, can significantly affect population processes and production at the system level (Possingham and Roughgarden 1990). Berry (1996) and Modde (1971), in the disturbed habitat in South Dakota, report that discharges released from Gavins Point Dam affect aquatic invertebrate populations but the degree to which shovelnose sturgeon are influenced by these affected populations seems unclear. I found little evidence to support this discharge and invertebrate population theory but perhaps the relation is more

subtle than my analysis was able to detect. If dynamic and abnormal discharges from Gavins Point Dam in South Dakota does affect the foods and feeding behavior of shovelnose sturgeon what does this mean to the shovelnose sturgeon population in the Missouri River basin?

A broader investigative approach toward factors influencing shovelnose sturgeon populations within the impounded Missouri River is needed. Perhaps a "waterscape" (Holling 1992) approach would be optimal. Weins and Milne (1989) argued that the size of a landscape (waterscape in this point) should be set from the perspecitve of the organism or ecological process under investigation. Determining the "waterscape" extent is important in that pertinent patterns, processes, and mechanisms may change over different spatial and temporal scales (Levin 1992). A standardized monitor program of the invertebrate community in the Missouri River may be warranted.

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APPENDICES

Appendix A
Prey availability in the Mainchannel, Midchannel, Shallow, Side Channel, and Drift Habitats.

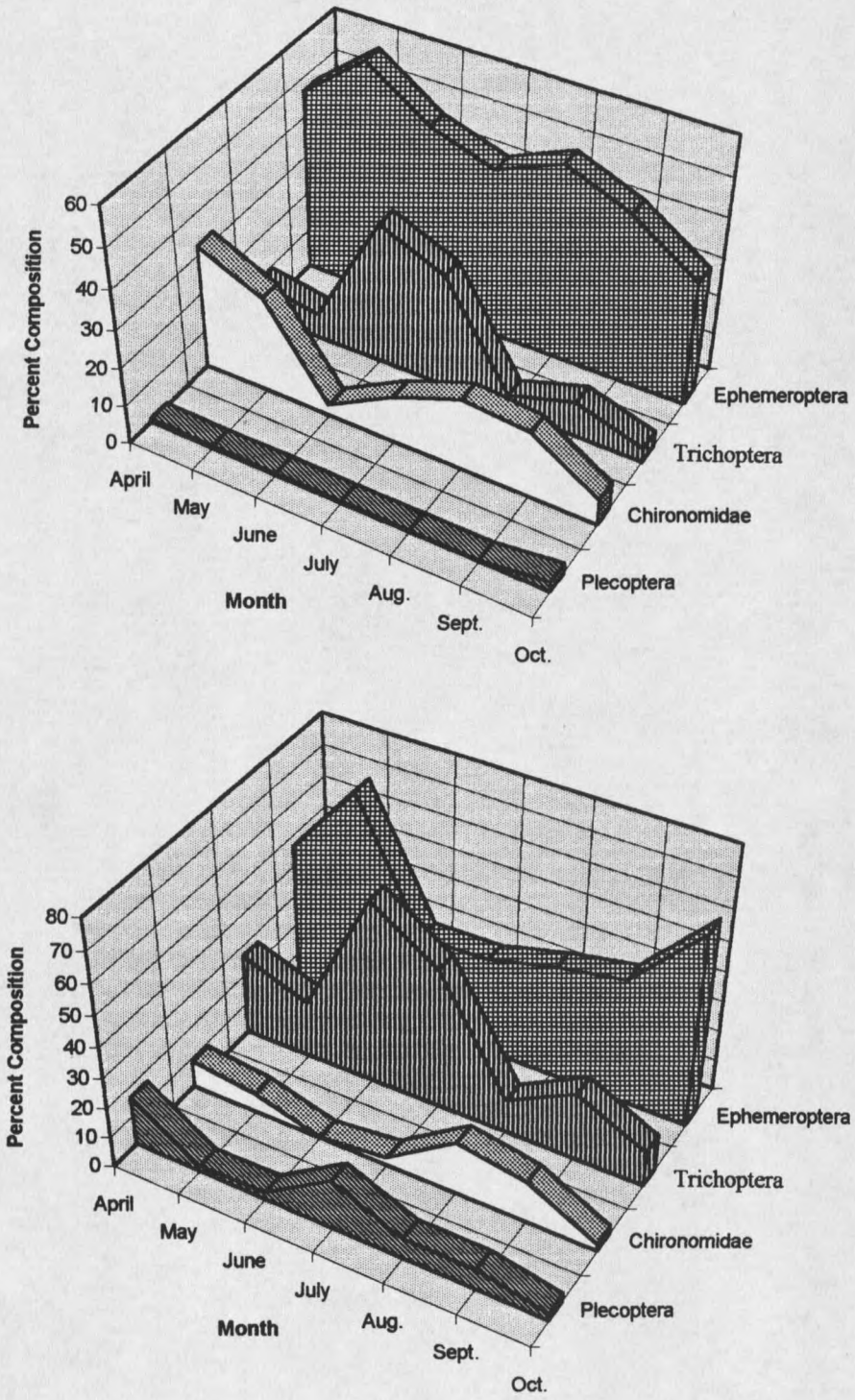


Figure 8. Percent compostion by number(P_n) (top) and weight (P_w) (bottom) per square meter for shovelnose sturgeon prey in the main channel habitat of the Missouri River above Fort Peck Reservoir, Montana in 1994.

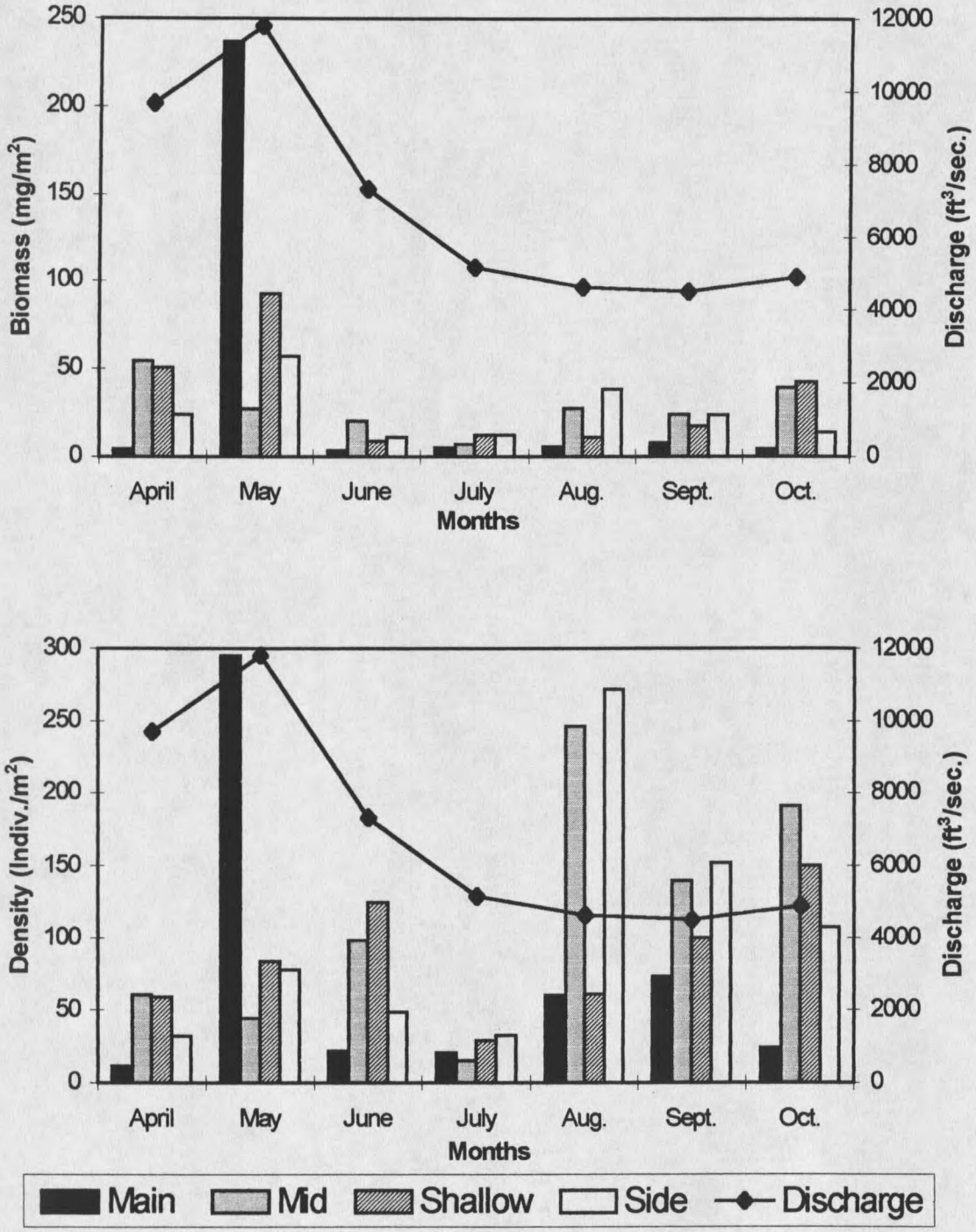


Figure 9. Missouri River discharge (ft^3/sec), average biomass (mg/m^2), average density ($\#/m^2$) of Ephemeroptera from the benthos in the main, mid, shallow, and side channel habitats from the Missouri River, Montana, above Fort Peck Reservoir in 1994. Only Ephemeroptera families which constituted >1% (P_n and/or P_w) of shovelnose sturgeon diets are included.

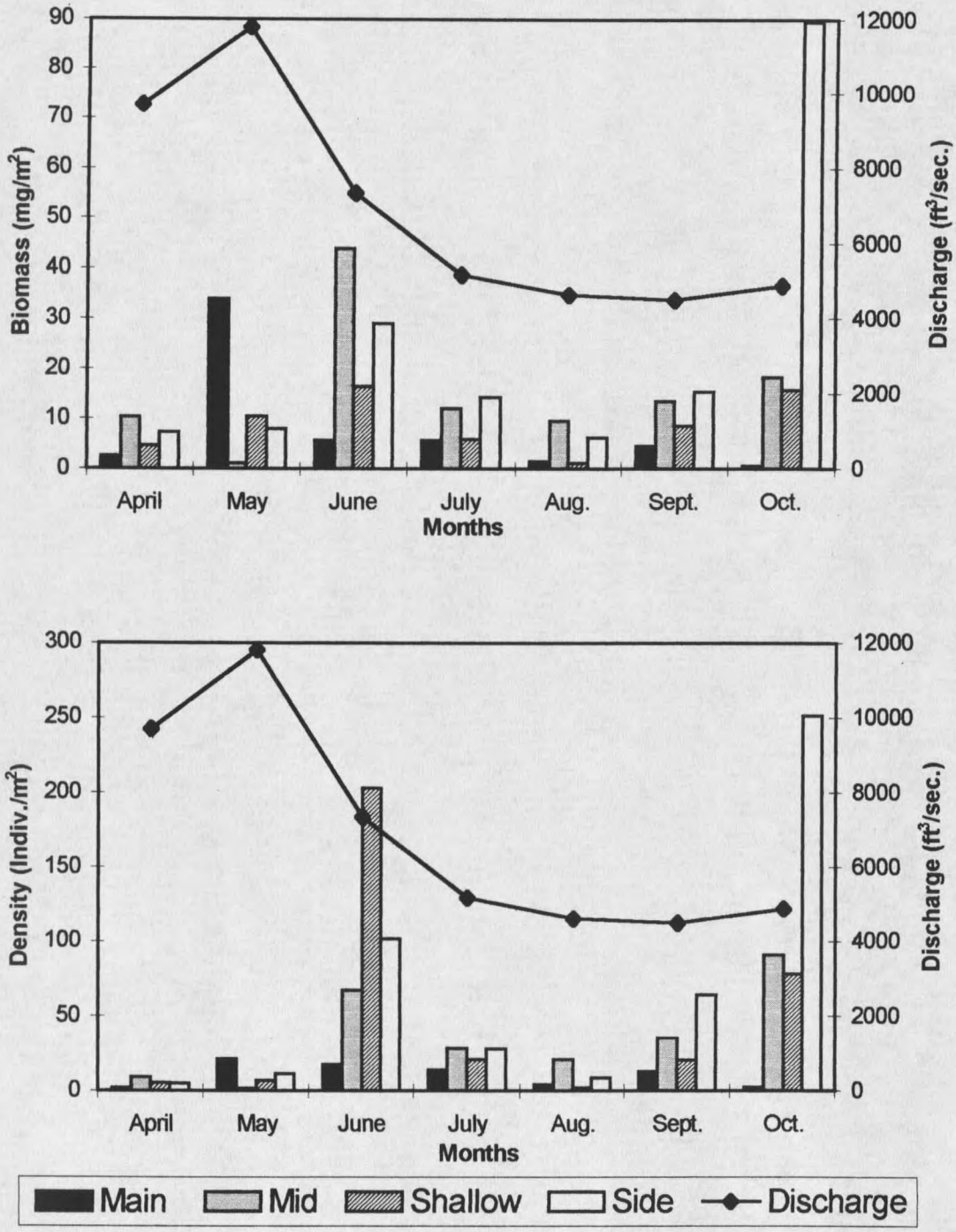


Figure 10. Missouri River discharge (ft^3/sec), average biomass (mg/m^2), average density ($\#/m^2$) of Trichoptera from the benthos in the main, mid, shallow, and side channel habitats from the Missouri River, Montana, above Fort Peck Reservoir in 1994. Only Trichoptera families which constituted >1% (P_n and/or P_w) of shovelnose sturgeon diets are included.

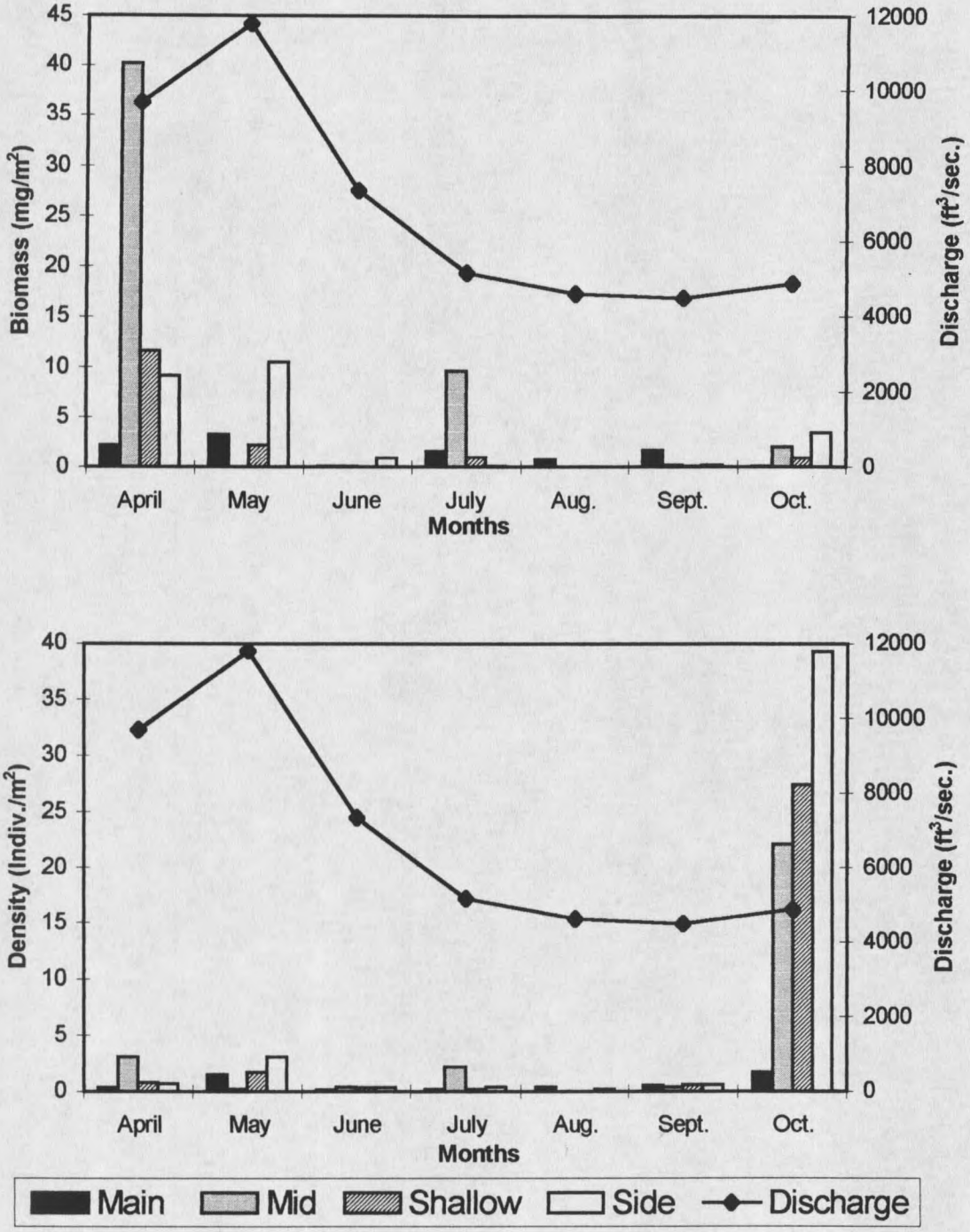


Figure 11. Missouri River discharge (ft^3/sec), average biomass (mg/m^2), average density ($\#/m^2$) of Plecoptera from the benthos in the main, mid, shallow, and side channel habitats from the Missouri River, Montana, above Fort Peck Reservoir in 1994. Only Plecoptera families which constituted >1% (P_n and/or P_w) of shovelnose sturgeon diets are included.

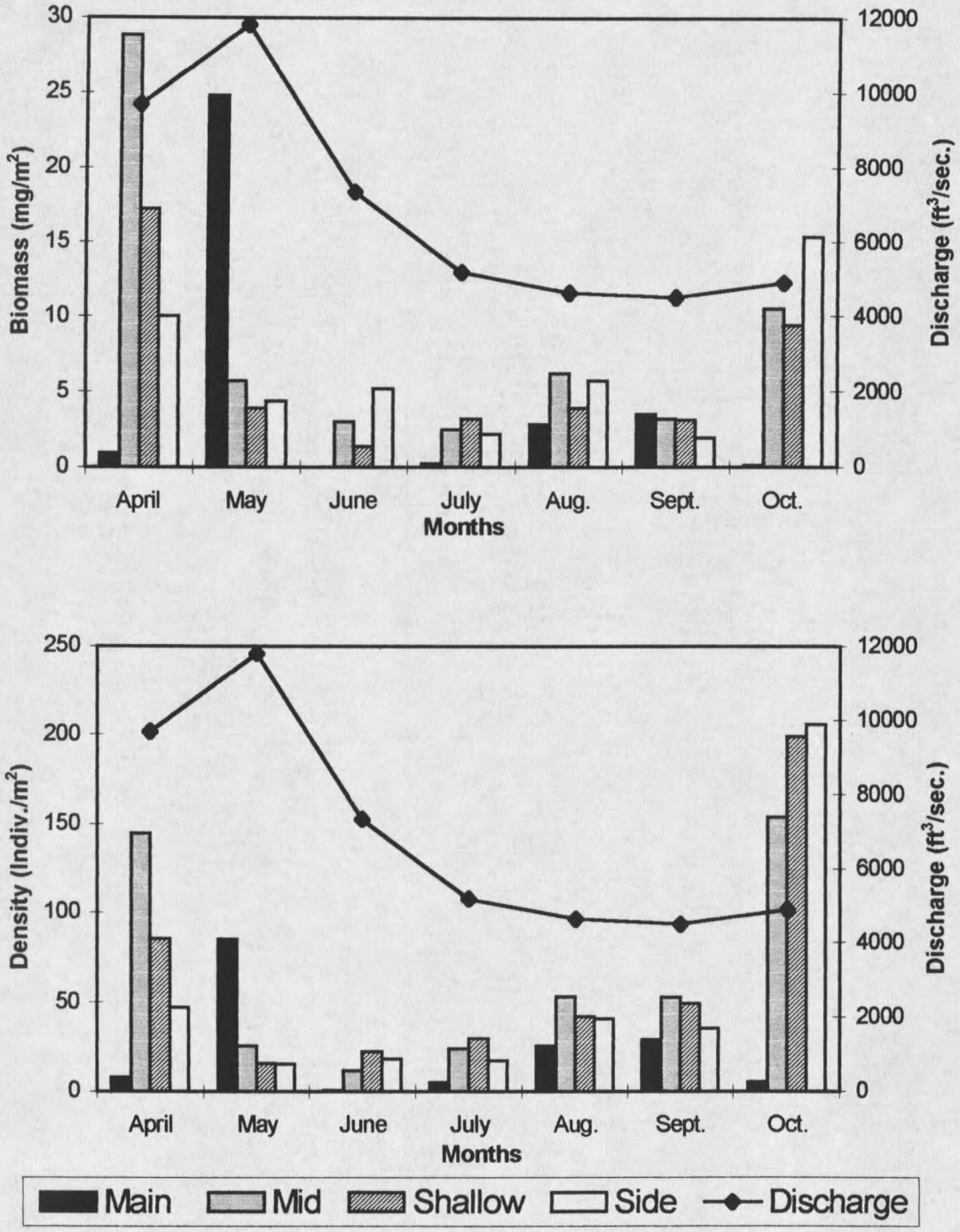


Figure 12. Missouri River discharge (ft^3/sec), average biomass (mg/m^2), average density ($\#/m^2$) of Diptera from the benthos in the main, mid, shallow, and side channel habitats from the Missouri River, Montana, above Fort Peck Reservoir in 1994. Only Diptera families which constituted >1% (P_n and/or P_w) of shovelnose sturgeon diets are included.

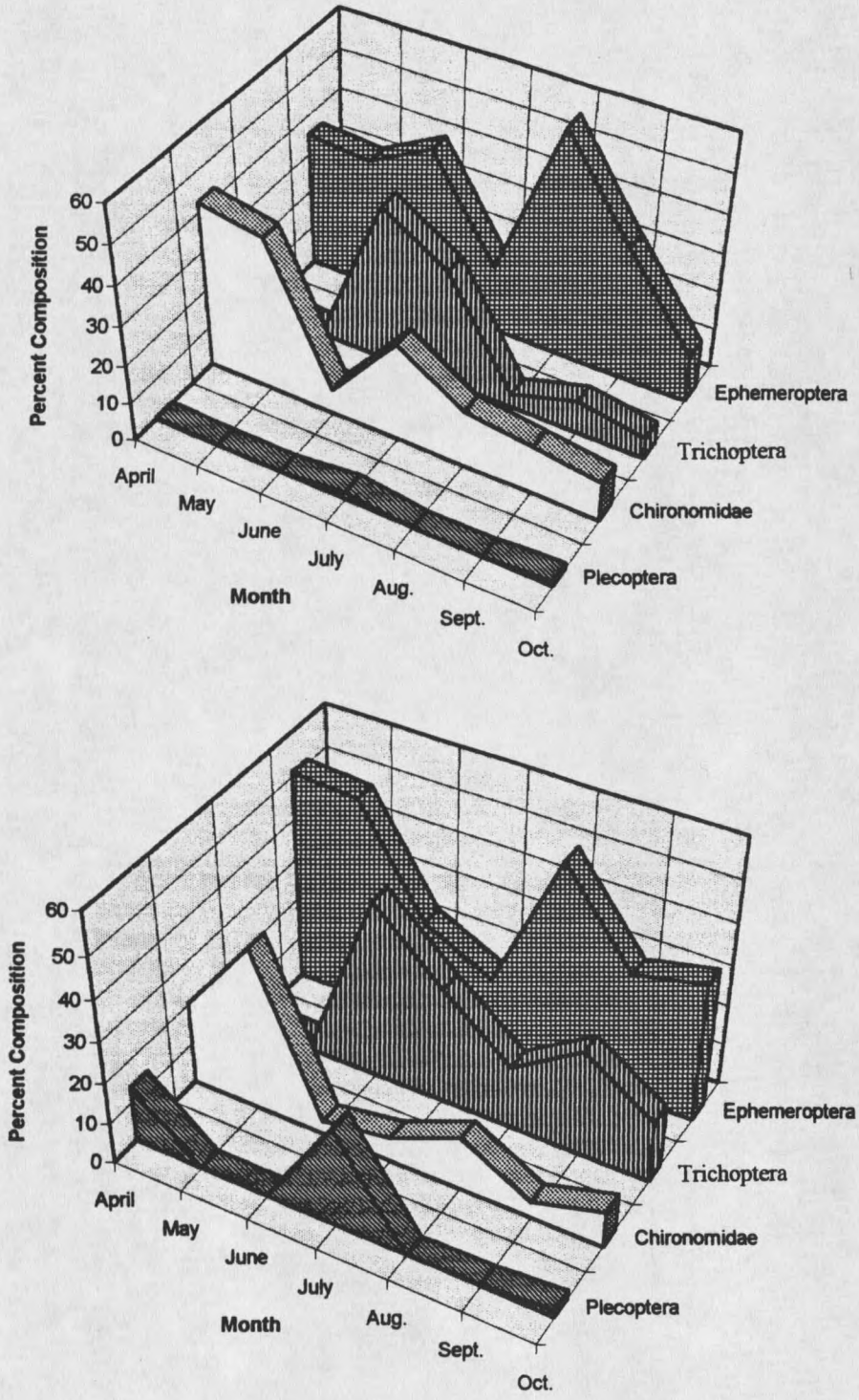


Figure 13. Percent composition by number (P_n) (top) and weight (P_w) (bottom) per square meter for shovelnose sturgeon prey in the midchannel habitat of the Missouri River above Fort Peck Reservoir, Montana in 1994.

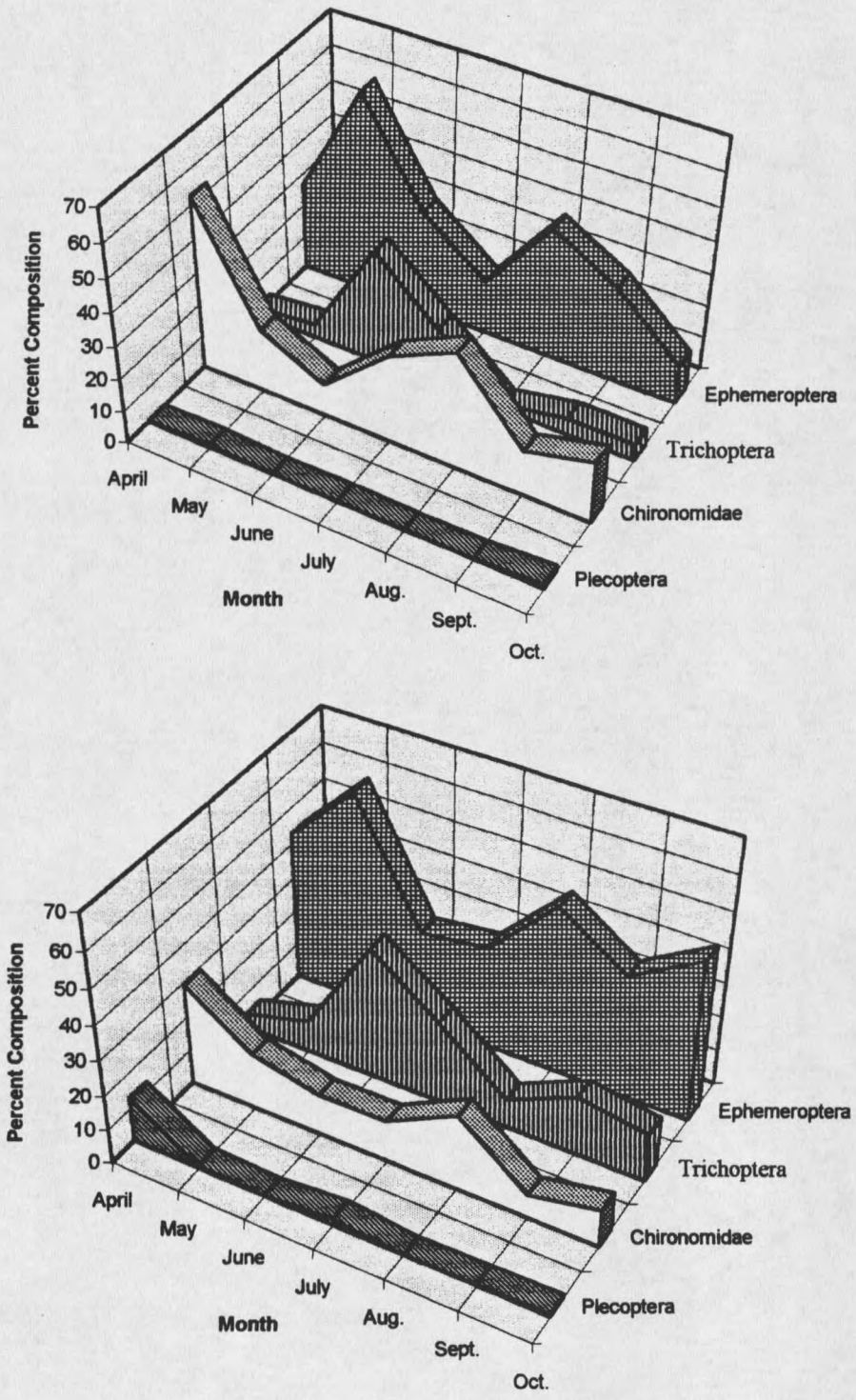


Figure 14. Percent composition by number (P_n) (top) and weight (P_w) (bottom) per square meter for shovelnose sturgeon prey in the shallow of the Missouri River above Fort Peck Reservoir, Montana in 1994.

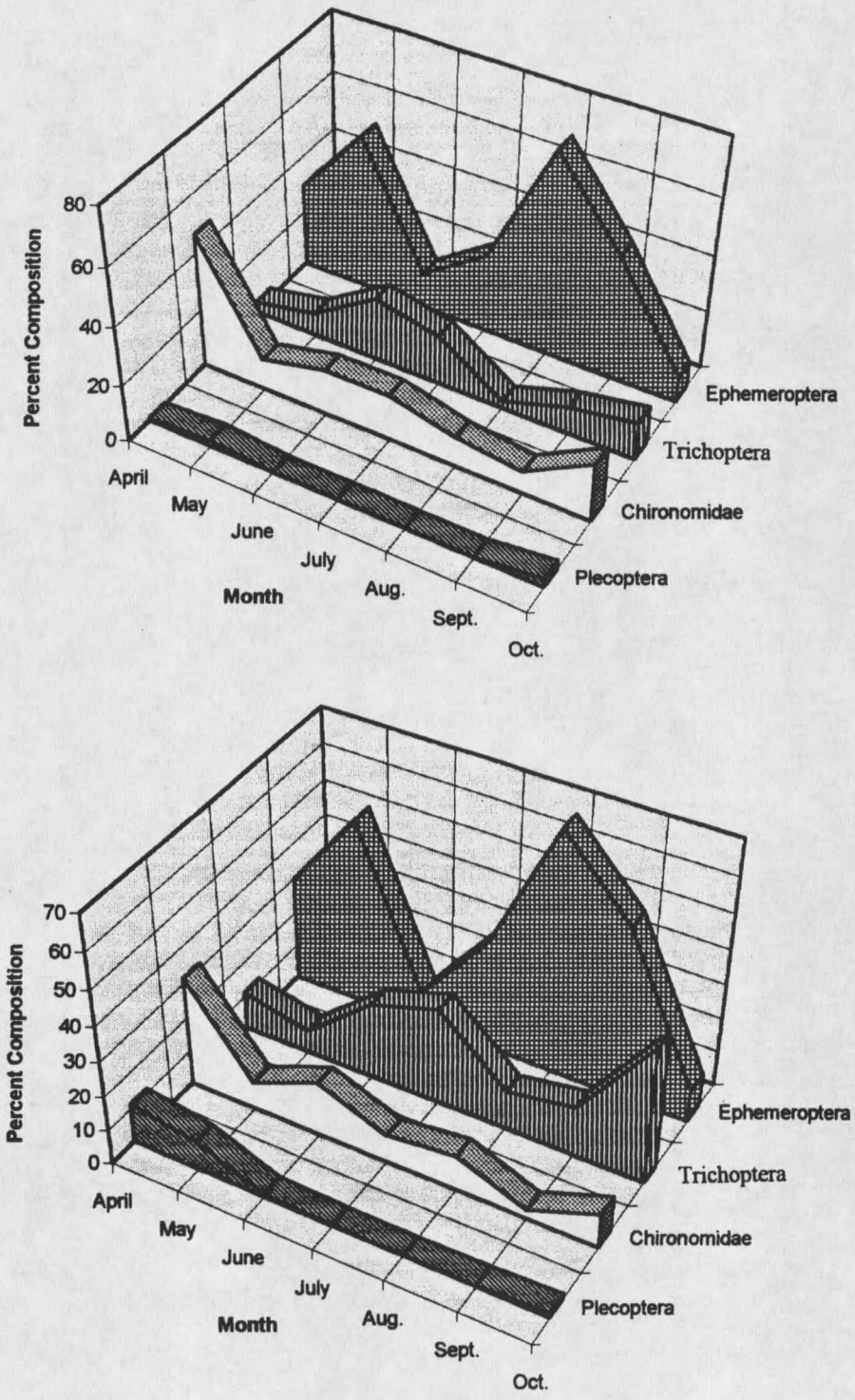


Figure 15. Percent composition by number (P_n) (top) and weight (P_w) (bottom) per square meter for shovelnose sturgeon prey in the side channel of the Missouri River above Fort Peck Reservoir, Montana in 1994.

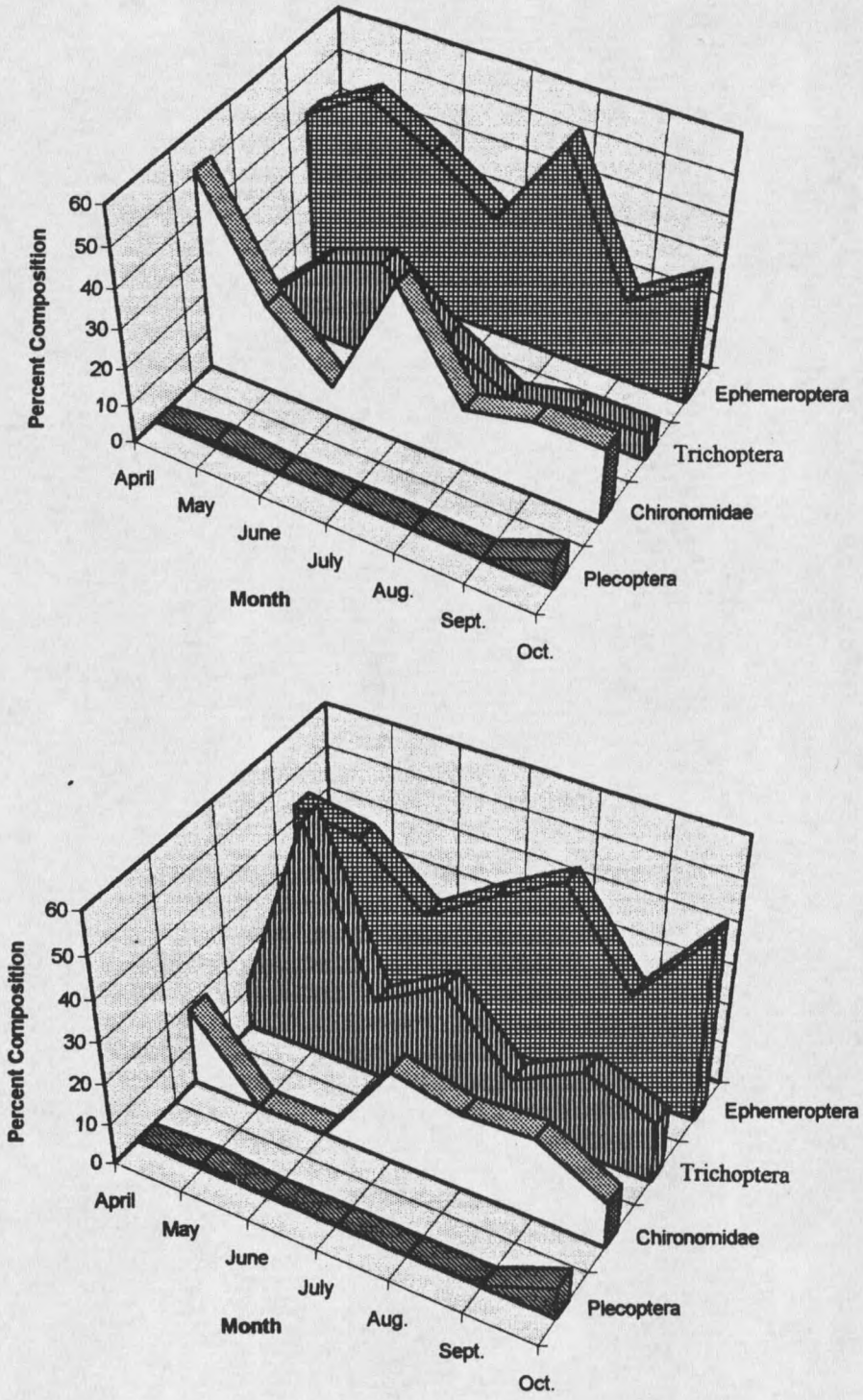


Figure 16. Percent composition by number (P_n) (top) and weight (P_w) (bottom) per cubic meter for shovelnose sturgeon prey in the drift (water column) of the Missouri River above Fort Peck Reservoir, Montana in 1994.

Appendix B
Relative Composition of Shovelnose Sturgeon Food Items

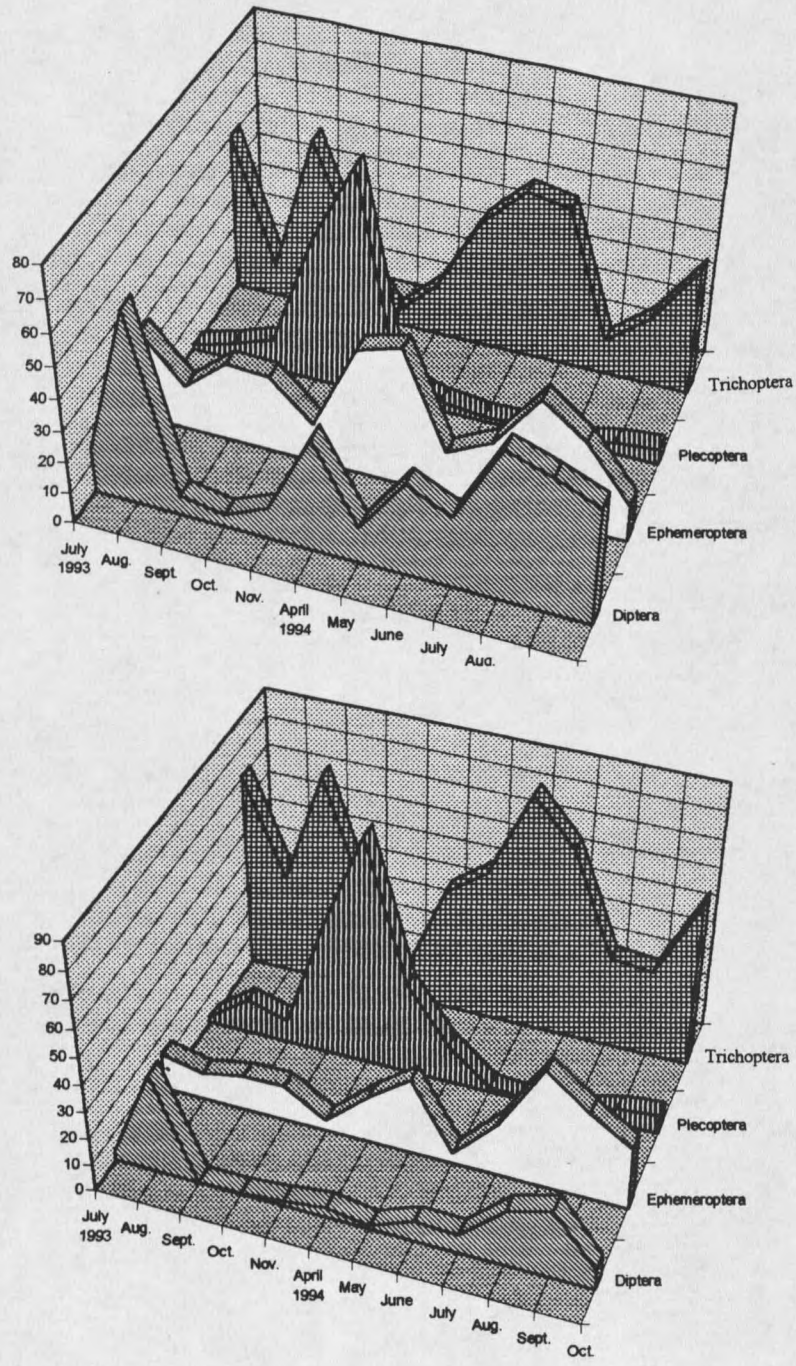


Figure 17. Percent composition of food items by numbers (top) and biomass (bottom) in sturgeon diets from the Missouri River above Fort Peck Reservoir, Montana in 1993 and 1994.

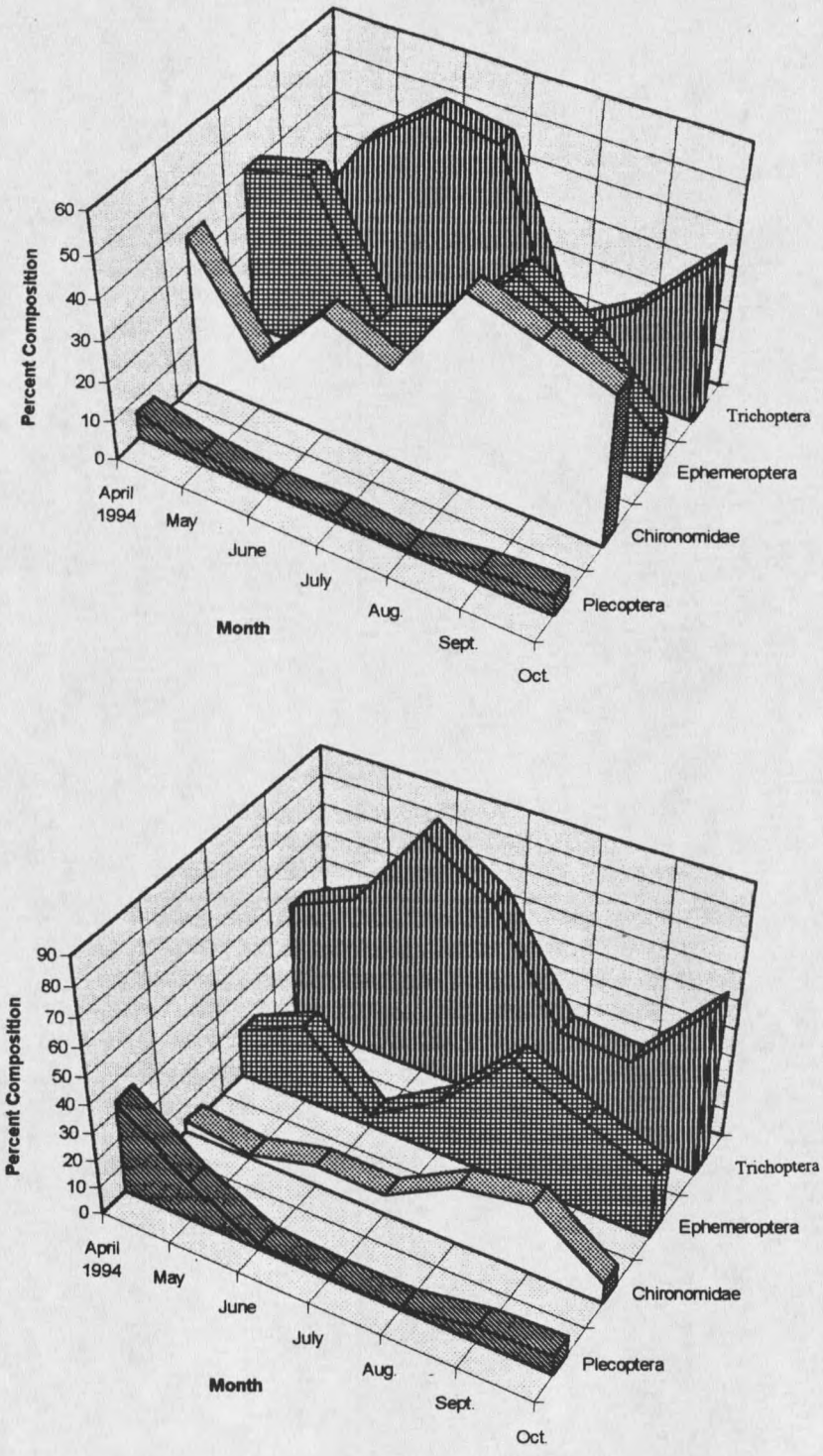


Figure 18. Percent composition of food items by number (P_n) (top) and biomass (P_w) (bottom) in sturgeon diets from the Missouri River above Fort Peck Reservoir, Montana in 1994.

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