Macroinvertebrate composition and patterns of prey use by juvenile pallid sturgeon (*Scaphirhynchus albus*) in the Missouri River, South Dakota and Nebraska.

By

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Abstract

Macroinvertebrate composition and patterns of prey use by juvenile pallid sturgeon (*Scaphirhynchus albus*) in the Missouri River, South Dakota and Nebraska.

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Macroinvertebrates were collected from the Missouri River downstream of Fort Randall and Gavins Point dams to evaluate spatial and temporal patterns in abundance and describe habitats important for macroinvertebrates. The most abundant families collected were Chironomidae, Ceratopogonidae, Isonychiidae, Baetidae, Caenidae, Heptageniidae, Hydropsychidae, and Polycentropodidae. Invertebrate abundance, richness, diversity, and evenness were generally higher in the Gavins Point reach than in the Fort Randall reach for most gear types (except Surber samples). In the Fort Randall reach, mean richness, diversity, and evenness were generally highest in the delta formed downstream of the Niobrara River.

We collected 31 juvenile pallid sturgeon during summer 2006 for diet analysis, of which 21 had prey in their stomachs. Percent occurrence of predominant prey was Ceratopogonidae (81%), Isonychiidae (67%), Chironomidae (52%), and fish (24%). Diets as percent composition by wet weight were fish (68%), Ephemeroptera (23%), Decapoda (6%), and Diptera (3%). As juvenile pallid sturgeon length increased (356 - 720 mm fork length), the proportion of fish in the diets increased (43 to 88%). This study

showed the importance of macroinvertebrates as a food source for juvenile pallid sturgeon (< 600 mm fork length).

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List of Abbreviations

ANOVA…….analysis of variance

BSNP……..…Bank Stabilization and Navigation Project

C…….Celsius

cm……..centimeter

CPOM……course particulate organic matter

d……day

FL…….fork length

FPOM……fine particulate organic matter

g…….gram

GPS……...global positioning system

h……..hour

ha…….hectare

JPS……juvenile pallid sturgeon

kg……....kilogram

L……...liter

m……...meter

mg……..……...milligram

ml……..……...…….milliliter

mm…….millimeter

MRNRC……....Missouri River Natural Resources Committee

N...……...sample size

NTU……..…….nephelometric turbidity units

PIT...……Passive integrated transponders

rkm....…….river kilometer

RPMA…….…Recovery Priority Management Area

µm……..micrometers

USACE……...United States Army Corps of Engineers

USFWS……...United States Fish and Wildlife Service

USGS…….…United States Geological Survey

wt…….weight

WRDA……...Water Resources Development Act

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Chapter 1.

Introduction

The Missouri River

The Missouri River is the longest river in the United States, extending 3,768 km from Three Forks, Montana, to the confluence with the Mississippi River at St. Louis, Missouri (U.S. Geological Survey [USGS] 1998; Galat and Lipkin 2000; U.S. Army Corps of Engineers [USACE] 2006). Being the second largest basin in the United States, the Missouri River drains one-sixth of the land in the United States within 10 states and 28 Native American reservations (USGS 1998; Galat and Lipkin 2000; National Research Council [NRC] 2002). Historically, the Missouri River was braided, with high turbidity and sediment transport. The river frequently shifted and contained sandbar, backwater, and island habitats (USGS 1998; Hesse et al. 1989).

The Missouri River can be separated into three distinct zones, upper, middle, and lower, based on current hydrology and geomorphology (USGS 1998; Galat and Lipkin 2000). Both the upper and middle zones are unchannelized. The upper zone originates at the Missouri River headwaters (river kilometer [rkm] 3,768) and extends 739 rkm to Fort Peck Dam, Montana (Galat et al. 2005a, 2005b), the first major main-stem impoundment on the Missouri River (Figure 1-1). The middle zone, characterized by a series of impoundments, extends from Fort Peck Dam (rkm 3,029) to Sioux City, Iowa (rkm 1,178; Galat et al. 2005a, 2005b). The lower zone is channelized beginning at Sioux City, Iowa and extends approximately 1,178 rkm to the confluence with the Mississippi

River at St. Louis, Missouri, (Galat and Lipkin 2000). The lower zone is also altered by bank stabilization and floodplain levees.

The majority of the Missouri River basin is in the Great Plains (70.3 %), which has a semiarid climate. The Missouri River basin annually receives less than 41 cm of precipitation, of which the majority of rainfall (70 %) occurs in April through August (USACE 2006). Air temperatures typically range from –34° C in the winter to above 41° C in the summer in parts of Kansas, Nebraska, and South Dakota (USACE 2006).

Flood pulse and river stage are reduced due to the flow regulation from dams (Pegg et al. 2003; Galat et al. 2005b). Flooding is critical in maintaining the ecological functions of the river-floodplain complex (Junk et al. 1989). Mean July to October water temperatures range from 21°C in the upper zone to 27°C in the lower zone (Galat et al. 2005a, 2005b). However, in the middle zone hypolimnetic releases from reservoirs affect water temperature (USGS 1998). In the middle zone of the Missouri River, the Fort Randall and Gavins Point dams regulate discharge, which has altered the historical hydrograph in these riverine sections (Pegg et al. 2003; Jordan et al. 2006). Between 1929 and 1996, the mean discharge ranged from 204 m^3/s at Fort Benton, Montana (upper zone), to 883 m^3/s at Omaha, Nebraska (middle zone), and 2,256 m^3/s at Hermann, Missouri (lower zone; Galat et al. 2005b). Seasonal runoff from ice-out in March, spring precipitation, and snowmelt from the Rocky Mountains in June increases runoff and discharge supplying water for annual flood pulses. The flood pulse concept in large floodplain rivers is based on biological communities evolving to utilize the timing, duration, and water level fluctuations associated with flooding, especially in the spring

(Junk et al. 1989). These floods maintain diversity within the system and trigger spawning in many species of fish. Absence of periodic flooding may cause negative responses in diversity and abundance of both macroinvertebrates and native fish.

Substrate composition varies between the three zones of the Missouri River. The river bed in the upper zone is composed primarily of gravel (>35%) in habitats such as outside bends, inside bends, and channel crossovers (Galat et al. 2005b). Percent gravel decreases to <10 % in the middle and lower zones. The primary substrate in the main channel is sand (> 80%), which is higher in the middle and lower zones (>85%) compared to the upper (45%) zone (Galat et al. 2005b). Silt is the primary substrate in tributary confluences and non-connected secondary channels, but represents <10% of the substrate in the main channel (Galat et al. 2005b).

The Missouri River was free flowing until the 1900's and considered the most diverse ecosystem in North America (NRC 2002; USACE 2006). Prior to modifications, the river had braided, shifting channels, islands, sandbars, snags, and backwater areas (Missouri River Natural Resources Committee [MRNRC] 1998; USGS 1998; Galat et al. 2005a, 2005b; USACE 2006). Between rkm 1,297 and 589, channel widths ranged from 610 – 1,829 m (Galat et al. 2005b). Nicknamed "Big Muddy," high turbidity and sediment transport were normal due to an erosive landscape and overbank flooding (Galat et al. 2005a, 2005b).

In the 1900's, the river was managed for flood control, navigation, irrigation, hydroelectric power generation, industrial and municipal water supply, recreation, and fish and wildlife (USGS 1998; Galat et al. 2005b). Constructed in 1937 in Montana, Fort

Peck Dam created the first main-stem reservoir on the Missouri River (Galat et al. 2005b). The Missouri River Bank Stabilization and Navigation project (BSNP) and the Pick/Sloan Act were implemented in the 1940's by the USACE using revetments, pile dikes, and dredging (MRNRC 1998; USGS 1998; USACE 2004; Galat et al. 2005b). These control structures stabilized the bank, provided flood control, and maintained a navigation channel on the Missouri River (USACE 2004; Galat et al. 2005b). Completed in 1981, these structures disconnected sloughs and side channels from the main river (USACE 2004).

In 1944, the Pick/Sloan Act resulted in the construction of the other five main-stem dams (NRC 2002; Galat et al 2005b). Since the completion of the dams, overbank flooding and sediment deposition have been substantially reduced in the floodplain because of flow regulation from these impoundments (Galat et al. 2005a, 2005b). Now sediment deposition occurs primarily in the six main-stem reservoirs, resulting in the formation of large deltas (USGS 1998; Galat et al. 2005b). The six main-stem reservoirs have a storage capacity of approximately 90.5 km^3, which is larger than any river in the United States (USGS 1998; Galat et al. 2005b).

Presently, the Missouri River is considered one of the most highly regulated rivers in the United States (USGS 1998; Galat et al. 2005b). American Rivers designated the Missouri River as the nation's most endangered river in 1997 and 2001 (American Rivers 1997; American Rivers 2001; Galat et al. 2005b). Currently, 35% of the river is impounded, 32% is channelized, and only 33% remains unchannelized (Hesse 1987; USGS 1998). The river has been shortened 116 km (8%) because of channelization,

resulting in a loss of 204 km of river shoreline habitat (MRNRC 1998; USGS 1998). Impoundments and channelization have eliminated approximately 50% of the river surface area as well as about 90% of shallow water (0-1.5 m) habitats by nearly eliminating flooding (USGS 1998; Galat et al. 2005b). Sediment deposition behind water-control structures has caused loss of aquatic habitat and decreases in turbidity. Compared to historic conditions, the current Missouri River has decreased numbers of sandbars, lowered depth diversity (i.e. shallow water habitat), and reduced river connectivity to side channels and backwater areas (Hesse et al. 1989; MRNRC 1998; USGS 1998).

Threatened and Endangered Species

Impoundments, channelization, and sediment deposition have decreased the diversity of aquatic habitat in the Missouri River, altering the hydrology and function of the river-floodplain connection (Galat et al. 1998). Several species of fish and wildlife have declined to the point that they are listed as federally endangered, threatened, or rare (Hesse and Mestl 1993; USACE 2004). There are two federally listed endangered species, the interior least tern *Sterna antillarum*, and the pallid sturgeon *Scaphirhynchus albus*. The piping plover *Charadrius melodus,* currently is a federally listed threatened species. Additionally, there have been substantial declines of other big-river fishes in the lower and middle river including, the paddlefish *Polydon spathula*, burbot *Lota lota*, silver chub *Macrhybopsis storeriana*, plains minnow *Hybognathus placitus*, western silvery minnow *H. argyritis*, and blue catfish *Ictalurus furcatus*. Rare species include

sicklefin chub *Macrhybopsis meeki* and sturgeon chub *M. gelida*, which have been suggested for federal listing and protection (Berry and Erickson 1995; Berry and Young 2004; Hoagstrom et al. 2006).

The Missouri River hydrologic regimes have been altered from the historical flow regimes that fish and wildlife evolved with, thus limiting the potential for native fauna and flora to maintain historic abundance and distributions (Hesse et al. 1988; MRNRC 1998). Because of these changes, in 1986 Congress approved Section 601 of the Water Resources Development Act (WRDA; USACE 2003) that made it possible to develop 12,100 ha of land and develop habitat on 7,365 ha of public land in Iowa, Nebraska, Kansas, and Missouri (USACE 2003). Habitats were developed by planting trees and food plots, creating shallow water habitats and wetlands, and by reestablishing terrestrial, wetland and prairie habitats (USACE 2003). Congress passed another WRDA bill in 1999, which increased the amount of land acquired under easement with the Natural Resource Conservation Service (NRCS) by 48,016 ha, for a total land acquisition of 67,481 ha for mitigation of habitat lost as a result of the construction, operation, and maintenance of the BSNP (USACE 2003). These, along with other recovery programs, strove to reconnect the river and its floodplain during high flows by acquiring floodplain lands in the lower zone and increasing the complexity of main-channel habitat, primarily the amount of shallow, low velocity habitats (USACE 2003; Galat et al. 2005b). Restoration of side channels and chutes also attempts to increase shallow water habitats (USACE 2003).

Fish and Wildlife of the Missouri River

There are approximately 183 (138 native) species of fish in the Missouri River basin, making it the richest freshwater fauna in the United States (Robison 1986, Galat et al. 2005b). Many species are considered big-river fishes that are adapted to large, turbid, main channel environments (Galat et al. 2005a). The blue sucker *Cycleptus elongatus*, pallid and shovelnose sturgeons *Scaphirhynchus platorynchus*, sicklefin and sturgeon chubs, and channel catfish *Ictalurus punctatus* are some of these "big-river" fishes (Bailey and Allum 1962; Galat et al. 2005a).

The Missouri River provides migration and wintering habitat for many species of waterfowl and wading birds. During migration, shorebirds, ducks, and geese use islands, sandbars, and surrounding wetlands and fields to rest and feed (Galat et al. 2005b). American white pelican *Pelecanus erythrorhynchos*, American coot *Fulica americana*, Bald eagle *Haliaeetus leucocephalus*, Canada goose *Branta canadensis*, mallard *Anas platyrhynchos*, wood duck *Aix sponsa*, and great blue heron *Ardea herodias* are some common waterfowl found along the Missouri River. Some common shorebirds are killdeer *Charadrius vociferus*, lesser yellowlegs *Tringa flavipes*, spotted sandpiper *Actitis macularius,* and semipalmated sandpiper (*Calidris pusilla*; Galat et al. 2005b).

Macroinvertebrates

Aquatic macroinvertebrates help to sustain streams, rivers and lakes as functional productive ecosystems. They aid in the breakdown of coarse particulate organic matter (CPOM) into fine particulate organic matter (FPOM) along the length of a river (Vannote

et al. 1980). Shredders utilize CPOM and depend on the microbial biomass associated with it; collectors filter FPOM transported downstream or from sediments, and scrapers shear attached algae from surfaces (Merrit and Cummins 1996). A dominance of scrapers causes shifts in primary production (Vannote et al. 1980). Macroinvertebrates are important in aquatic food chains providing food resources to many fishes, shorebirds, and waterfowl (Held 1969; Wilhm et al. 1978; Anderson and Smith 1996). Many macroinvertebrates have been used as indicators of water quality and have been the focal point of several ecological studies (Warren 1971; Troelstrup and Hergenrader 1990; Cairns and Pratt 1993; Blinn et al. 1995; Merrit and Cummins 1996; Arscott et al. 2005; Lee 2007).

Little information has been collected on macroinvertebrate diversity and distribution in the Missouri River downstream of Fort Randall and Gavins Point dams. This information would be beneficial especially because the pallid sturgeon, an endangered species, is found in both of these reaches, and uses macroinvertebrates as a prey source (Gerrity et al. 2006; Wanner et al. 2007). This study was designed to determine longitudinal distribution and habitat associations of macroinvertebrates downstream of Fort Randall and Gavins Point dams. Additionally, I looked at prey use and spatial variation in hatchery-reared juvenile pallid sturgeon [JPS] diet composition. Specific objectives of this study were to:

1) compare longitudinal distribution of macroinvertebrates downstream of the Fort Randall and Gavins Point dams, compare temporal variation of macroinvertebrates, and identify habitats important for macroinvertebrate production (Chapter 2);

and

(2) identify important prey items for the pallid sturgeon, determine if prey composition varies with fish size, and compare pallid sturgeon diet composition in the Fort Randall Reach to other areas of the Missouri River (Chapter 3).

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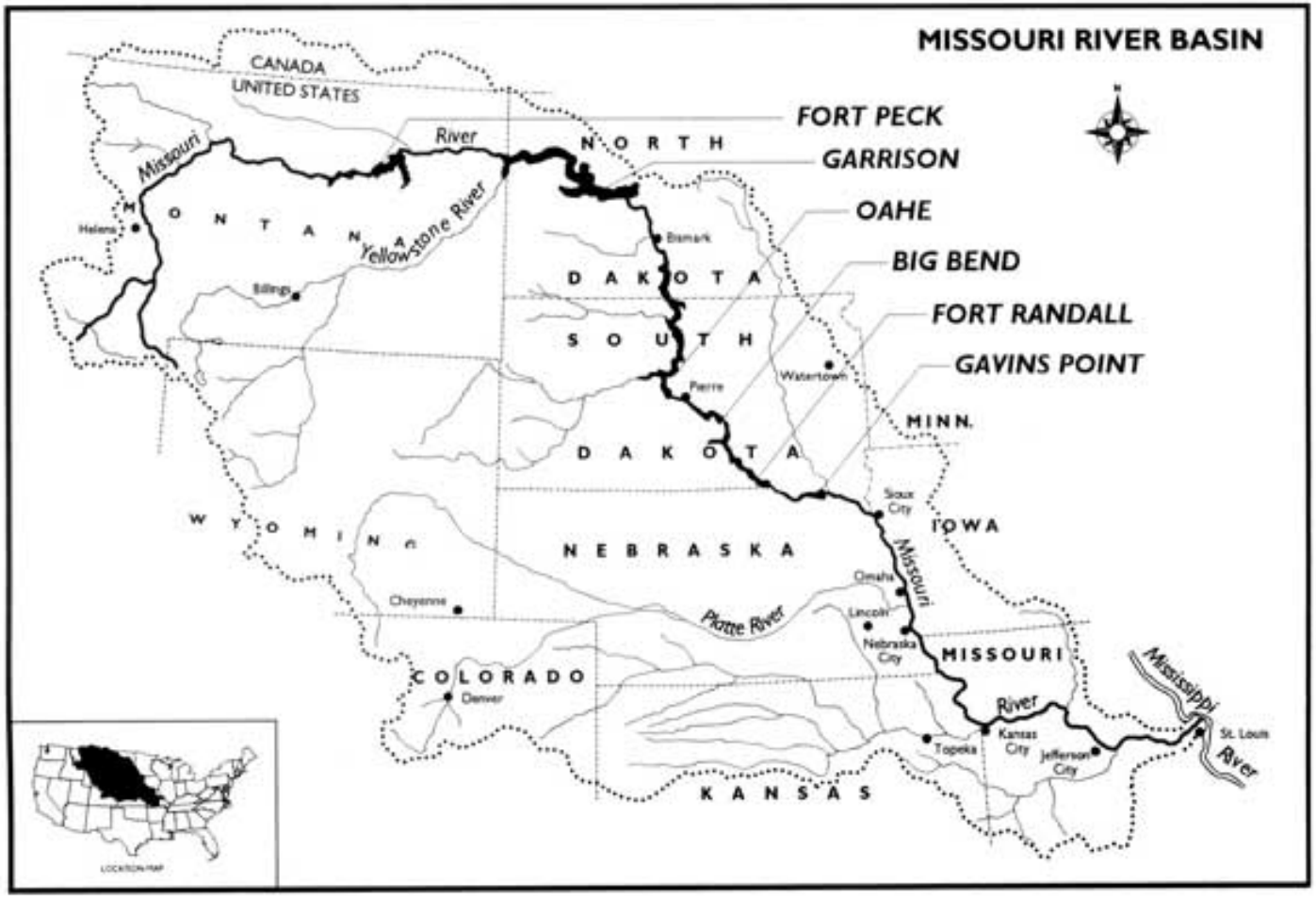

Figure 1-1: Map of the Missouri River Basin and its six mainstem dams (Missouri Department of Natural Resources 2008).

Chapter 2.

Macroinvertebrate composition and abundance in the Missouri River downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska.

Abstract

Macroinvertebrates were collected from the Missouri River at three sites downstream of Fort Randall and Gavins Point dams from June through October of 2005 and 2006 to evaluate spatial and temporal patterns in abundance and habitat associations. Macroinvertebrates were collected in shallow waters using Surber samplers and Hester-Dendy substrate samplers. Macroinvertebrates drifting near bottom and within the water column were collected with a 0.5-m conical zooplankton net. Benthos was collected with a ponar dredge and Hesse sampler. Fort Randall Dam sites included Boyd (upstream), Verdel (middle), and Delta (downstream). Gavins Point Dam sites included James (upstream), Clay (middle), and Ponca (downstream). Over 60 macroinvertebrate taxa were collected in 2005 and 2006 downstream of Fort Randall and Gavins Point dams. The most abundant families collected in both reaches were Chironomidae, Ceratopogonidae, Isonychiidae, Baetidae, Caenidae, Heptageniidae, Hydropsychidae, and Polycentropodidae. Rare taxa (< 1% composition by number) collected only in the Fort Randall reach in 2005 included Tipulidae, Pteronarcyidae, and Nemouridae; and Tipulidae, Perlidae, Pteronarcyidae, and Calopterygidae in 2006. Rare taxa collected only in the Gavins Point reach in 2005 included Chaoboridae, Empididae, Psychodidae, and Polymitarcyidae; and Chaoboridae, Empididae, and Isopoda in 2006.

Jaccard's similarity matrices indicated that adjacent sites were generally most similar to each other. Additionally, sites downstream from tributaries were most similar to other sites influenced by tributaries. The Delta site was unique compared to all the other sites in the Fort Randall and Gavins Point reaches with generally < 45% similarity of macroinvertebrate composition in shallow water habitats and < 60% similarity in main channel habitats.

Mean richness, diversity, and evenness of macroinvertebrates were generally higher in the Gavins Point reach for each gear; however, mean richness, diversity, and evenness from the Surber sampler were highest in the Fort Randall reach. Within the Fort Randall reach, mean richness, diversity, and evenness were generally highest in the Delta. These metrics tended to be highest at Ponca or near the James River in the Gavins Point reach. In both reaches during 2005, mean richness was significantly higher in the summer for most gears. Mean richness in 2005 and 2006 from the Hester-Dendy samples was highest in the spring. Mean richness trends in 2006 differed from 2005 with highest mean richness observed in fall for most gears. Shannon's diversity index for both years was significantly higher in the fall and summer for most gears. Diversity in column drifts in 2005 was highest in the spring and summer. In 2005 and 2006, diversity sampled with Hester-Dendy samplers was highest in the spring. Evenness was typically highest in the summer in 2005 and 2006 for most gears; however, evenness was highest in the spring for the Hester-Dendy substrate samplers.

Compared to the Fort Randall reach, mean densities of macroinvertebrates were generally higher in the Gavins Point reach for each gear. In 2005, mean densities tended

to be highest at the Delta and James sites. In 2006, mean densities tended to be highest at Delta, James, and Ponca sites. Although not always significant, in 2005, mean densities from each gear were generally higher in the summer and fall; however, mean densities from the Hester-Dendy and column drift net samples were generally highest in the spring. In 2006, mean densities were generally higher in the fall followed by the summer for each gear. Like 2005, mean densities were highest in the spring for the Hester-Dendy samplers during 2006.

This study showed the importance of braided and secondary connected channel habitats for macroinvertebrates. In the Fort Randall reach, mean densities of Diptera, Ephemeroptera, and Trichoptera in 2005 for each gear were generally higher in braided and secondary connected channels compared to the main channel. In 2006 mean density of Diptera, Ephemeroptera, and Trichoptera for each gear was generally highest in braided and outside bends in the Fort Randall reach. Mean density of Diptera, Ephemeroptera, and Trichoptera in the Gavins Point reach in 2005 for each gear was generally highest in channel crossovers and inside bends. However in 2006, mean densities of these three orders for each gear were generally highest in inside and outside bends in the Gavins Point reach. Densities of all taxa (except Chironomidae) were generally highest at the most downstream sites within each reach (Delta and Ponca) where water level and temperatures were more stable compared to the upstream sites. Densities were also generally highest at sites influenced by major tributaries, the Delta site in the Fort Randall reach and James and Ponca sites in the Gavins Point.

Introduction

There is a lack of historical information regarding macroinvertebrate communities on the Missouri River before the construction of the six mainstem dams. However, since impoundment, macroinvertebrates have been sampled throughout the Missouri River in both channelized (Carter et al. 1982; Poulton 2004; Lee 2007) and unchannelized portions of the river (Dixon 1986; Troelstrup and Hergenrader 1990; Mizzi and Berry 1994; Berry 1996; Megargle 1997). Macroinvertebrates are important in aquatic food chains (Wilhm et al. 1978; Fisher et al. 2001) and are prey for many fish, shorebirds, and waterfowl (Held 1969; Anderson and Smith 1996). Two endangered species in the Missouri River, the pallid sturgeon *Scaphirhynchus albus* and the interior least tern *Sterna antillarum* rely on macroinvertebrate prey for part of their life cycles (Wanner et al. 2007; Lee 2007).

Power peaking by hydroelectric dams generally produces a diel cycle of water-level fluctuation downstream, with maximum flows during the day when demand for electrical power peaks, and minimum flows at night when demand is lowest. The serial discontinuity concept views impoundments as major disruptions to the longitudinal resource gradients, resulting in an upstream to downstream shift in both biotic and abiotic processes (Ward and Stanford 1995). Physical variables within a system are a continuous gradient of conditions including width, depth, velocity, and temperature (Vannote et al. 1980). Large rivers receive inputs of fine particulate organic matter (FPOM) from upstream processing of leaves and woody debris by macroinvertebrates. Typically from headwaters to the mouth, invertebrate communities shift from dominance of shredders

and collectors to primarily collectors (Vannote et al. 1980). This gradation is due to the function of the feeding groups; shredders utilize coarse particulate organic matter (CPOM), while collectors filter or gather particles from sediments and FPOM (Merrit and Cummins 1996).

Macroinvertebrate communities may be influenced by fluctuating discharge (Modde and Schmulbach 1977; Carter et al. 1982; Troelstrup and Hergenrader 1990; Berry 1996; Megargle 1997). Modde and Schmulbach (1977) found that monthly changes in discharge from Gavins Point Dam affected the accessibility (drifting speed) of invertebrates, as well as the number and kinds of invertebrates in the drift and benthos. In the channelized Missouri River, Carter et al. (1982) indicated that river flow was a regulating factor in the development of benthic populations near two nuclear power stations in the Missouri River in Nebraska. However, no evidence of a relationship was found between macroinvertebrate density, biomass, and discharge in the Missouri River upstream from Fort Peck Reservoir, Montana (Megargle 1997). In the Missouri River downstream of the Fort Randall and Gavins Point dams in South Dakota and Nebraska, Troelstrup and Hergenrader (1990) found that artificial substrate samplers downstream of Gavins Point Dam were colonized in higher numbers compared to samplers placed downstream of Fort Randall Dam. However, when discharge was stable, the samplers downstream of Fort Randall Dam collected higher numbers of taxa (Troelstrup and Hergenrader 1990). In the Missouri River downstream of Gavins Point Dam, benthic and drifting invertebrate composition and quantity were compared among discharge levels and among three macrohabitats (Berry 1996). Differences among years in benthic

invertebrate biomass suggested a negative relationship between discharge and benthic biomass. In addition, benthic biomass was significantly higher in the low and medium-flow years than in the high-flow year (Berry 1996).

Studies on benthic and drifting macroinvertebrates in the Missouri River have focused on differences in benthic biomass in different riverine macrohabitats. Several studies have shown that backwater and chute habitats have been important for macroinvertebrates (Dixon 1986; Mizzi and Berry 1994; Megargle 1997). In main channel benthos, shoreline, and side channel macrohabitats upstream from Fort Peck Reservoir, in Montana, Ephemeroptera dominated macroinvertebrate communities in relative number and weight, followed by Trichoptera, Diptera, and Plecoptera (Megargle 1997). Mizzi and Berry (1994) found that backwaters had greater species richness, followed by main channel borders in the Missouri River in North Dakota. In the unchannelized Missouri River downstream of Gavins Point Dam, a study on clinging invertebrates found that mean biomass and production was highest in chute habitats followed by main channel borders and backwater areas, which had considerably lower production (Dixon 1986). Density was highest in main channel borders; however, in backwater areas and chutes density decreased by half (Dixon 1986). The main orders collected by Dixon (1986) were Diptera, Ephemeroptera, and Trichoptera. In backwater habitats, Diptera, especially Chironomidae, made up 41% of all invertebrates collected and represented 65% of the total production while Ephemeroptera made up < 5% of all invertebrates collected and only 14% of production (Dixon 1986). Trichoptera made up > 50% of all invertebrates collected and represented 85% of the total production in both

chute and main channel border habitats (Dixon 1986). Fisher et al. (2001) found that Chironomidae was an important trophic link conveying energy from primary producers to consumers in a large Missouri River backwater in North Dakota.

Seasonally, macroinvertebrate biomass was found to generally be highest in the late spring and early summer (Carter et al. 1982; Berry 1982; Poulton 2004). In the channelized Missouri River macroinvertebrate communities near two nuclear power stations in Nebraska had higher densities on multi-plate samplers in the early summer than in mid-autumn (Carter et al. 1982). In the Lisbon Bottom wetlands in the lower Missouri River flood plain, the number of macroinvertebrate taxa peaked in mid- to late May after water levels had stabilized (Poulton 2004). Berry (1996) reported higher drift biomass of macroinvertebrates in the Missouri River occurred in the summer compared to the spring and fall during 1994.

This was the first study to look at assemblage richness, diversity, evenness, density, and habitat associations of macroinvertebrates in the braided delta formed in the former headwaters of a reservoir in the unchannelized Missouri River downstream of Fort Randall Dam. Additionally, this study was the first to focus on spatial variation in macroinvertebrate assemblage and abundance between reaches and within each reach in shallow and main channel habitats. Other studies focused on one reach (Modde and Schmulbach 1977; Berry 1996), or one site in each reach (Troelstrup and Hergenrader 1990). Thus, the objectives of this study were to 1) compare macroinvertebrate assemblages, abundance and distribution downstream of the Fort Randall and Gavins

Point dams, 2) assess temporal variation in macroinvertebrate assemblages, abundance, and distribution, and 3) to describe habitats important for macroinvertebrates.

Study Area

The study area included two unchannelized reaches of the Missouri River downstream of two mainstem dams (Figures 2-1 and 2-2). The Fort Randall reach extended from Fort Randall Dam (river kilometer [rkm] 1,416) downstream to Springfield, South Dakota (rkm 1,340). The Gavins Point reach extended from Gavins Point Dam (rkm 1,305) downstream to Ponca, Nebraska (rkm 1,213). Four 250-m transects for each site were randomly selected from topographic maps sectioned off into 6 km areas surrounding an upstream, middle, and downstream locations. Shallow water and main channel habitats were sampled along transects, which made a cross-section of the river from shoreline to shoreline.

Habitats were classified into two hierarchical categories, macrohabitat and mesohabitat based on Drobish (2006). Macrohabitats included outside bends, inside bends, secondary connected channels, tributary confluences, and channel crossovers. Mesohabitats found within each macrohabitat included bars, pools, the channel border, and thalweg. The outside bend is the concave side of a river bend and the inside bend is the convex side of the river. Secondary connected channels possess an upstream and downstream connection to the main channel allowing water to flow but at volumes less than the main channel. A confluence extends downstream of the junction of a tributary for up to one river bend in length. Lastly, a channel crossover is where the thalweg

crosses from one concave side of the river to the other concave side (Figure 2-3). Bars are sand bar or shallow shoreline areas of sediment deposition at the terrestrial/aquatic interface found at depths < 1.2 m. Pools are found directly downstream of bars or obstructions that form scour holes deeper than 1.2 m. Channel borders are found along a shoreline or sandbar area between the maximum depth and 1.2 m depth. The thalweg is the deepest part of the main channel between the channel borders and conveys the majority of the flow.

The Fort Randall reach included three sites; each site encompassed approximately 6 km of the river. The most upstream site was located at Sunshine Bottoms (rkm 1,394) and extended to just downstream of the Boyd County, Nebraska boat ramp (rkm 1,387), herein referred to as the Boyd site. The middle site was located upstream of the Verdel boat ramp (rkm 1,376) to downstream of the Ponca Creek confluence (rkm 1,370), herein referred to as the Verdel site. The lowest site was located 3 km upstream and downstream of the Santee boat ramp on the Nebraska side (rkm 1,335), and 3 km upstream and downstream of the Springfield boat ramp (rkm 1,340) on the South Dakota side, herein referred to as the Delta site. This lower site is unique because it was within a large braided delta that formed as a result of sedimentation from the Niobrara River and is gradually expanding downstream into Lewis and Clark Lake (Kaemingk et al. 2007; Klumb 2007).

The Gavins Point reach included upstream, middle, and downstream sites of 6 rkm each. The upper site was located upstream of the St. Helena, Nebraska boat ramp (rkm 1,285) to the downstream tip of James River Island, herein referred to as the James

site. The middle site was located upstream to Goat Island downstream to the Clay County, South Dakota boat ramp (rkm 1,257), herein referred to as the Clay site. The lowest site was located upstream and downstream of the Ponca State Park, Nebraska boat ramp (rkm 1,213), herein referred to as the Ponca site. Ponca State Park is just upstream of where the Missouri River becomes channelized for navigation at Sioux City, Iowa.

Fort Randall and Gavins Point dams regulate discharge, which has altered the historical hydrograph in these riverine sections (Pegg et al. 2003; Jordan et al. 2006). Mean daily discharge in January through December 2005 ranged from 138 to 770 m^3/s from Fort Randall Dam and 254 to 736 m^3/s from Gavins Point Dam (Figure 2-4). Mean daily discharge in January through December 2006 ranged from 133 to 957 m^3/s from Fort Randall Dam and 254 to 892 m^3/s from Gavins Point Dam (Figure 2-5). Water levels fluctuate > 0.75 m daily downstream of Fort Randall Dam whereas daily outflows downstream of Gavins Point Dam are relatively constant (Klumb 2007). Discharge has also altered water temperatures and changed sediment and nutrient transport (USGS 1998).

Hypolimnetic water releases from Fort Randall Dam have caused lower water temperatures compared to downstream of Gavins Point Dam (Klumb 2007). Annual water temperatures in both reaches were recorded to the nearest 0.01°C every 30 min with submersible data loggers deployed at each site during 2005; however, in 2006 water temperatures were not available downstream of Gavins Point Dam due to low water levels. Water temperatures during June through October rarely exceeded 25°C in the Fort Randall reach. In late July through August, mean water temperatures only exceeded

24°C in inside bends and braided habitats found in the Delta in the Fort Randall reach, while mean water temperatures in all habitats and sites in the Gavins Point reach commonly exceeded 25°C (Figures 2-6 to 2-14). Water temperatures in 2005 were similar to water temperatures in 2006 in all habitats in the Fort Randall reach.

Methods

Macroinvertebrate assemblages

Macroinvertebrate samples were collected in the Missouri River downstream of the Fort Randall and Gavins Point dams on four randomly selected transects at each site. In both reaches sampling occurred on three occasions during 2005: June 2-17, August 1-12, and September 26 through October 6. In 2006, new transects at each study area were randomly selected and sampled on three occasions: June 5-13, July 31 through August 6, and September 28 through October 15. The sampling goal was 8-10 shoreline samples per site and 12-14 main channel samples per site.

Macroinvertebrates were sampled in shallow water using Hester-Dendy artificial (14 plate) substrate samplers and a Surber sampler. Total exposed surface area of Hester-Dendy samplers was approximately 0.13 m^2 (Hester and Dendy 1962). Hester-Dendy samplers were set so they remained constantly under water for 50 to 60 d to allow colonization by macroinvertebrates (Hilsenhoff 1969; Wilhm et al. 1978; Turner and Trexler 1997), recollected, and preserved with a ~10% concentration of formalin. The number of usable Hester-Dendy samples varied due to 1) vandalism at some sites, 2) lost samplers, or 3) water level fluctuations rendering the samples useless. A standard Surber

sampler (500-µm mesh, area = 0.09 m^2) was modified with a PVC pipe handle allowing for sampling in waist deep water. The Surber sampler was faced upstream to allow the current to deploy the net while an extendable three-pronged rake disrupted the substrate within the sample area. Surber samples were preserved in 70% ethyl alcohol. Density of shallow water macroinvertebrates collected with Hester-Dendy and Surber samplers was calculated as number/m^2.

Deep-water sampling for drifting macroinvertebrates was conducted using a 500-µm, 0.5-m diameter, 3-m length conical plankton net in the water column and along the river bottom. Samples were collected at 0.25, 0.50, and 0.75 times the channel width. The drift net had a 23-kg (50-lb) lead weight attached to the bottom of the net and a mechanical flow meter attached in the center of the net to calculate the volume of water filtered. To collect invertebrates drifting along the bottom, herein called bottom drifts, the net was deployed to the bottom and set for 1 - 10 min depending on detritus loads. An integrated water column sample of the drift, herein called a column drift, consisted of lowering the net to the bottom and immediately retrieving the net. Time (minutes) was recorded as the net was deployed to the bottom and retrieved to the surface for both bottom and column drifts. The drift samples were preserved in 70% ethyl alcohol. Density of drifting macroinvertebrates was calculated as number/100 m^3.

Deep-water sampling for benthic macroinvertebrates was conducted using a ponar dredge and Hesse substrate sampler. Samples were collected at the same locations as the drift samples. The ponar dredge had a scoop volume of 8,200 mL, and a sampling area of 0.01 m^2. In areas where the ponar dredge did not adequately collect a sample after three

attempts the sample was collected using a Hesse substrate sampler. The Hesse substrate sampler was a 61 cm long x 10 cm diameter metal pipe that was dragged along the bottom. Benthos samples were preserved in 10% formalin. Substrate samples were processed for benthic macroinvertebrates using a sugar solution. Macroinvertebrates were floated out of the substrate to the surface of each sample after soaking for approximately 20 minutes (Anderson 1959). Density of benthic macroinvertebrates was calculated as number of macroinvertebrates/10 kg sediment.

Macroinvertebrates were identified to genus when possible using Merrit and Cummins (1996), Voshell, Jr. (2002), Triplehorn and Johnson (2004), Thorp and Covich (2001), and Wiggins (2000). All Chironomidae were only identified to family. Terrestrial insects and adult life stages were kept separate from aquatic life stages (nymphs).

Community composition and diversity

Each reach was divided into three sites along a longitudinal gradient (upper, middle, and lower sites). Species density was calculated for each site and reach (Wilhm 1970), allowing comparisons to be made between the Fort Randall and Gavins Point reaches, and between upstream, middle, and downstream sites. Macroinvertebrate assemblage composition and density were also compared spatially among three seasons (spring, summer, and fall) sampled both years. Spring samples were collected in June, summer samples were collected in August, and fall samples were collected in late September and early October.

Similarity of macroinvertebrate assemblages was compared using Jaccard's Coefficients for each gear for both years sampled to create Jaccard's similarity matrices (Kwak and Peterson 2007). Jaccard's similarity matrices were used to determine similarities among sites in both reaches based on presence or absence of a given family sampled. Families were used due to the difficulty in identification of many invertebrates to lower taxonomic levels. Each site was treated as a station in order from most upstream site to most downstream site. Jaccard's Coefficient (C_{jk}) was calculated as:

$$C_{jk} = p/(p+m)$$

where p = the number of families present in both assemblages and m is the number of families present in one assemblage but not the other (Kwak and Peterson 2007). Jaccard's Coefficients vary from 0 to 1, with 0 indicating no families in common and 1 indicating identical family composition.

In each reach during 2005 and 2006, assemblage richness, Shannon's diversity index, and evenness were calculated for each gear. Richness is a count of the number of species represented in an assemblage, expressed at genus, family, or other taxonomic level. For this study genus was used to classify assemblage richness. Shannon's diversity index was calculated based on the total number of individuals for each macroinvertebrate genus for each sample. Shannon's diversity index (H') was calculated as:

$$H' = -\sum_{i=1}^{s} (p_i)(\log_e p_i)$$

where s = the number of genera, and p_i = the proportion of the total sample represented by the ith genus (Kwak and Peterson 2007). Evenness (J') was calculated from Shannon's diversity index as:

$$J' = H' / H'max = H' / \log_e s$$

where $H'_{max} = \log_e s$ = maximum possible value of Shannon's index, s = the number of species, and H' = Shannon's diversity index (Kwak and Peterson 2007). Evenness ranged from 0 (low) to 1 (high). Low evenness (J' = 0) indicated high single-species dominance, and high evenness (J' = 1) indicated equal abundance of all species. Assemblage richness, diversity, and evenness were analyzed with SAS 9.1 software using a three-factor repeated measure analysis of variance (ANOVA) with reach, site, and season as grouping factors. Season was used as a repeated measure. Interactions analyzed included: reach*site, reach*season, site*season, and reach*site*season. Duncan's multiple-range test was used for post-hoc comparisons of factor level means within significant factors and controlled for type 1 comparison wise errors. Analysis was done separately for each gear and for each year sampled. All statistical analyses were considered significant at $P \leq 0.05$.

Macroinvertebrate abundance

Macroinvertebrate density was analyzed using SAS 9.1 software, comparing density of the six most common taxa at the family level. A three-factor repeated measures ANOVA (Cody and Smith 1997) was used with grouping by reach, site, and season for both reaches pooled. Season was used as a repeated measure. Interactions

analyzed included reach*site, reach*season, site*season, and reach*site*season. A Duncan's multiple-range test was used to compare means within significant factors. Multiple samples taken in each transect were used as sub-samples for each gear type. Analyses were done separately for each gear and for each year sampled. All statistical analyses were considered significant at $P \leq 0.05$.

Macroinvertebrate habitat associations

To determine which habitats were important for macroinvertebrates richness, Shannon's diversity, and evenness were calculated and described graphically by habitat type for each gear in the Fort Randall and Gavins Point reaches during 2005 and 2006. Mean densities for Diptera, Ephemeroptera, and Trichoptera were described by habitat type for each gear to determine relative importance of habitats for macroinvertebrates. Additional habitat variables measured at each sampling location included: water temperate (C), water depth (m), dissolved oxygen (mg/L), turbidity (NTU), and surface velocity (m/s).

Results

Macroinvertebrate assemblages

Fort Randall

For each of three sites downstream of Fort Randall Dam > 140 macroinvertebrate samples were collected in the Missouri River during 2005 and 2006 (Table 2-1). In 2005, 527 samples were collected downstream of Fort Randall Dam; 179 in the spring, 189 in

summer, and 159 in the fall. In 2006, 517 samples were collected of which 175 were collected during spring, 185 in summer, and 155 in fall. Fewer Hester-Dendy plate samplers were recovered in 2006 due to lowered water levels. In 2005, a total of 9,984 individuals were collected using these six gears (Table 2-2; Appendix A). In 2006, a total of 8,318 individuals were collected (Table 2-3; Appendix B).

Fifty-one taxa were collected in 2005 and 48 taxa were collected in 2006 downstream of Fort Randall Dam. The primary orders collected in the Fort Randall reach were Diptera, Ephemeroptera, and Trichoptera. The most abundant families collected in 2005 and 2006 included: Chironomidae, Ceratopogonidae, Baetidae, Caenidae, Heptageniidae, Hydropsychidae, and Polycentropodidae (Appendices A and B). Rare taxa (i.e., $\leq$ 1% of the samples) included Tipulidae (N = 2), Pteronarcyidae (N = 10), and Nemouridae (N = 1) in 2005. Rare taxa collected in 2006 included Tipulidae (N = 1), Perlidae (N = 3), Pteronarcyidae (N = 5), and Calopterygidae (N = 1).

Percent composition of macroinvertebrate taxa differed between shallow water and main channel habitats during summer 2005 and 2006 (Figure 2-15; Appendices C - G). Diptera composed approximately 50% the Surber sampler and bottom drift net samples. Ephemeroptera occurred in low numbers composing < 30% of the overall samples but were most commonly collected in shallow water habitats with a Surber sampler and Hester-Dendy plate sampler. In both years sampled, Diptera represented over 90% (by number) of the benthic invertebrates collected in ponar dredge samples (Figure 2-15). Hester-Dendy plate samplers collected more Trichoptera (>70% by number) than Diptera or Ephemeroptera, and collected the highest percent of

Trichopterans for any gear (Figure 2-15). Additionally, larval and small juvenile fishes were collected with the Surber samplers and bottom drift nets.

Gavins Point

For each of three sites downstream of Gavins Point Dam > 120 macroinvertebrate samples were collected in the Missouri River during 2005 and 2006 (Table 2-1). In 2005, 499 samples were collected downstream of Gavins Point Dam; 176 in the spring, 175 in summer, and 148 in the fall. In 2006, 410 samples were collected of which 159 were collected during spring, 143 in summer, and 108 in the fall. Fewer Hester-Dendy plate samplers were recovered in 2006 due to lowered water levels. In 2005, a total of 33,943 individuals were collected using these six gears (Table 2-2; Appendix A). In 2006, a total of 11,190 individuals were collected (Table 2-3; Appendix B).

Fifty-four taxa were collected in 2005 and 48 taxa were collected in 2006 downstream of Gavins Point Dam. The primary orders collected were Diptera, Ephemeroptera, and Trichoptera. The most abundant families collected in 2005 and 2006 included: Chironomidae, Ceratopogonidae, Isonychiidae, Baetidae, Caenidae, Heptageniidae, Hydropsychidae, and Polycentropodidae (Appendices A and B). Rare taxa (i.e., $\leq$ 1% of the samples) included Chaoboridae (N = 3), Empididae (N = 1), Psychodidae (N = 8), and Polymitarcyidae (N = 12) in 2005. Rare taxa collected in 2006 included Chaoboridae (N = 1), Empididae (N = 5), and Isopoda (N = 3).

Percent composition of macroinvertebrate taxa differed between shallow water and main channel habitats similar to that observed in the Fort Randall reach (Figures 2-15

and 2-16; Appendices H - L). Diptera composed approximately 30-40% of the Surber sampler and bottom drift net samples. Ephemeroptera occurred in low numbers composing < 30% of the overall samples, but were most commonly collected with the Hester-Dendy plate samplers in shallow water. In both years, Diptera represented > 65% of the benthic invertebrates collected in ponar dredge samples (Figure 2-16). Hester-Dendy plate samplers collected more Trichoptera compared to Diptera and Ephemeroptera, > 85% of total numbers collected were Trichoptera (Figure 2-16). Additionally, larval and small juvenile fishes were collected with the Surber samplers and bottom drift nets.

Community composition and diversity

Jaccards similarity coefficients indicated that the Delta site was unique compared to all the other sites in the Fort Randall and Gavins Point reaches with generally < 45% similarity of macroinvertebrate composition in shallow water habitats (Tables 2-4 and 2-5) and < 60% similarity in main channel habitats (Tables 2-6 to 2-8). In general, similarity was highest for adjacent sites within each reach (Tables 2-4 to 2-8). Shallow water sampling gears showed that the most downstream sites in each reach were most similar to each other; this was also the case for the macroinvertebrate assemblage drifting in the water column (Tables 2-4, 2-6, and 2-8). Additionally, similarity was generally highest between sites influenced by tributaries. The two downstream sites in each reach (Delta and Ponca) are also downstream of the confluences of major tributaries, the

Niobrara River in the Fort Randall reach and the James and Vermillion rivers in the Gavins Point reach.

Mean invertebrate taxa richness tended to be higher in the Gavins Point reach for most gears in 2005 and 2006 compared to the Fort Randall reach. In shallow water habitats, mean taxa richness was significantly higher in the Gavins Point reach for multi-plate samplers in 2005 and 2006 (Figure 2-17). However, mean taxa richness in the Fort Randall reach from Surber samplers in 2005 and 2006 was similar to mean taxa richness found in the Gavins Point reach. In 2005 and 2006, in the Gavins Point reach, mean taxa richness exceeded five, which was the highest mean richness observed for all shallow water gears. Mean taxa richness in the Fort Randall reach rarely exceeded three for both shallow water gears in 2005 and 2006. Mean invertebrate taxa richness in main channel gears was significantly higher in the Gavins Point reach for all gears in 2005 and most gears in 2006. In bottom and column drift net samples, mean richness was significantly higher in the Gavins Point reach for both years sampled (Figure 2-17). Mean benthic invertebrate richness was significantly higher in the Gavins Point reach in 2005; however, mean benthic taxa richness in the Fort Randall reach was similar to mean richness in the Gavins Point reach in 2006. Bottom drift nets had the highest mean taxa richness of all the main channel gears.

Mean taxa richness generally increased from upstream to downstream in each reach in both shallow water and main channel habitats in 2005 and 2006. In the Fort Randall reach, mean taxa richness was generally highest in the Delta for each gear type used in 2005 and 2006 (Figure 2-18). In the Gavins Point reach, mean taxa richness was

generally highest at the Ponca site for each gear type used in 2005 and 2006 (Figure 2-19). Mean taxa richness in shallow water gears was highest at the most downstream site in Fort Randall reach for Surber samplers in 2005 and for Surber samplers and Hester-Dendy plate samplers in 2006. In the Gavins Point reach, mean richness did not differ among sites in 2005 or 2006 in shallow water habitats. Mean taxa richness of drifting macroinvertebrates along the bottom and within the water column was highest at the most downstream site in both reaches during 2005 but did not differ among sites within each reach during 2006. Mean benthic taxa richness from ponar dredge samples did not vary among the three sites in the Fort Randall reach during both years but was significantly lower at the most downstream site in the Gavins Point reach during 2005.

Seasonal variation in mean taxa richness in both reaches (pooled) was generally highest during summer and fall sampling periods. In 2006, mean taxa richness was significantly higher in the fall for most gear types. In 2005 and 2006, mean taxa richness in the summer and fall was generally > 2; however, mean richness in the spring was < 2 for most gears (Figure 2-20). Mean taxa richness calculated from Hester-Dendy samples was significantly higher in the spring (> 4) than in the summer (< 4) for both years (Figure 2-20).

Shannon's diversity index generally did not differ between reaches, especially for shallow water gears in 2005 and 2006. Diversity of macroinvertebrates in shallow water habitats in the Fort Randall reach were similar to the diversity in the Gavins Point reach in both years sampled. Shannon's diversity index calculated from main channel gears was highest in the Gavins Point reach in 2005 and 2006, especially for bottom and

column drifting invertebrates (Figure 2-17). Benthic diversity from ponar dredge samples was similar between reaches. Hester-Dendy plate samplers had the highest diversity in the Fort Randall reach (> 0.8) in 2005 and 2006. The bottom drift nets had the highest diversity in the Gavins Point reach (> 0.9) in 2005 and 2006.

For all gears there was a general increasing trend in Shannon's diversity index from upstream to downstream within the Fort Randall and Gavins Point reaches. In the Fort Randall reach, Shannon's diversity index in shallow water gears was highest in the Delta in 2005 and 2006 (Figure 2-18). In Surber samplers, diversity in shallow water was lowest at the most upstream site (< 0.1) in the Fort Randall reach during both years. Diversity of bottom and column drifting invertebrates was highest at the Delta in the Fort Randall reach in 2005. In 2006, column drifting invertebrates and diversity in benthic samples generally did not vary among sites in the Fort Randall reach. In 2005 and 2006, diversity from shallow water gears was generally highest at Ponca in the Gavins Point reach. Diversity of benthic samples was highest at the most upstream site by the James River (Figure 2-19). In the Fort Randall reach the bottom drifts had the highest diversity in 2005 (1.3), in the Gavins Point reach the Hester-Dendy plate sampler had the highest diversity of all the gears in 2005 and 2006 (> 1.2).

Shannon's diversity index in both reaches (pooled) varied seasonally and was generally highest during fall and summer for most gears in 2005 and 2006. However, diversity in the summer and fall did not differ in 2005 or 2006. In 2005, Shannon's diversity index calculated from column drift net samples in main channel habitats were significantly higher in the spring and summer compared to the fall. Shannon's diversity

index calculated from Hester-Dendy samples was significantly higher in the spring for both years (Figure 2-20).

Trends in evenness differed between reaches and was generally > 0.4 for the Gavins Point reach but was often < 0.4 for the Fort Randall reach (Figure 2-17). Compared to the Fort Randall reach, evenness was significantly higher in the Gavins Point reach for bottom and column drifting macroinvertebrates in 2005 and 2006, and for benthic invertebrates in 2006 (Figure 2-17). In shallow water habitats, evenness was generally higher in the Fort Randall reach in 2005 and 2006 for Hester-Dendy samples compared to the Gavins Point reach (Figure 2-17).

There was a general increasing trend of evenness from upstream to downstream within each reach in 2005 and 2006. In the Fort Randall reach, evenness was highest in the Delta for shallow water gears and bottom and column drifting invertebrates in 2005 and 2006 (Figure 2-18). Evenness from column drifts and benthic invertebrate samples did not differ among sites in the Fort Randall reach in 2006. In shallow water Surber samplers, evenness in the Fort Randall reach during 2005 and 2006 was lowest at the most upstream site (< 0.2) near the dam. Although evenness in the Gavins Point reach was 0.1 – 0.3 higher at Ponca compared to upstream sites for shallow water gears in 2005 and 2006 differences were not significant (Figure 2-19). Evenness for drifting macroinvertebrates was similar among sites in the Gavins Point reach for 2005 but 2006 bottom drifts were significantly higher at the Clay site and column drifts were significantly higher at Ponca. Evenness for the benthic main channel samples in 2005

was significantly higher at the Clay site, but did not vary among sites in 2006 (Figure 2-19).

Seasonal variation in taxa evenness for both reaches (pooled) was generally highest in the summer for most gears in 2005 and 2006. Taxa evenness calculated from Hester-Dendy samples did not vary among seasons for both years. Taxa evenness of drifting macroinvertebrates along the bottom and within the water column drifts was highest in the fall (Figure 2-20).

Macroinvertebrate abundance

In shallow water habitats, the six most common families in the Missouri River downstream of Fort Randall and Gavins Point dams during 2005 and 2006 were Chironomidae, Baetidae, Caenidae, Ephemeridae, Hydropsychidae, and Corixidae. Additionally, densities of Isonychiidae, Heptageniidae, and Polycentropodidae from Hester-Dendy multi-plate samplers were also compared (Tables 2-9 and 2-10). There were significant differences between reach, site, season, reach*site, and reach*site*season in 2005 and 2006 for most families. Densities of most taxa in shallow water habitats were generally highest in the Fort Randall reach in 2005 and 2006. However, densities calculated from Hester-Dendy multi-plate samplers were highest in the Gavins Point reach in both years sampled except for Polycentropodidae. Compared to the Gavins Point reach, Chironomidae density was nearly twice as high in the shallow water samples in the Fort Randall reach in 2005. Additionally, Caenidae and Ephemeridae densities were three to four times higher in the Fort Randall reach in 2005

and 2006 compared to densities in the Gavins Point reach. Compared to the Fort Randall reach, most families from Hester-Dendy multi-plate samplers were > 4 times higher in the Gavins Point reach in 2005 and 2006. Hester-Dendy multi-plate samplers consistently collected high densities of Isonychiidae (> 301 Isonychiidae/m^2) in the Gavins Point reach in 2005 and 2006.

Common families in shallow water habitats (Chironomidae, Baetidae, and Hydropsychidae) varied among the six sites and trends were consistent between years but not seasonally. Additionally, densities of Isonychiidae, Caenidae, Ephemeridae, Heptageniidae, Polycentropodidae, and Corixidae were compared among sites and seasons in 2005 and 2006. Most families collected in shallow water habitats with a Surber sampler, especially Chironomidae, Caenidae, and Ephemeridae had higher densities at the Delta site in the Fort Randall reach in both years sampled (Tables 2-9 and 2-10). Densities of Chironomidae calculated from Hester-Dendy multi-plate samplers were similar among most sites but were highest at the Boyd site in the Fort Randall reach during 2005 (> 1,395 Chironomidae/m^2) and in 2006 (> 2,916 Chironomidae/m^2). Hester-Dendy multi-plate sampler densities of Isonychiidae, Baetidae, Heptageniidae, were highest at the Ponca site in the Gavins Point reach in both years. Hydropsychidae was consistently highest at the James and Clay sites in the Gavins Point reach (> 15,000 Hydropsychidae/m^2) in 2005 and 2006. Polycentropodidae density was similar among the James and Fort Randall sites for both years sampled. In general, densities of most familes were twice as high in sites influenced by tributaries (Niobrara, James, and Vermillion rivers). There were no real trends in seasonal variation in macroinvertebrates

density in 2005 or 2006; however, samples collected with the Hester-Dendy multi-plate samplers were highest in the spring for most families.

The most common familes collected in bottom and column drifts in the main channel downstream of Fort Randall and Gavins Point dams in 2005 and 2006 were: Chironomidae, Simulidae, Caenidae, and Hydropsychidae. Additionally, Ceratopogonidae and Isonychiidae were compared between reaches for bottom drifts and Baetidae and Ephemeridae for column drifts in 2005 and 2006 (Tables 2-9 and 2-10). In general, there were significant differences for bottom and column drifting invertebrates between reaches, sites, seasons, reach*site, and reach*site*season in 2005 and 2006. Bottom and column drifting invertebrates generally tended to be highest in the Gavins Point reach for both years sampled, except for Caenidae, which was highest in the Fort Randall reach. The most commonly collected family, Chironomidae, had similar densities in the drift between reaches in both years. Hydropsychidae density was generally two to three times larger in the Gavins Point reach in 2005 and 2006 for both bottom and column drifts.

Densities of drifting macroinvertebrates generally differed among sites, but trends were not consitstent between years and seasons. In general, densities of most taxa were highest at the Delta and James sites for bottom drifts in 2005 and 2006 (Tables 2-9 and 2-10). In 2005, densities in the Delta site were similar to all the sites in the Gavins Point reach for column drift net samples. However, in 2006 density of drifting macroinvertebrates was generally highest at Ponca for most taxa. Chironomidae had similar densities in the drift for James and all sites in the Fort Randall reach. In 2005,

drifting invertebrates from bottom and column drift nets were highest in the spring and in the fall in 2006.

The six most common benthic invertebrate families from the main channel, Chironomidae, Ceratopogonidae, Hydropsychidae, Polycentropodidae, Corbiculidae, and Lymnaeidae generally did not vary between the Fort Randall and Gavins Point reaches in both years sampled (Tables 2-9 and 2-10). There were significant differences in benthic invertebrate densities between reach, site, and reach*site*season in 2005 and 2006. In the Fort Randal reach, densities of all taxa were similar to densities in the Gavins Point reach, except for Corbiculidae in 2005, which was significantly higher (5 times higher) in the Gavins Point reach. In 2006, densities of all taxa in the Fort Randall reach were similar to densities in the Gavins Point reach, except for Chironomidae, which was significantly higher (4 times higher) in the Fort Randall reach. Chironomidae density in 2006 was significantly higher in the Fort Randall reach with four times higher density than in the Gavins Point reach.

In general benthic invertebrates varied among sites but trends were not consistent between seasons or years. For most of the benthic taxa, densities were highest at the Verdel and James sites (Tables 2-9 and 2-10). In 2005, densities of Chironomidae, Hydropsychidae, and Polycentropodidae were similar among all sites in both reaches. In 2006, density of Ceratopogonidae, Hydropsychidae, Corbiculidae, and Lymnaeidae did not differ among sites in either reach. In the Fort Randall reach, Chironomidae and Ceratopogonidae densities were generally twice as high at Verdel compared to the Boyd and Delta sites in 2005 and 2006. Benthic invertebrate densities were similar among

seasons in 2005 and 2006; however, Ceratopogonidae density was significantly higher in the summer and fall of 2005.

Macroinvertebrate habitat associations

Fort Randall

Mean richness was similar among all macrohabitats for all gears in 2005 and 2006 (Figure 2-21). However, mean richness was generally > 2 in braided macrohabitats for all gears in 2005 and 2006 except for column drift net samples in 2006. Mean richness in all other macrohabitats was ≤ 2 for both years sampled.

Shannon's diversity index was generally higher (> 0.6) in braided macrohabitats for all gears in 2005 and 2006 except for 2006 column drifts and the ponar dredge in both years (Figure 2-21). In 2006 column drifts, diversity was highest in the secondary connected channels followed by braided macrohabitats. Diversity in ponar dredges was low (< 0.6) in both years in all macrohabitats. Low diversity in ponar dredges was likely due to the low taxonomic resolution of Chironomidae, the most commonly collected family.

Evenness was typically highest in braided and secondary connected channels for each gear in 2005 and 2006 except the ponar dredge (Figure 2-21). Ponar dredge evenness was similar among habitats in 2005 but high in channel crossovers for 2006. Evenness was highest in secondary connected channels (0.85) in 2006 for Hester-Dendy multi-plate samplers. In 2005, evenness was lowest in inside bends (0.1) for Surber samplers and secondary connected channels (0.1) for ponar dredge samples.

Densities of Diptera, Ephemeroptera, and Trichoptera for each gear were generally similar among macrohabitats or differences among habitats were inconsistent between years. For shallow water gears, densities were generally highest in braided and secondary connected channel habitats in 2005 and outside bends and braided habitats in 2006 (Tables 2-11 and 2-12). In main channel drift along the bottom and in the water column, densities of Diptera were generally highest in inside bends followed by secondary connected channels for both years sampled. In 2005 and 2006 main channel drift net samples, Ephemeroptera was highest in braided habitats. In the main channel benthos, densities of Diptera and Ephemeroptera were highest in channel crossovers and secondary connected channels in 2005; however, in 2006 densities were highest in outside bends. Trichoptera density in main channel benthos was highest in secondary connected channels in 2005 and inside bends in 2006.

Gavins Point

Mean richness was similar among macrohabitats for all gears in 2005 and 2006 (Figure 2-22). In all shallow water macrohabitats, mean richness was < 2 from Surber samplers but was > 5 from Hester-Dendy multi-plate samplers in 2005 and 2006. For all macrohabitats, mean richness in the main channel was generally higher in bottom drift nets (> 2) compared to column drift nets and ponar dredge (< 2). The highest mean richness (7) was from Hester-Dendy multi-plate samplers in secondary connected channels in 2006.

Shannon's diversity index was similar among macrohabitats for all gears in 2005 and 2006 (Figure 2-22). In all shallow water macrohabitats, diversity was < 0.6 from Surber samplers but was > 0.6 from Hester-Dendy multi-plate samplers. In all shallow water macrohabitats, diversity in the main channel was generally > 0.5 for the bottom drift net; however, diversity was generally < 0.5 for column drift nets and the ponar dredge. Diversity was > 1 only in bottom drift nets for inside bends in 2005 and Hester-Dendy multi-plate samplers in inside and outside bends in 2005 and 2006.

Evenness was similar among macrohabitats for bottom drift net, column drift net, and ponar dredge samplers in 2005 and 2006. Evenness was the highest in main channel habitats (> 0.6), especially in the bottom drift nets in braided and secondary connected channel macrohabitats in 2006. Evenness was generally lowest (< 0.5) in all shallow water macrohabitats compared to the main channel.

Densities of Diptera, Ephemeroptera, and Trichoptera generally did not vary among macrohabitats for most gears in 2005 and 2006. In shallow water habitats, densities were > 100 macroinvertebrates/m^2 for all taxa in all macrohabitats for both years. In 2005 and 2006, in main channel habitats densities for all drifting macroinverterates were < 100 macroinvertebrates/100 m^3 in all macrohabitats, except for Diptera (Tables 2-13 and 2-14). Benthic macroinvertebrates in main channel habitats did not vary greatly among macrohabitats with densities generally < 100 macroinvertebrates/10 kg sediment. Hester-Dendy multi-plate samplers collected high densities of Diptera (> 590 Diptera/m^2), Ephemeroptera (> 1,870 Ephemeroptera/m^2), and Trichoptera (> 11,790 Trichoptera/m^2) for shallow waters in all macrohabitats sampled.

Discussion

My study identified 68 macroinvertebrate genera representing 49 families and 21 orders in the Fort Randall and Gavins Point reaches of the Missouri River, South Dakota and Nebraska during 2005 and 2006. Troelstrup and Hergenrader (1990) identified 39 genera representing 16 families and 11 orders in the same reaches of the Missouri River during 1983 and 1984, but they only sampled with a single gear type. Mizzi and Berry (1994) identified 138 species representing 69 families and 18 orders in the upper Missouri River in North Dakota. Families and genera collected in previous macroinvertebrate studies on the Missouri River were similar to those collected in this study. However, my study collected three families, Chaoboridae, Psychodidae, and Polymitarcyidae, not seen in previous macroinvertebrate studies, probably because of different sampling effort and gears. My study and previous studies that included colonizing and benthic macroinvertebrates did not find any aquatic nuisance species, specifically zebra mussels *Dreissena polymorpha* (Carter et al. 1982; Troelstrup and Hergenrader 1990; Mizzi and Berry 1994). My study suggests that there is not an established adult zebra mussel population in the Missouri River downstream of Fort Randall and Gavins Point dams.

I collected drifting invertebrates along the bottom and in the water column during daytime hours when daily water fluctuations occurred, especially downstream of Fort Randall Dam. The diel periodicity of drift (i.e. the downstream transport of organisms in the water column) is an important process in the ecology of stream invertebrates. Numbers in drift are typically low and constant during the day and increase at night for

many invertebrate groups (Minshall and Winger 1968; Kohler 1985; Flecker 1992). Some studies suggested that diel periodicity could be an adaptation to minimize exposure to drift feeding fishes and fluctuations in discharges (Minshall and Winger 1986; Flecker 1992). Due to the diel periodicity of drift, community assemblage and abundance estimates in this study may be lower than they would be if sampling had occurred at night.

According to Wilhm (1970), diversity of macroinvertebrates usually varied between three or four in clear nonstressed streams and was usually less than one in polluted, highly stressed streams. Diversity in the Missouri River in my study was generally 30% lower downstream of Fort Randall Dam compared to the Gavins Point reach, especially for main channel drift. Additionally, diversity was < 1 for both reaches, indicating that the macoinvertebrate community was exposed to stress. Carter et al. (1982) found that diversity indices were low and ranged from 0.75 to 2.91 in the Missouri River, Nebraska. Arscott et al. (2005) found diversity increased in mid-order streams, while headwaters and high-order streams had lower diversity, in a braided floodplain river in Italy, confirming predictions from the river continuum concept (Vannote et al. 1980). According to Reese and Batzer (2007), in a floodplain in the southern United States invertebrate communities changed predictably from upper to lower reaches; upper reaches were dominated by terrestrial taxa and mid reaches were dominated by mayflies and oligochaetes, while lower reaches were dominated by lentic aquatic taxa. Species richness was highest in backwaters (2.8) compared to main channels (0.3) in the Missouri River, North Dakota (Mizzi and Berry 1994). In the Missouri River in North Dakota,

macroinvertebrate diversity was highest (> 1.3) in the upstream reach (Williston reach) for backwater and side channel habitats; however, in the downstream reach (Bismark reach) diversity was highest (> 1.5) in the tributaries (Mizzi and Berry 1994).

In 2005 and 2006, mean density of major taxa collected was generally higher in the Gavins Point reach compared to the Fort Randall reach where daily water levels fluctuate > 0.75 m (Klumb 2007). Gavins Point Dam is managed to re-regulate flow for navigation downstream, as a result diel water levels are relatively stable (Klumb 2007). Other studies have found that diel fluctuations in flow may negatively impact invertebrate density (Gislason 1985; Trotzky and Gregory 1974; Troelstrup and Hergenrader 1990, Blinn et al. 1995). Fluctuating discharge from the dams may change biological, chemical, and physical conditions in the system resulting in stress to organisms intolerant of sub-optimal conditions that cannot drift, or migrate. Discharge from Fort Randall and Gavins Point dams was higher in 2006 compared to 2005 (Figures 2-4 and 2-5). Additionally, downstream of Gavins Point Dam discharge was relatively stable throughout sampling in 2005 compared to downstream of Fort Randall Dam. In the Fort Randall reach, discharge peaked at 770 m^3/s during 2005 and 957 m^3/s during 2006; however, in the Gavins Point reach discharge peaked at 736 m^3/s during 2005 and 892 m^3/s during 2006. Fluctuating flows may result in lower macroinvertebrate densities especially for Trichopterans (Trotzky and Gregory 1974; Gislason 1985). I found Diptera, primarily Chironomidae, to be tolerant of flow fluctuations with higher mean densities in the Fort Randall reach. However, Trichoptera were less tolerant of flow fluctuations with generally 3 – 6 times higher densities in the Gavins Point reach

compared to the Fort Randall reach (Tables 2-9 and 2-10). Comparing macroinvertebrate abundance downstream of Fort Randall and Gavins Point dams, Troelstrup and Hergenrader (1990), used modified Hilsenhoff basket samplers and found that Polycentropodidae, Chironomidae, and Oligochaeta tolerated diel fluctuations downstream of Fort Randall Dam, while Hydropsychidae and Heptegeniidae were extremely intolerant. Troelstrup and Hergenrader (1990) also found that samplers in the Gavins Point reach were colonized by significantly greater numbers of invertebrates (2 – 10 times) than Fort Randall samplers. Trotzky and Gregory (1974) also found Hydropsychidae and Heptageniidae to be extremely intolerant of fluctuating discharges on the upper Kennebec River in Maine.

Macroinvertebrates, especially Chironomidae, are used as an energy resource by secondary consumers, and are important for energy transfer from the detritus and periphyton to secondary consumers (Fisher et al. 2001). Therefore, fish would be expected to generally have high abundance in areas with abundant macroinvertebrates to rely on as a food resource. Spindler (2008) found that pallid sturgeon captures were positively associated with abundance of aquatic macroinvertebrate drift, especially Diptera and Ephemeroptera downstream of Fort Randall Dam. A shallow water fish community study found that generally for all gears used, relative abundance of fish tended to be higher in the Gavins Point reach compared to the Fort Randall Reach (Klumb 2007).

This study was the first to look at assemblage richness, diversity, evenness, and density of macroinvertebrates in the braided delta formed by the Niobrara River in the

headwaters of Lewis and Clark Lake. Although not always significant, in the Fort Randall reach, richness, diversity, evenness, and mean density of major taxa tended to be highest at the Delta site in 2005 and 2006. In addition, Jaccard's similarity matrices showed that the Delta site was unique compared to all the other sites in the Fort Randall and Gavins Point reaches; similarity to other sites was generally < 45% in 2005 and 2006. The Delta provides aquatic habitat similar to the historic Missouri River, such as shallow water habitats, backwaters, shifting sand bars, side channels, and the presence of large woody debris. Sediment transport and habitat formation is present and dynamic in the delta, which increases habitat diversity. Thus, deltas with high species diversity and abundance of macroinvertebrates likely can serve as key feeding areas for fish, especially the endangered pallid sturgeon (Shuman et al. 2006, 2007; Spindler 2008). Kaemingk et al. (2007) reported significantly higher fish species diversity (Fisher's α) in the Niobrara delta compared to Lewis and Clark Lake, and attributed it mainly to higher habitat diversity. Higher numbers of macroinvertebrates and fish in the Delta may also be influenced by inputs from the Niobrara River upstream from the Delta. Klumb (2007) found that median catches of fish in shallow water habitats with minnow traps, bag seines, and mini-fyke nets did not differ significantly between upstream and downstream sites; however, fish abundance was generally highest at the site closest to the Niobrara River and Lewis and Clark Lake. Additionally, water levels in the Niobrara River delta are relatively stable and water temperatures less depressed (0.7 – 1.5^{o}C) compared to the sites upstream that are close to Fort Randall Dam (Klumb 2007).

Although not always significant, in the Gavins Point reach, richness, diversity, evenness, and mean density of major taxa collected was generally highest at the Ponca site followed by the James site in 2005 and 2006. High numbers at the James site may be related to the inputs of nutrients and drifting macroinvertebrates from the James River directly upstream from the James site. The Ponca site may be influenced by another tributary, the Vermillion River. Klumb (2007) found that median catches of fish in shallow water habitats with minnow traps, a bag seine, and mini-fyke nets did not differ significantly between upstream and downstream sites; however, fish abundance was generally highest at the site closest to the James River.

For all gears except the Hester-Dendy, this study found that richness, diversity, evenness, and mean density tended to be highest in the summer and fall in 2005 and 2006. However, richness, diversity, evenness, and mean density from the Hester-Dendy were highest in spring for both years. This seasonality is likely related to the life cycles of each different taxon (Merrit and Cummins 1996). In 2004 and 2005, Lee (2007) found that family richness and diversity were highest in May through August on sandbars in the lower Missouri River. According to Carter et al. (1982), densities and number of taxa in the benthos in the Missouri River in Nebraska were generally lowest in June. Carter et al. (1982) also suggested that benthos densities increased after river flows stabilized in summer.

In 2005 and 2006, mean density of macroinvertebrates did not consistently vary among macrohabitats, which was probably influenced by patchy distributions of macroinverebrate communities and the variability in sampling effort. Mean density of

major taxa collected in Gavins Point reach during 2005 for each gear was generally higher in channel crossovers and inside bends, while in 2006 densities were higher in inside and outside bends. Megargle (1997) found Ephemeroptera, Diptera, Trichoptera, and Plecoptera to be the most commonly collected taxa in the main channel of the Missouri River above Fort Peck Reservoir in Montana. Additionally, the main channel habitat was generally dominated by Ephemeroptera (114 Ephemeroptera/m^2) and Diptera (67 Diptera/m^2), followed by Trichoptera (36 Trichoptera/m^2) and Plecoptera (4 Plecoptera/m^2; Megargle 1997). Similar to my study, Megargle (1997) found that Ephemeroptera generally dominated shallow habitats and side channels. In a study of clinging macroinvertebrates in the unchannelized Missouri River downstream of Gavins Point Dam invertebrate density was highest in main channel borders, with 50% lower densities in chutes and backwater areas (Dixon 1986). Additionally, Trichoptera contributed the highest total production ($\geq$85%) in chutes and main channel border habitats, whereas, Diptera, specifically Chironomids contributed 65% of total production in backwater areas (Dixon 1986). Ephemeroptera made up 14% of production in backwater areas and 6% in other habitats (Dixon 1986). The highest production of invertebrates in the Bazile Creek Wildlife Management Area in Nebraska occurred in side channel habitats, especially for Caenidae, *Hexagenia* spp., and *Neureclipsis* spp. (Mestl and Hesse 1989).

Macroinvertebrate communities are complex in large river systems and require a multiple gear approach to adequately sample all habitats in the river. If Hester-Dendy artificial plate samplers were not used in my study, Trichopterans would have been under

represented in both the Fort Randall and Gavins Point reaches. Several studies incorporated multiple gears to sample main channel and shallow water habitats (Carter et al. 1982; Megargle 1997; Lee 2007). Studies that incorporate only one gear to sample macroinvertebrates (Troelstrup and Hergenrader 1990) are limited when describing the community, especially when macroinvertebrates have a patchy distribution throughout the heterogeneous habitats of large rivers.

In accordance with the River Continuum Hypothesis (Vannote et al. 1980), macroinvertebrate community assemblages were hypothesized to be more diverse in the Gavins Point reach, as well as the most downstream sites within each reach. Additionally, macroinvertebrate abundance was hypothesized to be significantly higher in the Gavins Point reach, as well as the most downstream sites within each reach. These hypotheses were generally supported by my study, especially for Trichoptera. The delta and sites influenced by a major tributary (Delta, James, and Ponca) were found to be important to macroinvertebrates, as shown through a more diverse assemblage and higher densities. In this study, classifying macroinvertebrate community metrics by macrohabitat was not an adequate classification scheme for macroinvertebrates. Sampling effort for each macrohabitat was unequal and macrohabitats available to sample varied among sites in this study. When classifying macroinvertebrates by macrohabitats, extensive sampling is needed in each macrohabitat throughout the study area, and should include various additional habitat measurements for example, substrate composition, water temperature, water depth, water velocity, dissolved oxygen, organic matter, and turbidity.

Channelization and impoundments within the Missouri River have eliminated approximately 90% of shallow water (≤ 1.5 m) habitats by reducing flooding events (Galat et al. 2005). This has modified the ecosystem by decreasing sandbars, depth diversity, and river connectivity to side channels and backwater areas (Hesse et al. 1989; MRNRC 1998). Shallow water areas are important for macroinvertebrates, fish, and shorebirds, especially the endangered pallid sturgeon and the interior least tern; which rely on macroinvertebrate prey for part of their life cycles (Wanner et al. 2007; Lee 2007). For most shorebirds, sandbar habitat in shallow water (< 3 cm deep) with abundant invertebrates are preferred areas for foraging (Lee 2007). Diet data from my study (Chapter 3) and Wanner et al. (2007) have shown aquatic macroinvertebrates, especially Ephemeroptera and Diptera (Chironomidae) as an important component of pallid sturgeon diets, especially for juvenile fish < 600 mm. Spindler (2008) found that juvenile pallid sturgeon habitat use was strongly associated with invertebrate abundance, and developed a model that correctly classified 95% of capture and non-capture locations for pallid sturgeon. My study indicated that shallow water habitats, especially the delta formed by the Niobrara River, are important habitats for macroinvertebrates, having higher abundance and more diverse assemblages. To benefit the pallid sturgeon, interior least terns, and piping plovers modifications to the Bank Stabilization and Navigation Project resulted in the creation of 1,365 acres of shallow water habitat from Gavins Point Dam to Sioux City, Iowa in 2001 to 2003 (USFWS 2003). Habitat restoration and management efforts should incorporate shallow water habitats important for macroinvertebrate production (i.e., the delta). This would allow supplementation of

physical habitat and prey availability in areas currently lacking suitable pallid sturgeon and interior least tern habitats in the Missouri River basin. Combining the information from my study, previous pallid sturgeon studies (Gerrity et al. 2006; Wanner et al. 2007), and Spindler's (2008) habitat assessment tool, would allow managers to monitor populations and locate habitat suitable for stocking juvenile pallid sturgeon so they have the greatest chance at survival.

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Table 2-1: Total macroinvertebrate samples collected from the Missouri River on three occasions in 2005 and 2006 at three sites downstream of Fort Randall and Gavins Point dams for each gear type used. For Hester-Dendy artificial substrate samplers, numbers in parentheses are the total samplers deployed. Not all Hester-Dendy artificial substrate samplers were recovered. Sites in each reach are in order from upstream to downstream.

	Fort Randall			Gavins Point		
Sample type	Boyd	Verdel	Delta	James	Clay	Ponca
			2005			
Hester-Dendy	14 (20)	12 (15)	23 (26)	18 (21)	20 (20)	13 (20)
Surber sampler	29	25	48	33	28	27
Bottom drift	41	36	48	42	42	36
Column drift	41	36	48	42	42	36
Ponar dredge	40	35	48	40	40	34
Hesse sampler	1	2	0	2	2	2
Totals	166	146	215	177	174	148
			2006			
Hester-Dendy	11 (18)	10 (16)	25 (32)	9 (18)	4 (20)	6 (16)
Surber sampler	28	24	48	22	29	25
Bottom drift	39	36	48	31	41	33
Column drift	39	36	48	31	41	33
Ponar dredge	39	36	48	31	41	33
Hesse sampler	0	0	0	0	0	0
Totals	156	142	217	124	156	130

Table 2-2: Total number of individuals collected at three sites with six gears in 2005 in the Missouri River downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska. Sites in each reach are in order from upstream to downstream. Numbers listed by family names could not be distinguished to genus.

	Fort Randall			Gavins Point		
Family and genus	Boyd	Verdel	Delta	James	Clay	Ponca
		Diptera				
Chironomidae	1082	725	1149	1453	1221	1094
Ceratopogonidae	92	127	137	184	231	187
Simuliidae	2	7	78	62	65	71
Chaoboridae						
Chaoborus	0	0	0	3	0	0
Empididae	0	0	0	0	1	0
Psychodidae	0	0	0	8	0	0
Tipulidae	0	0	2	0	0	0
Terrestrial	172	144	148	160	356	238
		Ephemeroptera				
Isonychiidae						
Isonychia	0	1	14	41	50	215
Baetidae						
Baetis	0	0	51	29	129	213
Barbaetis	0	0	2	10	15	26
Procloeon	3	11	27	3	15	24
Unidentifiable	1	0	1	6	0	0
Caenidae						
Caenis	0	17	233	4	11	36
Brachycercus	0	1	7	4	0	2
Cerobrachys	0	0	10	18	13	25
Americaenis	0	0	30	0	2	5
Ephemeridae						
Hexagenia	13	18	95	44	19	13
Pentagenia	0	0	0	0	2	1
Polymitarcyidae						
Ephoron	0	0	0	2	2	8
Heptegeniidae						
Stenacron	0	0	10	15	158	106
Stenonema	6	10	99	93	133	190
Heptagenia	0	0	1	0	0	0

Table 2-2 (Continued).

Family and genus	Fort Randall			Gavins Point		
	Boyd	Verdel	Delta	James	Clay	Ponca
Ephemeroptera						
Heptegeniidae						
Unidentifiable	0	0	5	1	0	0
Tricorythidae						
Tricorythodes	5	10	74	0	20	6
Unidentifiable	0	2	8	1	2	2
Trichoptera						
Hydropsychidae	1	45	6	184	125	65
Hydropsyche	1112	650	783	7698	8411	3923
Ceratopsyche	3	0	3	18	3	22
Cheumatopsyche	20	0	44	541	1364	840
Potomyia	0	0	0	0	0	3
Polycentropodidae	30	15	10	5	0	0
Neureclipsis	335	382	754	244	120	92
Polycentropus	35	45	45	95	55	0
Cyrnellus	0	0	0	5	0	1
Leptoceridae	0	0	0	0	0	0
Oecetis	0	0	7	0	1	0
Nectopsyche	0	0	3	7	0	0
Hydroptilidae	1	5	1	6	38	7
Stactobiella	0	2	0	0	0	0
Ochrotrichia	0	0	0	1	0	0
Unidentifiable	9	7	17	7	5	8
Plecoptera						
Pteronarcyidae						
Pteronarcys	0	0	10	0	0	0
Perlidae						
Agnetina	0	0	2	0	0	1
Nemouridae	0	0	1	0	0	0
Unidentifiable	4	3	0	5	3	7

Table 2-2 (Continued).

Family and genus	Fort Randall			Gavins Point		
	Boyd	Verdel	Delta	James	Clay	Ponca
Hemiptera						
Corixidae						
Hesperocorixa	16	29	100	116	73	27
Belostomatidae						
Belostoma	0	0	0	0	0	1
Terrestrial	145	131	80	72	49	130
Hymenoptera						
Formicidae	2	1	5	1	5	6
Terrestrial	30	23	27	25	20	670
Odonata						
Gomphidae						
Gomphus	1	0	11	0	1	10
Stylurus	2	6	5	0	1	2
Dromogomphus	0	0	2	0	0	0
Coenagrionidae	0	0	1	0	0	0
Amphiagrion	0	5	27	10	11	2
Unidentifiable	0	1	0	0	0	0
Gastropoda						
Lymnaeidae	10	1	7	131	3	0
Physidae	1	0	6	1	0	0
Planorbidae	0	1	1	3	1	1
Ancylidae	0	0	1	2	1	0
Bivalvia						
Sphaeriidae	0	0	2	44	2	1
Corbiculidae	0	0	0	0	0	0
Corbicula fluminea	0	1	17	186	4	2
Amphipoda						
Hyallelidae						
Hyallela	0	0	21	0	6	6

Table 2-2 (Continued).

	Fort Randall			Gavins Point		
Family and genus	Boyd	Verdel	Delta	James	Clay	Ponca
		Lepidoptera				
Lepidoptera	0	0	2	0	1	0
		Coleoptera				
Staphylinidae	0	0	9	0	0	0
Dytiscidae						
Dytiscus	0	0	0	0	0	1
Gyrinidae						
Gyrinus	0	0	0	0	1	0
Hydrophilidae	0	0	0	0	1	0
Haliplidae	0	0	1	0	0	0
Terrestrial	16	40	27	32	24	19
		Isopoda				
Asellidae	5	0	7	3	1	0
Unidentifiable	0	0	0	0	1	1
		Thysanoptera				
Thysanoptera	1	2	6	1	2	5
		Neuroptera				
Neuroptera	0	0	0	1	0	0
		Megaloptera				
Sialidae	0	0	1	0	0	0
Corydalidae	0	0	1	0	0	0
		Collembola				
Poduridae						
Podura	0	1	0	0	0	0
Onychiuridae	0	0	0	0	1	0
Unidentifiable	4	0	1	1	0	0
		Larval Fish				
Larval Fish	3	41	45	440	472	286

Table 2-2 (Continued).

	Fort Randall			Gavins Point		
Family and genus	Boyd	Verdel	Delta	James	Clay	Ponca
		Decapoda				
Palaemonidae	0	0	1	0	0	0
Astacidae/Cambaridae	0	0	0	0	0	1
		Acariformes				
Hydracarina/Hydrachnid a	1	0	1	0	4	8
		Hirudinea				
Hirudinea	0	0	5	0	0	0
		Araneae				
Araneae	8	7	9	13	22	17
		All Macroinvertebrates and Fish				
Total	3171	2517	4296	12039	13277	8627

Table 2-3: Total number of individuals collected at three sites with six gears in 2006 in the Missouri River downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska. Sites in each reach are in order from upstream to downstream. Numbers listed by family names could not be distinguished to genus.

	Fort Randall			Gavins Point		
Family and genus	Boyd	Verdel	Delta	James	Clay	Ponca
Diptera						
Chironomidae	1937	1093	536	1093	487	341
Ceratopogonidae	144	122	89	96	159	172
Sphaeromias	0	0	1	0	0	0
Simuliidae	10	41	12	50	18	16
Chaoboridae						
Chaoborus	0	0	0	1	0	0
Empididae	0	0	0	5	0	0
Tipulidae	0	0	1	0	0	0
Terrestrial	20	32	4	20	12	15
Ephemeroptera						
Isonychiidae						
Isonychia	0	0	37	25	16	134
Baetidae	0	0	6	4	0	5
Baetis	0	0	19	41	91	142
Barbaetis	0	0	0	20	15	10
Procloeon	32	14	16	9	18	19
Pseudocentoptiloides	0	0	0	0	1	0
Paracloeodes	0	0	0	0	0	1
Caenidae						
Caenis	1	14	40	2	8	12
Brachycercus	0	2	27	0	2	4
Cerobrachys	0	3	2	0	6	6
Americaenis	0	0	5	0	5	15
Ephemeridae						
Hexagenia	6	6	58	1	4	2
Pentagenia	0	0	0	0	0	1
Polymitarcyidae						
Ephoron	1	0	5	0	0	2
Heptegeniidae	0	0	0	0	0	3
Stenacron	0	0	30	20	6	92
Stenonema	0	0	70	13	11	116

Table 2-3 (Continued).

Family and genus	Fort Randall			Gavins Point		
	Boyd	Verdel	Delta	James	Clay	Ponca
Ephemeroptera						
Pseudironidae						
Pseudiron	0	0	0	0	0	2
Oligoneuriidae						
Homoeoneuria	0	2	1	0	0	1
Tricorythidae						
Tricorythodes	0	10	47	5	1	0
Unidentifiable	0	2	1	0	1	1
Trichoptera						
Hydropsychidae	15	0	25	95	85	61
Hydropsyche	418	167	1305	2494	1662	1089
Ceratopsyche	0	0	1	3	0	0
Cheumatopsyche	0	0	25	190	205	512
Potomyia	0	0	0	0	3	21
Polycentropodidae	5	0	40	0	0	5
Neureclipsis	115	173	785	141	7	44
Polycentropus	5	0	35	25	5	0
Leptoceridae						
Oecetis	0	1	3	1	0	0
Nectopsyche	0	10	7	0	0	0
Hydroptilidae	0	11	0	5	0	0
Unidentifiable	2	0	2	1	3	16
Plecoptera						
Pteronarcyidae						
Pteronarcys	0	0	5	0	0	0
Perlidae						
Agnetina	0	0	3	0	0	0
Unidentifiable	0	1	0	0	0	0
Hemiptera						
Corixidae						
Hesperocorixa	6	36	67	20	19	49
Terrestrial	12	28	12	8	13	20

Table 2-3 (Continued).

	Fort Randall			Gavins Point		
Family and genus	Boyd	Verdel	Delta	James	Clay	Ponca
	Hymenoptera					
Formicidae	2	2	2	3	1	1
Terrestrial	42	44	2	4	7	28
	Odonata					
Gomphidae						
Gomphus	1	0	1	0	0	3
Stylurus	0	3	4	0	1	0
Coenagrionidae	0	0	2	0	0	5
Amphiagrion	0	0	6	20	0	0
Calopterygidae						
Hetaerina	0	0	1	0	0	0
Unidentifiable	1	0	0	0	0	0
	Gastropoda					
Lymnaeidae	0	4	6	3	6	1
Physidae	0	8	11	0	2	0
Planorbidae	1	12	5	1	9	0
Ancylidae	0	0	1	0	0	0
	Bivalvia					
Sphaeriidae	3	5	12	35	6	5
Corbiculidae						
Corbicula fluminea	2	4	5	7	6	2
	Amphipoda					
Hyallelidae						
Hyallela	0	0	61	0	2	0
	Lepidoptera					
Pyralidae						
Crambus	0	0	5	0	0	0
Acentria	0	0	1	0	0	0
Terrestrial	6	1	3	0	2	2

Table 2-3 (Continued).

	Fort Randall			Gavins Point		
Family and genus	Boyd	Verdel	Delta	James	Clay	Ponca
Coleoptera						
Hydrochidae						
Hydrochus	0	2	0	0	0	0
Hydrophilidae	0	0	1	0	0	0
Terrestrial	9	5	6	7	0	4
Isopoda						
Isopoda	0	0	0	2	0	1
Thysanoptera						
Thysanoptera	2	0	0	0	0	0
Megaloptera						
Corydalidae	0	0	0	1	0	0
Larval Fish						
Larval Fish	68	43	68	426	176	225
Acariformes						
Hydracarina/Hydrachnida	0	0	0	0	1	1
Hirudinea						
Hirudinea	0	0	10	0	0	0
Araneae						
Araneae	2	4	3	0	0	5
Oligochaete						
Oligochaete	0	1	0	0	0	0
Nematomorpha						
Gordiidae						
Gordius	0	5	0	0	0	0
All Macroinvertebrates and Fish						
Total	2869	1911	3538	4897	3082	3211

Table 2-4: Jaccard's Similarity Matrix for macroinvertebrate assemblages in 2005 and 2006 collected with Surber samplers at three stations in the Missouri River downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska. Fort Randall stations ordered from upstream to downstream were Boyd, Verdel, and Delta. Gavins Point stations ordered from upstream to downstream were James, Clay, and Ponca.

	Station					
Station	Boyd	Verdel	Delta	James	Clay	Ponca
			2005			
Boyd	1.00					
Verdel	0.56	1.00				
Delta	0.25	0.33	1.00			
James	0.33	0.50	0.31	1.00		
Clay	0.63	0.88	0.29	0.55	1.00	
Ponca	0.46	0.62	0.42	0.44	0.54	1.00
			2006			
Boyd	1.00					
Verdel	0.27	1.00				
Delta	0.14	0.41	1.00			
James	0.43	0.45	0.29	1.00		
Clay	0.25	0.40	0.39	0.21	1.00	
Ponca	0.23	0.38	0.32	0.20	0.53	1.00

Table 2-5: Jaccard's Similarity Matrix for macroinvertebrate assemblages in 2005 and 2006 collected with Hester-Dendy artificial substrate samplers at three stations in the Missouri River downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska. Fort Randall stations ordered from upstream to downstream were Boyd, Verdel, and Delta. Gavins Point stations ordered from upstream to downstream were James, Clay, and Ponca.

	Station					
Station	Boyd	Verdel	Delta	James	Clay	Ponca
			2005			
Boyd	1.00					
Verdel	0.60	1.00				
Delta	0.38	0.41	1.00			
James	0.33	0.57	0.40	1.00		
Clay	0.38	0.67	0.44	0.60	1.00	
Ponca	0.36	0.40	0.50	0.39	0.64	1.00
			2006			
Boyd	1.00					
Verdel	0.33	1.00				
Delta	0.19	0.32	1.00			
James	0.27	0.25	0.42	1.00		
Clay	0.43	0.33	0.44	0.50	1.00	
Ponca	0.30	0.27	0.53	0.62	0.70	1.00

Table 2-6: Jaccard's Similarity Matrix for drifting macroinvertebrate assemblages in 2005 and 2006 collected with a conical plankton net at three stations from the bottom of the Missouri River downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska. Fort Randall stations ordered from upstream to downstream were Boyd, Verdel, and Delta. Gavins Point stations ordered from upstream to downstream were James, Clay, and Ponca.

	Station					
Station	Boyd	Verdel	Delta	James	Clay	Ponca
			2005			
Boyd	1.00					
Verdel	0.50	1.00				
Delta	0.42	0.38	1.00			
James	0.37	0.56	0.52	1.00		
Clay	0.48	0.43	0.63	0.52	1.00	
Ponca	0.45	0.48	0.62	0.57	0.76	1.00
			2006			
Boyd	1.00					
Verdel	0.60	1.00				
Delta	0.39	0.39	1.00			
James	0.36	0.36	0.33	1.00		
Clay	0.37	0.30	0.52	0.45	1.00	
Ponca	0.44	0.28	0.45	0.44	0.57	1.00

Table 2-7: Jaccard's Similarity Matrix for drifting macroinvertebrate assemblages in 2005 and 2006 collected with a conical plankton net at three stations from the water column of the Missouri River downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska. Fort Randall stations ordered from upstream to downstream were Boyd, Verdel, and Delta. Gavins Point stations ordered from upstream to downstream were James, Clay, and Ponca.

	Station					
Station	Boyd	Verdel	Delta	James	Clay	Ponca
			2005			
Boyd	1.00					
Verdel	0.40	1.00				
Delta	0.31	0.28	1.00			
James	0.31	0.46	0.53	1.00		
Clay	0.46	0.50	0.56	0.60	1.00	
Ponca	0.40	0.35	0.58	0.44	0.65	1.00
			2006			
Boyd	1.00					
Verdel	0.36	1.00				
Delta	0.33	0.28	1.00			
James	0.45	0.50	0.33	1.00		
Clay	0.64	0.31	0.37	0.38	1.00	
Ponca	0.50	0.42	0.44	0.29	0.54	1.00

Table 2-8: Jaccard's Similarity Matrix for macroinvertebrate assemblages in 2005 and 2006 collected with a ponar dredge at three stations in the Missouri River downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska. Fort Randall stations ordered from upstream to downstream were Boyd, Verdel, and Delta. Gavins Point stations ordered from upstream to downstream were James, Clay, and Ponca.

	Station					
Station	Boyd	Verdel	Delta	James	Clay	Ponca
			2005			
Boyd	1.00					
Verdel	0.30	1.00				
Delta	0.31	0.40	1.00			
James	0.46	0.38	0.47	1.00		
Clay	0.33	0.67	0.46	0.62	1.00	
Ponca	0.31	0.33	0.33	0.47	0.46	1.00
			2006			
Boyd	1.00					
Verdel	0.53	1.00				
Delta	0.54	0.59	1.00			
James	0.70	0.41	0.50	1.00		
Clay	0.38	0.39	0.69	0.36	1.00	
Ponca	0.45	0.35	0.33	0.55	0.20	1.00

Table 2-9: Comparison of macroinvertebrate mean densities (one standard error in parentheses) for the top six taxa sampled for each gear in 2005 in the Missouri River downstream of Fort Randall and Gavins Point dams. Comparisons analyzed with a three-factor repeated measure ANOVA with reach, site, and season as grouping factors. Significant differences of levels within each factor tested with Duncan's multiple-range test indicated by different letters.

	Source of Variation										
	Reach		Site						Season		
Taxa	Randall	Gavins	Boyd	Verdel	Delta	James	Clay	Ponca	Spring	Summer	Fall
Surber Sampler (Number of Macroinvertebrates/m^2)											
Chironomidae	621 (112)a	342 (52)b	200 (65)b	499 (194)b	946 (205)a	434 (100)b	326 (85)b	247 (76)b	397 (96)b	815 (146)a	259 (74)b
Baetidae	39 (11)	34 (10)	9 (6)b	54 (36)ab	50 (12)ab	11 (6)ab	22 (14)ab	73 (26)a	39 (12)ab	55 (16)a	16 (7)b
Caenidae	145 (51)	41 (23)	0 (0)b	64 (41)b	278 (104)a	64 (60)b	22 (9)b	32 (14)b	62 (32)b	29 (11)b	201 (81)a
Ephemeridae	53 (15)a	13 (4)b	0 (0)b	5 (5)b	110 (30)a	11 (8)b	9 (6)b	18 (9)b	10 (8)b	22 (8)b	72 (22)a
Hydropsychidae	16 (7)	25 (8)	26 (18)	10 (7)	13 (9)	34 (16)	4 (4)	37 (17)	4 (3)b	10 (4)b	48 (15)a
Corixidae	132 (38)	269 (101)	0 (0)	128 (48)	215 (76)	389 (227)	287 (166)	105 (51)	106 (39)	349 (131)	133 (71)
Hester-Dendy (Number of Macroinvertebrates/m^2)											
Chironomidae	978	1585	1395	962	733	1545	1287	2032	1518	1109	-
	(158)	(298)	(378)	(273)	(194)	(298)	(226)	(958)	(174)	(282)	
Isonychiidae	0 (0)b	301 (107)a	0 (0)b	0 (0)b	0 (0)b	131 (55)b	133 (66)b	730 (348)a	289 (123)a	48 (21)b	-
Baetidae	18 (18)	413 (126)	0 (0)	0 (0)	39 (39)	131 (73)	385 (134)	789 (390)	444 (144)a	42 (22)b	-
Heptageniidae	145 (50)b	748 (137)a	21 (21)c	49 (49)c	270 (96)bc	345 (108)bc	843 (280)ab	1105 (252)a	476 (119)	444 (111)	-
Hydropsychidae	2953	23507	4501	3328	1814	24852	27648	16371	11288	15559	-
	(662)b	(2407)a	(1500)c	(1528)c	(701)c	(4327)a	(3949)a	(3889)b	(2016)	(2476)	
Polycentropodidae	1956	625	1670	2170	2020	1019	503	316	1235	1289	-
	(242)a	(116)b	(429)ab	(586)a	(334)a	(260)abc	(164)bc	(93)c	(224)	(193)	

Table 2-9 (Continued).

	Source of Variation										
	Reach		Site						Season		
Taxa	Randall	Gavins	Boyd	Verdel	Delta	James	Clay	Ponca	Spring	Summer	Fall
Bottom Drift Net (Number of Macroinvertebrates/100 m^3)											
Chironomidae	58 (2)	116 (15)	37 (15)b	84 (35)ab	53 (15)ab	304 (229)a	19 (3)b	26 (4)b	29 (2)	195 (118)	39 (14)
Ceratopogonidae	2 (< 1)	1 (< 1)	< 1 (< 1)	2 (2)	2 (1)	1 (< 1)	1 (< 1)	2 (1)	1 (< 1)	2 (1)	< 1 (< 1)
Simuliidae	2 (< 1)	3 (< 1)	1 (1)c	1 (1)c	6 (1)a	3 (1)abc	2 (1)bc	4 (1)ab	5 (1)a	3 (1)a	1 (< 1)b
Isonychiidae	< 1 (< 1)	1 (< 1)	0 (0)b	0 (0)b	1 (< 1)ab	< 1 (< 1)a	< 1 (< 1)b	2 (1)b	1 (< 1)ab	1 (< 1)a	< 1 (< 1)b
Caenidae	6 (1)a	1 (< 1)b	0 (0)b	1 (1)b	17 (5)a	1 (< 1)b	1 (< 1)b	3 (1)b	1 (< 1)b	7 (3)a	5 (2)ab
Hydropsychidae	19 (< 1)	72 (6)	18 (13)	25 (23)	15 (4)	144 (112)	30 (6)	41 (7)	3 (< 1)	85 (58)	48 (12)
Column Drift Net (Number of Macroinvertebrates/100 m^3)											
Chironomidae	27 (1)	30 (1)	42 (19)	17 (5)	24 (5)	35 (7)	23 (5)	31 (8)	38 (5)	26 (4)	21 (9)
Simuliidae	2 (< 1)	5 (< 1)	0 (0)b	0 (0)b	7 (2)a	4 (2)ab	4 (1)ab	8 (2)a	7 (2)a	3 (1)b	1 (1)b
Baetidae	1 (< 1)	1 (< 1)	0 (0)c	0 (0)c	3 (1)a	0 (0)c	1 (< 1)bc	2 (1)ab	2 (1)a	1 (1)ab	< 1 (< 1)b
Caenidae	6 (1)	5 (< 1)	0 (0)c	1 (1)c	16 (5)a	1 (1)c	3 (1)bc	11 (7)ab	5 (3)	6 (2)	6 (3)
Ephemeridae	< 1 (< 1)b	2 (< 1)a	< 1 (< 1)c	< 1 (< 1)c	< 1 (< 1)c	2 (1)a	2 (1)ab	1 (< 1)bc	2 (1)a	0 (0)b	1 (< 1)b
Hydropsychidae	12 (1)b	52 (2)a	3 (1)c	18 (15)bc	16 (4)bc	75 (34)a	35 (8)abc	47 (8)ab	5 (1)b	55 (19)a	37 (8)ab
Ponar Dredge (Number of Macroinvertebrates/10 kg sediment)											
Chironomidae	133 (16)	30 (1)	33 (10)	337 (304)	30 (13)	44 (21)	30 (7)	17 (7)	153 (132)	49 (12)	25 (5)
Ceratopogonidae	15 (1)	17 (< 1)	12 (2)ab	22 (6)a	10 (2)b	15 (4)ab	17 (3)ab	18 (3)ab	11 (2)b	20 (2)a	16 (3)ab
Hydropsychidae	< 1 (< 1)	31 (5)	< 1 (< 1)	0 (0)	0 (0)	89 (66)	< 1 (< 1)	4 (4)	< 1 (< 1)	33 (32)	16 (13)
Polycentropodidae	< 1 (< 1)	5 (1)	< 1 (< 1)	0 (0)	0 (0)	15 (15)	0 (0)	1 (1)	0 (0)	8 (8)	1 (< 1)
Corbiculidae	< 1 (< 1)b	5 (1)a	0 (0)b	< 1 (< 1)b	< 1 (< 1)b	14 (5)a	< 1 (< 1)b	< 1 (< 1)b	2 (1)	3 (1)	3 (2)
Lymnaeidae	< 1 (< 1)	3 (< 1)	1 (1)b	< 1 (< 1)b	< 1 (< 1)b	9 (4)a	< 1 (< 1)b	0 (0)b	1 (1)	1 (1)	3 (2)

Table 2-10: Comparison of macroinvertebrate mean densities (one standard error in parentheses) for the top six taxa sampled for each gear in 2006 in the Missouri River downstream of Fort Randall and Gavins Point dams. Comparisons analyzed with a three-factor repeated measure ANOVA with reach, site, and season as grouping factors. Significant differences of levels within each factor tested with Duncan's multiple-range test indicated by different letters.

	Source of Variation										
	Reach		Site						Season		
Taxa	Randall	Gavins	Boyd	Verdel	Delta	James	Clay	Ponca	Spring	Summer	Fall
Surber Sampler (Number of Macroinvertebrates/m^2)											
Chironomidae	335 (44)	218 (42)	313 (88)ab	329 (62)ab	350 (71)ab	438 (124)a	111 (27)b	148 (36)b	327 (60)	290 (57)	229 (40)
Baetidae	73 (21)	65 (18)	137 (65)	62 (32)	41 (15)	51 (28)	60 (29)	84 (35)	32 (16)b	158 (36)a	14 (7)b
Caenidae	57 (13)a	21 (8)b	0 (0)b	21 (12)b	108 (25)a	0 (0)b	30 (19)b	30 (13)b	22 (8)	51 (16)	53 (19)
Ephemeridae	59 (24)a	3 (2)b	0 (0)b	0 (0)b	123 (49)a	0 (0)b	0 (0)b	10 (7)b	24 (12)ab	2 (2)b	85 (42)a
Hydropsychidae	2 (2)	153 (119)	0 (0)	5 (5)	3 (3)	0 (0)	55 (34)	400 (359)	4 (3)	12 (5)	201 (168)
Corixidae	122 (59)	140 (36)	26 (15)	185 (104)	147 (110)	112 (56)	81 (38)	232 (87)	102 (39)	195 (90)	89 (49)
Hester-Dendy (Number of Macroinvertebrates/m^2)											
Chironomidae	1191	1651	2916	2170	444	2498	666	1036	1690	625	-
	(407)	(459)	(1722)	(1178)	(161)	(877)	(222)	(339)	(431)	(254)	
Isonychiidae	56 (34)	483 (230)	0 (0)b	0 (0)b	86 (52)b	164 (164)ab	148 (85)ab	1183 (625)a	288 (122)a	16 (16)b	-
Baetidae	24 (18)b	965 (255)a	0 (0)b	0 (0)b	37 (27)b	394 (178)b	1553 (142)a	1430 (685)a	491 (148)a	33 (33)b	-
Heptageniidae	160 (60)	732 (389)	0 (0)b	0 (0)b	247 (88)b	197 (70)b	148 (148)b	1923 (1135)a	483 (203)	82 (40)	-
Hydropsychidae	2831	16973	2790	1036	3291	15713	25740	13018	7887	7084	-
	(1039)b	(3330)a	(1978)cd	(600)d	(1499)cd	(6125)ab	(1584)a	(4640)bc	(1878)	(3011)	
Polycentropodidae	1799	654	1014	1627	2071	1052	74	444	1339	1561	-
	(208)a	(198)b	(562)abc	(469)ab	(240)a	(353)abc	(74)c	(213)bc	(196)	(328)	

Table 2-10 (Continued).

	Source of Variation										
	Reach		Site						Season		
Taxa	Randall	Gavins	Boyd	Verdel	Delta	James	Clay	Ponca	Spring	Summer	Fall
Bottom Drift Net (Number of Macroinvertebrates/100 m^3)											
Chironomidae	21 (2)	12 (< 1)	40 (20)a	18 (4)ab	5 (1)b	20 (3)ab	12 (3)ab	5 (1)b	24 (10)	9 (1)	14 (2)
Ceratopogonidae	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)	1 (< 1)	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)ab	< 1 (< 1)b	1 (< 1)a
Simuliidae	< 1 (< 1)b	1 (< 1)a	< 1 (< 1)b	< 1 (< 1)b	< 1 (< 1)b	2 (< 1)a	< 1 (< 1)b	< 1 (< 1)b	< 1 (< 1)	1 (< 1)	< 1 (< 1)
Isonychiidae	< 1 (< 1)b	< 1 (< 1)a	0 (0)b	0 (0)b	< 1 (< 1)b	0 (0)b	< 1 (< 1)ab	< 1 (< 1)a	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)
Caenidae	< 1 (< 1)	< 1 (< 1)	0 (0)b	0 (0)b	< 1 (< 1)a	0 (0)b	< 1 (< 1)ab	< 1 (< 1)ab	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)
Hydropsychidae	2 (< 1)b	17 (< 1)a	5 (2)c	< 1 (< 1)c	< 1 (< 1)c	13 (2)b	17 (2)ab	22 (4)a	3 (< 1)c	8 (1)b	18 (2)a
Column Drift Net (Number of Macroinvertebrates/100 m^3)											
Chironomidae	42 (3)	45 (3)	57 (11)abc	60 (33)ab	10 (2)c	85 (23)a	27 (6)bc	24 (7)bc	53 (10)	26 (5)	45 (17)
Simuliidae	2 (< 1)	2 (< 1)	2 (1)	4 (2)	< 1 (< 1)	4 (2)	2 (< 1)	< 1 (< 1)	1 (< 1)	3 (1)	2 (< 1)
Baetidae	< 1 (< 1)	2 (< 1)	0 (0)b	0 (0)b	< 1 (< 1)b	0 (0)b	0 (0)b	5 (2)a	2 (< 1)	< 1 (< 1)	< 1 (< 1)
Caenidae	1 (< 1)	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)	2 (1)	< 1 (< 1)	< 1 (< 1)	1 (1)	< 1 (< 1)	1 (< 1)	1 (< 1)
Ephemeridae	< 1 (< 1)	< 1 (< 1)	1 (1)	0 (0)	< 1 (< 1)	< 1 (< 1)	1 (< 1)	0 (0)	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)
Hydropsychidae	4 (< 1)b	27 (< 1)a	7 (3)bc	4 (2)bc	< 1 (< 1)c	16 (5)b	31 (9)a	33 (7)a	5 (2)b	12 (2)b	28 (6)a
Ponar Dredge (Number of Macroinvertebrates/10 kg sediment)											
Chironomidae	131 (5)a	33 (3)b	131 (27)ab	183 (97)a	79 (66)ab	66 (39)ab	22 (6)b	11 (2)b	70 (42)	48 (12)	136 (51)
Ceratopogonidae	94 (12)	16 (< 1)	16 (4)	249 (232)	19 (13)	19 (8)	13 (2)	16 (4)	119 (106)	14 (2)	23 (9)
Hydropsychidae	3 (< 1)	23 (4)	3 (3)	5 (5)	1 (1)	69 (63)	0 (0)	< 1 (< 1)	1 (1)	< 1 (< 1)	34 (28)
Polycentropodidae	< 1 (< 1)	2 (< 1)	< 1 (< 1)b	< 1 (< 1)b	1 (1)b	6 (4)a	0 (0)b	< 1 (< 1)b	1 (1)	< 1 (< 1)	2 (1)
Corbiculidae	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)	0 (0)	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)
Lymnaeidae	< 1 (< 1)	< 1 (< 1)	0 (0)	< 1 (< 1)	< 1 (1)	0 (0)	< 1 (< 1)	0 (0)	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)

Table 2-11: Mean densities of Diptera, Ephemeroptera, and Trichoptera (one standard error in parentheses) by macrohabitat for each gear in 2005 in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska. Macrohabitats classified as braided channels (BRAD), channel crossovers (CHXO), inside bends (ISB), outside bends (OSB) and secondary connected channels (SCC).

	Macrohabitats				
Taxa	BRAD	CHXO	ISB	OSB	SCC
Surber Sampler (Number of Macroinvertebrates/m^2)					
Diptera	975 (207)	384 (114)	96 (26)	734 (266)	233 (52)
Ephemeroptera	447 (122)	165 (120)	7 (7)	41 (20)	137 (100)
Trichoptera	24 (10)	14 (14)	34 (28)	14 (9)	14 (14)
Hester-Dendy (Number of Macroinvertebrates/m^2)					
Diptera	746 (196)	828 (412)	1243 (580)	1297 (390)	1381 (711)
Ephemeroptera	669 (241)	118 (72)	178 (118)	91 (52)	0 (0)
Trichoptera	3872 (878)	5207 (1937)	6213 (3537)	5098 (1327)	9862 (3790)
Bottom Drift Net (Number of Macroinvertebrates/100 m^3)					
Diptera	87 (27)	68 (42)	206 (137)	25 (4)	55 (19)
Ephemeroptera	27 (6)	< 1 (< 1)	6 (5)	< 1 (< 1)	2 (2)
Trichoptera	19 (5)	33 (32)	30 (25)	2 (< 1)	22 (9)
Column Drift Net (Number of Macroinvertebrates/100 m^3)					
Diptera	70 (18)	141 (113)	75 (20)	41 (15)	88 (32)
Ephemeroptera	24 (6)	0 (0)	< 1 (< 1)	1 (< 1)	0 (0)
Trichoptera	17 (4)	3 (2)	21 (17)	4 (2)	0 (0)
Ponar Dredge (Number of Macroinvertebrates/10 kg Sediment)					
Diptera	41 (13)	705 (663)	48 (8)	54 (18)	76 (32)
Ephemeroptera	< 1 (< 1)	54 (51)	0 (0)	0 (0)	0 (0)
Trichoptera	0 (0)	0 (0)	0 (0)	< 1 (< 1)	3 (3)

Table 2-12: Mean densities of Diptera, Ephemeroptera, and Trichoptera (one standard error in parentheses) by macrohabitat for each gear in 2006 in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska. Macrohabitats classified as braided channels (BRAD), channel crossovers (CHXO), inside bends (ISB), outside bends (OSB) and secondary connected channels (SCC).

	Macrohabitats				
Taxa	BRAD	CHXO	ISB	OSB	SCC
Surber Sampler (Number of Macroinvertebrates/m^2)					
Diptera	358 (71)	-	251 (48)	447 (115)	82 (41)
Ephemeroptera	293 (64)	-	53 (17)	194 (90)	82 (82)
Trichoptera	21 (9)	-	4 (4)	0 (0)	0 (0)
Hester-Dendy (Number of Macroinvertebrates/m^2)					
Diptera	468 (162)	-	2465 (1170)	3550 (2372)	888 (0)
Ephemeroptera	530 (132)	-	99 (62)	118 (118)	0 (0)
Trichoptera	5375 (1428)	-	4734 (2038)	1953 (952)	5030 (0)
Bottom Drift Net (Number of Macroinvertebrates/100 m^3)					
Diptera	6 (1)	10 (3)	56 (24)	16 (3)	39 (18)
Ephemeroptera	2 (< 1)	< 1 (< 1)	< 1 (< 1)	< 1 (< 1)	0 (0)
Trichoptera	1 (< 1)	< 1 (< 1)	4 (2)	3 (1)	4 (3)
Column Drift Net (Number of Macroinvertebrates/100 m^3)					
Diptera	11 (3)	16 (16)	123 (53)	40 (7)	41 (12)
Ephemeroptera	3 (1)	0 (0)	2 (1)	1 (< 1)	0 (0)
Trichoptera	2 (< 1)	4 (4)	9 (4)	4 (3)	13 (9)
Ponar Dredge (Number of Macroinvertebrates/10 kg Sediment)					
Diptera	98 (79)	28 (10)	174 (42)	447 (353)	210 (165)
Ephemeroptera	40 (39)	3 (3)	<1 (<1)	52 (51)	0 (0)
Trichoptera	2 (2)	0 (0)	7 (7)	4 (4)	0 (0)

Table 2-13: Mean densities of Diptera, Ephemeroptera, and Trichoptera (one standard error in parentheses) by macrohabitat for each gear in 2005 in the Missouri River downstream of Gavins Point Dam, South Dakota and Nebraska. Macrohabitats classified as braided channels (BRAD), channel crossovers (CHXO), inside bends (ISB), outside bends (OSB) and secondary connected channels (SCC).

	Macrohabitats				
Taxa	BRAD	CHXO	ISB	OSB	SCC
Surber Sampler (Number of Macroinvertebrates/m^2)					
Diptera	397 (132)	535 (320)	280 (79)	325 (96)	486 (120)
Ephemeroptera	53 (38)	0 (0)	142 (39)	55 (23)	189 (129)
Trichoptera	9 (9)	21 (21)	28 (17)	50 (24)	33 (15)
Hester-Dendy (Number of Macroinvertebrates/m^2)					
Diptera	1124 (181)	789 (356)	2663 (1077)	1266 (243)	1644 (515)
Ephemeroptera	1124 (326)	1085 (356)	1479 (314)	2005 (596)	1249 (303)
Trichoptera	30355 (5445)	33432 (4888)	18639 (5276)	21746 (4392)	27153 (3803)
Bottom Drift Net (Number of Macroinvertebrates/100 m^3)					
Diptera	5 (2)	3 (<1)	31 (22)	3 (<1)	4 (1)
Ephemeroptera	<1 (<1)	<1 (<1)	1 (<1)	<1 (<1)	1 (<1)
Trichoptera	4 (1)	3 (1)	16 (11)	3 (<1)	2 (1)
Column Drift Net (Number of Macroinvertebrates/100 m^3)					
Diptera	7 (2)	6 (1)	7 (1)	4 (1)	8 (2)
Ephemeroptera	1 (<1)	<1 (<1)	1 (1)	1 (<1)	1 (1)
Trichoptera	3 (1)	3 (1)	9 (3)	2 (<1)	5 (2)
Ponar Dredge (Number of Macroinvertebrates/kg Sediment)					
Diptera	4 (1)	11 (8)	4 (1)	3 (1)	7 (3)
Ephemeroptera	0 (0)	<1 (0)	0 (0)	0 (0)	<1 (0)
Trichoptera	<1 (0)	21 (21)	<1 (0)	4 (4)	0 (0)

Table 2-14: Mean densities of Diptera, Ephemeroptera, and Trichoptera (one standard error in parentheses) by macrohabitat for each gear in 2006 in the Missouri River downstream of Gavins Point Dam, South Dakota and Nebraska. Macrohabitats classified as braided channels (BRAD), channel crossovers (CHXO), inside bends (ISB), outside bends (OSB) and secondary connected channels (SCC).

	Macrohabitats				
Taxa	BRAD	CHXO	ISB	OSB	SCC
Surber Sampler (Number of Macroinvertebrates/m^2)					
Diptera	163 (37)	-	233 (93)	333 (84)	106 (68)
Ephemeroptera	140 (47)	-	151 (59)	99 (54)	88 (70)
Trichoptera	28 (11)	-	361 (333)	25 (25)	141 (141)
Hester-Dendy (Number of Macroinvertebrates/m^2)					
Diptera	592 (296)	-	1701 (659)	2282 (974)	888 (0)
Ephemeroptera	1874 (99)	-	1960 (1220)	2874 (1151)	2367 (0)
Trichoptera	26627 (2014)	-	18787 (6480)	11792 (4046)	23373 (0)
Bottom Drift Net (Number of Macroinvertebrates/100 m^3)					
Diptera	1 (<1)	1 (1)	2 (<1)	1 (<1)	<1 (<1)
Ephemeroptera	<1 (<1)	<1 (<1)	<1 (<1)	<1 (<1)	<1 (<1)
Trichoptera	2 (<1)	3 (2)	2 (<1)	2 (<1)	<1 (<1)
Column Drift Net (Number of Macroinvertebrates/100 m^3)					
Diptera	3 (1)	22 (20)	6 (1)	5 (2)	2 (1)
Ephemeroptera	<1 (<1)	0 (0)	1 (<1)	1 (<1)	0 (0)
Trichoptera	2 (<1)	11 (1)	2 (<1)	3 (1)	8 (6)
Ponar Dredge (Number of Macroinvertebrates/kg Sediment)					
Diptera	3 (1)	2 (<1)	9 (4)	3 (1)	3 (1)
Ephemeroptera	<1 (<1)	0 (0)	<1 (<1)	<1 (<1)	0 (0)
Trichoptera	0 (0)	0 (0)	7 (7)	<1 (<1)	0 (0)

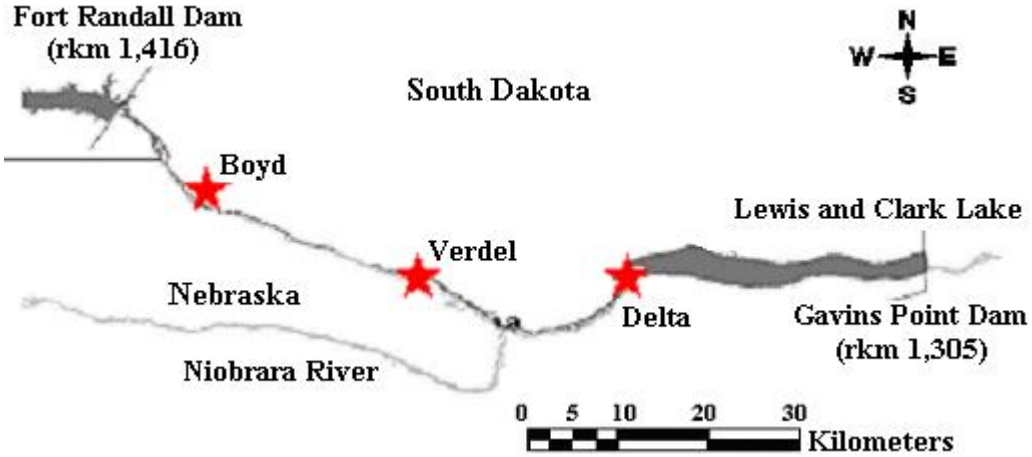

Figure 2-1: Sampling locations (stars) for macroinvertebrates in the Fort Randall Reach, Missouri River, South Dakota and Nebraska during June to October 2005 and 2006.

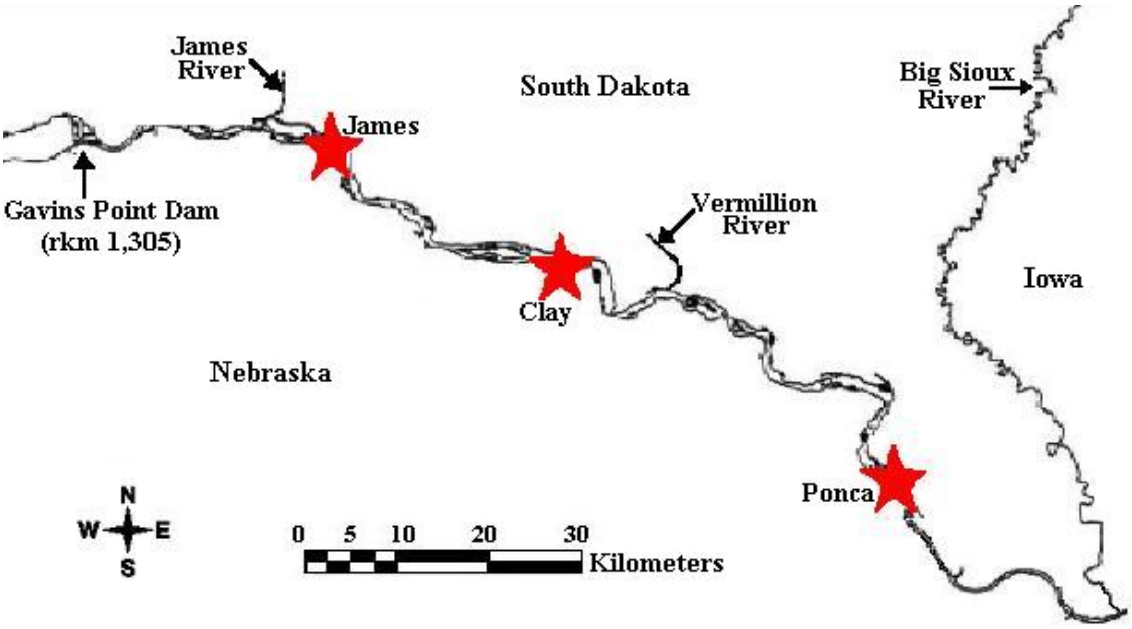

Figure 2-2: Sampling locations (stars) for macroinvertebrates in the Gavins Point Reach, Missouri River, South Dakota and Nebraska during June to October 2005 and 2006.

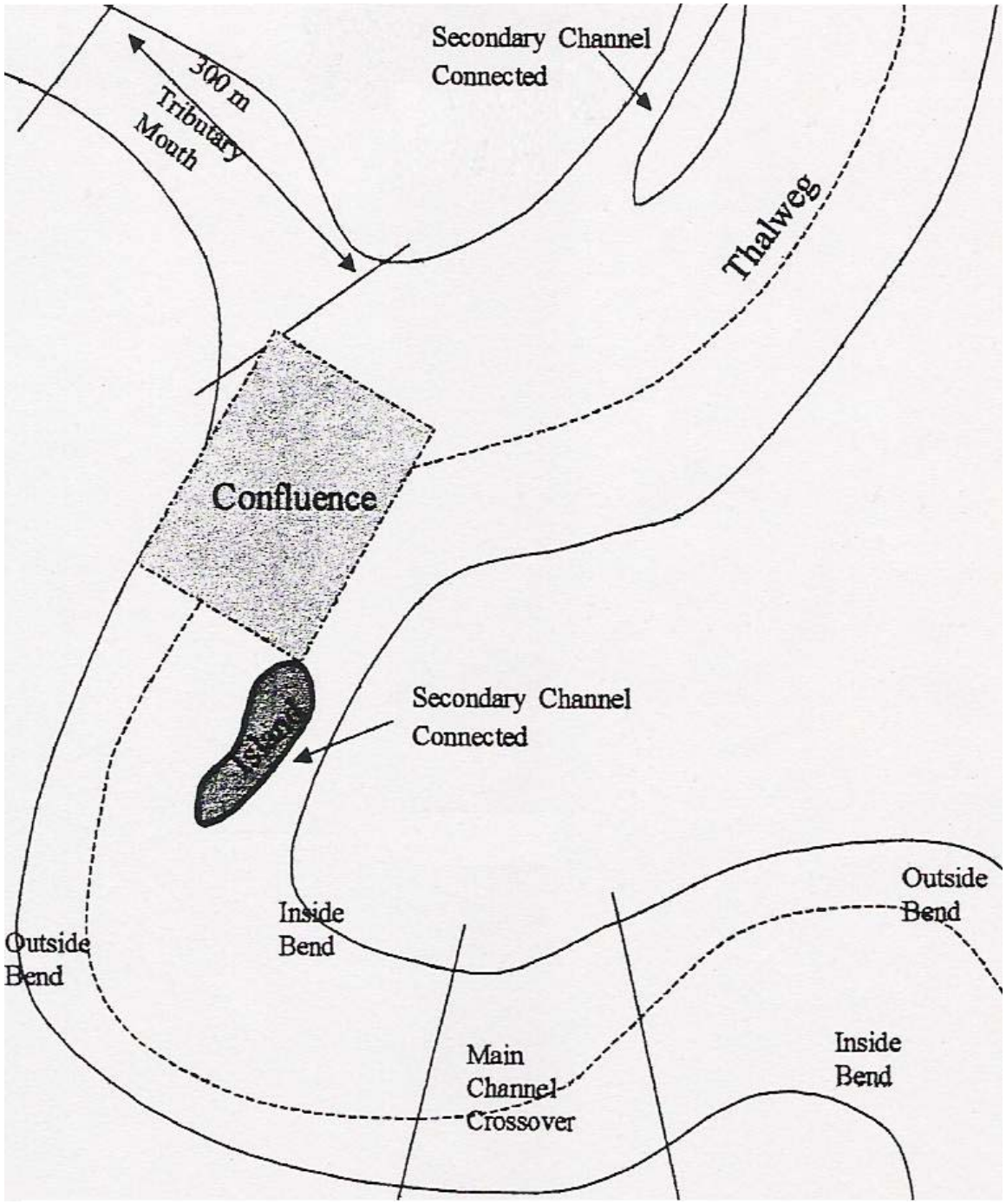

Figure 2-3: Modified version of a hypothetical map of Missouri River macrohabitats (USACE 2005).

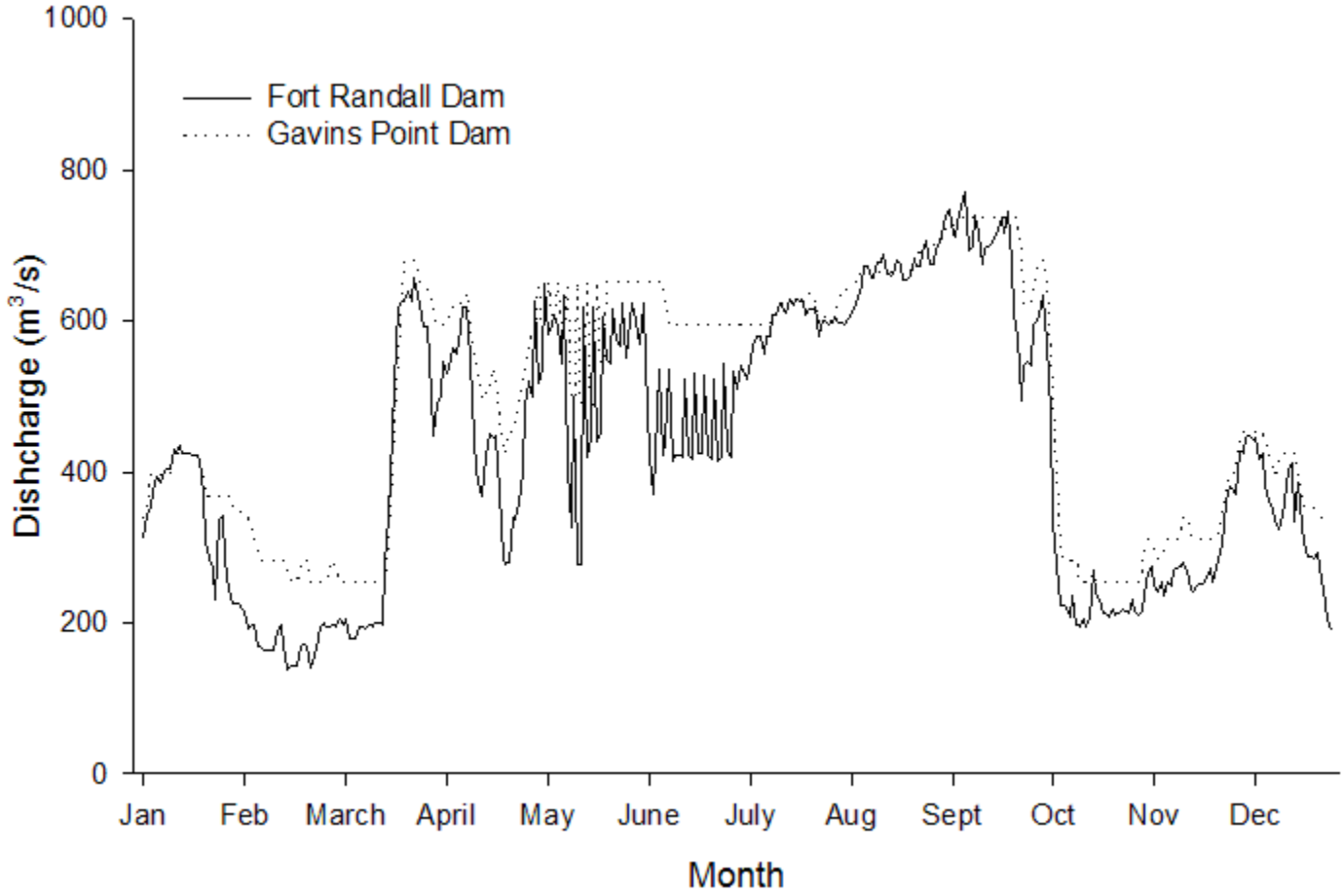

Figure 2-4: Missouri River mean daily discharge (m^3/s) downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska, during 2005. Discharge data provided by the U.S. Army Corps of Engineers, Northwest Division, Missouri River Basin Water Management Division, Omaha, Nebraska.

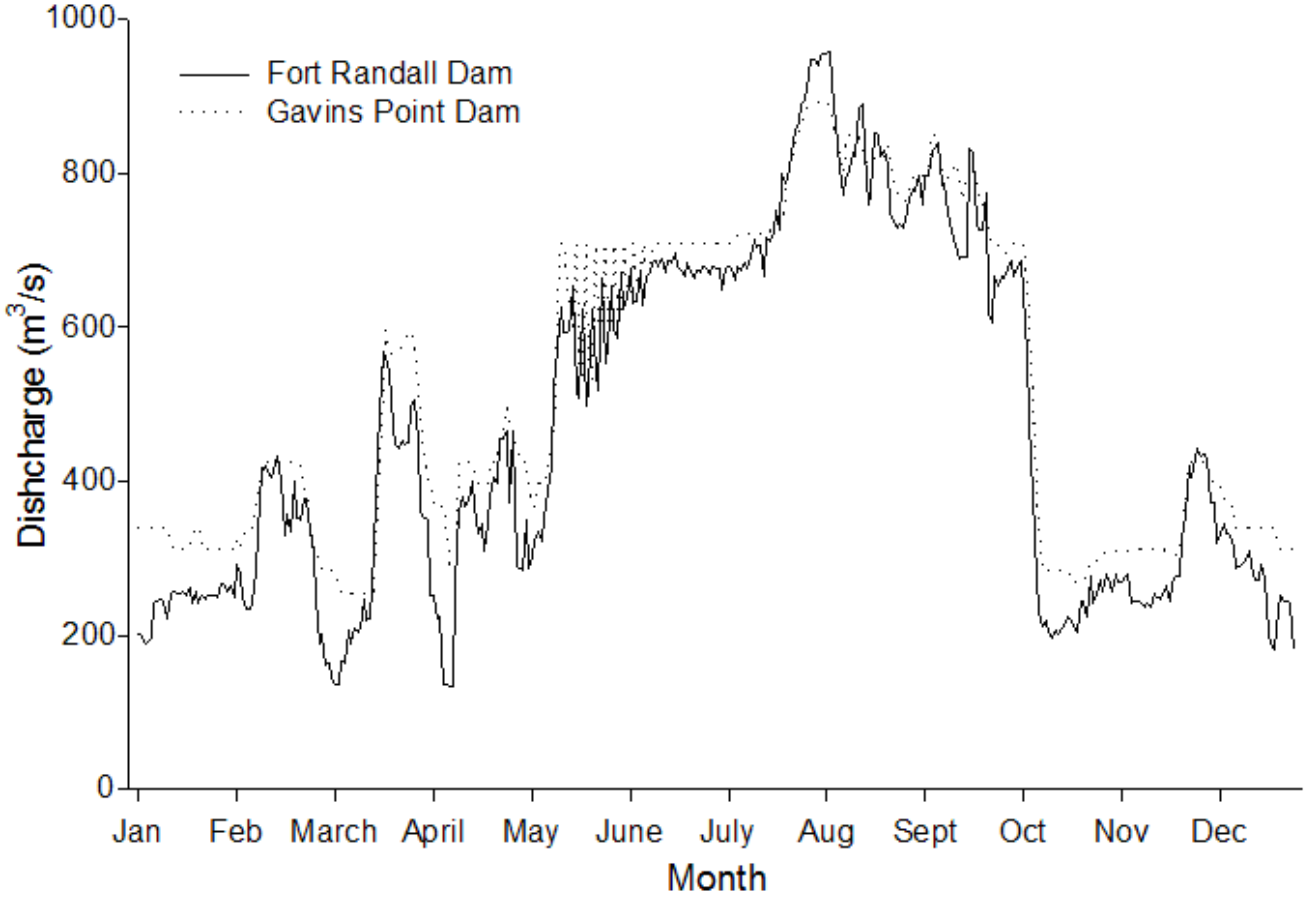

Figure 2-5: Missouri River mean daily discharge (m^3/s) downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska, during 2006. Discharge data provided by the U.S. Army Corps of Engineers, Northwest Division, Missouri River Basin Water Management Division, Omaha, Nebraska.

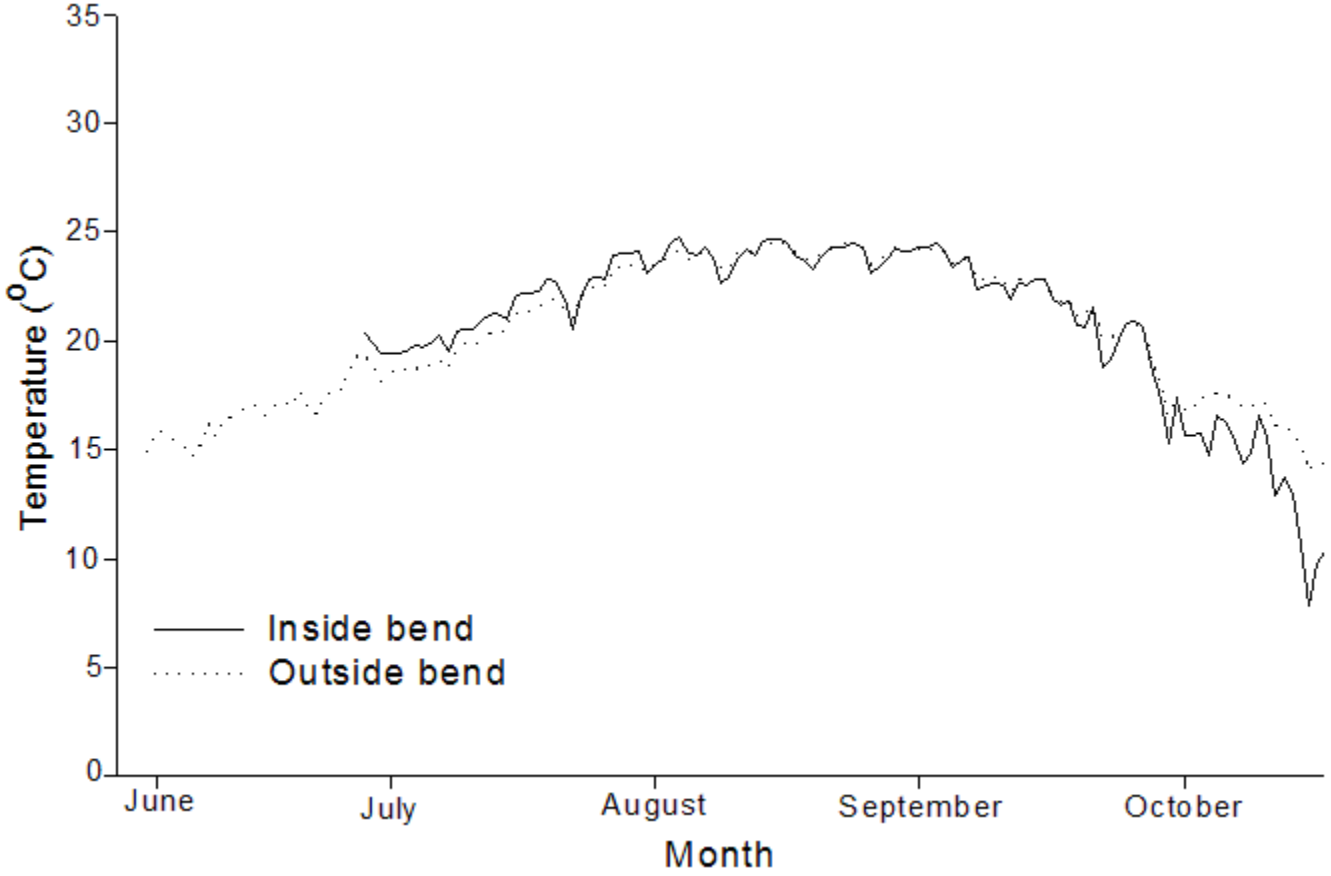

Figure 2-6: Mean daily temperature by habitat type at the Boyd site downstream of Fort Randall Dam, South Dakota and Nebraska during 2005.

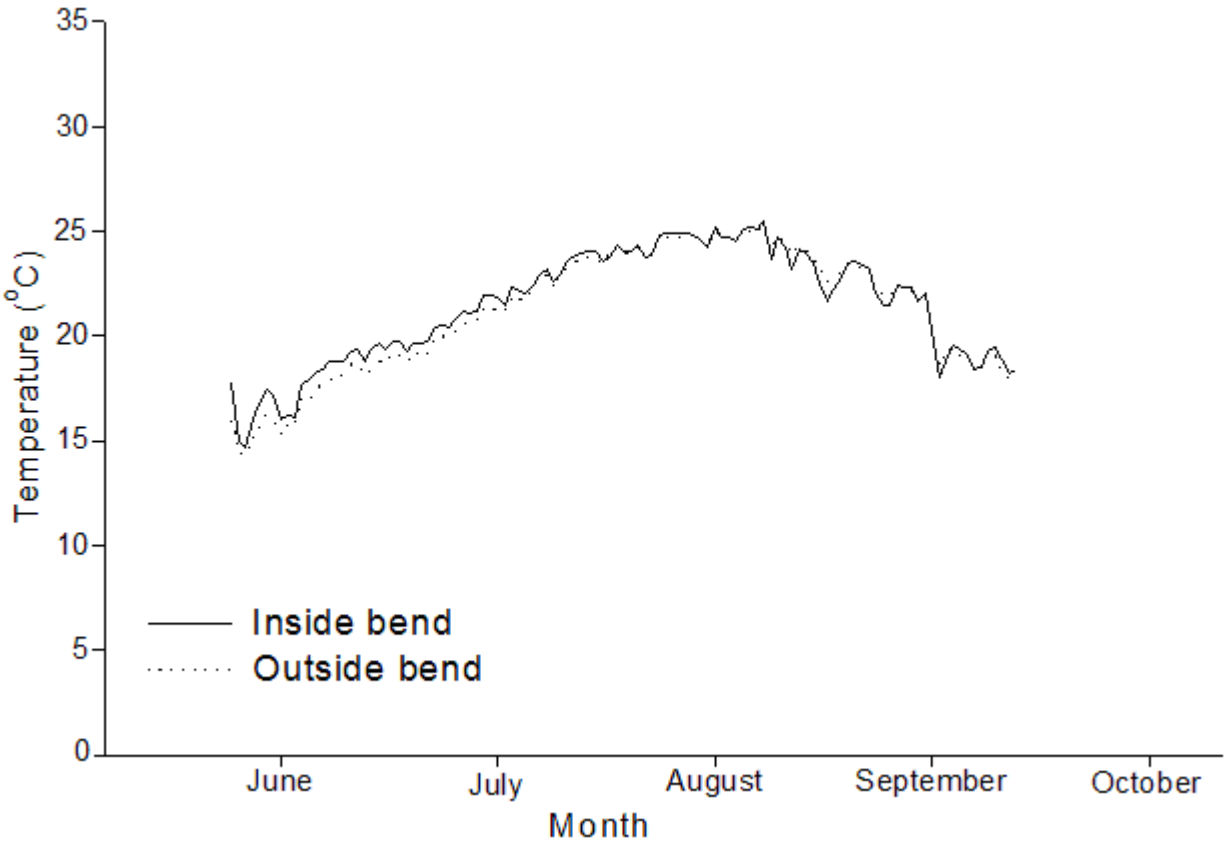

Figure 2-7: Mean daily temperature by habitat type at the Boyd site downstream of Fort Randall Dam, South Dakota and Nebraska during 2006.

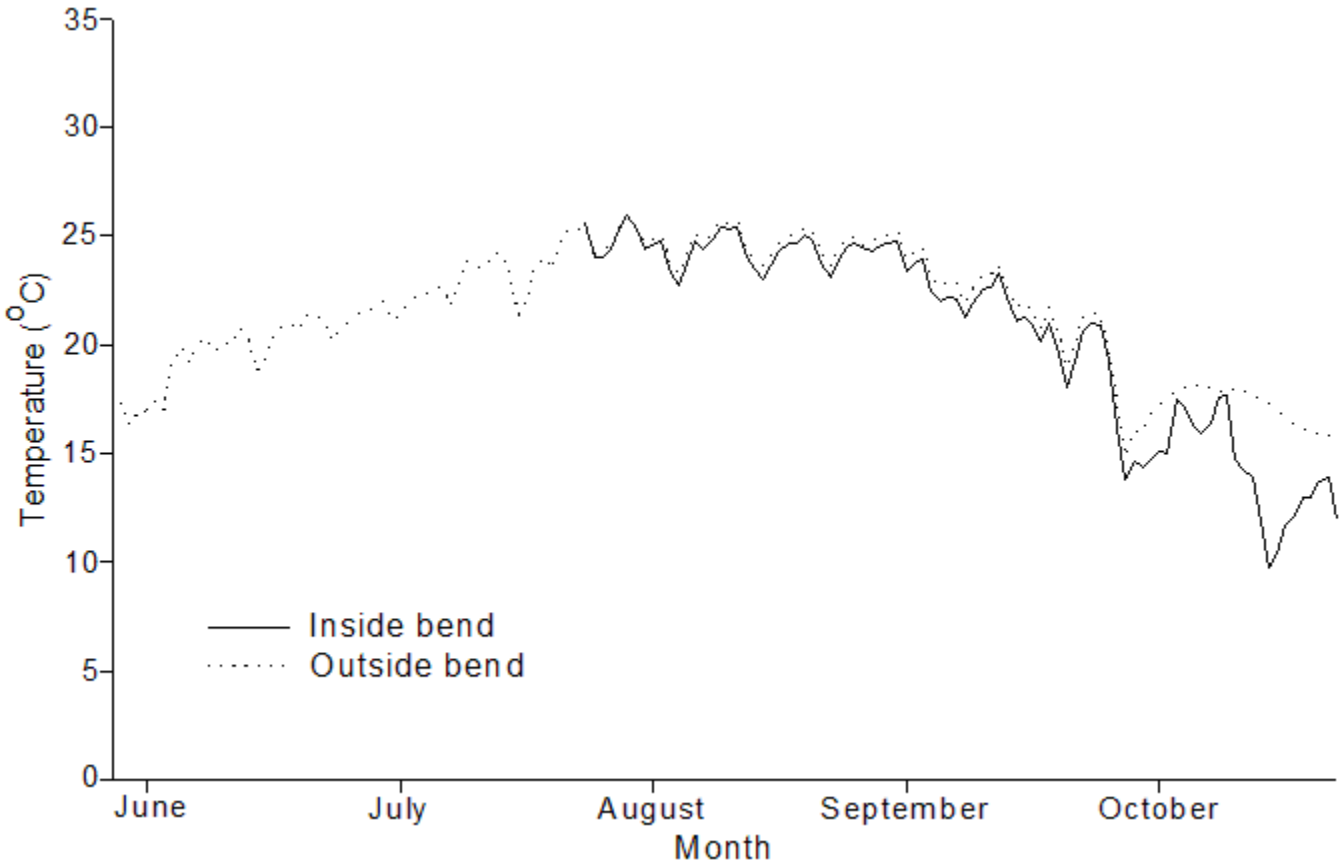

Figure 2-8: Mean daily temperature by habitat type at the Verdel site downstream of Fort Randall Dam, South Dakota and Nebraska during 2005.

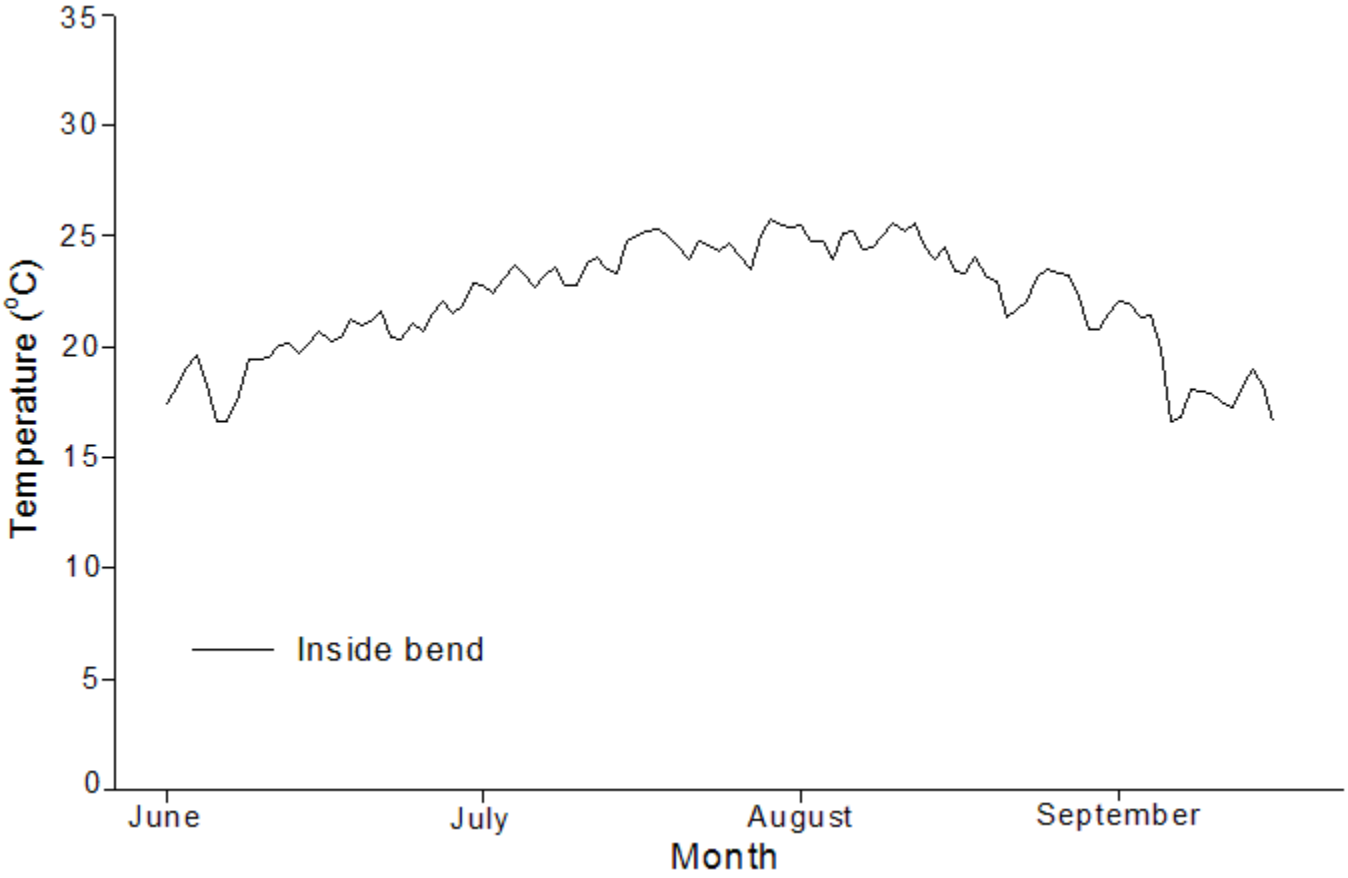

Figure 2-9: Mean daily temperature at the Verdel site downstream of Fort Randall Dam, South Dakota and Nebraska during 2006.

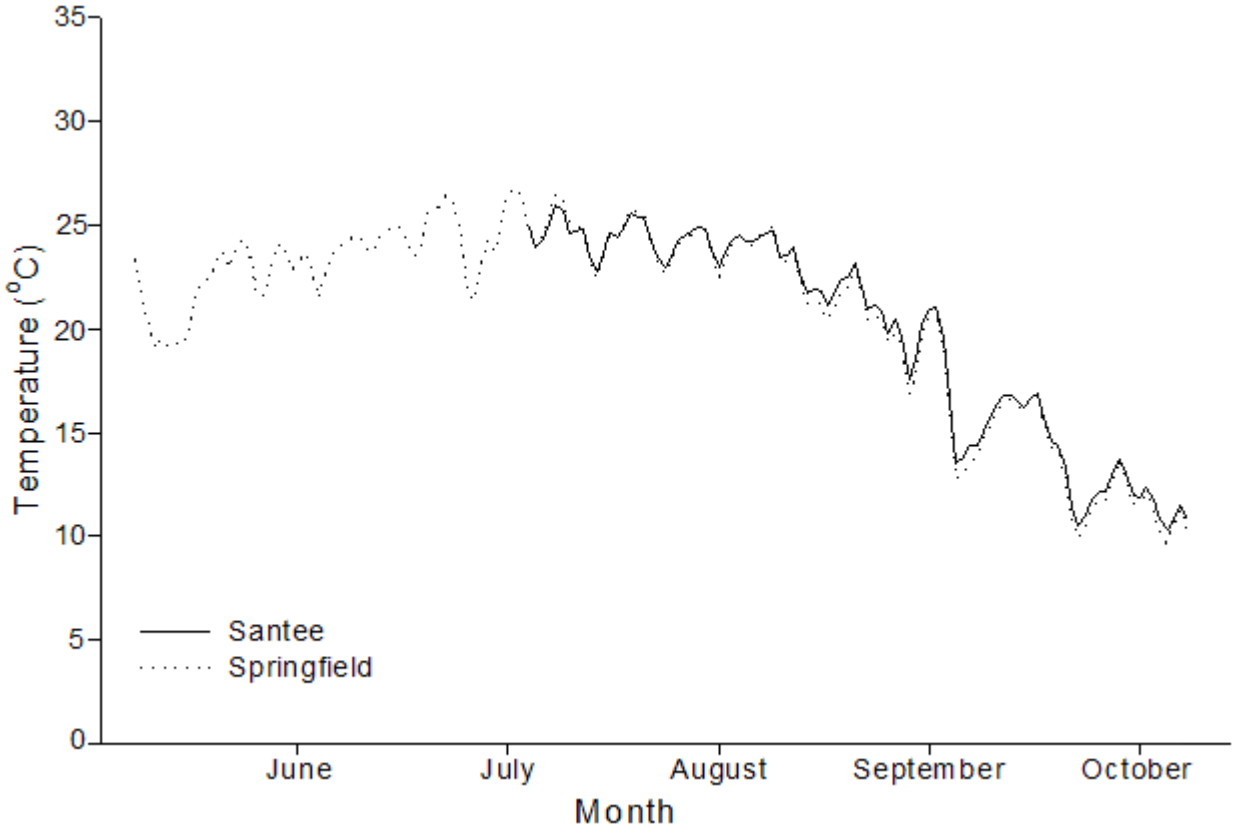

Figure 2-10: Mean daily temperature for 2005 at the Delta site downstream of Fort Randall Dam, South Dakota and Nebraska. Santee was along the Nebraska shoreline while Springfield was along the South Dakota shoreline.

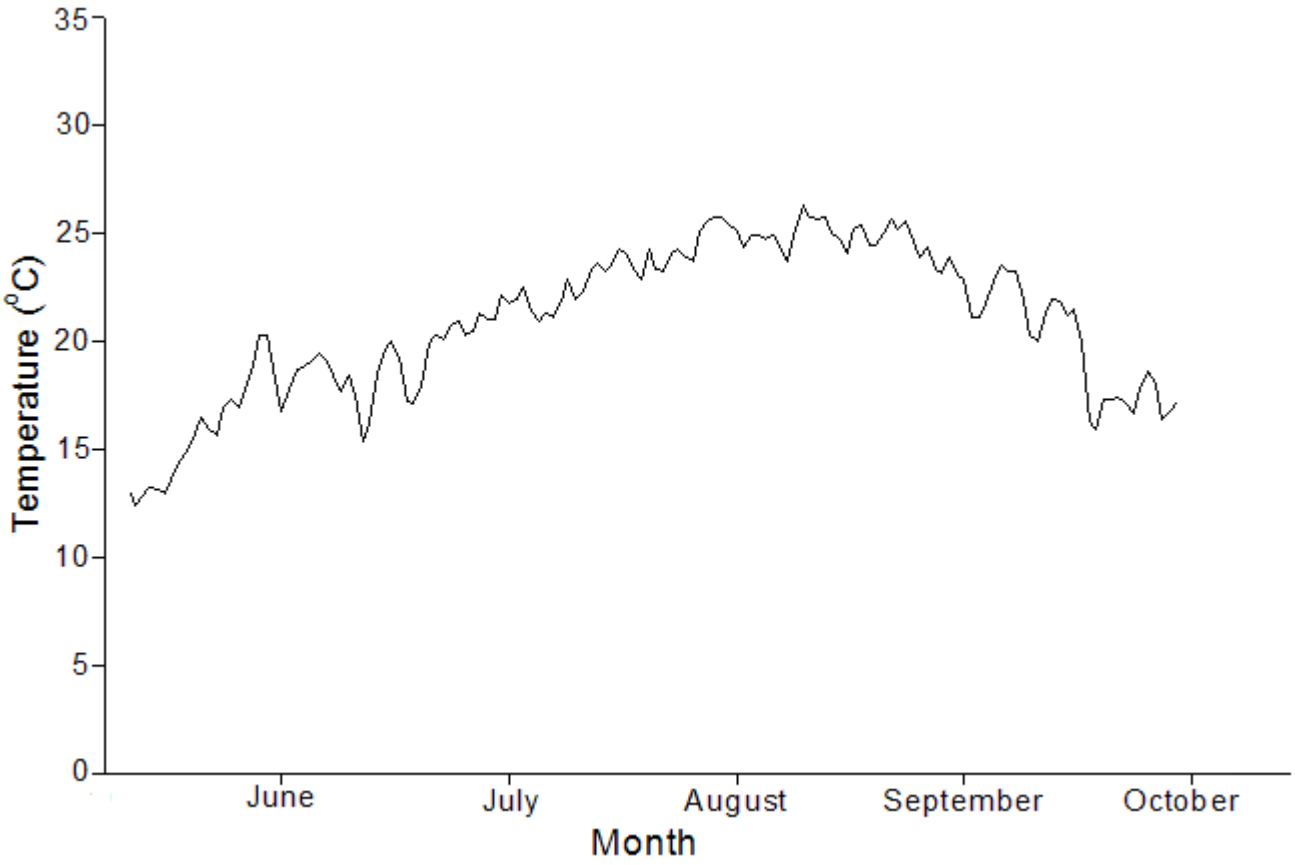

Figure 2-11: Mean daily temperature for 2006 on the Santee side of the Delta site downstream of Fort Randall Dam, South Dakota and Nebraska. Santee was along the Nebraska shoreline.

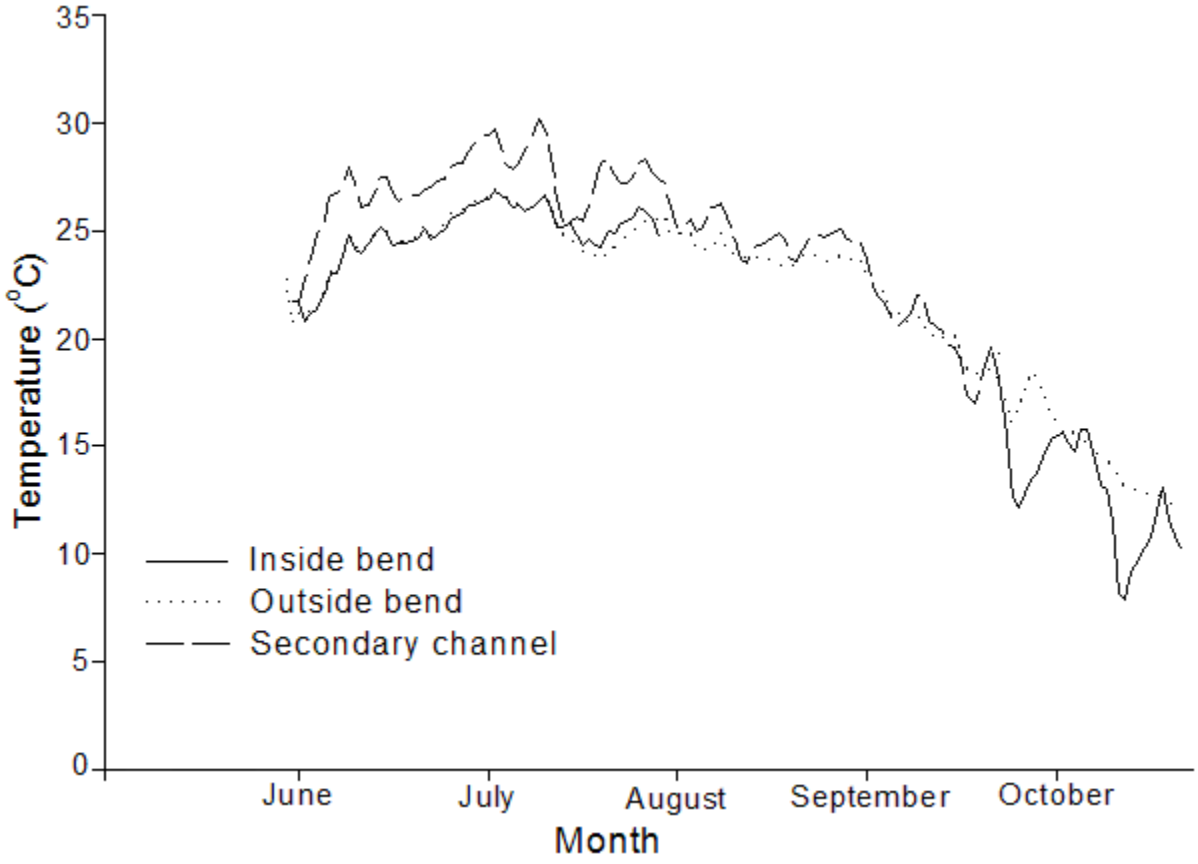

Figure 2-12: Mean daily temperature by habitat type at the James site downstream of Gavins Point Dam, South Dakota and Nebraska during 2005.

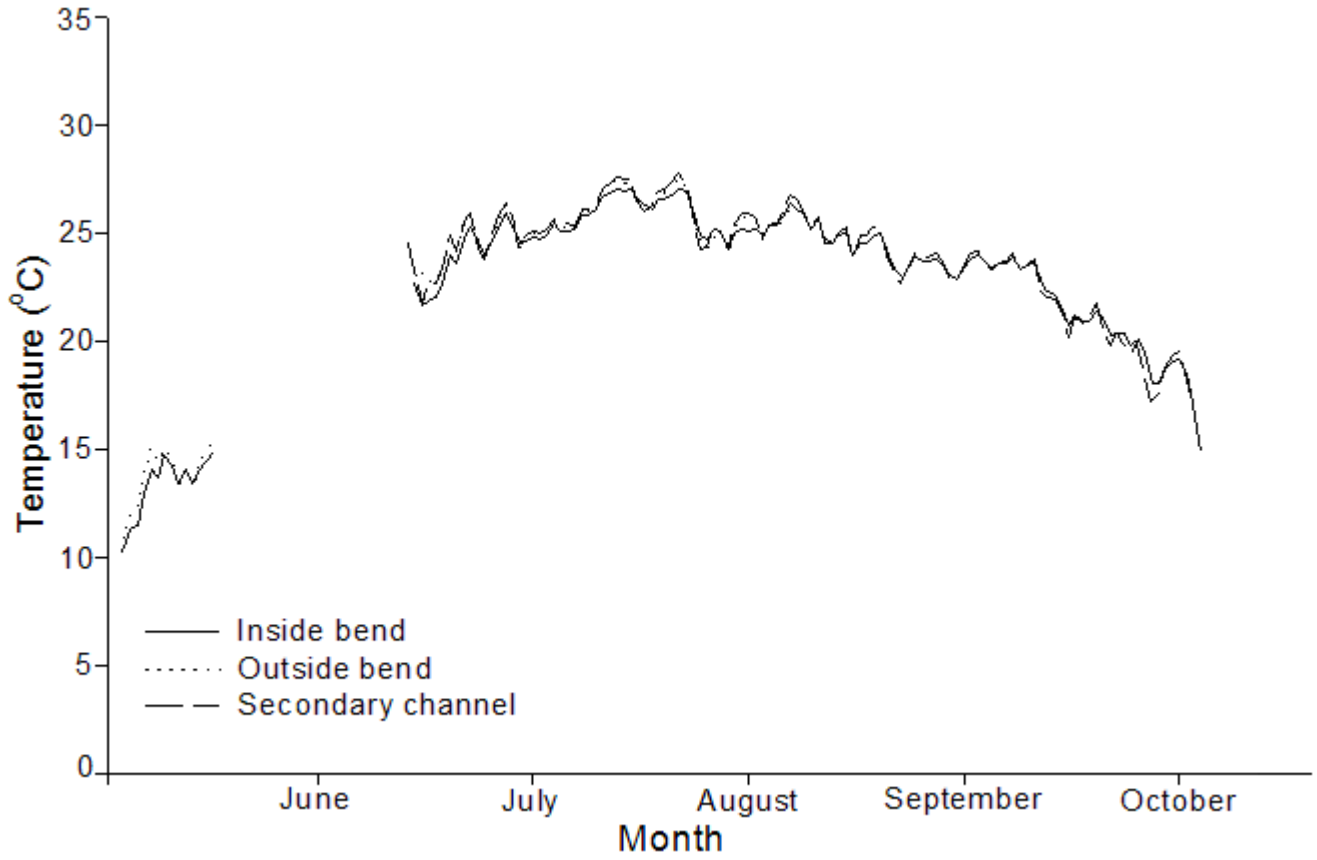

Figure 2-13: Mean daily temperature by habitat type at the Clay site downstream of Gavins Point Dam, South Dakota and Nebraska during 2005.

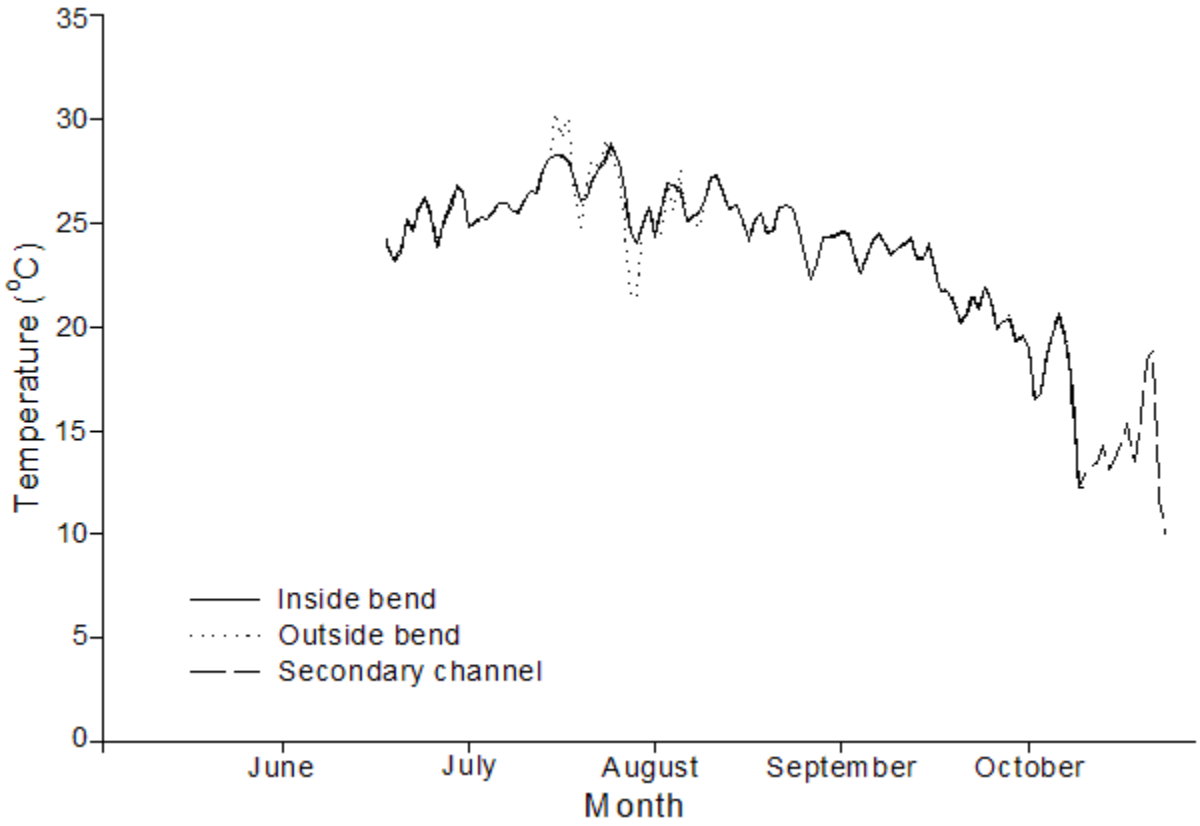

Figure 2-14: Mean daily temperature by habitat type at the Ponca site downstream of Gavins Point Dam, South Dakota and Nebraska during 2005.

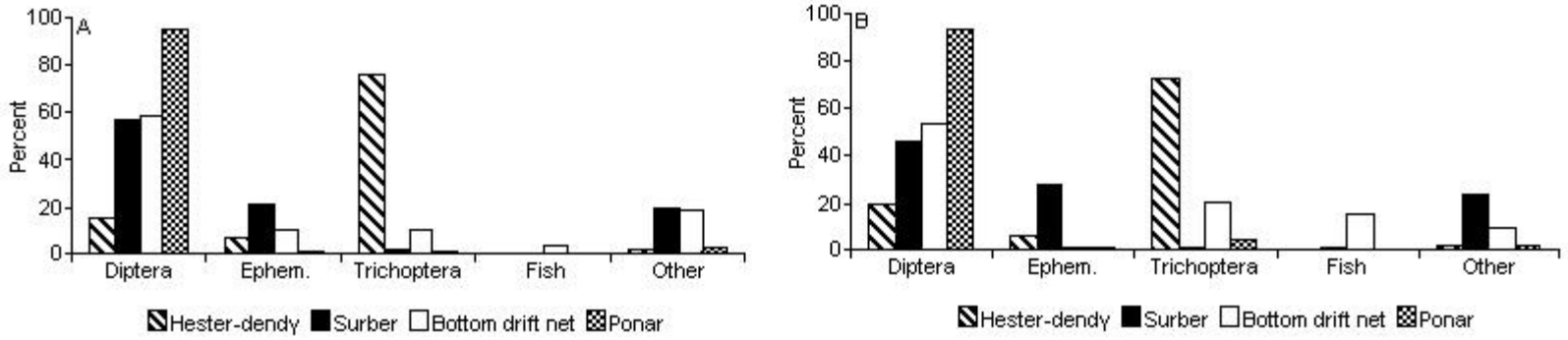

Figure 2-15: Percent composition (by number) of Diptera, Ephemeroptera (Ephem.), Trichoptera, Fish, and other taxa collected downstream of Fort Randall Dam, South Dakota and Nebraska by gear type in 2005 (A) and 2006 (B).

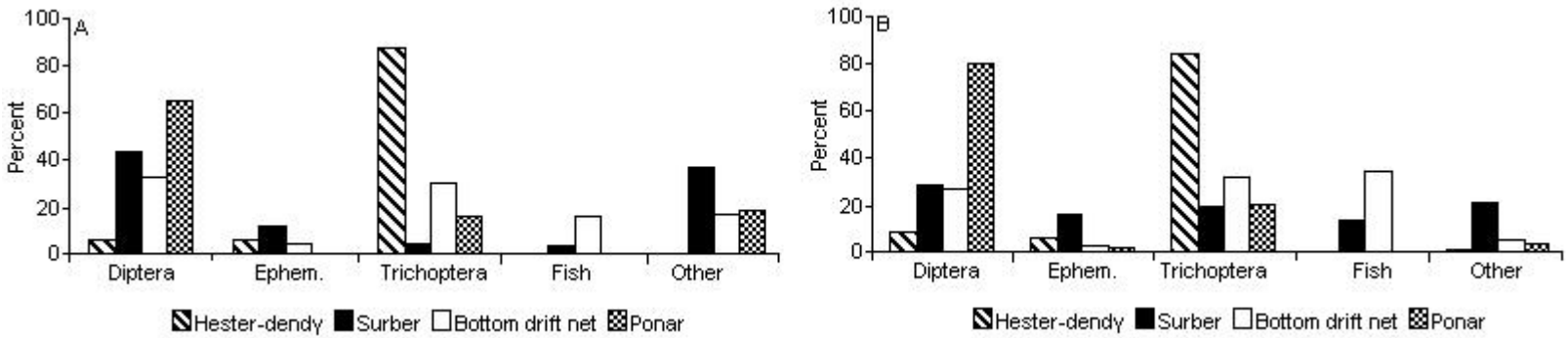

Figure 2-16: Percent composition (by number) of Diptera, Ephemeroptera (Ephem.), Trichoptera, Fish, and other taxa collected downstream of Gavins Point Dam, South Dakota and Nebraska by gear type in 2005 (A) and 2006 (B).

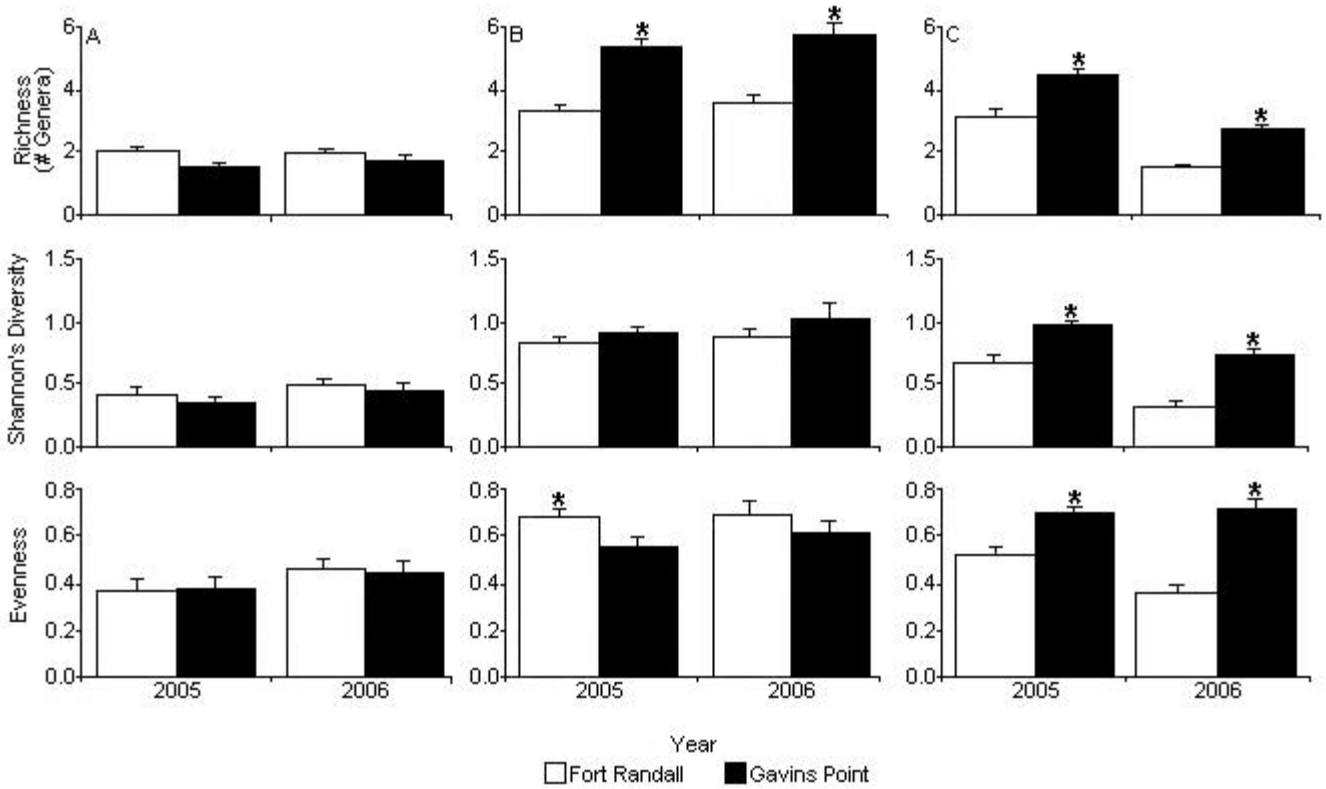

Figure 2-17: Comparison of mean taxa richness (by genera), Shannon's diversity index, and evenness between reaches from A) Surber samplers, B) Hester-Dendy artificial substrate samplers, C) bottom drift nets, D) column drift nets, and E) ponar dredges in the Missouri River downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska during 2005 and 2006. Significant differences between reaches indicated by asterisk for each year based on three-factor repeated measure ANOVAs with reach, site, and season as grouping factors. Season was used as a repeated measure. Differences were considered significant at $P \leq 0.05$.

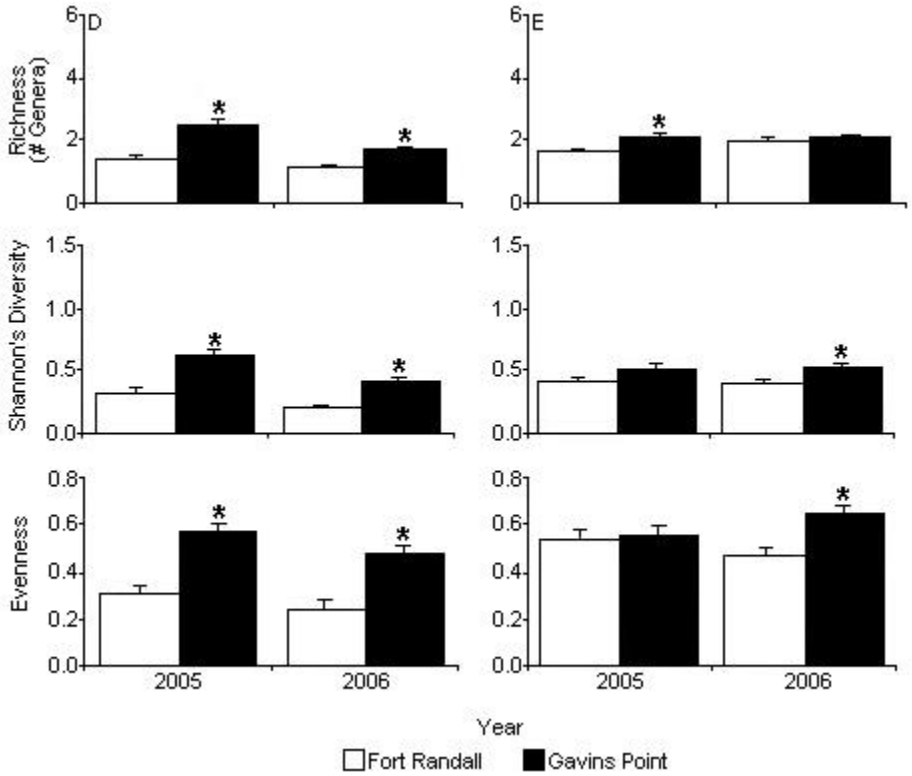

Figure 2-17: (Extended).

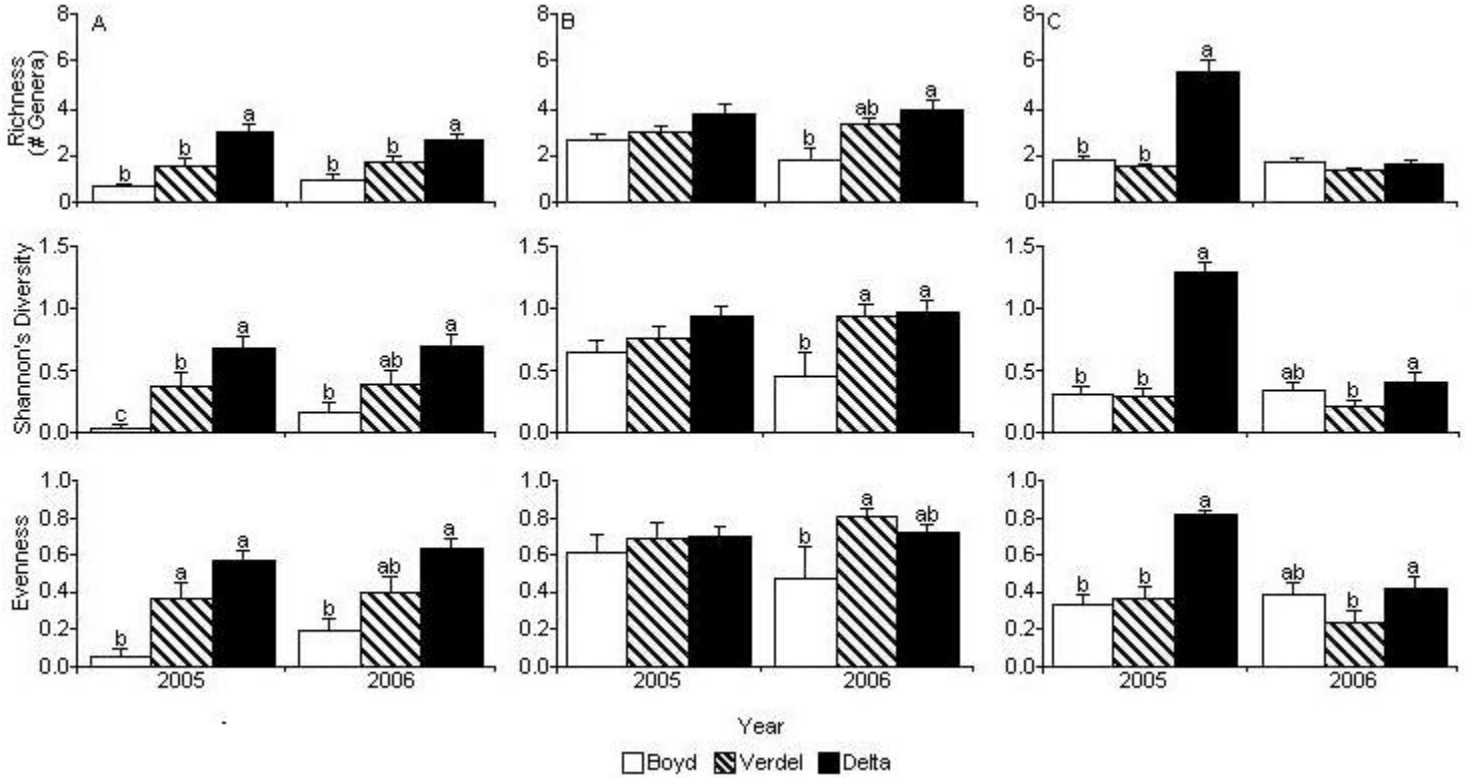

Figure 2-18: Comparison of mean taxa richness (by genera), Shannon's diversity index, and evenness among sites from A) Surber samplers, B) Hester-Dendy artificial substrate samplers, C) bottom drift nets, D) column drift nets, and E) ponar dredges in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska during 2005 and 2006. Significant differences among sites within a year indicated by letters based on three-factor repeated measure ANOVAs with reach, site, and season as grouping factors. Season was used as a repeated measure. Differences were considered significant at $P \leq 0.05$.

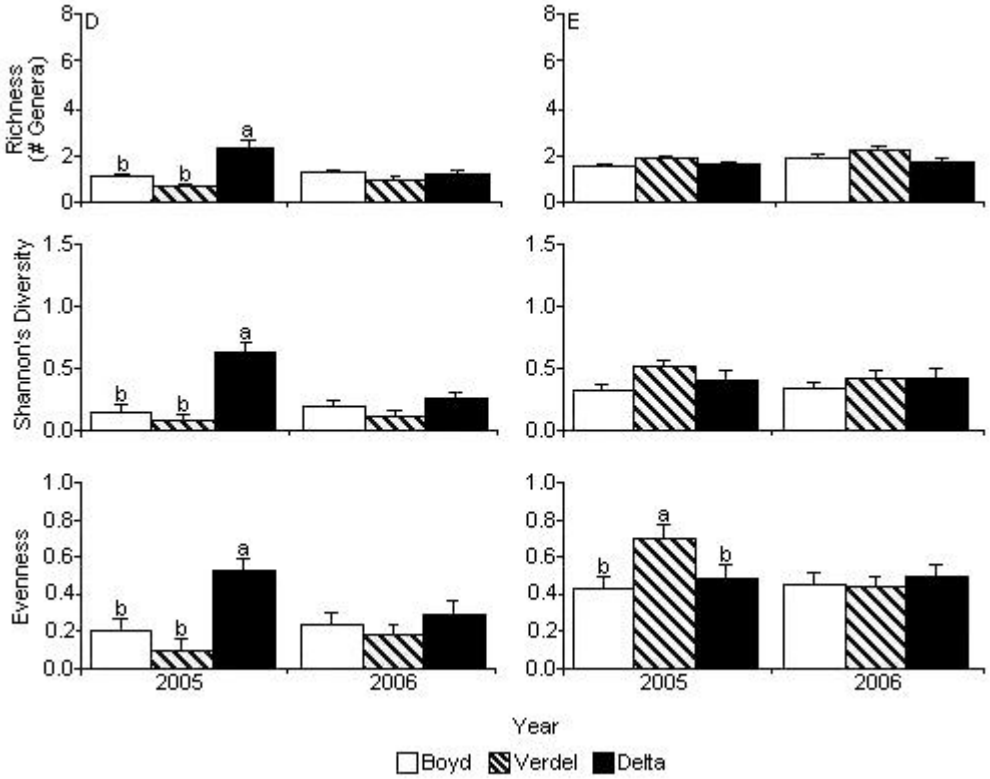

Figure 2-18: (Extended).

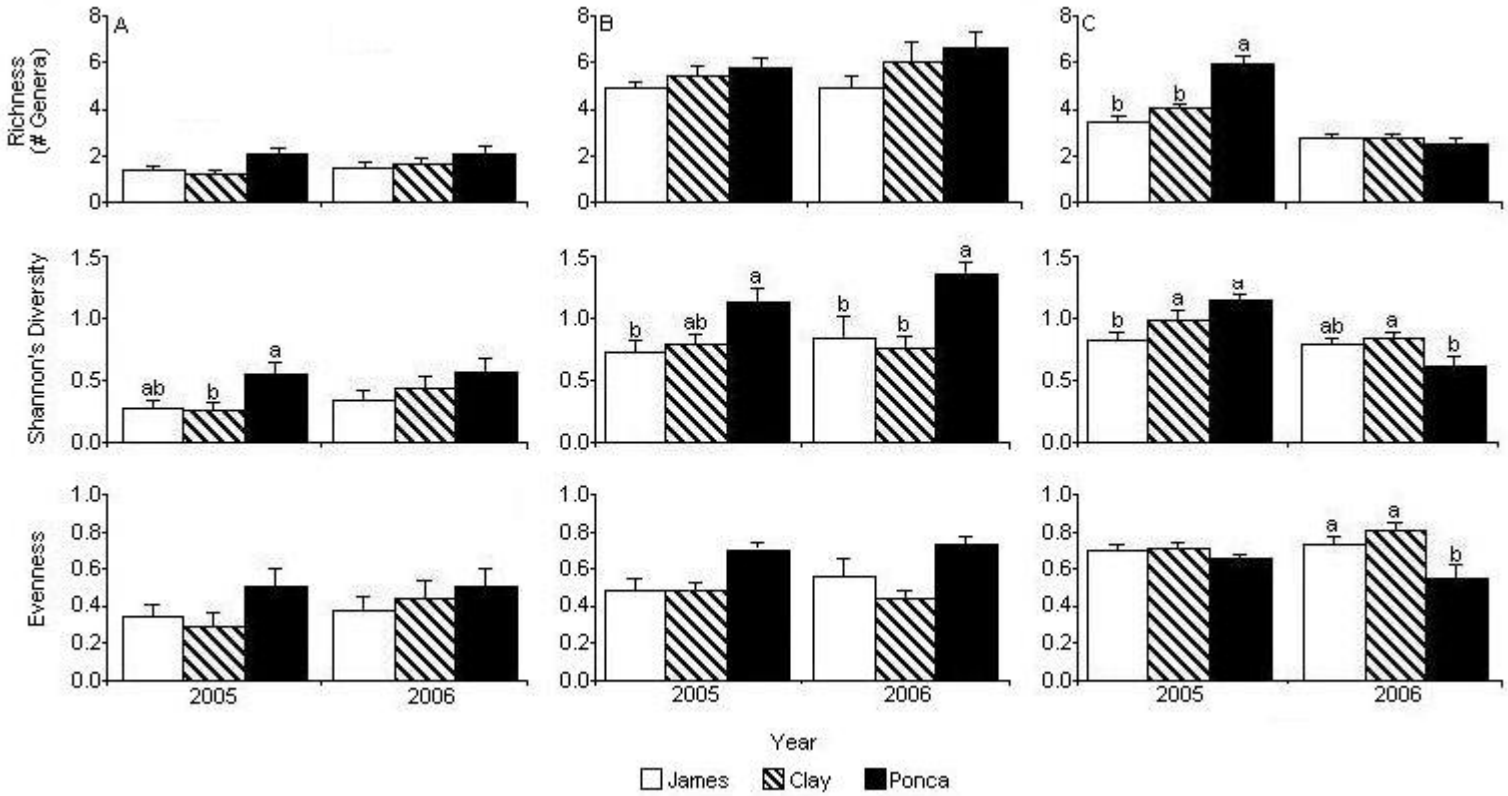

Figure 2-19: Comparison of mean taxa richness (by genera), Shannon's diversity index, and evenness among sites from A) Surber samplers, B) Hester-Dendy artificial substrate samplers, C) bottom drift nets, D) column drift nets, and E) ponar dredges in the Missouri River downstream of Gavins Point Dam, South Dakota and Nebraska during 2005 and 2006. Significant differences among sites within a year indicated by letters based on three-factor repeated measure ANOVAs with reach, site, and season as grouping factors. Season was used as a repeated measure. Differences were considered significant at $P \leq 0.05$.

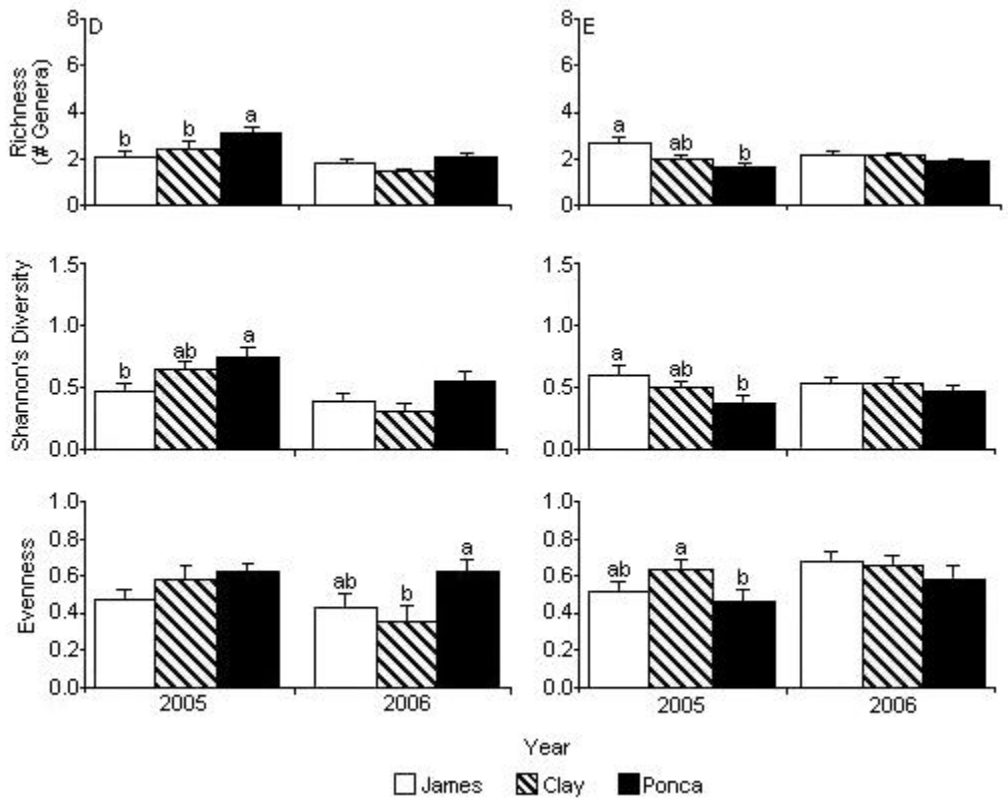

Figure 2-19: (Extended).

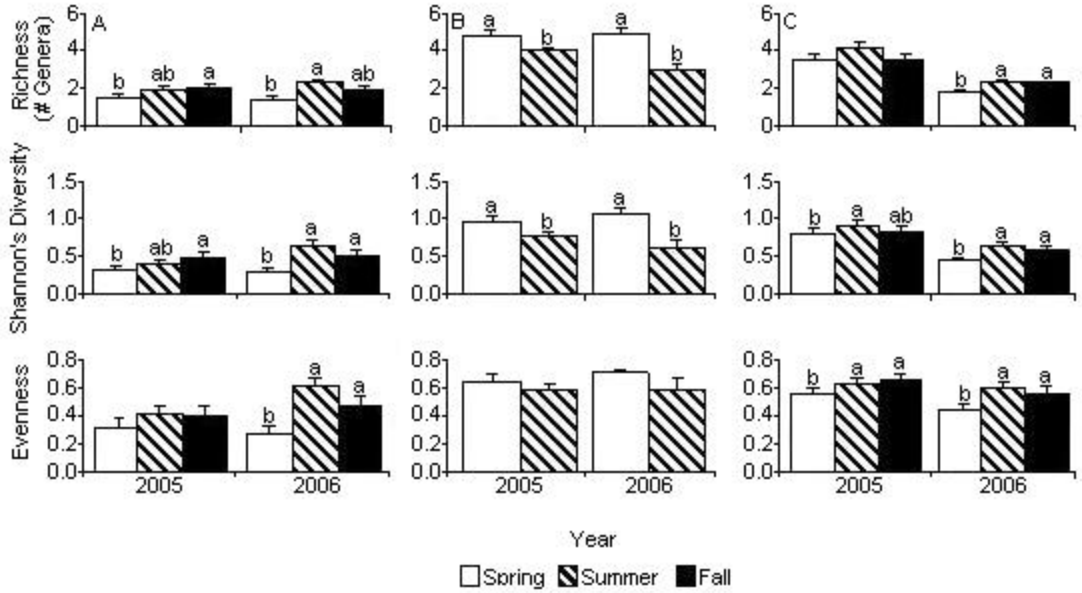

Figure 2-20: Comparison of mean taxa richness (by genera), Shannon's diversity index, and evenness by season from A) Surber samplers, B) Hester-Dendy artificial substrate samplers, C) bottom drift nets, D) column drift nets, and E) ponar dredges in the Missouri River downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska during 2005 and 2006. Significant differences among seasons within a year indicated by letters based on three-factor repeated measure ANOVAs with reach, site, and season as grouping factors. Season was used as a repeated measure. Differences were considered significant at P < 0.05.

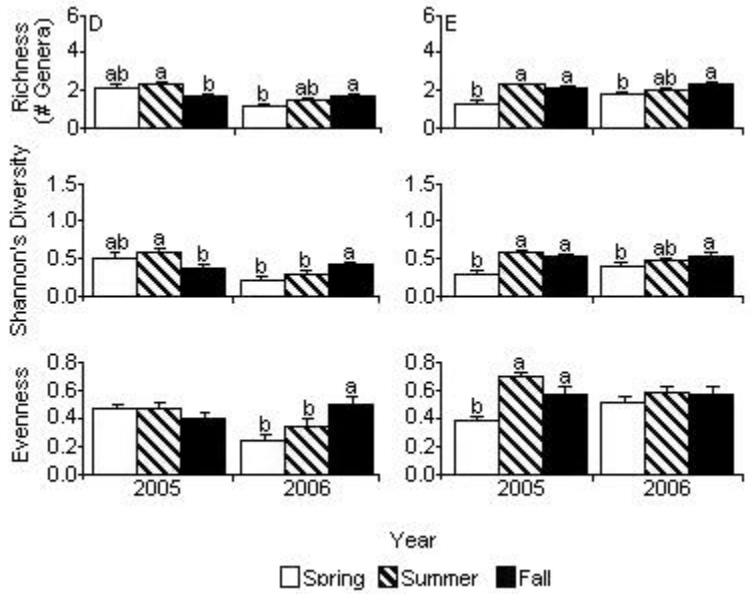

Figure 2-20: (Extended).

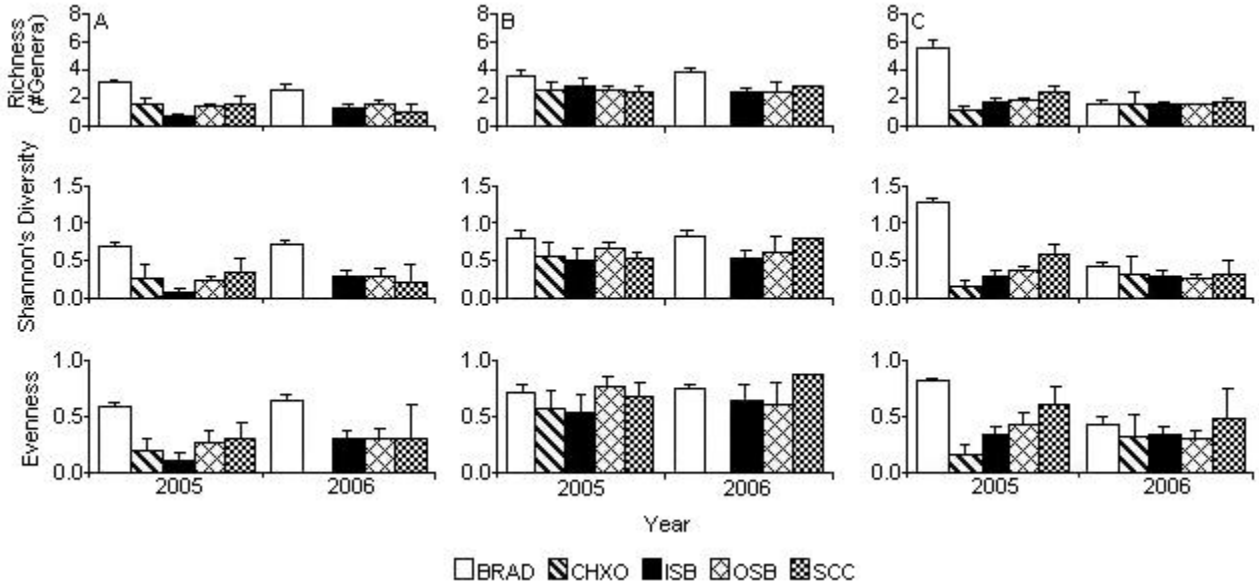

Figure 2-21: Comparison of mean taxa richness (by genera), Shannon's diversity index, and evenness by habitat from A) Surber samplers, B) Hester-Dendy artificial substrate samplers, C) bottom drift nets, D) column drift nets, and E) ponar dredges in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska during 2005 and 2006.

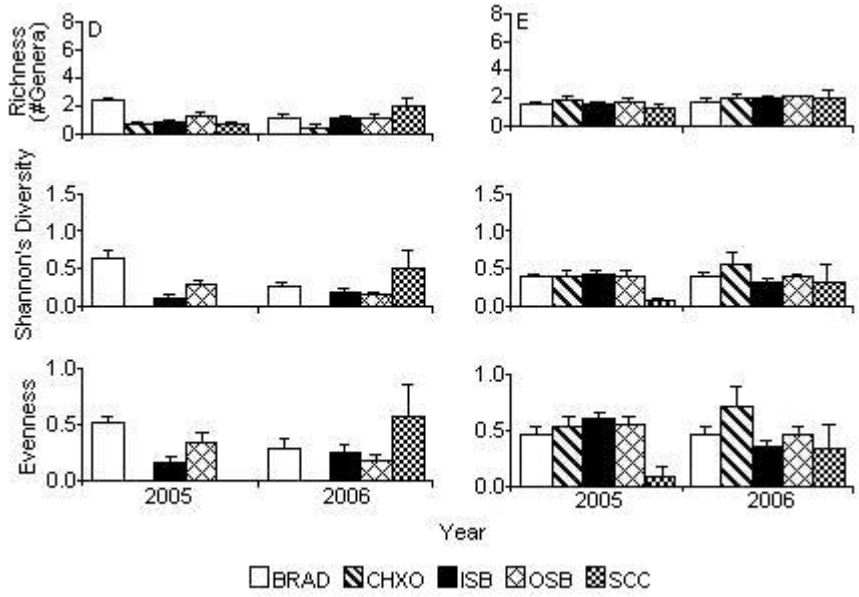

Figure 2-21: (Extended).

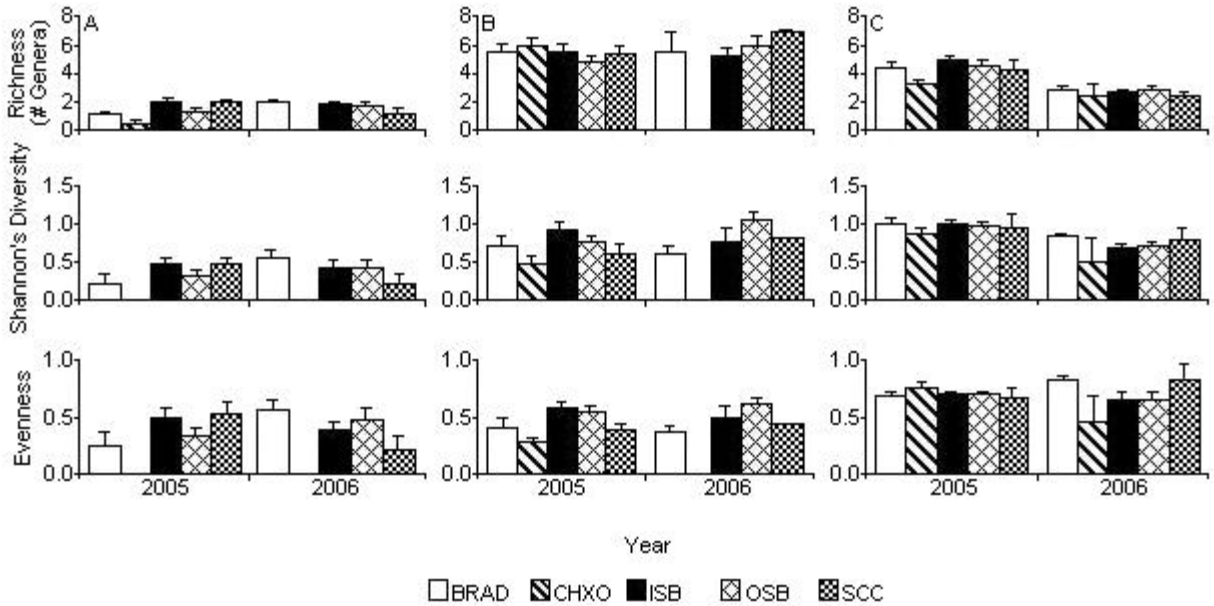

Figure 2-22: Comparison of mean taxa richness (by genera), Shannon's diversity index, and evenness by habitat from A) Surber samplers, B) Hester-Dendy artificial substrate samplers, C) bottom drift nets, D) column drift nets, and E) ponar dredges in the Missouri River downstream of Gavins Point Dam, South Dakota and Nebraska during 2005 and 2006.

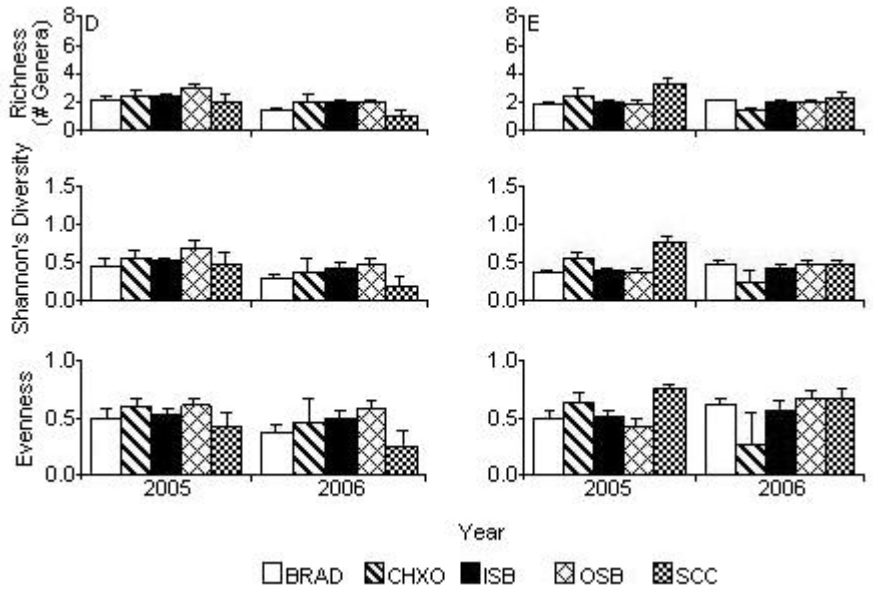

Figure 2-22: (Extended).

Chapter 3.

Prey use by juvenile pallid sturgeon in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska

Abstract

The pallid sturgeon, *Scaphirhynchus albus,* is an endangered species native to the Missouri and Mississippi rivers. Although recovery efforts have focused on stocking juvenile fish, little is known about spatial variation in diet composition or food availability for pallid sturgeon once they are stocked into the river. I collected 29 juvenile pallid sturgeon (JPS) 356 - 720 mm fork length [FL] (mean = 549; SE = 23) from the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska during summer 2006 for diet analysis. The percent occurrence of predominant prey was Ceratopogonidae (81%), Isonychiidae (67%), Chironomidae (52%), and fish (24%). Based on percent composition by wet weight, diets were composed of fish (68%), Ephemeroptera (23%), Decapoda (6%), and Diptera (3%). In general, the percent of fish in juvenile pallid sturgeon diets, mostly johnny darters *Etheostoma nigrum*, increased with body size; whereas, the proportion of mayflies decreased. Graphical analysis of diet composition showed that mayflies, particularly Isonychiidae, were an important component of JPS diets. Based on graphical analysis, JPS are typically generalized feeders for most of their prey. Fish composed a smaller portion of JPS diets (68%) in South Dakota and Nebraska compared to a 2003-2004 study on the upper Missouri River in Montana where 90% of JPS diets (as wet weight) were composed of fish. Pallid sturgeon diets in this study were primarily composed (% dry weight) of fish and

Ephemeroptera, especially johnny darters and Isonychiidae. This study showed that percent of fish in pallid sturgeon diets increased with body size and pallid sturgeon < 600 mm typically consumed more macroinvertebrates than did larger fish. The majority of JPS were captured within the delta formed by the Niobrara River in the headwaters of Lewis and Clark Lake. Macroinvertebrate abundance in the delta was generally higher than at upstream locations, highlighting the importance of this unique habitat to JPS growth and survival.

Introduction

The pallid sturgeon *Scaphirhynchus albus* is a long-lived species native to the Missouri River and lower Mississippi River Basins (Forbes and Richardson 1905; Dryer and Sandvol 1993). The species is ranked as critically endangered because of its rarity and vulnerability to extinction due to an apparent lack of natural reproduction and recruitment (Carlson et al. 1985). Sexual maturity is reached at ages 5 to 7 for males and 9-12 years of age for females (Keenlyne and Jenkins 1993). However, first spawn does not typically occur until age 15 and spawning does not occur every year (Keenlyne and Jenkins 1993; Keenlyne 1997).

The Missouri River has been anthropogenically modified by such activities as the construction of large impoundments behind six mainstem dams, dredging, and channelization (Kallemeyn 1983; Gilbraith et al. 1988; Keenlyne 1989,1997; Dryer and Sandvol 1993). About 51% of the pallid sturgeon's range has been channelized for barge navigation, 28% has been impounded, and the remaining 21% is downstream of dams (Keenlyne 1989). Six mainstem dams have blocked spawning migrations, isolated populations, decreased rearing and spawning habitats, and altered food supply. Fragmentation by dams has also altered flow, turbidity, and temperature regimes of the Missouri River (Dryer and Sandvol 1993; Pegg et al. 2003).

Pallid sturgeon have been federally listed as an endangered species since 1990 (Dryer and Sandvol 1993). To benefit the pallid sturgeon population, the U.S. Fish and Wildlife Service (USFWS) developed a recovery plan in 1993 (Dryer and Sandvol 1993). In addition, long-term monitoring programs have been implemented to assess pallid

sturgeon populations and associated fish communities through out the Missouri River system (Drobish 2006). Four reaches of the Missouri River have been selected for recovery based on the status of pallid sturgeon in these reaches and the availability of existing riverine habitat (Dryer and Sandvol 1993). These areas are referred to as Recovery Priority Management Areas (RPMAs). From 1992 to 2004, a total of 114,117 juvenile pallid sturgeon have been stocked throughout the Missouri River (Krentz et al. 2005). As part of evaluating these stocking efforts, all pallid sturgeon stocked in the Missouri River are marked (Krentz et al. 2005; Jaeger et al. 2007). Passive integrated transponder (PIT) tags allow identification of individual fish, whereas visible implant elastomer (VIE) tags and genetic markers can identify only year class (i.e., batch mark).

Aquatic insect larvae (Diptera and Ephemeroptera) were found to be the most important food items in juvenile pallid sturgeon diets in the states of Missouri (Carlson et al. 1985), South Dakota and Nebraska (Wanner et al. 2007a), and in the lower Mississippi River (Hoover et al. 2007). However, in 2003 and 2004, a study in the Missouri River above Fort Peck Reservoir, Montana found that fish occurred in 54% of the pallid sturgeon diets and composed 90% of the diets based on wet weight (Gerrity et al. 2006).

Although recovery efforts have focused on stocking juvenile fish, little is known about spatial variation in diet composition or food availability for pallid sturgeon once they are stocked into the river. Previous studies lacked concurrent information on macroinvertebrate composition, abundance, and distribution in the Missouri River (Carlson et al. 1985; Gerrity et al. 2006; Wanner et al. 2007a). Moreover, because the relative importance of prey items can be assessed using a variety of different diet

measures, selecting an appropriate index is often dependent on the questions being asked. When summarized using a single diet index, such as percent by weight, diet data are usually presented in tabulated format; thus, the relative importance of different prey items is often based on subjective interpretation (Chipps and Garvey 2007). Recent developments in graphical diet analysis are generally easier to interpret and can incorporate more than one diet measure. The objectives of this study were to 1) identify patterns of prey use by juvenile pallid sturgeon using a graphical approach, 2) explore changes in prey use as a function of pallid sturgeon size, and 3) compare pallid sturgeon diet composition in the Fort Randall reach to other areas of the Missouri River.

Study Area

The study area was located on the Missouri River downstream of Fort Randall Dam (river kilometer [rkm] 1,416) extending to Lewis and Clark Lake (rkm 1,305), herein referred to as the Fort Randall reach (Chapter 2). Habitat types included inside bends, outside bends, secondary connected channels, channel crossovers, and braided areas. Habitats are specifically defined in Drobish (2006). Flows from Fort Randall Dam are regulated for power generation and navigation downstream in the channelized section of the Missouri River. Because Fort Randall Dam regulates discharge, it has caused alterations from the historical hydrograph in the riverine section including daily and seasonal water level fluctuations (Pegg et al. 2003; Jordan et al. 2006). In addition, hypolimnetic water releases from the dam cause lowered downstream water temperatures.

Three sampling sites for macroinvertebrates were selected in the Fort Randall reach (Chapter 2). The upstream site was located from Sunshine Bottoms (rkm 1,394) to downstream of the Boyd County boat ramp in Nebraska. The middle site was located upstream of the Verdel boat ramp, Nebraska (rkm 1,376) to downstream of the Ponca Creek confluence. The most downstream site was unique because it was located within a braided, deltaic section of the river resulting from sedimentation by the Niobrara River into the headwaters of Lewis and Clark Lake. There are two main river channels along each bank line in the delta. This delta site was located upstream and downstream of the Santee boat ramp on the Nebraska side, and upstream and downstream of the Springfield boat ramp (rkm 1,365) on the South Dakota side.

Methods

Pallid sturgeon diets

Pallid sturgeon were collected using drifting trammel nets or an otter trawl during summer of 2006. Multifilament trammel nets were drifted perpendicular to the current for a targeted maximum distance of 300 m. Actual distance sampled was quantified with a GPS unit. Trammel nets were 38 m in length, 1.8 m in depth, with outside wall panels of 15.2 cm bar mesh (number 9 nylon twine), and inside wall panels of 2.5 cm bar mesh (number 139 nylon twine). Float lines were constructed of 1.3 cm poly-foamcore and leadlines were 22.7 kg leadcore. Typical duration of a drift was 5–15 min depending on water velocity. The otter trawl was a 4.9 m wide by 0.9 m high skate trawl. Otter boards were 38.1 cm high, 76.2 cm long, and weighed 13.6 kg each. The outer chafing mesh

was a sapphire twine with a 1.9 cm bar mesh and the inner netting was 0.6 cm bar mesh. The codend opening was 0.4 m. The footrope was 4.9 m long having a 4.8 mm diameter chain attached to help maintain contact with the substrate. The headrope was 4.6 m long with floats spaced every 0.9 m. Typical towing duration was 2–3 min for a targeted maximum distance of 300 m (Wanner et al. 2007b).

Each pallid sturgeon captured was measured for fork length (FL) to the nearest mm, weighed (g), and stomach contents collected non-lethally using pulsed gastric lavage. (Haley 1998; Brosse et al. 2002; Wanner 2006; Shuman and Peters 2007) Gastric lavage requires inserting a tube down the esophagus into the stomach where water is flushed to induce regurgitation (Hyslop 1980). After stomach contents were flushed, the fish were then placed in a recovery tank and monitored (Wanner 2006). This technique has been shown to have no effects on sturgeon mortality (Brosse et al. 2002; Shuman and Peters 2007) or short-term growth and condition (Wanner 2006) with food recovery rates of over 70% (Brosse et al. 2002; Wanner 2006; Shuman and Peters 2007). Stomach contents were collected in a 500 μm mesh sieve and preserved in a 10% formalin solution. In the laboratory, prey items were identified to at least the family level and fish were identified to species, when possible, using dichotomous keys (Merrit and Cummins 1996; Pflieger 1997; Voshell, Jr. 2002; Thorp and Covich 2001; Wiggins 2000). After prey items were identified and counted they were dried at 65°C for 24 h and then weighed to the nearest 0.01 g. For each prey type, stomach contents were expressed as frequency of occurrence, percent composition by number (Bowen 1996), percent composition by dry weight, and prey-specific abundance (Amundsen et al. 1996).

Relative prey importance

The relative importance of prey in pallid sturgeon diets was assessed by plotting prey-specific abundance (PSA_i) against percent occurrence (PO_i) of prey items in juvenile pallid sturgeon diets (Amundsen et al. 1996). Prey - specific abundance (PSA_i) was calculated as:

$$PSA_i = (\Sigma S_i/\Sigma S_{ti}) * 100,$$

where PSA_i is the prey – specific abundance of prey item i, S_i the stomach contents (by dry weight) comprised of prey i, and S_{ti} the total stomach contents (dry weight) in only predators with prey i in their stomach (Amundsen et al. 1996). To explore patterns of prey use, I constructed bivariate plots of PSA_i versus PO_i (Chipps and Garvey 2007). Prey items were grouped into four quadrants representing feeding strategy (generalized and opportunistically consumed) and prey importance (dominant and rare taxa). Opportunistic prey items have low percent occurrence in the diets and a high PSA so prey items do not occur in a lot of the diets but when they do, they represent a large portion. Dominant prey items have high percent occurrence in the diets and a high PSA values. Generalized feeding is characterized by prey items that have a high percent occurrence and low PSA. Rare prey items have both a low percent occurrence and low PSA value. When plotted in this fashion, graphical techniques can be used to evaluate relative prey dominance and the degree of homogeneity of the diet (Costello 1990; Amundsen et al. 1996; Strand et al. 2007).

Results

Pallid sturgeon diets

Twenty-nine age-2 to age-9 JPS were collected for diet analysis from June through October 2006, of which 21 had prey items in their diets (Table 3-1). These 21 pallid sturgeon ranged from 356 to 720 mm FL (mean = 494; SE = 25). The eight JPS from which prey items were not recovered ranged from 495 to 711 mm FL (mean = 603, SE = 30). The percent occurrence of predominant prey was Ceratopogonidae (81%), Isonychiidae (67%), Chironomidae (52%), and fish (24%; Table 3-2). Based on percent composition by wet weight, diets were composed of fish (68%), Ephemeroptera (23%), Decopoda (6%), and Diptera (3%).

Relative prey importance

Pallid sturgeon diets were primarily composed (% dry weight) of fish and Ephemeroptera, especially johnny darters and Isonychiidae. Based on dry weights, Isonychiidae was the dominant prey item in the diets. johnny darters, Astacidae, and Polymitarcyidae were opportunistically consumed; whereas, generalized feeding by JPS focused on Ceratopogonidae and Chironomidae. Rare prey items included Caenidae, Pseudironidae, Hydropsychidae, unidentifiable fish, channel catfish *Ictalurus punctatus*, Perlodidae, Simulidae, and Formicidae. Graphical analysis of diet composition showed that mayflies, particularly Isonychiidae, were an important component of JPS diets (Figure 3-1). In general, the percent of fish in pallid sturgeon diets (mostly johnny

darters) increased with body size whereas the proportion of mayflies (Ephemeroptera) decreased (Figure 3-2).

Discussion

Macroinvertebrates, especially mayflies and to a lesser extent Diptera were found to be dominant in the diet of JPS in the Missouri River downstream of Fort Randall Dam. In 2006, fishes and Ephemeroptera, especially johnny darters and *Isonychia spp*. occurred the most in the sturgeon diets. Even though juvenile pallid sturgeon in this study consumed more macroinvertebrates in terms of numbers of prey, fish (mostly johnny darters) generally made up a larger proportion of the diet by weight (Wanner et al. 2007a, Gerrity et al. 2006). However, based on graphical diet analysis, mayflies (Ephemeroptera) represented a dominant prey item, occurring in a high proportion of the diets sampled and representing an appreciable amount of consumed prey. Although johnny darters represented a high proportion of consumed biomass, they occurred in only 20% of JPS diets. Therefore, johnny darters were opportunistically consumed. Diptera, while present in >50% of the diets, represented a small proportion of consumed mass. These patterns are difficult to discern from simple diet measures (i.e. % by number or mass) and illustrate the importance of macroinvertebrates as a food source for pallid sturgeon, especially for fish < 600 mm FL.

In this study, length of JPS in which prey items were recovered ranged from 356 to 720 mm fork length (FL, n = 21; mean = 494; SE = 25). Size ranges from this study were similar to the size range sampled by Wanner et al. (2007a), which ranged from 355

to 706 mm FL (n = 28; mean = 549; SE = 23). However, JPS collected in Gerrity et al. (2006) had a mean FL of 538 mm. In this study, I found that juvenile pallid sturgeon (> 300 mm FL) relied on fish as their primary prey, and the reliance of macroinvertebrates substantially decreased when lengths reached > 600 mm FL. Sub-adult and adult pallid sturgeon (age 6+) are piscivorous and prey on riverine cyprinid species (Gerrity et al. 2006). According to USFWS (2008), juvenile pallid sturgeon undergo an ontogenetic diet shift to piscivory between 5 and 6 years of age; my study supports the findings of the USFWS (2008) and other studies (Gerrity et al. 2006; Wanner et al. 2007a).

Diet composition of pallid sturgeon has been shown to vary with location in the Missouri and Mississippi rivers (Gerrity et al. 2006, Wanner et al. 2007a; Carlson et al. 1985; Hoover et al. 2007). In 2003-2004, Wanner et al. (2007a) conducted a study in the same area as this study, and found that fish composed the greatest proportion (38%) of JPS diets, followed by Diptera (29%) and Ephemeroptera (28%; Figure 3-3). In my study, I found similar results; however, fish composed a greater portion of the diets (66%), followed by Ephemeroptera (24%) based on dry weights (Figure 3-3). Another study in 2003-2004, in a relatively unaltered stretch of the Missouri River above Fort Peck Reservoir, found that native benthic cyprinids, especially sturgeon chub *Macrhybopsis gelida* and sicklefin chub *Macrhybopsis meeki* were important in JPS diets and composed 90% of the diets based on wet weight (Gerrity et al. 2006). Additionally, in a study in the Mississippi River, the primary prey for pallid sturgeon was fish, based on volume; however, diets were primarily immature Diptera, Ephemeroptera, and Trichoptera by number (Hoover et al. 2007). Based on these findings, JPS in the Fort

Randall Reach of the Missouri River relied less on fish as a prey source (68%) than fish in the upper Missouri River in Montana (90%; Figure 3-4).

Prey fish assemblages in the Missouri River differ between Montana and South Dakota. Downstream of Fort Randall Dam, no sturgeon chubs or sicklefin chubs were collected from 2003 to 2006 in the Missouri River (USFWS 2004; Shuman et al. 2005; Hoagstrom et al. 2006; Shuman et al. 2006, 2007). In the upper Missouri River, Montana and North Dakota, native cyprinids such as sturgeon chubs and sicklefin chubs are still moderately abundant in main channel habitats (Gardner 2004; Welker and Scarnecchia 2004). However, throughout the Missouri River, declines of sturgeon chubs and sicklefin chubs have occurred (Galat et al. 2005). Macroinvertebrates collected in my study included Diptera, Ephemeroptera, and Trichoptera (Chapter 2), which were also found above Fort Peck Reservoir (Megargle 1997). Perhaps the lack of native cyprinids available to pallid sturgeon downstream of Fort Randall Dam causes JPS to rely more on macroinvertebrates as a food resource. A current study (USFWS unpublished data) suggests that JPS downstream of Fort Randall Dam have faster growth rates than the JPS upstream and downstream of Fort Peck Reservoir; however, this growth rate does not take into account length of the growing season.

Bramblett and White (2001) found that adult pallid sturgeon used substrates ranging from fines to cobble with a significantly higher use of fines and sands. Smaller pallid sturgeon (< 5 kg) tended to use larger substrates according to Erickson (1992). Perhaps prey fishes are easier to capture over sand rather than larger substrate. In

addition, benthic insects are generally more abundant on larger substrates such as gravel and cobble (Junk et al. 1998).

Macroinvertebrates were collected in conjunction with pallid sturgeon diets downstream of Fort Randall Dam, South Dakota and Nebraska during 2006 (Chapter 2). Macroinvertebrates consumed by pallid sturgeon such as Chironomidae, Ceratopogonidae, Isonychiidae, Caenidae, and Hydropsychidae were found to have relatively high abundance, especially in the delta formed downstream of the Niobrara and Missouri river confluence. Macroinvertebrates such as Simulidae, Pseudironidae, and Polymitarcyidae were collected in the river samples but had low abundance in the samples. In my study, 21 out of 29 JSP (72%) sampled were collected in the delta, the most downstream site where macroinvertebrates were collected. Isonychiidae, Polymitarcyidae, johnny darters, Chironomidae, and Ceratopogonidae were the prey items that represented the majority of JSP diets sampled in this study. All of the major prey items collected in the JPS diets except Chironomidae were generally collected in higher densities at the Delta site. Wanner et al. (2007c) evaluated habitat use and movement of adult pallid sturgeon downstream of Fort Randall Dam, and found that fish were primarily located in main channel habitats, except one that was found in a deep secondary channel in the delta. Another study in the Missouri River downstream of Fort Randall Dam reported that JPS were primarily located in the main channel, although 14 JPS were located in the delta in 2002 (Jordan et al. 2006). In the delta downstream of Fort Randall Dam, Shuman et al. (2005, 2006) collected five JPS in the delta area in 2004 – 2005 and 27 JPS in the delta in 2005 to 2006. Spindler (2008) found that the areas with

the highest pallid sturgeon captures were in the delta of the Missouri River downstream of Fort Randall Dam, based on abiotic and biotic variables. Sediment transport and habitat formation is present and dynamic in the delta, which has increased habitat diversity (Chapter 2). This suggests that deltas have the potential to enhance production of macroinvertebrates and be key feeding areas for fish, including juvenile pallid sturgeon.

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Table 3-1: Pallid sturgeon lengths and weights at stocking and recapture for fish that received gastric lavage for diet analyses during 2006 in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska. Individual fish were tagged either at stocking or recapture with passive integrated transponder tags (PIT). Asterisks indicate fish with empty stomachs.

		Stocking			Recapture			
PIT #	Year Class	Date	Fork Length (mm)	Weight (g)	Date	Fork Length (mm)	Weight (g)	Age
4626721356					8/7/2006	330	90	
46257E300A	2004	8/30/2005	225	37	7/19/2006	350	145	2
46264B5C5C	2004	8/30/2005	290	101	6/28/2006	356	120	2
4624146A5D	2003	10/7/2004	268	81	6/29/2006	382	170	3
4443430D34	2003	10/7/2004	259	56	6/29/2006	402	200	3
4626014C73	2004	8/30/2005	296	99	6/29/2006	403	180	2
4256526126	2002	7/26/2003	218	40	7/19/2006	412	250	4
435E112709	2002	7/26/2003	245	57	9/8/2006	438	268	4
435E200C34					7/21/2006	452	350	
4626041D4F					9/6/2006	459	320	
460E553F18					6/29/2006	460	270	
435D432E15*	2002	7/26/2003	277	85	6/30/2006	495	365	4
462833371B					9/8/2006	503	420	
42561D5112*	2002	7/26/2003	272	81	6/29/2006	509	420	4
431C2B0062	2001	4/21/2002	230		7/21/2006	510	420	5

Table 3-1: (Continued).

PIT #	Year Class	Stocking			Recapture			
		Date	Fork Length (mm)	Weight (g)	Date	Fork Length (mm)	Weight (g)	Age
4443170D35	2002	7/26/2003	226	47	9/7/2006	533	495	4
432355121E*	2001	4/21/2002	190		6/29/2006	545	560	5
435E3E2D44	2002	7/26/2003	268	73	9/7/2006	550	540	4
431B4C4564	2001	4/21/2002	230		9/6/2006	565	540	5
46277B5D60					6/29/2006	575	580	
460E4B2B2C*					6/29/2006	595	680	
460D416213*					6/29/2006	600	710	
424D4F3527	1999	4/27/2002	393	200	6/29/2006	606	710	
406E65467A*	1997	6/6/2000	526	538	6/29/2006	665	1000	9
406E630351	1997	6/6/2000	390	163	7/27/2006	670	940	9
406E523F1F	1997	6/6/2000	582	869	7/27/2006	702	1015	9
46282F7F13*					6/30/2006	705	835	
411B6E3866*	1997	6/6/2000	567	800	6/29/2006	711	1200	9
411A7C0B63	1997	6/6/2000	414	344	7/27/2006	720	1320	9

Table 3-2: Number of prey items (N), percent of fish with a particular prey item (i.e., frequency of occurrence), proportion of total diet by numbers of prey (i.e. composition), and percent composition of overall diet by dry weight (g) recovered from 21 juvenile pallid sturgeon stomachs in summer of 2006 in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska.

Prey Item	*N*	Occurrence (%)	Composition (% number)	Dry Weight (g)
Diptera	309	80.95	36.74	2.05
Chironomidae	29	52.38	3.45	0.42
Simuliidae	1	5.00	0.12	0.02
Ceratopogonidae	279	81.00	33.17	1.61
Ephemeroptera	499	90.48	59.33	24.24
Isonychiidae	371	66.67	44.11	19.93
Caenidae	116	33.33	13.79	2.24
Pseudironidae	11	23.81	1.31	1.89
Polymitarcyidae	1	4.76	0.12	0.17
Trichoptera	4	19.00	0.48	0.31
Hydropsychidae	4	19.00	0.48	0.31
Plecoptera	1	4.76	0.12	0.17
Perlodidae	1	5.00	0.12	0.17
Decapoda	1	5.00	0.12	7.32
Astacidae	1	5.00	0.12	7.32
Hymenoptera	1	5.00	0.12	0.03
Formicidae	1	5.00	0.12	0.03
Fish	26	24.00	3.09	65.87
Johnny Darter	24	19.05	2.85	65.65
Channel Catfish	1	4.76	0.12	0.21
Unidentified Fish	1	4.76	0.12	0.01

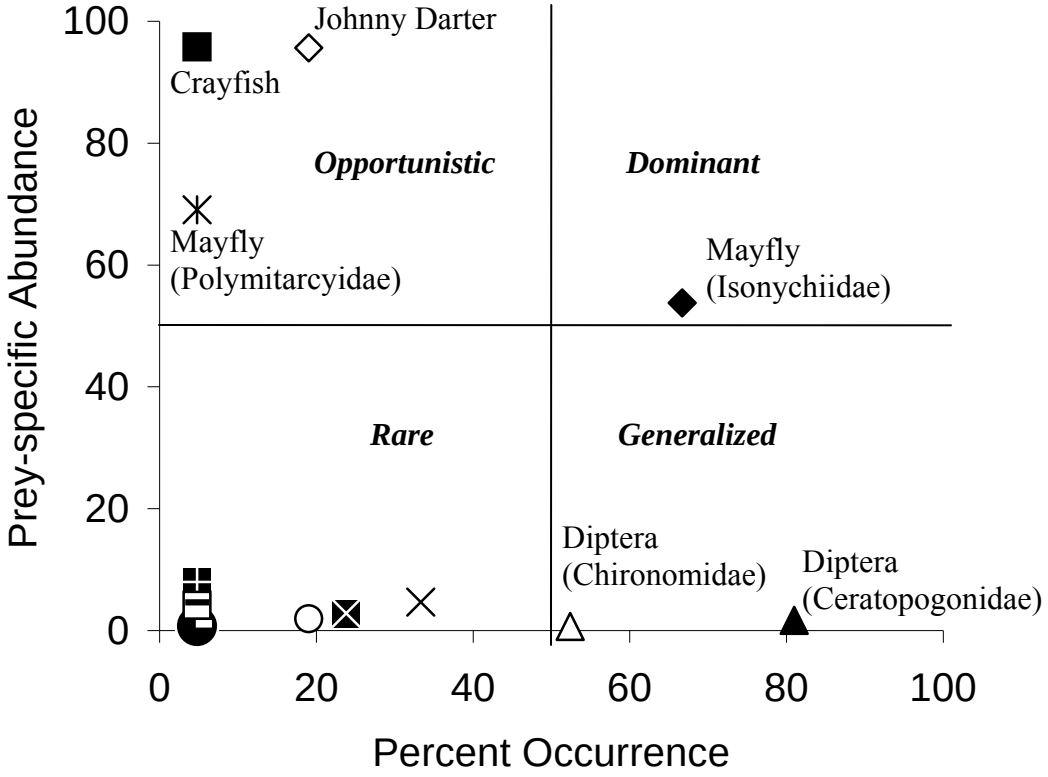

Figure 3-1: Graphical representation of prey-specific abundance (% dry wt) versus percent occurrence (Amundsen et al. 1996) from diets of 21 juvenile pallid sturgeon from the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska from June to September of 2006. The four quadrants represent feeding strategy (generalized and opportunistically consumed) and prey importance (dominant and rare taxa). Rare taxa included other Ephemeroptera, Trichoptera, Plecoptera, fish, and terrestrial insects.

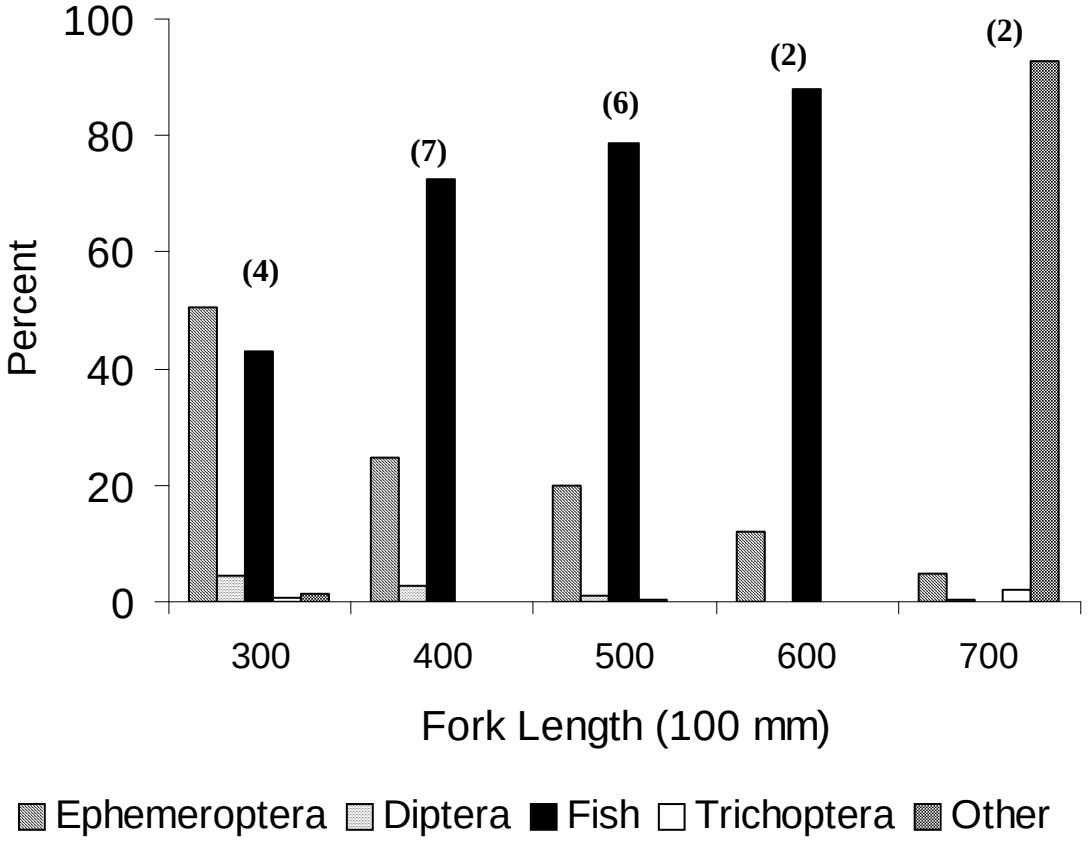

Figure 3-2: Percent composition by dry weight (g) from diets of 21 juvenile pallid sturgeon in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska from June to September of 2006 by 100 mm fork length category (numbers of fish in parentheses). Other taxa included Plecoptera, Hymenoptera, and Decapoda.

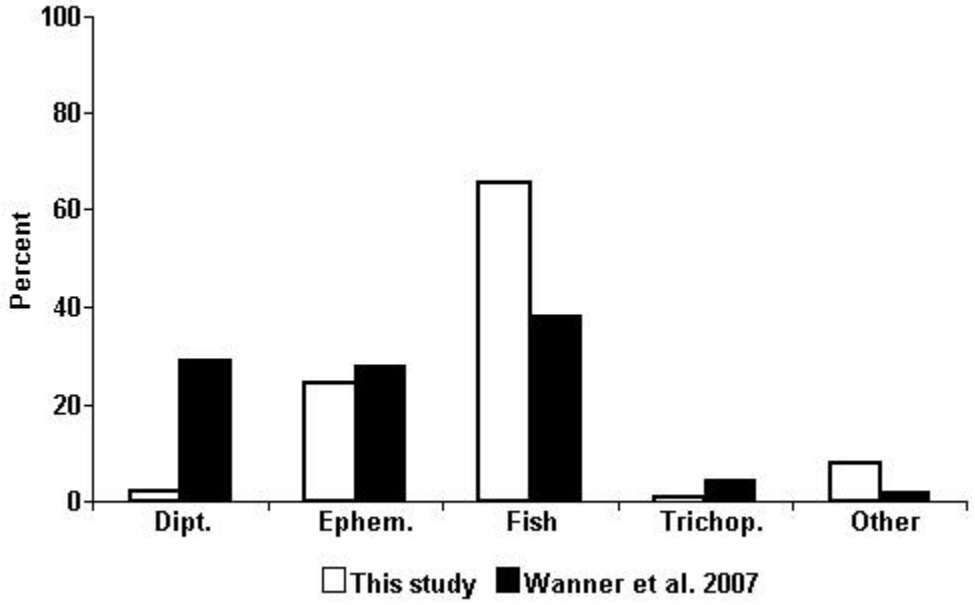

Figure 3-3: Percent composition by dry weight (g) of Diptera (Dipt.), Ephemeroptera (Ephem.), Fish, Trichoptera (Trichop.), and Other prey in the diets of juvenile pallid sturgeon sampled in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska in 2003 – 2004 (Wanner et al. 2007; N = 28) and 2006 (This study; N = 21). Other taxa included Plecoptera, Hymenoptera, and Decapoda.

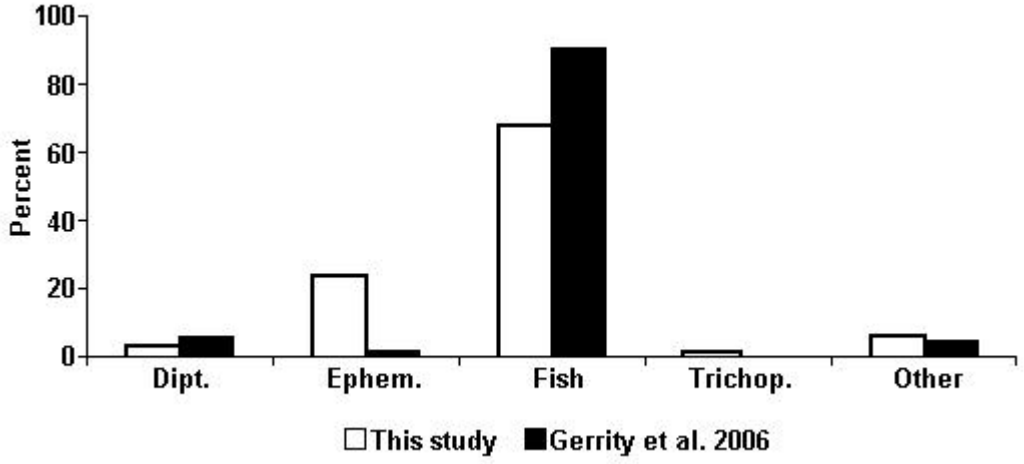

Figure 3-4: Percent composition by wet weight (g) of Diptera (Dipt.), Ephemeroptera (Ephem.), Fish, Trichoptera (Trichop.), and Other prey in the diets of juvenile pallid sturgeon sampled in the Missouri River upstream of Fort Peck Reservoir, Montana in 2003 – 2004 (Gerrity et al. 2006; N = 50) and downstream of Fort Randall Dam, South Dakota in 2006 (This study; N = 21). Other taxa included Plecoptera, Hymenoptera, and Decapoda.

Chapter 4.

Summary and Management Implications

The construction of six main stem dams along the Missouri River has dramatically altered environmental conditions. Downstream of Fort Randall and Gavins Point dams, flow fluctuates, both seasonally and daily, with lower temperatures and turbidity than in historical times. In my study, the most abundant macroinvertebrate families collected in 2005 and 2006 included Chironomidae, Ceratopogonidae, Isonychiidae, Baetidae, Caenidae, Heptageniidae, Hydropsychidae, and Polycentropodidae. The Jaccards similarity matrices showed that the Niobrara River Delta site was unique compared to all the other sites in the Fort Randall and Gavins Point reaches having macroinvertebrate compositions with $\leq$ 45% similarity in 2005 and 2006 in shallow water habitats and $\leq$ 60% similarity in main channel habitats. My analysis showed significant differences in mean richness, diversity, evenness, and mean density between reaches, sites, and among seasons for most gears used. I found that mean richness, diversity, evenness, and mean density of major taxa collected were generally higher in the Gavins Point reach compared to the Fort Randall reach during 2005 and 2006. In the Fort Randall reach, mean richness, diversity, evenness, and mean density of major taxa collected tended to be highest in the Delta site in 2005 and 2006. In the Gavins Point reach, mean richness, diversity, evenness, and mean density of major taxa collected was generally highest at the Ponca site followed by the James site in 2005 and 2006. For most gears my study indicated that mean richness, diversity, evenness, and mean density tended to be highest in the summer and fall in 2005 and 2006; however,

mean richness, diversity, evenness, and mean density from the Hester-Dendy plate samplers were highest in the spring. In 2005 and 2006, mean richness, diversity, evenness, and mean density of major taxa collected were typically highest in braided and secondary connected channels in the Fort Randall reach. In the Gavins Point reach, there were no distinct trends in mean richness, diversity, or evenness among macrohabitats. Mean density of major taxa collected in Gavins Point reach during 2005 for each gear was generally higher in channel crossovers and inside bends, while in 2006 densities were higher in inside and outside bends.

Several federal and state agencies are trying to recover the endangered pallid sturgeon *Scaphirhynchus albus*. Juvenile pallid sturgeon have been stocked into the Missouri River in an attempt to help facilitate short-term recovery. A long-term monitoring program has been implemented to assess pallid sturgeon populations and related fish communities throughout the Missouri River system (Drobish 2006). However, limited information is available on the suitability of the systems where juvenile pallid sturgeon are stocked. I found fishes and macroinvertebrates were both important food resources for juvenile pallid sturgeon in the Missouri River downstream of Fort Randall Dam. Even though juvenile pallid sturgeon consumed macroinvertebrates, in my study there was a greater portion of fish (mostly johnny darters *Etheostoma nigrum*) found in the diets, similar to results found in previous studies (Wanner et al. 2007, Gerrity et al. 2006). Additionally, my study showed the importance of macroinvertebrates as a food source for juvenile pallid sturgeon, especially for fish < 600 mm fork length. An understanding of the community composition, abundance, and

diversity of macroinvertebrates and fishes would assist in the choice of stocking locations for juvenile pallid sturgeon into the system. Based on the findings of my study, current stocking locations at Verdel and Running Water are suitable for pallid sturgeon; however, stocking near the Delta could be more beneficial due to its importance to macroinvertebrates and high incidence of past pallid sturgeon captures (Shuman et al. 2005; Shuman et al. 2006, 2007). Spindler (2008) found that juvenile pallid sturgeon habitat use was strongly associated with invertebrate abundance and developed a model that accurately determined pallid sturgeon capture locations based on macroinvertebrate abundance. Abundant food resources may increase the growth, condition, and survival of juvenile pallid sturgeon stocked in these areas. Additionally, identification of highly productive areas may help identify habitats suitable for nursery areas for young from pallid sturgeon spawning in the wild, a key factor towards ultimate recovery.

Management Implications

1. Data collected during this study created a baseline of macroinvertebrate composition and abundance vital to future assessments of ecological changes in the Missouri River. Over 60 macroinvertebrate taxa were collected in 2005 and 2006 downstream of the Fort Randall and Gavins Point dams.
2. This study found that macroinvertebrate mean richness, diversity, evenness, and mean density were generally higher in the Gavins Point reach compared to the Fort Randall reach. Diel fluctuations in flow downstream of Gavins Point Dam were relatively stable compared to downstream of Fort Randall Dam in 2005 and 2006. Previous studies have reported that diel fluctuations in flow may negatively

impact macroinvertebrate densities (Trotzky and Gregory 1974; Troelstrup and Hergenrader 1990; Blinn et al. 1995). Higher macroinvertebrate community metrics suggest that diel fluctuations from Fort Randall Dam had a negative impact on macroinvertebrates. Secondary production of macroinvertebrates is important to support higher trophic levels, such as fish and birds. Therefore, this study suggests flows from Fort Randall Dam be managed to minimize instream flows to benefit both fish and macroinvertebrates.

3. This study found that macroinvertebrate mean richness, diversity, and evenness tended to be significantly higher in the delta. In addition, mean densities of various taxa important to pallid sturgeon, e.g. Isonychiidae, were generally highest in the delta. High macroinvertebrate abundance suggests that the delta is very important source for macroinvertebrate production, including prey important to pallid sturgeon. The majority of the delta is shallow and unnavigable, but production within these shallow water habitats may be a key component to overall secondary production within the Fort Randall reach of the Missouri River.
4. Although I found significant differences between Fort Randall and Gavins Point reaches, mean macroinvertebrate densities were low for the majority of the taxa collected, partially due to timing of sampling. Further research is needed to verify my results and determine with specific objectives to find the optimal sampling time (night versus day) to maximize sampling efforts.
5. Habitat associations for macroinvertebrates and fish need to be determined for highly regulated large river systems. Areas sampled must include the river

directly downstream of each dam and the reservoirs, to allow comparisons directly related to the impacts of flow regulations and its effect on macroinvertebrates and fish. Several physical and chemical components should also be measured, including but not limited to, temperature, velocity, depth, substrate, benthic organic matter, pH, organic carbon, total nitrogen, phosphorous, total suspended solids, and chlorophyll *a* (Young et al. 2008).

6. The efficiency and sampling biases for gears that I used to sample macroinvertebrates needs to be evaluated. Different gears may be biased toward specific habitats and taxa. This knowledge would allow researchers to focus studies on specific habitats and taxa in those habitats, as well as better describe the entire macroinvertebrate assemblage.
7. I found that juvenile pallid sturgeon (FL< 600 mm) were not exclusively piscivorous and fed extensively on macroinvertebrates in the Fort Randall Reach of the Missouri River. Future research is needed to verify my results, determine specific age and size when ontogenetic diet shifts occur, and assess diet overlap and competition with other fish species. Diet overlap and competition for prey fish, a potentially limited resource, may be occurring and could explain, in part, why juvenile pallid sturgeon are relying on macroinvertebrates as a primary food source downstream of Fort Randall Dam.
8. Food habit research in conjunction with habitat data and bioenergetics modeling is needed to provide a greater understanding of JPS growth.

9. This study included an active monitoring program for macroinvertebrate aquatic nuisance species, specifically zebra mussels *Dreissena polymorpha*. No zebra mussels collected in 2005 and 2006 suggests that there is not an established adult zebra mussel population in the Missouri River downstream of Fort Randall and Gavins Point dams.

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Appendices

Appendix A: Number of individuals (N), frequency of occurrence, and percent composition by number of macroinvertebrates and larval fish collected in 2005 with all gears in the Missouri River downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska.

	Fort Randall			Gavins Point		
Taxa	N	Occurrence	Composition	N	Occurrence	Composition
Diptera						
Chironomidae	2956	71.9	29.6	3768	78.1	11.1
Ceratopogonidae	356	21.0	3.6	602	25.3	1.8
Simuliidae	87	8.3	0.9	198	17.1	0.6
Chaoboridae						
Chaoborus				3	0.6	< 0.1
Tipulidae	2	0.4	< 0.1			
Empididae				1	0.2	< 0.1
Psychodidae				8	0.2	< 0.1
Terrestrial	473	28.5	4.7	754	34.1	2.2
Ephemeroptera						
Isonychiidae						
Isonychia	15	2.3	0.2	306	8.4	0.9
Baetidae						
Baetis	51	4.8	0.5	371	11.0	1.1
Barbaetis	2	0.4	< 0.1	51	1.2	0.2
Procloeon	41	5.8	0.4	42	4.8	0.1
Unidentifiable	2	0.4	< 0.1	6	0.4	< 0.1

Appendix A (Continued).

Taxa	Fort Randall			Gavins Point		
	N	Occurrence	Composition	N	Occurrence	Composition
Ephemeroptera						
Caenidae						
Caenis	250	11.9	2.5	51	5.8	0.2
Brachycercus	8	1.3	0.1	6	0.8	< 0.1
Cerobrachys	10	1.5	0.1	56	6.6	0.2
Americaenis	30	2.7	0.3	7	1.4	< 0.1
Ephemeridae						
Hexagenia	126	8.1	1.3	76	9.4	0.2
Pentagenia				3	0.6	< 0.1
Polymitarcyidae						
Ephoron				12	1.6	< 0.1
Heptegeniidae						
Stenacron	10	0.4	0.1	279	2.8	0.8
Stenonema	115	3.8	1.2	416	9.2	1.2
Heptagenia	1	0.2	< 0.1			
Unidentifiable	5	0.2	0.1	1	0.2	< 0.1
Tricorythidae						
Tricorythodes	89	3.8	0.9	26	1.2	0.1
Terrestrial	8	1.2	0.1	5	1.0	< 0.1
Unidentifiable	2	0.4	< 0.1			

Appendix A (Continued).

	Fort Randall			Gavins Point		
Taxa	N	Occurrence	Composition	N	Occurrence	Composition
Trichoptera						
Hydropsychidae						
Hydropsyche	2545	23.7	25.5	20032	49.0	59.0
Ceratopsyche	6	1.2	0.1	43	2.4	0.1
Potomyia				3	0.4	< 0.1
Cheumatopsyche	64	1.7	0.6	2745	17.5	8.1
Terrestrial	2	0.4	< 0.1	39	1.0	0.1
Pupae	50	1.2	0.5	335	3.4	1.0
Polycentropodidae						
Neureclipsis	1471	11.9	14.7	456	10.4	1.3
Polycentropus	125	1.2	1.3	150	1.2	0.4
Cyrnellus				6	0.4	< 0.1
Pupae	55	1.3	0.6	5	0.2	< 0.1
Leptoceridae						
Oecetis	7	1.3	0.1	1	0.2	< 0.1
Nectopsyche	3	0.6	< 0.1	7	0.6	< 0.1
Hydroptilidae	7	0.6	0.1			
Ochrotrichia				1	0.2	< 0.1
Stactobiella	2	0.4	< 0.1			
Terrestrial				46	2.8	0.1
Pupae				5	0.2	< 0.1
Terrestrial	13	1.5	0.1	20	3.4	0.1
Pupae	20	0.8	0.2			

Appendix A (Continued).

	Fort Randall			Gavins Point		
Taxa	N	Occurrence	Composition	N	Occurrence	Composition
Plecoptera						
Perlidae						
Agnetina	2	0.4	< 0.1	1	0.2	< 0.1
Pteronarcyidae						
Pteronarcys	10	0.4	0.1			
Nemouridae	1	0.2	< 0.1			
Terrestrial	7	1.3	0.1	15	2.2	< 0.1
Hemiptera						
Corixidae						
Hesperocorixa	129	8.8	1.3	216	7.8	0.6
Belostoma				1	0.2	< 0.1
Terrestrial	356	18.7	3.6	251	16.7	0.7
Hymenoptera						
Formicidae	8	1.3	0.1	12	2.0	< 0.1
Terrestrial	80	9.6	0.8	715	11.8	2.1
Odonata						
Gomphidae	1	0.2	< 0.1			
Gomphus	12	0.8	0.1	11	0.6	< 0.1
Stylurus	13	2.1	0.1	3	0.6	< 0.1
Dromogomphus	2	0.4	< 0.1			

Appendix A (Continued).

	Fort Randall			Gavins Point		
Taxa	N	Occurrence	Composition	N	Occurrence	Composition
Odonata						
Coenagrionidae	1	0.2	< 0.1			
Amphiagrion	32	1.9	0.3	23	1.4	0.1
Gastropoda						
Lymnaeidae	18	1.5	0.2	134	2.0	0.4
Physidae	7	0.6	0.1	1	0.2	< 0.1
Planorbidae	2	0.4	< 0.1	5	1.0	< 0.1
Ancylidae	1	0.2	< 0.1	3	0.6	< 0.1
Bivalvia						
Sphaeriidae	2	0.4	< 0.1	47	2.0	0.1
Corbiculidae						
Corbicula fluminea	18	1.2	0.2	192	5.0	0.6
Amphipoda						
Hyallelidae						
Hyallela	21	1.5	0.2	12	0.8	< 0.1
Lepidoptera	2	0.4	< 0.1	1	0.2	< 0.1

Appendix A (Continued).

	Fort Randall			Gavins Point		
Taxa	N	Occurrence	Composition	N	Occurrence	Composition
Coleoptera						
Dytiscidae						
Dytiscus				1	0.2	< 0.1
Gyrinidae						
Gyrinus				1	0.2	< 0.1
Haliplidae	1	0.2	< 0.1			
Hydrophilidae				1	0.2	< 0.1
Staphylinidae	9	0.2	0.1			
Terrestrial	83	7.7	0.8	79	10.4	0.2
Isopoda						
Asellidae	12	1.2	0.1	4	0.8	< 0.1
Unidentifiable				2	0.4	< 0.1
Thysanoptera	9	1.5	0.1	8	1.2	< 0.1
Megaloptera						
Corydalidae	1	0.2	< 0.1			
Sialidae	1	0.2	< 0.1			
Neuroptera				1	0.2	< 0.1

Appendix A (Continued).

	Fort Randall			Gavins Point		
Taxa	N	Occurrence	Composition	N	Occurrence	Composition
Collembola						
Poduridae						
Podura	1	0.2	< 0.1			
Onychiuridae				1	0.2	< 0.1
Unidentifiable	5	0.8	0.1	1	0.2	< 0.1
Larval Fish	89	7.7	0.9	1198	18.7	3.5
Decapoda						
Astacidae/Cambaridae				1	0.2	< 0.1
Palaemonidae	1	0.2	< 0.1			
Acariformes						
Hydracarina/Hydrachnida	2	0.4	< 0.1	12	1.0	< 0.1
Hirudinea	5	0.2	0.1			
Araneae	24	4.2	0.2	52	7.6	0.2
Total	9977			33947		

Appendix B: Number of individuals (N), frequency of occurrence, and percent composition by number of macroinvertebrates and larval fish collected in 2006 with all gears in the Missouri River downstream of Fort Randall and Gavins Point dams, South Dakota and Nebraska.

	Fort Randall			Gavins Point		
Taxa	N	Occurrence	Composition	N	Occurrence	Composition
Diptera						
Chironomidae	3566	70.3	42.9	1921	74.4	17.2
Ceratopogonidae	355	18.6	4.3	427	27.3	3.8
Sphaeromias	1	0.2	< 0.1			
Simuliidae	63	5.9	0.8	84	11.7	0.8
Chaoboridae						
Chaoborus				1	0.2	< 0.1
Tipulidae	1	0.2	< 0.1			
Empididae				5	0.2	< 0.1
Terrestrial	56	6.5	0.7	47	6.3	0.4
Ephemeroptera						
Isonychiidae						
Isonychia	37	1.0	0.4	175	5.9	1.6
Baetidae						
Baetis	19	0.6	0.2	274	4.6	2.4
Barbaetis				45	1.5	0.4
Procloeon	62	5.0	0.7	46	6.6	0.4
Pseudocentoptiloides				1	0.2	< 0.1
Paracloeodes				1	0.2	< 0.1
Unidentifiable	6	0.8	0.1	9	1.2	0.1

Appendix B (Continued).

	Fort Randall			Gavins Point		
Taxa	N	Occurrence	Composition	N	Occurrence	Composition
Ephemeroptera						
Caenidae						
Caenis	55	4.6	0.7	22	3.2	0.2
Brachycercus	29	3.8	0.3	6	1.2	0.1
Cerobrachys	5	1.0	0.1	12	1.2	0.1
Americaenis	5	0.2	0.1	20	0.7	0.2
Ephemeridae						
Hexagenia	70	5.9	0.8	7	1.7	0.1
Pentagenia				1	0.2	< 0.1
Polymitarcyidae						
Ephoron	6	0.4	0.1	2	0.5	< 0.1
Heptegeniidae						
Stenacron	30	0.6	0.4	118	2.2	1.1
Stenonema	70	1.6	0.8	140	4.1	1.3
Unidentifiable				3	0.2	< 0.1
Oligoneuridae						
Homoeneuria	3	0.6	< 0.1	1	0.2	< 0.1
Tricorythidae						
Tricorythodes	57	2.2	0.7	6	0.5	0.1
Terrestrial	1	0.2	< 0.1	2	0.5	< 0.1
Unidentifiable	2	0.4	< 0.1	2	0.2	< 0.1

Appendix B (Continued).

Taxa	Fort Randall			Gavins Point		
	N	Occurrence	Composition	N	Occurrence	Composition
Trichoptera						
Hydropsychidae						
Hydropsyche	1890	13.5	22.7	5245	44.9	46.9
Ceratopsyche	1	0.2	< 0.1	3	0.2	< 0.1
Potomyia				24	1.2	0.2
Cheumatopsyche	25	0.4	0.3	907	3.9	8.1
Terrestrial				1	0.2	< 0.1
Pupae	40	1.4	0.5	240	2.9	2.1
Polycentropodidae						
Neureclipsis	1073	9.5	12.9	192	4.6	1.7
Polycentropus	40	1.2	0.5	30	0.5	0.3
Pupae	45	1.0	0.5	5	0.2	< 0.1
Leptoceridae						
Oecetis	4	0.8	< 0.1	1	0.2	< 0.1
Nectopsyche	17	0.8	0.2			
Hydroptilidae	11	0.2	0.1	5	0.2	< 0.1
Terrestrial	4	0.8	< 0.1	20	1.5	0.2
Plecoptera						
Perlidae						
Agnetina	3	0.4	< 0.1			
Pteronarcyidae						
Pteronarcys	5	0.2	0.1			

Appendix B (Continued).

Taxa	Fort Randall			Gavins Point		
	N	Occurrence	Composition	N	Occurrence	Composition
Plecoptera						
Terrestrial	1	0.2	< 0.1			
Hemiptera						
Corixidae						
Hesperocorixa	109	6.7	1.3	88	5.9	0.8
Terrestrial	52	7.1	0.6	41	6.8	0.4
Hymenoptera						
Formicidae	6	1.0	0.1	5	1.2	< 0.1
Terrestrial	88	9.1	1.1	39	7.1	0.3
Odonata						
Gomphidae						
Gomphus	2	0.4	< 0.1	3	0.2	< 0.1
Stylurus	7	1.4	0.1	1	0.2	< 0.1
Coenagrionidae	2	0.4	< 0.1	5	0.2	< 0.1
Amphiagrion	6	0.4	0.1	20	0.5	0.2
Calopterygidae						
Hetaerina	1	0.2	< 0.1			
Terrestrial	1	0.2	< 0.1			

Appendix B (Continued).

	Fort Randall			Gavins Point		
Taxa	N	Occurrence	Composition	N	Occurrence	Composition
Gastropoda						
Lymnaeidae	10	1.0	0.1	10	2.2	0.1
Physidae	19	1.8	0.2	2	0.5	< 0.1
Planorbidae	18	1.8	0.2	10	1.5	0.1
Ancylidae	1	0.2	0.0			
Bivalvia						
Sphaeriidae	20	3.0	0.2	46	3.2	0.4
Corbiculidae						
Corbicula fluminea	11	2.0	0.1	15	3.2	0.1
Amphipoda						
Hyallelidae						
Hyallela	61	3.2	0.7	2	0.5	< 0.1
Lepidoptera						
Pyralidae						
Crambus	5	1.0	0.1			
Acentria	1	0.2	< 0.1			
Terrestrial	10	1.6	0.1	4	1.0	< 0.1
Megaloptera						
Corydalidae				1	0.2	< 0.1

Appendix B (Continued).

	Fort Randall			Gavins Point		
Taxa	N	Occurrence	Composition	N	Occurrence	Composition
Coleoptera						
Hydrochidae						
Hydrochus	2	0.4	< 0.1	1	0.2	< 0.1
Hydrophilidae	1	0.2	< 0.1			
Terrestrial	20	3.2	0.2	11	2.7	0.1
Isopoda				3	0.7	< 0.1
Thysanoptera	2	0.4	< 0.1			
Larval Fish	179	11.9	2.2	827	24.4	7.4
Acariformes						
Hydracarina/Hydrachnida				1	0.2	< 0.1
Hirudinea	10	0.4	0.1			
Araneae	9	1.8	0.1	5	1.2	< 0.1
Oligochaete	1	0.2	< 0.1			

Appendix B (Continued).

	Fort Randall			Gavins Point		
Taxa	N	Occurrence	Composition	N	Occurrence	Composition
Nematomorpha						
Gordiidae						
Gordius	5	0.2	0.1			
Total	8317			11191		

Appendix C: Number of individuals (N), mean percent composition by number (2 standard errors in parentheses), and mean density (number of taxa/m^2) of macroinvertebrates and larval fish collected with a Surber sampler in 2005 and 2006 in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska.

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Diptera						
Chironomidae	508	48.4 (1.2)	548.2 (433.3)	271	54.3 (14.7)	330.7 (21.3)
Ceratopogonidae	4	1.3 (1.4)	4.1 (4.6)			
Sphaeromias				1	0.8 (1.6)	0.9 (1.7)
Simuliidae	2	0.1 (0.2)	1.8 (3.5)	2	0.2 (0.3)	1.7 (3.4)
Terrestrial	23	10.6 (12.2)	29.8 (34.2)			
Ephemeroptera						
Baetidae						
Baetis	6	1.1 (2.1)	5.3 (10.5)			
Procloeon	26	4.8 (1.2)	32.3 (26.5)	56	8.6 (6.1)	77.3 (61.6)
Unidentifiable	1	0.5 (1.0)	1.4 (2.8)	3	< 0.1 (< 0.1)	2.6 (5.1)
Caenidae						
Caenis	117	4.6 (5.8)	112.5 (164.9)	26	3.8 (5.9)	24.9 (35.4)
Brachycercus	1	< 0.1 (< 0.1)	0.9 (1.8)	17	2.1 (4.2)	14.6 (29.2)
Cerobrachys	1	< 0.1 (< 0.1)	0.9 (1.8)	3	0.4 (0.6)	3.4 (3.4)
Tricorythidae						
Tricorythodes	2	<0.1 (< 0.1)	1.8 (3.5)	7	0.8 (1.5)	6.0 (12.0)
Ephemeridae						
Hexagenia	43	2.7 (4.9)	38.4 (71.9)	48	3.0 (6.0)	41.2 (82.3)

Appendix C (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Ephemeroptera						
Heptegeniidae						
Stenonema	1	< 0.1 (< 0.1)	0.9 (1.8)			
Unidentifiable	1	1.7 (3.3)	1.7 (3.3)	1	0.3 (0.5)	0.9 (1.7)
Trichoptera						
Hydropsychidae						
Hydropsyche	12	3.1 (4.9)	15.3 (10.2)	2	0.4 (0.6)	2.6 (2.9)
Cheumatopsyche	1	< 0.1 (< 0.1)	0.9 (1.8)			
Polycentropodidae						
Neureclipsis	4	0.2 (0.2)	4.3 (4.6)	7	0.7 (1.3)	6.0 (12.0)
Leptoceridae						
Oecetis	1	< 0.1 (< 0.1)	0.9 (1.8)			
Hemiptera						
Corixidae						
Hesperocorixa	108	7.4 (7.4)	114.6 (125.1)	99	11.6 (7.1)	119.4 (95.6)
Terrestrial	13	2.2 (1.4)	14.6 (6.7)	4	2.2 (2.8)	4.3 (4.5)
Hymenoptera						
Formicidae	1	< 0.1 (< 0.1)	0.9 (1.8)	2	0.1 (0.2)	2.9 (5.9)
Terrestrial	3	< 0.1 (0.1)	2.6 (5.3)			

Appendix C (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Amphipoda						
Hyallelidae						
Hyallela	3	0.2 (0.5)	2.6 (5.3)			
Odonata						
Gomphidae						
Gomphus				1	0.2 (0.3)	0.9 (1.7)
Stylurus	8	4.7 (3.7)	9.9 (6.1)	6	1.3 (1.5)	6.9 (6.9)
Dromogomphus	1	< 0.1 (0.1)	0.9 (1.8)			
Coenagrionidae						
Amphiagrion	2	0.3 (0.6)	1.8 (3.5)			
Unidentifiable				2	0.1 (0.2)	1.7 (3.4)
Calopterygidae						
Hetaerina				1	< 0.1 (0.1)	0.9 (1.7)
Unidentifiable				1	< 0.1 (0.1)	1.5 (2.9)
Gastropoda						
Lymnaeidae	4	0.2 (0.4)	3.5 (7.0)	3	0.2 (0.4)	4.3 (6.2)
Physidae	5	0.4 (0.7)	4.4 (8.8)	4	0.6 (0.8)	4.3 (4.5)
Ancylidae	1	< 0.1 (0.1)	0.9 (1.8)	1	0.4 (0.8)	0.9 (1.7)
Planorbidae				4	0.7 (1.0)	4.3 (4.5)

Appendix C (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Bivalvia						
Sphaeriidae				2	0.3 (0.6)	1.3 (2.6)
Corbiculidae						
Corbicula fluminea	6	0.3 (0.7)	5.3 (10.5)	3	0.7 (1.4)	2.6 (5.1)
Araneae	1	0.1 (0.3)	0.9 (1.8)	2	0.6 (1.0)	2.6 (2.9)
Lepidoptera						
Pyralidae						
Acentria				1	0.1 (0.2)	0.9 (1.7)
Terrestrial	1	0.1 (0.2)	0.9 (1.8)	1	0.9 (1.8)	1.5 (2.9)
Coleoptera						
Hydrophilidae				1	0.2 (0.4)	0.9 (1.7)
Haliplidae	1	< 0.1 (< 0.1)	0.9 (1.8)			
Staphylinidae	9	0.2 (0.3)	7.9 (15.8)			
Terrestrial	12	4.2 (5.9)	14.9 (11.8)			
Isopoda						
Asellidae	1	< 0.1 (0.1)	0.9 (1.8)			
Megaloptera						
Sialidae	1	< 0.1 (< 0.1)	0.9 (1.8)			

Appendix C (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Oligochaete				1	0.1 (0.2)	1.7 (3.4)
Larval Fish	3	0.2 (0.3)	2.6 (5.3)	7	2.7 (2.8)	7.5 (5.4)
Total Aquatic Macroinvertebrates	882	82.4 (12.7)	926.3 (877.4)	576	93.7 (2.2)	669.2 (181.9)
Grand Total	938	100	992.6 (877.0)	590	100	685.0 (188.6)

Appendix D: Number of individuals (N), mean percent composition by number (2 standard errors in parentheses), and mean density (number of taxa/m^2) of macroinvertebrates and larval fish collected with Hester-Dendy artificial substrate samplers in 2005 and 2006 in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska.

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Diptera						
Chironomidae	810	22.1 (10.87)	1029.8 (388.0)	745	25.4 (19.2)	2005.3 (1716.0)
Ceratopogonidae	5	< 0.1 (0.2)	4.3 (8.6)	10	0.2 (0.4)	8.2 (16.4)
Simuliidae	5	< 0.1 (< 0.1)	8.2 (16.4)			
Ephemeroptera						
Isonychiidae						
Isonychia				35	0.5 (0.9)	28.8 (57.5)
Baetidae						
Baetis	15	< 0.1 (0.2)	12.9 (25.7)	15	0.1 (0.2)	12.3 (24.7)
Caenidae						
Caenis	30	0.4 (0.8)	25.7 (51.5)	25	1.8 (2.5)	45.2 (57.5)
Americaenis	10	< 0.1 (0.1)	8.6 (17.2)	5	< 0.1 (0.2)	4.1 (8.2)
Tricorythidae						
Tricorythodes	70	1.8 (2.5)	70.7 (72.7)	50	1.2 (1.3)	65.8 (65.8)
Ephemeridae						
Hexagenia	60	2.3 (2.4)	60.9 (55.8)			
Polymitarcyidae						
Ephoron				5	< 0.1 (0.2)	4.1 (8.2)

Appendix D (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Ephemeroptera						
Heptegeniidae						
Stenonema	105	1.9 (2.6)	100.7 (131.9)	70	1.1 (2.2)	57.5 (115.1)
Stenacron	10	0.2 (0.3)	8.6 (17.2)	30	0.7 (1.3)	24.7 (49.3)
Unidentifiable	5	0.2 (0.5)	4.3 (8.6)			
Trichoptera						
Hydropsychidae						
Hydropsyche	2335	28.9 (12.9)	3073.7 (1570.0)	1705	24.1 (10.2)	2436.7 (1401.7)
Cheumatopsyche	60	0.7 (0.9)	62.5 (63.4)	25	0.1 (0.2)	20.6 (41.1)
Pupae	50	0.9 (1.7)	78.3 (143.8)	40	3.5 (5.7)	69.9 (85.8)
Polycentropodidae						
Neureclipsis	1440	30.5 (5.8)	1715.5 (320.8)	1040	33.4 (13.5)	1532.7 (472.2)
Polycentropus	125	4.9 (4.1)	161.9 (62.8)	40	1.3 (2.1)	45.2 (49.9)
Pupae	55	0.8 (0.3)	75.5 (58.4)	45	1.6 (1.7)	49.3 (56.9)
Leptoceridae						
Nectopsyche				15	1.0 (1.6)	36.9 (62.1)
Hydroptilidae						
Pupae	5	0.1 (0.2)	8.2 (16.4)			
Pupae	20	2.2 (2.9)	19.9 (22.3)			

Appendix D (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Odonata						
Gomphidae						
Gomphus	10	0.5 (0.9)	8.6 (17.2)			
Coenagrionidae						
Amphiagrion	25	0.5 (0.6)	25.4 (29.7)	5	0.1 (0.2)	4.1 (8.2)
Plecoptera						
Pteronarcyidae						
Pteronarcys	10	< 0.1 (0.2)	8.6 (17.2)	5	< 0.1 (0.2)	4.1 (8.2)
Amphipoda						
Hyallelidae						
Hyallela	15	0.3 (0.7)	12.9 (25.7)	50	0.9 (1.8)	41.1 (82.2)
Isopoda						
Asellidae	5	0.1 (0.3)	7.0 (14.1)			
Gastropoda						
Planorbidae				10	1.4 (2.8)	32.9 (65.8)
Physidae				5	0.7 (1.4)	16.4 (32.9)

Appendix D (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Bivalvia						
Sphaeriidae				5	< 0.1 (0.2)	4.1 (8.2)
Corbiculidae						
Corbicula fluminea	10	0.3 (0.7)	8.6 (17.2)			
Hyrudinea						
Hirudinidae	5	0.1 (0.2)	4.3 (8.6)	10	0.2 (0.3)	8.2 (16.4)
Nematomorpha						
Gordiidae						
Gordius				5	0.4 (0.8)	16.4 (32.9)
Total Aquatic Macroinvertebrates	5295	100	6605.4 (1285.8)	3995	100	6201.3 (880.8)
Grand Total	5295	100	6605.4 (1285.8)	3995	100	6201.3 (880.8)

Appendix E: Number of individuals (N), mean percent composition by number (2 standard errors in parentheses), and mean density (number of taxa/100 m^3) of macroinvertebrates and larval fish collected in bottom drift net samples in 2005 and 2006 in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska.

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Diptera						
Chironomidae	803	48.1 (14.3)	58.8 (27.6)	355	41.1 (18.7)	20.7 (20.6)
Ceratopogonidae	23	1.3 (1.03)	1.7 (1.5)	18	2.9 (2.9)	0.6 (0.5)
Simuliidae	60	2.2 (3.4)	2.5 (3.3)	12	2.2 (2.8)	0.4 (0.3)
Tipulidae	1	< 0.1 (< 0.1)	< 0.1 (0.1)	1	0.1 (0.2)	< 0.1 (0.1)
Terrestrial	248	12.3 (3.1)	43.6 (59.6)	36	3.6 (2.9)	2.6 (2.3)
Ephemeroptera						
Isonychiidae						
Isonychia	12	0.3 (0.6)	0.4 (0.9)	1	0.4 (0.8)	< 0.1 (0.1)
Baetidae						
Baetis	22	0.6 (1.1)	0.8 (1.6)			
Barbaetis	1	< 0.1 (0.1)	0.1 (0.2)			
Procloeon	11	0.4 (0.8)	0.4 (0.08)	5	0.9 (0.8)	0.1 (0.1)
Unidentifiable	1	< 0.1 (< 0.1)	< 0.1 (< 0.1)	3	0.5 (0.9)	0.1 (0.2)
Caenidae						
Caenis	82	2.5 (3.8)	5.4 (10.0)			
Brachycercus	4	0.2 (0.2)	0.2 (0.3)	4	0.9 (1.7)	0.1 (0.2)
Cerobrachys	5	0.2 (0.3)	0.2 (0.3)			
Americaenis	15	0.5 (1.0)	0.6 (1.2)			

Appendix E (Continued).

Taxa	2005 N	2005 Composition	2005 Density	2006 N	2006 Composition	2006 Density
Ephemeroptera						
Tricorythidae						
Tricorythodes	12	0.2 (0.5)	0.6 (1.2)			
Ephemeridae						
Hexagenia	11	0.4 (0.2)	1.9 (2.7)	9	1.1 (1.2)	0.3 (0.5)
Polymitarcyidae						
Ephoron				1	0.1 (0.3)	< 0.1 (< 0.1)
Heptegeniidae						
Stenonema	4	0.3 (0.3)	0.1 (0.2)			
Unidentifiable	7	0.4 (0.4)	0.3 (0.4)	2	0.3 (0.7)	0.1 (0.1)
Trichoptera						
Hydropsychidae						
Hydropsyche	144	7.6 (5.1)	19.1 (6.1)	92	8.5 (9.9)	2.3 (3.0)
Ceratopsyche	6	0.3 (0.3)	0.2 (0.2)			
Unidentifiable	1	< 0.1 (< 0.1)	0.1 (0.1)			
Polycentropodidae						
Neureclipsis	22	1.4 (2.4)	1.0 (1.8)	7	1.9 (2.3)	0.2 (0.2)
Leptoceridae						
Oecetis	4	0.2 (0.4)	0.2 (0.5)	2	0.2 (0.2)	< 0.1 (0.1)
Nectopsyche	3	< 0.1 (0.2)	0.1 (0.2)	1	0.8 (1.6)	< 0.1 (0.1)

Appendix E (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Trichoptera						
Hydroptilidae						
Stactobiella	1	0.2 (0.4)	< 0.1 (0.1)			
Unidentifiable	1	< 0.1 (< 0.1)	< 0.1 (0.1)			
Terrestrial	11	0.5 (0.4)	0.6 (0.6)	2	0.2 (0.2)	0.1 (0.1)
Hemiptera						
Corixidae						
Hesperocorixa	19	0.8 (0.8)	0.8 (1.3)	5	1.7 (3.4)	0.2 (0.3)
Terrestrial	189	7.9 (5.5)	11.2 (14.1)	34	5.1 (3.9)	4.4 (6.2)
Hymenoptera						
Formicidae	6	0.2 (0.3)	0.2 (0.2)	2	0.5 (1.0)	0.1 (0.2)
Terrestrial	49	2.2 (0.9)	7.1 (11.7)	54	6.6 (6.1)	1.9 (2.1)
Amphipoda						
Hyallelidae						
Hyallela	2	0.1 (0.2)	1.3 (2.6)	6	1.8 (3.6)	0.2 (0.4)
Odonata						
Gomphidae						
Gomphus	2	0.1 (0.1)	0.1 (0.1)			
Stylurus	5	0.3 (0.3)	0.5 (0.7)			

Appendix E (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Odonata						
Gomphidae						
Dromogomphus	1	< 0.1 (< 0.1)	< 0.1 (0.1)			
Unidentifiable	1	< 0.1 (0.1)	< 0.1 (< 0.1)			
Coenagrionidae						
Amphiagrion	3	< 0.1 (0.1)	0.2 (0.3)			
Unidentifiable	1	< 0.1 (0.1)	1.2 (2.5)			
Plecoptera						
Nemouridae	1	< 0.01 (< 0.1)	< 0.1 (0.1)			
Perlidae						
Agnetina	2	0.1 (0.2)	0.1 (0.1)	1	0.1 (0.2)	< 0.1 (0.1)
Terrestrial	4	0.1 (0.2)	1.6 (3.1)	1	0.1 (0.2)	< 0.1 (0.1)
Araneae	14	0.7 (0.5)	0.4 (0.2)	2	0.1 (0.2)	0.1 (0.3)
Thysanoptera	6	0.2 (0.3)	0.2 (0.4)			
Lepidoptera						
Pyralidae						
Crambus				3	0.5 (1.1)	0.1 (0.2)
Unidentifiable	1	0.2 (0.4)	< 0.1 (0.1)	4	1.0 (1.8)	0.1 (0.1)

Appendix E (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Coleoptera						
Hydrochidae						
Hydrochus				1	0.3 (0.7)	0.1 (0.1)
Terrestrial	34	1.6 (1.3)	5.5 (8.8)	11	0.9 (0.5)	0.5 (0.3)
Colembolla	3	0.1 (0.2)	0.1 (0.1)			
Isopoda						
Asellidae	6	0.1 (0.3)	0.2 (0.5)			
Megaloptera						
Corydalidae	1	0.1 (0.2)	0.1 (0.1)			
Acariformes						
Hydracarina/Hydrachnida	2	0.1 (0.1)	< 0.1 (< 0.1)			
Bivalvia						
Sphaeriidae				1	0.8 (1.6)	< 0.1 (< 0.1)
Decapoda						
Palaemonidae	1	0.7 (1.5)	0.6 (1.2)			
Larval Fish	71	3.9 (4.3)	4.3 (4.6)	154	14.7 (6.7)	6.0 (2.2)

Appendix E (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Total Aquatic Macroinvertebrates	1313	70.6 (11.2)	98.5 (41.6)	536	68.6 (9.1)	25.9 (21.3)
Grand Total	1939	100	172.3 (114.6)	830	100	41.5 (16.6)

Appendix F: Number of individuals (N), mean percent composition by number (2 standard errors in parentheses), and mean density (number of taxa/100 m^3) of macroinvertebrates and larval fish collected in column drift net samples in 2005 and 2006 in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska.

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Diptera						
Chironomidae	145	27.4 (7.4)	27.3 (15.0)	198	48.2 (13.26)	42.1 (32.4)
Ceratopogonidae	9	0.8 (0.7)	0.8 (0.7)	1	< 0.1 (< 0.1)	0.1 (0.2)
Simuliidae	20	2.1 (4.2)	2.4 (4.8)	13	5.3 (1.9)	2.2 (1.7)
Tipulidae	1	< 0.1 (0.1)	0.1 (0.2)			
Terrestrial	180	22.5 (9.9)	45.0 (8.6)	20	5.1 (3.6)	9.5 (11.8)
Ephemeroptera						
Isonychiidae						
Isonychia	1	0.25 (0.49)	0.1 (0.2)	1	0.3 (0.6)	< 0.1 (0.1)
Baetidae						
Baetis	8	0.6 (1.2)	0.6 (1.2)			
Barbaetis	1	0.06 (0.1)	0.1 (0.3)			
Procloeon	3	0.2 (0.5)	0.2 (0.5)	1	0.3 (0.6)	0.1 (0.3)
Caenidae						
Caenis	21	2.0 (2.9)	3.7 (6.6)	4	0.8 (0.4)	0.4 (0.3)
Brachycercus	3	0.3 (0.5)	0.2 (0.4)	6	2.8 (5.6)	0.6 (1.1)
Cerobrachys	2	0.2 (0.5)	0.1 (0.2)			
Americaenis	5	0.9 (1.8)	1.6 (3.1)			
Tricorythidae						
Tricorythodes	5	0.4 (0.8)	0.4 (0.9)			

Appendix F (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Ephemeroptera						
Ephemeridae						
Hexagenia	3	0.4 (0.2)	0.3 (0.2)	4	0.6 (0.6)	0.5 (0.9)
Heptegeniidae						
Stenonema	4	0.6 (1.2)	0.5 (0.9)			
Heptagenia	1	0.2 (0.3)	0.5 (0.9)			
Oligoneuriidae						
Homoeoneuria				2	1.2 (2.0)	0.2 (0.3)
Unidentifiable	2	< 0.1 (0.2)	0.1 (0.3)			
Trichoptera						
Hydropsychidae						
Hydropsyche	50	10.3 (2.4)	12.1 (9.8)	19	5.8 (2.6)	3.7 (3.3)
Cheumatopsyche	3	0.1 (0.3)	0.2 (0.4)			
Pupae	1	0.3 (0.6)	0.1 (0.1)			
Polycentropodidae						
Neureclipsis	2	1.7 (1.7)	0.3 (0.4)	3	0.8 (0.9)	0.5 (0.8)
Leptoceridae						
Oecetis	2	0.2 (0.3)	0.3 (0.6)	2	0.8 (1.5)	0.2 (0.3)
Nectopsyche				1	0.9 (1.9)	< 0.1 (0.1)
Hydroptilidae	1	< 0.1 (< 0.1)	0.1 (0.2)			
Terrestrial	2	< 0.1 (< 0.1)	0.1 (0.3)	2	0.4 (0.4)	0.5 (0.7)

Appendix F (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Hemiptera						
Corixidae						
Hesperocorixa	2	0.6 (1.1)	0.4 (0.7)	5	1.8 (3.6)	0.3 (0.6)
Terrestrial	146	12.4 (6.4)	25.8 (19.4)	13	3.9 (3.8)	2.7 (2.3)
Hymenoptera						
Formicidae	1	0.1 (0.2)	0.1 (0.1)	2	0.6 (1.2)	0.2 (0.4)
Terrestrial	28	4.9 (2.4)	9.4 (11.5)	34	5.6 (5.6)	5.1 (6.7)
Amphipoda						
Hyallelidae						
Hyallela	1	0.2 (0.3)	0.2 (0.4)	4	2.3 (4.6)	0.6 (1.2)
Odonata						
Gomphidae						
Gomphus				1	0.2 (0.4)	0.2 (0.5)
Coenagrionidae						
Amphiagrion	2	0.2 (0.4)	0.3 (0.7)	1	0.2 (0.3)	< 0.1 (< 0.1)
Plecoptera						
Perlidae						
Agnetina				2	0.5 (0.9)	< 0.1 (0.1)
Terrestrial	3	1.3 (2.6)	0.4 (0.7)			

Appendix F (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Araneae	9	1.6 (1.5)	1.2 (0.8)	3	1.6 (2.6)	0.6 (0.8)
Thysanoptera	3	0.6 (1.1)	0.6 (1.1)	2	0.5 (1.0)	0.7 (1.5)
Lepidoptera						
Pyralidae						
Crambus				2	0.9 (1.8)	0.2 (0.4)
Unidentifiable				2	0.49 (0.9)	1.3 (2.5)
Coleoptera						
Hydrochidae						
Hydrochus				1	0.4 (0.7)	0.2 (0.3)
Terrestrial	36	2.7 (2.2)	10.0 (11.8)	8	2.2 (2.0)	2.1 (1.3)
Colembolla						
Poduridae						
Podura	1	< 0.1 (< 0.1)	0.1 (0.1)			
Unidentifiable	2	1.3 (2.5)	0.4 (0.7)			
Bivalvia						
Sphaeriidae				3	0.6 (1.2)	1.0 (1.9)
Larval Fish	15	2.6 (2.7)	2.1 (2.3)	18	4.9 (0.1)	4.1 (3.0)

Appendix F (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Total Aquatic Macroinvertebrates	302	51.4 (20.1)	53.2 (23.6)	278	75.8 (7.3)	54.8 (33.0)
Grand Total	724	100	147.7 (16.7)	378	100	80.1 (49.9)

Appendix G: Number of individuals (N), mean percent composition by number (2 standard errors in parentheses), and mean density (number of taxa/10 kg sediment) of macroinvertebrates and larval fish collected with a ponar dredge in 2005 and 2006 in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska.

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Diptera						
Chironomidae	690	53.8 (5.1)	133.4 (203.7)	1997	67.5 (12.7)	131.3 (60.2)
Ceratopogonidae	315	38.2 (0.9)	14.5 (7.3)	326	25.5 (10.6)	94.4 (154.2)
Simuliidae				36	0.2 (0.3)	1.5 (3.0)
Terrestrial	13	2.1 (2.3)	0.6 (0.5)			
Ephemeroptera						
Isonychiidae						
Isonychia	2	0.4 (0.8)	< 0.1 (< 0.1)			
Baetidae						
Baetis				4	< 0.1 (0.1)	0.2 (0.5)
Procloeon	1	< 0.1 (< 0.1)	< 0.1 (0.1)			
Caenidae						
Brachycercus				2	< 0.1 (0.1)	0.1 (0.1)
Cerobrachys	2	0.2 (0.4)	< 0.1 (0.1)	2	0.2 (0.4)	0.1 (0.2)
Ephemeridae						
Hexagenia	9	0.9 (1.8)	8.1 (16.2)	9	1.2 (1.8)	29.1 (29.5)
Heptegeniidae						
Stenonema	1	0.3 (0.6)	0.1 (0.2)			
Oligoneuridae						
Homoeneuria				1	< 0.1 (< 0.1)	< 0.1 (0.1)

Appendix G (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Trichoptera						
Hydropsychidae						
Hydropsyche	4	0.2 (0.4)	0.2 (0.3)	72	1.1 (0.9)	3.1 (2.1)
Ceratopsyche				1	< 0.1 (0.2)	< 0.1 (0.1)
Polycentropodidae						
Neureclipsis	3	< 0.1 (< 0.1)	0.1 (0.2)	16	0.3 (0.3)	0.8 (0.5)
Hydroptilidae						
Stactobiella	1	< 0.1 (0.1)				
Unidentifiable				11	< 0.1 (< 0.1)	0.4 (0.7)
Hemiptera						
Terrestrial	8	0.4 (0.8)	0.1 (0.3)	1	< 0.1 (0.2)	< 0.1 (0.1)
Odonata						
Gomphidae						
Stylurus				1	< 0.1 (< 0.1)	0.1 (0.2)
Amphipoda						
Hyallelidae						
Hyallela				1	0.1 (0.3)	< 0.1 (0.0)
Lepidoptera				3	0.2 (0.4)	13.2 (26.3)

Appendix G (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Coleoptera						
Terrestrial	1	< 0.1 (0.2)	< 0.1 (0.1)	1	< 0.1 (0.1)	< 0.1 (0.1)
Gastropoda						
Lymnaeidae	14	1.8 (0.9)	0.4 (0.4)	7	0.6 (0.6)	0.2 (0.2)
Physidae	2	0.2 (0.2)	< 0.1 (< 0.1)	10	1.4 (1.5)	0.7 (1.0)
Planorbidae	2	0.3 (0.4)	0.1 (0.2)	4	0.3 (0.3)	0.1 (0.1)
Bivalvia						
Sphaeriidae	2	0.9 (1.8)	< 0.1 (0.1)	9	0.4 (0.3)	0.5 (0.5)
Corbiculidae						
Corbicula fluminea	2	0.2 (0.2)	0.1 (0.1)	8	0.6 (0.5)	0.3 (0.2)
Araneae				2	0.2 (0.3)	0.1 (0.1)
Total Aquatic Macroinvertebrates	1050	97.4 (3.0)	157.1 (226.7)	2517	99.5 (0.4)	262.7 (231.5)
Grand Total	1072	100	157.8 (226.2)	2524	100	276.0 (219.1)

Appendix H: Number of individuals (N), mean percent composition by number (2 standard errors in parentheses), and mean density (number of taxa/m^2) of macroinvertebrates and larval fish collected with a Surber sampler in 2005 and 2006 in the Missouri River downstream of Gavins Point Dam, South Dakota and Nebraska.

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Diptera						
Chironomidae	244	42.9 (9.0)	335.7 (108.4)	134	42.4 (23.5)	232.2 (206.7)
Ceratopogonidae	1	0.7 (1.4)	1.5 (3.1)	2	1.2 (2.4)	2.8 (5.7)
Simuliidae				3	0.4 (0.8)	4.3 (8.5)
Terrestrial	15	9.5 (3.1)	20.9 (3.4)	1	1.9 (3.9)	1.9 (3.7)
Ephemeroptera						
Isonychiidae						
Isonychia	2	0.5 (0.9)	3.1 (6.1)	6	2.9 (3.5)	9.4 (11.4)
Baetidae						
Baetis	4	1.7 (2.2)	5.9 (5.9)	6	0.7 (1.4)	9.9 (19.8)
Procloeon	19	4.0 (4.8)	28.2 (35.9)	33	8.6 (3.2)	53.4 (2.9)
Pseudocentoptiloides				1	0.7 (1.5)	1.4 (2.8)
Unidentifiable	1	0.2 (0.3)	1.3 (2.5)			
Caenidae						
Caenis	3	0.6 (0.4)	4.2 (0.5)	5	1.1 (1.3)	7.8 (8.6)
Brachycercus				2	0.6 (1.1)	3.3 (6.6)
Cerobrachys	26	3.1 (1.1)	34.9 (25.5)	6	1.1 (1.3)	8.7 (12.9)
Tricorythidae						
Tricorythodes	1	0.2 (0.5)	1.5 (3.1)			

Appendix H (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Ephemeroptera						
Ephemeridae						
Hexagenia	7	1.3 (1.8)	9.8 (5.6)	1	0.4 (0.8)	1.7 (3.3)
Pentagenia	2	0.7 (0.8)	3.0 (3.0)	1	0.3 (0.6)	1.7 (3.3)
Polymitarcyidae						
Ephoron	2	0.8 (1.5)	2.5 (5.0)			
Heptegeniidae						
Stenonema	3	0.8 (1.6)	4.6 (9.2)	12	0.9 (1.3)	19.1 (26.4)
Stenacron				1	0.3 (0.7)	1.7 (3.3)
Unidentifiable	1	0.6 (1.2)	1.3 (2.5)	3	0.5 (1.0)	4.9 (9.9)
Pseudironidae						
Pseudiron				2	0.2 (0.5)	3.3 (6.6)
Trichoptera						
Hydropsychidae						
Hydropsyche	17	5.0 (2.5)	23.6 (19.6)	92	6.4 (6.4)	148.7 (248.1)
Cheumatopsyche	1	0.2 (0.4)	1.3 (2.5)			
Potomyia				2	0.5 (0.6)	3.1 (3.1)
Polycentropodidae						
Neureclipsis	1	0.1 (0.2)	1.5 (3.1)	1	0.3 (0.7)	1.7 (3.3)
Hydroptilidae	1	0.2 (0.3)	1.3 (2.5)			
Terrestrial	3	0.4 (0.4)	4.3 (5.3)	1	0.7 (1.5)	1.4 (2.8)

Appendix H (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Hemiptera						
Corixidae						
Hesperocorixa	192	13.3 (2.7)	260.3 (166.0)	86	13.5 (6.9)	141.7 (92.2)
Terrestrial	7	2.8 (2.1)	9.2 (9.5)	1	0.2 (0.3)	1.9 (3.7)
Hymenoptera	7	3.0 (2.0)	10.1 (8.4)			
Odonata						
Gomphidae						
Gomphus				3	0.4 (0.8)	4.9 (9.9)
Stylurus	2	0.4 (0.5)	3.0 (3.0)	1	0.5 (1.0)	1.4 (2.8)
Gastropoda						
Lymnaeidae				1	0.2 (0.3)	1.9 (3.7)
Planorbidae				1	0.2 (0.4)	1.9 (3.7)
Bivalvia						
Sphaeriidae				1	0.7 (1.5)	1.4 (2.8)
Corbiculidae						
Corbicula fluminea				5	1.4 (2.8)	11.2 (22.5)
Araneae	4	1.3 (0.9)	5.8 (3.4)	1	0.8 (1.7)	1.7 (3.3)

Appendix H (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Coleoptera	3	1.4 (0.8)	4.2 (0.5)	2	0.9 (1.7)	3.7 (7.5)
Isopoda				1	0.1 (0.2)	1.7 (3.3)
Asellidae	1	1.2 (2.3)	1.3 (2.5)			
Decapoda	1	0.1 (0.3)	1.5 (3.1)			
Larval Fish	21	3.4 (3.5)	30.2 (27.2)	67	8.9 (3.2)	114.9 (99.6)
Total Aquatic Macroinvertebrates	532	78.2 (1.3)	731.3 (239.8)	412	86.6 (5.3)	685.0 (368.7)
Grand Total	592	100	816.1 (231.3)	485	100	810.5 (444.1)

Appendix I: Number of individuals (N), mean percent composition by number (2 standard errors in parentheses), and mean density (number of taxa/m^2) of macroinvertebrates and larval fish collected with Hester-Dendy artificial substrate samplers in 2005 and 2006 in the Missouri River downstream of Gavins Point Dam, South Dakota and Nebraska.

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Diptera						
Chironomidae	1420	9.7 (3.0)	1621.2 (436.6)	530	13.6 (14.2)	1399.9 (1119.1)
Simuliidae	30	0.2 (0.4)	30.1 (44.9)	10	0.2 (0.2)	27.4 (28.9)
Empididae				5	< 0.1 (< 0.1)	11.0 (22.0)
Ephemeroptera						
Isonychiidae						
Isonychia	270	2.1 (3.2)	331.5 (398.3)	155	2.5 (3.6)	498.6 (684.9)
Baetidae						
Baetis	315	1.3 (1.5)	370.9 (352.5)	260	3.5 (2.1)	958.8 (696.4)
Barbaetis	50	0.2 (0.2)	58.6 (40.5)	45	0.6 (0.3)	150.7 (73.7)
Unidentifiable	5	< 0.1 (< 0.1)	5.5 (10.9)	5	0.2 (0.3)	16.4 (32.9)
Caenidae						
Caenis	20	0.3 (0.6)	26.3 (52.6)	10	0.3 (0.3)	41.1 (43.5)
Cerobrachys				5	< 0.1 (0.1)	16.4 (32.9)
Americaenis				20	0.2 (0.3)	73.9 (85.4)
Tricorythidae						
Tricorythodes	25	0.2 (0.2)	26.3 (34.8)	5	0.3 (0.6)	10.9 (21.9)
Ephemeridae						
Hexagenia	15	0.3 (0.7)	16.4 (32.9)			

Appendix I (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Ephemeroptera						
Heptegeniidae						
Stenonema	395	3.2 (3.7)	483.2 (290.6)	120	2.1 (3.6)	391.7 (643.8)
Stenacron	275	4.3 (3.6)	281.1 (242.4)	115	4.3 (6.8)	364.3 (524.3)
Trichoptera						
Hydropsychidae						
Hydropsyche	18045	55.9 (15.8)	19630.7 (6682.2)	4285	48.9 (28.1)	14162.8 (8233.9)
Cheumatopsyche	2675	13.3 (6.7)	2958.6 (1324.3)	905	13.2 (9.9)	3103.8 (2183.8)
Potomyia				20	0.2 (0.4)	65.8 (131.5)
Pupae	335	1.2 (< 0.1)	367.6 (127.2)	240	3.0 (1.5)	824.6 (433.2)
Polycentropodidae						
Neureclipsis	400	5.1 (3.3)	443.2 (231.1)	175	3.5 (4.4)	427.4 (513.5)
Polycentropus	150	1.5 (2.1)	158.3 (180.4)	30	1.5 (2.8)	79.4 (95.1)
Cyrnellus	5	< 0.1 (< 0.1)	5.5 (11.0)			
Pupae	5	< 0.1 (0.1)	5.5 (110)	5	< 0.1 (0.1)	16.4 (32.9)
Hydroptilidae						
Pupae	5	< 0.1 (< 0.1)	4.9 (9.9)			
Unidentifiable	40	0.2 (0.3)	41.6 (47.2)	5	< 0.1 (< 0.1)	11.0 (21.9)
Leptoceridae						
Nectopsyche	5	< 0.1 (0.2)	5.5 (11.0)			
Unidentifiable				15	0.5 (0.9)	49.3 (98.6)

Appendix I (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Odonata						
Gomphidae						
Gomphus	10	< 0.1 (< 0.1)	13.2 (26.3)			
Coenagrionidae						
Amphiagrion	20	0.2 (0.3)	20.8 (20.9)	20	0.6 (1.3)	43.8 (87.7)
Unidentifiable				5	0.4 (0.9)	16.4 (32.9)
Amphipoda						
Hyallelidae						
Hyallela	10	0.2 (0.3)	11.5 (11.9)			
Bivalvia						
Sphaeriidae	5	< 0.1 (0.2)	5.5 (11.0)	5	0.4 (0.9)	16.4 (32.9)
Corbiculidae						
Corbicula fluminea	5	< 0.1 (0.1)	5.5 (11.0)			
Acariformes						
Hydracarina/Hydrachnida	5	< 0.1 (< 0.1)	6.6 (13.2)			
Larval Fish	45	0.2 (0.4)	45.5 (61.1)			
Total Aquatic Macroinvertebrates	24540	99.8 (0.4)	26935.7 (5649.4)	6995	100	22778.3 (5712.6)
Grand Total	24585	100	26981.2 (5705.0)	6995	100	22778.3 (5712.6)

Appendix J: Number of individuals (N), mean percent composition by number (2 standard errors in parentheses), and mean density (number of taxa/100 m^3) of macroinvertebrates and larval fish collected in bottom drifts net samples in 2005 and 2006 in the Missouri River downstream of Gavins Point Dam, South Dakota and Nebraska.

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Diptera						
Chironomidae	979	23.8 (9.2)	116.3 (187.7)	350	23.9 (14.2)	12.1 (8.3)
Ceratopogonidae	44	1.0 (0.6)	1.2 (1.0)	16	1.3 (0.9)	0.6 (0.3)
Simuliidae	107	3.7 (1.2)	3.2 (1.3)	42	3.4 (2.4)	1.3 (0.9)
Chaoboridae						
Chaoborus	3	0.1 (0.2)	0.1 (0.2)	1	< 0.1 (0.1)	< 0.1 (0.1)
Empididae	1	< 0.1 (0.1)	< 0.1 (< 0.1)			
Terrestrial	459	7.2 (3.3)	10.1 (5.2)	22	1.3 (0.2)	0.7 (0.1)
Ephemeroptera						
Isonychiidae						
Isonychia	30	0.7 (0.9)	0.9 (1.4)	8	0.6 (0.6)	0.3 (0.3)
Baetidae						
Baetis	43	0.9 (0.7)	1.1 (1.1)	1	< 0.1 (< 0.1)	< 0.1 (0.1)
Procloeon	20	0.5 (0.7)	0.6 (0.5)	9	0.9 (0.9)	0.3 (0.3)
Unidentifiable				4	0.4 (0.9)	0.1 (0.3)
Caenidae						
Caenis	23	0.6 (0.4)	0.6 (0.5)	3	0.1 (0.2)	0.1 (0.1)
Brachycercus	5	0.2 (0.3)	0.2 (0.2)	2	0.1 (0.2)	0.1 (0.1)
Cerobrachys	17	0.4 (0.4)	0.5 (0.7)	1	< 0.1 (< 0.1)	< 0.1 (< 0.1)
Americaenis	3	< 0.1 (< 0.1)	0.1 (0.1)			

Appendix J (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Ephemeroptera						
Tricorythidae						
Tricorythodes				1	< 0.1 (0.2)	< 0.1 (0.1)
Ephemeridae						
Hexagenia	35	1.8 (1.9)	0.8 (0.5)	3	0.2 (0.2)	0.1 (0.1)
Pentagenia	1	< 0.1 (< 0.1)	< 0.1 (< 0.1)			
Polymitarcyidae						
Ephoron	9	0.1 (0.2)	0.2 (0.3)	2	0.1 (0.2)	0.1 (0.2)
Heptegeniidae						
Stenonema	16	0.4 (0.3)	0.3 (0.3)	5	0.8 (0.8)	0.2 (0.1)
Stenacron	3	0.1 (0.2)	0.1 (0.1)	1	0.3 (0.5)	0.1 (0.1)
Unidentifiable	3	0.2 (0.3)	0.2 (0.4)	1	< 0.1 (0.2)	< 0.1 (< 0.1)
Trichoptera						
Hydropsychidae						
Hydropsyche	1309	29.2 (4.6)	68.9 (72.7)	499	37.4 (10.9)	16.9 (5.3)
Cheumatopsyche	54	1.4 (0.8)	1.5 (1.6)	2	0.2 (0.4)	0.1 (0.2)
Ceratopsyche	38	0.6 (0.5)	0.7 (0.6)			
Potomyia	3	< 0.1 (0.1)	0.1 (0.2)	2	0.3 (0.6)	0.1 (0.2)
Unidentifiable	37	0.6 (1.1)	0.4 (0.8)	1	0.1 (0.2)	< 0.1 (< 0.1)
Polycentropodidae						
Neureclipsis	18	0.5 (0.2)	0.4 (0.2)	5	0.5 (1.0)	0.1 (0.3)
Cyrnellus	1	< 0.1 (< 0.1)	< 0.1 (< 0.1)			

Appendix J (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Trichoptera						
Hydroptilidae						
Ochrotrichia	1	< 0.1 (< 0.1)	< 0.1 (0.1)			
Nectopsyche	1	< 0.1 (< 0.1)	< 0.1 (0.1)			
Unidentifiable	2	< 0.1 (< 0.1)	0.1 (0.1)			
Terrestrial	9	0.2 (0.2)	0.2 (0.1)	3	0.1 (0.2)	0.1 (0.1)
Hemiptera						
Corixidae						
Hesperocorixa	12	0.3 (0.2)	0.3 (0.1)	1	< 0.1 (< 0.1)	< 0.1 (0.1)
Belostoma	1	< 0.1 (< 0.1)	< 0.1 (< 0.1)			
Terrestrial	156	2.6 (1.7)	3.3 (2.0)	18	1.2 (0.5)	0.7 (0.4)
Amphipoda						
Hyallelidae						
Hyallela	2	< 0.1 (< 0.1)	< 0.1 (< 0.1)	1	< 0.1 (0.2)	< 0.1 (0.1)
Hymenoptera						
Formicidae	8	0.2 (0.3)	0.2 (0.2)	3	0.1 (< 0.1)	0.1 (< 0.1)
Terrestrial	548	4.5 (8.2)	20.7 (40.1)	19	1.8 (2.7)	0.7 (0.9)

Appendix J (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Odonata						
Gomphidae						
Gomphus	1	< 0.1 (< 0.1)	< 0.1 (0.1)			
Stylurus	1	< 0.1 (< 0.1)	< 0.1 (0.1)			
Coenagrionidae						
Amphiagrion	2	< 0.1 (0.1)	< 0.1 (< 0.1)			
Gastropoda						
Lymnaeidae				4	0.5 (0.4)	0.2 (0.1)
Physidae				1	< 0.1 (0.1)	0.1 (0.1)
Planorbidae				7	0.5 (1.1)	0.3 (0.6)
Bivalvia						
Sphaeriidae				9	0.5 (0.7)	0.3 (0.4)
Corbiculidae						
Corbicula fluminea				2	0.2 (0.4)	0.1 (0.1)
Araneae	31	0.6 (0.5)	0.8 (0.6)	2	0.2 (0.4)	0.1 (0.1)
Coleoptera						
Gyrinidae						
Gyrinus	1	< 0.1 (< 0.1)	< 0.1 (< 0.1)			

Appendix J (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Coleoptera						
Dytiscidae						
Dytiscus	1	< 0.1 (< 0.1)	< 0.1 (0.1)			
Hydrophilidae	1	< 0.1 (< 0.1)	< 0.1 (< 0.1)			
Terrestrial	43	0.8 (0.3)	1.1 (0.2)	3	0.2 (0.5)	0.1 (0.1)
Collembola						
Onychiuridae	1	< 0.1 (< 0.1)	< 0.1 (0.1)			
Lepidoptera	1	< 0.1 (< 0.1)	< 0.1 (< 0.1)	1	0.2 (0.4)	< 0.1 (0.1)
Thysanoptera	2	< 0.1 (0.2)	< 0.1 (0.1)			
Plecoptera	11	0.3 (0.2)	0.3 (0.1)			
Isopoda						
Asellidae	2	< 0.1 (< 0.1)	< 0.1 (< 0.1)			
Unidentifiable	1	< 0.1 (< 0.1)	< 0.1 (< 0.1)	2	0.1 (0.2)	0.1 (0.1)
Acariformes						
Hydracarina/Hydrachnida	5	< 0.1 (< 0.1)	0.1 (0.1)	2	0.2 (0.2)	0.1 (0.1)
Larval Fish	803	15.8 (3.0)	24.8 (6.0)	561	21.7 (1.7)	20.1 (7.4)

Appendix J (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Total Aquatic Macroinvertebrates	2845	67.9 (8.9)	199.4 (256.8)	991	73.3 (4.4)	33.9 (3.0)
Grand Total	4908	100	260.8 (240.3)	1620	100	56.3 (9.1)

Appendix K: Number of individuals (N), mean percent composition by number (2 standard errors in parentheses), and mean density (number of taxa/100 m^3) of macroinvertebrates and larval fish collected in column drifts net samples in 2005 and 2006 in the Missouri River downstream of Gavins Point Dam, South Dakota and Nebraska.

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Diptera						
Chironomidae	311	18.9 (3.9)	29.5 (7.4)	220	29.7 (17.1)	45.2 (39.8)
Ceratopogonidae	21	0.8 (0.5)	1.3 (0.4)	8	1.3 (1.3)	1.2 (1.3)
Simuliidae	51	2.9 (0.7)	5.2 (2.3)	13	2.7 (2.6)	1.9 (2.2)
Terrestrial	273	15.7 (5.1)	25.5 (12.7)	24	2.3 (0.9)	3.8 (2.1)
Ephemeroptera						
Isonychiidae						
Isonychia	4	0.2 (0.3)	0.2 (0.3)	5	0.5 (0.9)	0.5 (1.0)
Baetidae						
Baetis	9	0.5 (0.5)	0.8 (1.0)	4	0.6 (1.3)	1.1 (2.3)
Barbaetis	1	< 0.1 (< 0.1)	0.1 (0.3)			
Procloeon	3	0.2 (0.2)	0.1 (0.1)	4	0.5 (0.9)	0.6 (1.1)
Paracloeodes				1	< 0.1 (< 0.1)	0.1 (0.1)
Caenidae						
Caenis	5	0.3 (< 0.1)	0.8 (0.4)	4	0.6 (0.6)	0.7 (0.8)
Brachycercus	1	< 0.1 (< 0.1)	0.1 (0.1)	1	0.9 (1.7)	0.3 (0.5)
Cerobrachys	13	1.8 (1.8)	3.7 (5.0)			
Americaenis	4	0.2 (0.3)	0.4 (0.5)			
Ephemeridae						
Hexagenia	18	0.8 (0.3)	1.7 (0.9)	3	0.3 (0.3)	0.4 (0.6)

Appendix K (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Ephemeroptera						
Polymitarcyidae						
Ephoron	1	< 0.1 (0.1)	< 0.1 (0.1)			
Heptegeniidae						
Stenonema	2	0.1 (0.1)	0.2 (0.3)	1	0.4 (0.8)	0.2 (0.4)
Stenacron	1	< 0.1 (0.1)	< 0.1 (0.1)	1	0.2 (0.3)	0.2 (0.3)
Oligoneuriidae						
Homoeoneuria				1	0.2 (0.4)	0.2 (0.5)
Unidentifiable				1	0.1 (0.2)	0.1 (0.2)
Trichoptera						
Hydropsychidae						
Hydropsyche	361	26.1 (1.1)	49.7 (24.2)	157	30.9 (11.3)	26.8 (10.6)
Cheumatopsyche	15	0.8 (0.6)	1.9 (2.0)			
Ceratopsyche	5	0.3 (0.4)	0.4 (0.6)			
Unidentifiable	2	0.3 (0.6)	0.2 (0.3)			
Polycentropodidae						
Neureclipsis	3	0.1 (0.1)	0.3 (0.3)	4	0.8 (0.9)	1.2 (1.2)
Hydroptilidae	3	0.3 (0.6)	0.4 (0.7)			
Leptoceridae						
Oectis	1	0.1 (0.2)	< 0.1 (< 0.1)	1	< 0.1 (0.2)	0.1 (0.2)
Nectopsyche	1	0.1 (0.2)	0.2 (0.4)			
Terrestrial	7	0.6 (0.3)	0.4 (0.3)			

Appendix K (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Hemiptera						
Corixidae						
Hesperocorixa	12	0.7 (0.6)	1.2 (1.4)			
Terrestrial	85	5.6 (3.1)	8.4 (4.5)	22	3.5 (3.6)	4.0 (1.5)
Hymenoptera						
Formicidae	3	0.2 (0.2)	0.2 (0.3)	2	0.1 (0.3)	1.2 (2.5)
Terrestrial	160	5.5 (6.8)	21.4 (36.1)	20	3.1 (1.7)	2.6 (1.3)
Odonata						
Coenagrionidae						
Amphiagrion	1	< 0.1 (< 0.1)	0.1 (0.3)			
Gastropoda						
Planorbidae				1	0.1 (0.3)	0.1 (0.2)
Bivalvia						
Sphaeriidae				1	< 0.1 (0.2)	0.1 (0.2)
Araneae	16	0.7 (0.2)	1.7 (0.3)	2	< 0.1 (0.1)	0.1 (0.2)
Coleoptera	29	1.6 (0.8)	4.2 (1.3)	6	1.3 (1.6)	2.0 (2.0)

Appendix K (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Collembola						
Unidentifiable	1	0.1 (0.3)	0.2 (0.5)			
Lepidoptera				3	0.4 (0.5)	0.3 (0.3)
Megaloptera						
Corydalidae				1	< 0.1 (0.1)	0.1 (0.3)
Thysanoptera	3	0.2 (0.4)	0.9 (1.7)			
Plecoptera	4	0.4 (0.5)	4.4 (8.3)			
Neuroptera	1	< 0.1 (0.1)	0.1 (0.2)			
Isopoda						
Asellidae	1	< 0.1 (< 0.1)	< 0.1 (0.1)			
Unidentifiable	1	0.1 (0.2)	< 0.1 (< 0.1)			
Acariformes						
Hydracarina/Hydrachnida	1	< 0.1 (< 0.1)	< 0.1 (0.1)			
Larval Fish	328	13.4 (2.9)	38.2 (17.1)	199	19.1 (2.4)	37.3 (14.3)

Appendix K (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Total Aquatic Macroinvertebrates	857	56.3 (0.8)	99.3 (30.1)	433	70.1 (2.5)	82.4 (28.2)
Grand Total	1762	100	204.4 (44.6)	709	100	132.6 (41.9)

Appendix L: Number of individuals (N), mean percent composition by number (2 standard errors in parentheses), and mean density (number of taxa/10 kg sediment) of macroinvertebrates and larval fish collected with a ponar dredge in 2005 and 2006 in the Missouri River downstream of Gavins Point Dam, South Dakota and Nebraska.

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Diptera						
Chironomidae	814	40.9 (11.3)	30.4 (15.6)	687	51.4 (6.7)	33.1 (33.6)
Ceratopogonidae	536	41.4 (13.9)	16.9 (1.8)	401	43.9 (10.1)	15.9 (3.5)
Simuliidae	10	0.2 (0.4)	1.2 (2.7)	16	0.2 (0.4)	0.8 (1.6)
Psychodidae	8	< 0.1 (< 0.1)	1.3 (2.7)			
Terrestrial	7	0.9 (0.9)	0.3 (0.7)			
Ephemeroptera						
Isonychiidae						
Isonychia				1	0.2 (0.3)	< 0.1 (0.1)
Baetidae						
Baetis				3	0.4 (0.6)	0.1 (< 0.1)
Caenidae						
Brachycercus				1	0.1 (0.2)	< 0.1 (0.1)
Ephemeridae						
Hexagenia	1	< 0.1 (0.1)	< 0.1 (0.0)			
Pentagenia						
Heptegeniidae						
Stenonema				2	< 0.1 (< 0.1)	0.2 (0.5)
Unidentifiable	2	< 0.1 (< 0.1)	< 0.1 (0.0)			

Appendix L (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Trichoptera						
Hydropsychidae						
Hydropsyche	300	4.2 (3.9)	31.3 (58.0)	212	1.7 (2.9)	22.9 (45.4)
Ceratopsyche				3	0.1 (0.2)	0.1 (0.2)
Polycentropodidae						
Neureclipsis	34	0.4 (0.4)	5.3 (9.7)	7	0.4 (0.7)	1.9 (3.7)
Terrestrial	1	0.1 (0.2)	< 0.1 (0.0)	1	< 0.1 (0.1)	0.1 (0.1)
Hemiptera						
Corixidae						
Hesperocorixa				1	0.2 (0.4)	< 0.1 (< 0.1)
Terrestrial	3	0.5 (0.5)	0.2 (0.0)			
Amphipoda						
Hyallelidae						
Hyallela				1	< 0.1 (0.2)	< 0.1 (0.1)
Hymenoptera						
Formicidae	1	0.2 (0.5)	< 0.1 (0.0)			
Terrestrial						

Appendix L (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Gastropoda						
Lymnaeidae	134	1.9 (3.6)	3.0 (6.0)	5	0.3 (0.5)	0.1 (0.2)
Physidae	1	< 0.1 (< 0.1)	< 0.1 (0.0)	1	< 0.1 (0.1)	< 0.1 (0.1)
Planorbidae	5	0.4 (0.3)	0.1 (0.0)	1	< 0.1 (< 0.1)	< 0.1 (0.1)
Ancylidae	3	0.5 (0.6)	0.1 (0.0)			
Bivalvia						
Sphaeriidae	42	1.4 (1.4)	1.9 (4.0)	30	0.3 (0.3)	3.4 (6.7)
Corbiculidae						
Corbicula fluminea	187	5.5 (9.7)	4.9 (9.3)	7	0.4 (0.6)	0.2 (0.2)
Araneae	1	0.3 (0.6)	0.1 (0.0)			
Thysanoptera	3	0.7 (1.4)	0.1 (0.0)			
Plecoptera						
Perlidae						
Agnetina	1	0.4 (0.8)	0.1 (0.0)			
Acariformes						
Hydracarina/Hydrachnida	1	< 0.1 (< 0.1)	< 0.1 (0.0)			
Larval Fish	1	0.2 (0.3)	< 0.1 (0.0)	1	0.2 (0.3)	< 0.1 (0.1)

Appendix L (Continued).

	2005			2006		
Taxa	N	Composition	Density	N	Composition	Density
Total Aquatic Macroinvertebrates	2080	97.5 (2.7)	96.7 (103.5)	1379	99.8 (0.3)	78.9 (93.7)
Grand Total	2096	100	97.5 (102.7)	1381	100	79.0 (93.7)