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Food Habits of Juvenile Pallid Sturgeon and Adult Shovelnose Sturgeon in the Missouri River Downstream of Fort Randall Dam, South Dakota

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ABSTRACT

We examined the seasonal food habits and diet overlap of juvenile pallid sturgeon (*Scaphirhynchus albus*) and adult shovelnose sturgeon (*S. platorynchus*) in the Missouri River downstream of Fort Randall Dam, South Dakota. Seasonal trends were found for both sturgeon species as chironomids were consumed in the greatest numbers and dry weights during early summer, ephemeropterans dominated during late summer, and trichopterans were most abundant in early spring and late fall diets. However, diet overlap between juvenile pallid sturgeon and adult shovelnose sturgeon was low based on a Schoener index value of 0.53 in 2003 and 0.21 in 2004. Juvenile pallid sturgeon consumed a greater proportion of fish in 2003 and Ephemeroptera in 2004 compared to shovelnose sturgeon. Shovelnose sturgeon consumed a greater proportion of Chironomidae in both years compared to juvenile pallid sturgeon. These results illustrate that shovelnose sturgeon is not an acceptable surrogate for the endangered pallid sturgeon based on food habits.

INTRODUCTION

The pallid sturgeon (*Scaphirhynchus albus*) was listed as a federally endangered species in 1990 (U. S. Fish and Wildlife Service [USFWS] 1993), while the sympatric shovelnose sturgeon (*S. platorynchus*) has also declined in overall abundance (Keenlyne 1997). To the apparent detriment of both sturgeon species, substantial anthropogenic habitat alterations have occurred on the Missouri River primarily through the construction of six mainstem dams. An inter-reservoir reach of the Missouri River downstream of Fort Randall Dam, South Dakota has been listed as one of six recovery priority areas for pallid sturgeon based on suitable habitat diversity (USFWS 1993), and the U. S. Fish and Wildlife Service initiated a pallid sturgeon stocking program in 2000.

Early life history of the pallid sturgeon is not completely understood and is difficult to assess because of low abundance resulting from no recruitment in the river downstream of Fort Randall Dam for more than 40 years, since the closure of the mainstem dams (Keenlyne and Jenkins 1993). Both the Upper Basin Pallid Sturgeon Work Group (UBPSWG 2002) and technical experts from state and federal agencies, universities, and private organizations (Quist et al. 2004) identified food habits of age-1 and older pallid sturgeon as a high priority research item.

Gerrity et al. (2006) evaluated the food habits of age-6 and age-7 juvenile pallid sturgeon in a relatively unaltered stretch of the Missouri River above Fort Peck Reservoir, Montana and determined that native benthic cyprinids were important in their diet. Thus, the objectives of this study were to 1) assess food habits of juvenile pallid sturgeon in the highly altered Missouri River between two mainstem dams and 2) compare seasonal food habits and diet overlap between juvenile pallid sturgeon and shovelnose sturgeon. We hypothesized that juvenile pallid sturgeon would have high diet overlap with shovelnose sturgeon because of high overlap in habitat use (Gerrity 2005).

METHODS

All pallid sturgeon stocked into the Missouri River below Fort Randall Dam and above Lewis and Clark Lake have been marked with passive integrated transponder tags to identify individual fish. Secondary marks of either elastomer or dangler tags have been added to some year classes of stocked pallid sturgeon (Krentz et al. 2005). Sampling of this reach took place from April through November in 2003 and 2004. Juvenile pallid sturgeon and adult shovelnose sturgeon were collected using a variety of techniques, including drifted trammel nets, stationary gill nets, hoop nets, set lines, and towed beam trawls (Wanner 2006a). Each sturgeon was measured for fork length (FL; mm) and weighed (g).

Stomach contents were removed using non-lethal gastric lavage (Wanner 2006b, Shuman and Peters in press), a procedure in which water is pumped through the esophagus to flush food items from the stomach. The lavage continued for each specimen until regurgitation of food ceased. The procedure lasted approximately 2-3 min for each fish, during which time the gills were constantly flushed with fresh water. The food items were collected on a 500-µm mesh sieve and preserved in 10% formalin. No anesthetics were used during this procedure.

Aquatic insects were identified using Merrit and Cummins (1996). Food items were identified to genus when possible for Ephemeroptera, Trichoptera, and Odonata. All Diptera were identified to family. Fish were identified to species when possible. All other less common food items found in the stomachs of sturgeon were identified to order. Stomach contents were expressed for each prey type as frequency of occurrence, percent by number, and percent of total weight (Bowen 1996). After we identified and counted the prey items, the stomach contents were dried at 65°C for 24 h and then weighed to the nearest 0.1 mg.

Diet overlap between juvenile pallid sturgeon and adult shovelnose sturgeon was appraised with the Schoener index (Schoener 1970), which ranges from 0 (no overlap) to 1 (complete overlap) and measures the overlap between the two species (Wallace 1981). Diet overlap is considered to be biologically significant when the overlap exceeds 0.60 (Zaret and Rand 1971, Mathur 1977).

RESULTS

Juvenile pallid sturgeon

Eighty-two age-1 to age-7 hatchery-reared juvenile pallid sturgeon (HRJPS) were collected. In 2003, prey items were recovered from 18 out of 59 HRJPS; these 18 fish ranged from 355 to 700 mm FL (mean = 531.5; SE = 29.50) (Fig. 1). In 2004, prey items were recovered from 10 out of 23 HRJPS. The 10 HRJPS ranged from 385 to 706 mm FL (mean = 581.7; SE = 34.42).

In both 2003 and 2004, HRJPS preyed upon a variety of benthic organisms (Table 1) and seasonal trends were found in the diets by dry weight (Fig. 2). Chironomids were preyed upon from July to October in 2003 and were the highest by percent composition of dry weight among prey types with 91.2% in October. In 2004, chironomids were preyed on in all months sampled and had the highest dry weight among prey types with 67.6% in April. Ephemeropterans were found in the diets in April and from July to September in 2003 and were the highest prey type by dry weight in July (88.7%) and September (98.1%). In 2004, ephemeropterans were only recovered in May and July. However, Ephemeroptera was the most abundant prey type by dry weight with 94.4% in July. Trichopterans demonstrated an increase in the diets from August to November in

2003 and were also found in May, July, and November in 2004. In 2004, Trichoptera was the highest prey type in May with 57.7% of dry weight. Johnny darter (*Etheostoma nigrum*), channel catfish (*Ictalurus punctatus*), a silver chub (*Macrhybopsis storeriana*), and an emerald shiner (*Notropis atherinoides*) were recovered from the diets of HRJPS in August, and one unidentified fish was collected in November of 2003. Fish made up over 46% of the dry weight in August and November in 2003. Only one unidentified fish was found in the diets in May and July in 2004. Isopods were not a substantial prey type in the diets of HRJPS in 2003. However, isopods made up over 20% of the diet dry weight in April, May, and November in 2004.

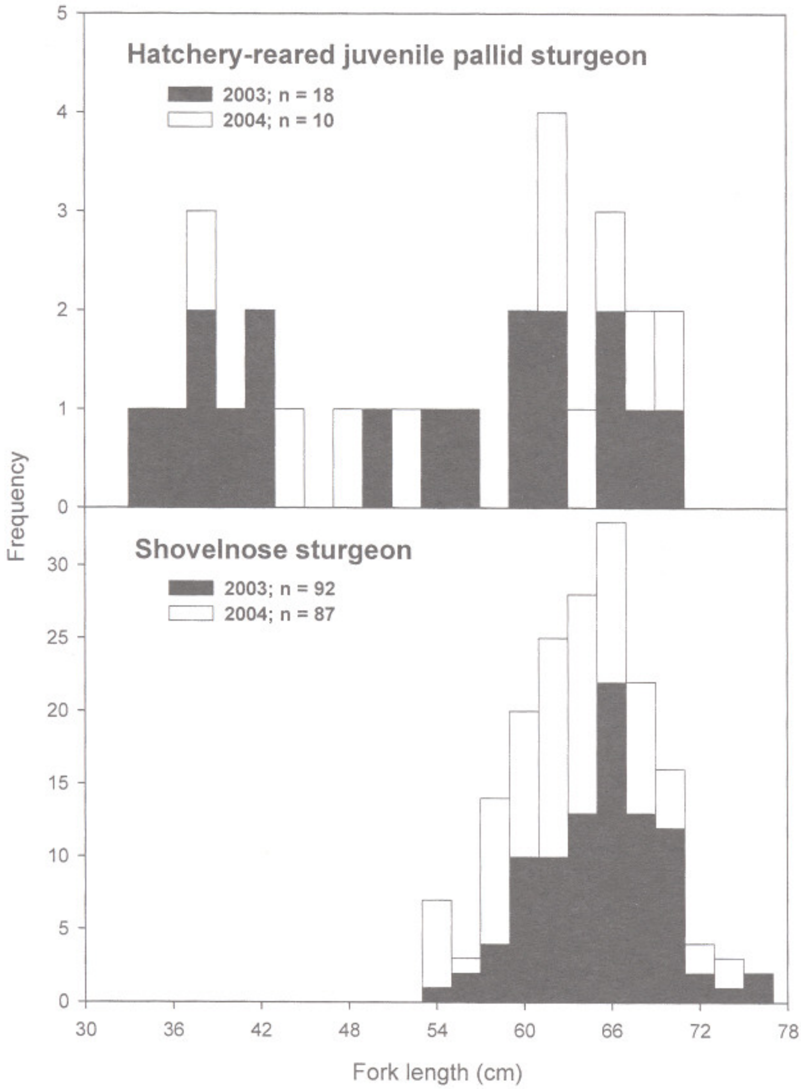

Figure 1. Fork length frequencies (2-cm length groups) of hatchery-reared juvenile pallid sturgeon (top) and shovelnose sturgeon (bottom) which prey items were recovered by gastric lavage in the Missouri River downstream of Fort Randall Dam in 2003 and 2004.

Table 1. Number of prey items (n), frequency of occurrence (% O), percent composition by number (% N), and percent composition by dry weight (% W) of prey items found in hatchery-reared juvenile pallid sturgeon stomachs in 2003 and 2004 in the Missouri River downstream of Fort Randall Dam.

	2003 (18 fish)				2004 (10 fish)			
Prey item	n	% O	% N	% W	n	% O	% N	% W
Chironomidae	2,601	61.1	95.9	35.5	49	80.0	23.0	3.6
Ephemeroptera								
Isonychia spp.	86	27.8	3.2	13.4	125	30.0	58.7	63.0
Pseudiron spp.	1	5.6	0.0	0.6	8	10.0	3.8	10.0
Hexagenia spp.	1	5.6	0.0	0.8				
Cercobrachys spp.	3	5.6	0.1	0.2				
Trichoptera								
Hydropsyche spp.	7	27.8	0.3	1.1	14	30.0	6.6	12.4
Potamyia flava	1	5.6	0.0	0.1	3	20.0	1.4	1.5
Odonata								
Gomphus spp.					2	20.0	0.9	1.4
Coleoptera	1	5.6	0.0	0.1				
Isopoda	1	5.6	0.0	0.4	10	40.0	4.7	5.4
Fish								
Unidentified fish	2	11.1	0.1	1.8	2	20.0	0.9	2.7
Johnny darter	3	11.1	0.1	12.4				
Channel catfish	4	5.6	0.1	2.0				
Silver chub	1	5.6	0.0	26.4				
Emerald shiner	1	5.6	0.0	5.3				

Shovelnose sturgeon

No juvenile shovelnose sturgeon were collected. In 2003, prey items were recovered from 92 out of 231 shovelnose sturgeon. The 92 shovelnose sturgeon ranged from 558 to 770 mm (mean= 659.1; SE = 4.50) (Fig. 1). In 2004, prey items were recovered from 87 out of 137 shovelnose sturgeon stomachs. Fork lengths for the 87 shovelnose sturgeon ranged from 540 to 755 mm with a mean of 639.8 (SE = 5.1).

Shovelnose sturgeon preyed upon a variety of benthic organisms in both 2003 and 2004 (Table 2) and monthly trends were found in the diets (dry weight) (Fig. 3). Chironomids were found in shovelnose sturgeon diets from April to October in 2003 and from April to November in 2004. Chironomids made up over 51% of the diet by composition of dry weight from April to July and in October in 2003 and from April to July and in November in 2004. Ephemeropterans were found in the diet from May to October in 2003 and from April to May, July to August, and October to November in 2004. Ephemeroptera made up over 72% of the diet by dry weight in August and September in 2003 and over 98% of the diet in August of 2004. Trichopterans were found in the diets of shovelnose sturgeon from April to June and August to October in 2003 and from April to July and October to November in 2004. Trichoptera made up over 35% of the diet by dry weight in April and over 41% in October of 2003 and over 34% of the diet in November of 2004. Isopods were only found in the diets in May of 2003 but made up over 31% of the diet by dry weight. In 2004, isopods were found from April to May, July, and in November, but were not a substantial part of the diet by dry weight throughout the year (Fig. 3). Only two johnny darter and two unidentified fish were found in the diets in November of 2004. However, 186 fish eggs were found in the stomach of one shovelnose sturgeon in October of 2004.

Diet overlap

In 2003, the proportions by dry weight of ephemeropterans, trichopterans, odonatans, and isopods in HRJPS and shovelnose sturgeon were similar, while substantial differences were observed in the proportions of chironomids and fish consumed (Tables 1 and 2). Diet overlap was low between HRJPS and shovelnose sturgeon based on Schoener index value of 0.53 in 2003. In 2004, diet overlap was even lower with a Schoener index value of 0.21. Shovelnose sturgeon consumed a greater proportion by dry weight of chironomids throughout 2004 compared to HRJPS, which consumed a greater proportion of ephemeropterans.

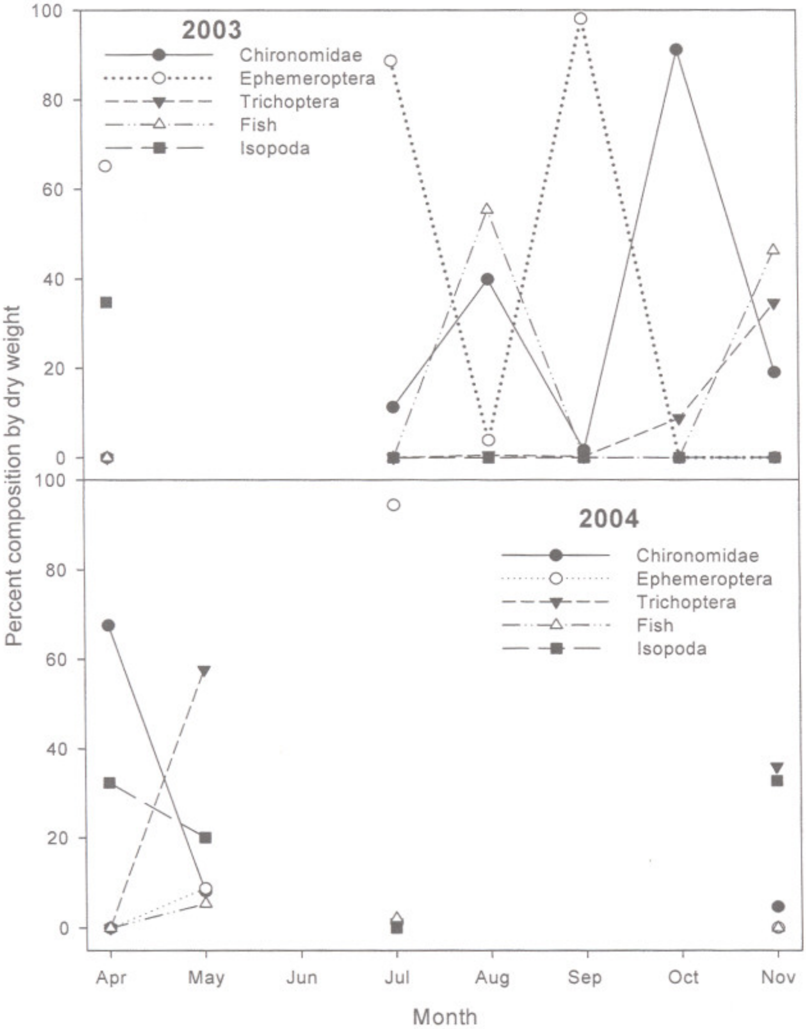

Figure 2. Monthly percent composition by dry weight of Chironomidae, Ephemeroptera, Trichoptera, fish, and Isopoda in the diets of hatchery-reared juvenile pallid sturgeon captured in 2003 and 2004 in the Missouri River downstream of Fort Randall Dam (Wanner 2006a).

Table 2. Number of prey items (n), frequency of occurrence (% O), percent composition by number (% N), and percent composition by dry weight (% W) for prey items found in adult shovelnose sturgeon stomach rations in 2003 and 2004 in the Missouri River downstream of Fort Randall Dam.

	2003 (92 fish)				2004 (87 fish)			
Prey item	n	% O	% N	% W	n	% O	% N	% W
Chironomidae	9,427	92.4	93.3	72.1	49,027	94.3	96.5	75.3
Ephemeroptera								
Isonychia spp.	478	32.6	4.7	17.2	308	24.1	0.6	3.7
Pseudiron spp.	8	2.2	0.1	0.5	2	2.3	0.0	0.0
Parameletus spp.	21	1.1	0.2	0.4	1	1.1	0.0	0.0
Hexagenia spp.					30	10.3	0.1	0.5
Litobrancha spp.	1	1.1	0.0	0.0	11	4.6	0.0	0.1
Pentagenia spp.					3	3.4	0.0	0.0
Tortopus spp.					3	2.3	0.0	0.1
Ephoron spp.					1	1.1	0.0	0.1
Brachycercus spp.	1	1.1	0.0	0.0	1	1.1	0.0	0.0
Cercobrachys spp.	58	7.6	0.6	0.8	4	3.4	0.0	0.0
Trichoptera								
Hydropsyche spp.	72	10.9	0.7	4.0	508	41.4	1.1	8.0
Potamyia flava	7	6.5	0.1	0.2	42	25.3	0.1	0.5
Odonata								
Coenagrionidae					1	1.1	0.0	0.0
Libellula spp.	1	1.1	0.0	0.5				
Gomphus spp.					14	10.3	0.0	0.7
Stylurus spp.	1	1.1	0.0	1.3	8	8.0	0.0	1.2
Coleoptera					1	1.1	0.0	0.0
Oligochaete	15	3.3	0.1	0.8	615	1.1	1.1	2.2
Isopoda	16	1.1	0.2	2.1	50	25.3	0.1	0.6
Amphipoda	2	2.2	0.0	0.0	4	4.6	0.0	0.0
Branchiura	1	1.1	0.0	0.0				
Fish eggs					186	1.1	0.4	5.2
Fish								
Unidentified fish					2	1.1	0.0	0.2
Johnny darter					2	1.1	0.0	1.5

DISCUSSION

Due to the endangered status of pallid sturgeon and the decline in overall abundance of shovelnose sturgeon, a non-lethal gastric lavage method was used to collect prey items from the stomachs. Wanner (2006b) found that food items were recovered from 100% of the HRJPS with food items in their stomach and food items were recovered up to 2 h after fish were fed. However, he also reported differential recovery rates by prey item with an overall recovery rate of 74.9% for all prey items. Brosse et al. (2002) similarly reported variations in the recovery rate of prey items from Siberian sturgeon (*Acipenser baeri*); approximately 50% of the vermiform prey (earthworms

[*Lumbriscus terrestris*] and chironomid larvae) and 75% of larger prey (sand goby [*Pomatoschistus minutus*] and brown shrimp [*Crangon crangon*]) were recovered. They also found that the recovery rate of food items 2 h or more after feeding was lower, indicating that gastric lavage would most likely recover only the most recently ingested food items. Recovery rates of prey may also be affected by a technician's experience in performing gastric lavage. Although we did not quantify the recovery rate of prey items in this study, Gerrity et al. (2006) suggested that the recovery rates of prey types between the two morphologically similar sturgeon species were similar. Without knowledge of recovery rates, the gastric lavage technique may only provide a qualitative determination of food habits (Haley 1998) and future bioenergetics modeling should consider recovery rates.

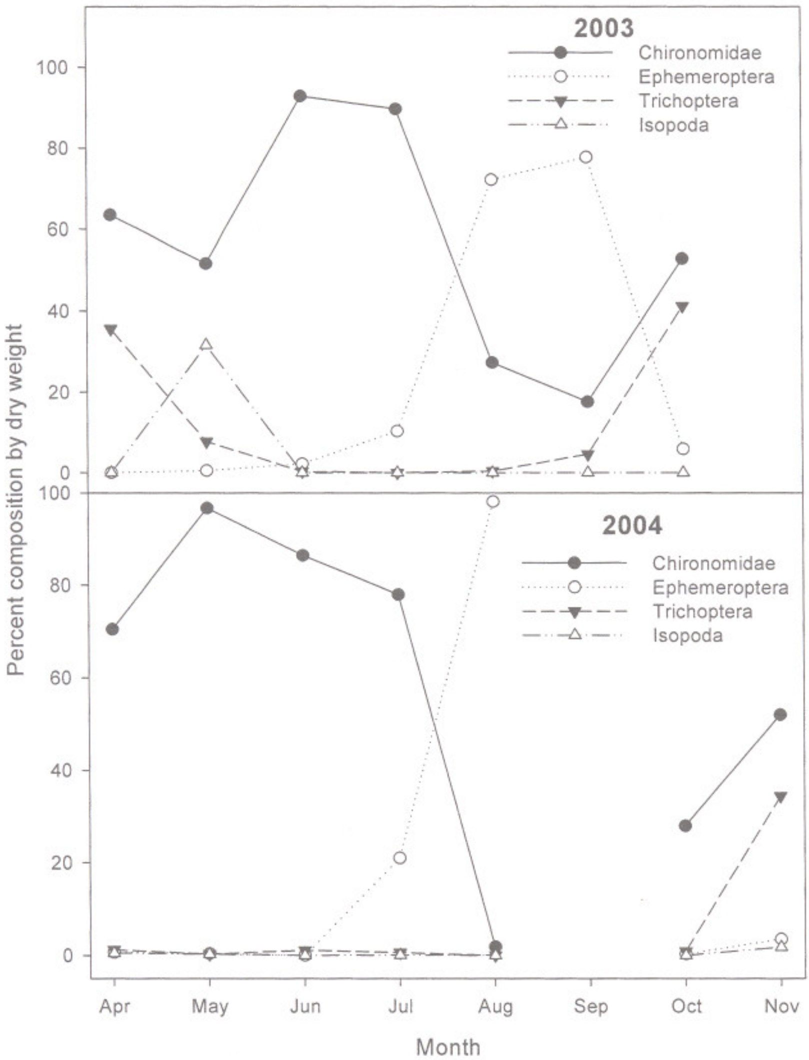

Figure 3. Monthly percent composition by dry weight of Chironomidae, Ephemeroptera, Trichoptera, and Isopoda in the diets of shovelnose sturgeon captured in 2003 and 2004 in the Missouri River downstream of Fort Randall Dam (Wanner 2006a).

Juvenile pallid sturgeon

Aquatic insects and fishes were important in the diet of HRJPS in the Missouri River downstream of Fort Randall Dam. Chironomids occurred more often than any other prey type in both sturgeon species and in both years. However, fishes were the most abundant prey by dry weight in 2003, followed by Chironomidae. Ephemeroptera, specifically *Isonychia* spp., was the most abundant by dry weight in 2004, while all other prey types were less than 14% of the diet. While adult pallid sturgeon do utilize aquatic insect larvae, there is a greater proportion of fish (mostly cyprinids) in their diet (Coker 1930, Cross 1967, Carlson et al. 1985).

Our results differed substantially from those of Gerrity et al. (2006), who found that fishes, especially sicklefin chub (*Macrhybobsis meeki*) and sturgeon chub (*Macrhybopsis gelida*), occurred in the diets of HRJPS in the Missouri River above Fort Peck Reservoir over 54% of the time and made up over 90% of the diet by weight. Gerrity et al. (2006) also reported that Chironomidae, Ephemeroptera, Trichoptera, and detritus each occurred in over 10% of the diets but did not make up a substantial part of the diet composition by weight for HRJPS. Sicklefin and sturgeon chub were abundant in the deep main channel of the Missouri River where HRJPS were located (Gerrity 2005). In the Missouri River below the Yellowstone River confluence in North Dakota, Welker and Scarnecchia (2004) found that sicklefin and sturgeon chub catches were higher in areas with naturally high fluctuations of the hydrograph and high sediment loads compared to the Missouri River above the Yellowstone River confluence, which is influenced by Fort Peck Dam (i.e., regulated flows and lower turbidity). The Missouri River below Fort Randall Dam has an altered hydrograph and low sediment loads, and Berry et al. (2004) reported low catches of native benthic cyprinids in the main channel. No sicklefin or sturgeon chubs were captured from 2003 to 2005 in our study area downstream of Fort Randall Dam (USFWS 2004, Shuman et al. 2005 and 2006).

Monthly trends in food habits of HRJPS were difficult to determine due to the low sample size and differences between years. However, it appears that chironomids were important prey throughout the year. In every month when prey items were recovered from a HRJPS, except in April 2003, chironomids were found in the diet. Across all seasons, chironomids have been an important trophic link in the food chain feeding secondary and tertiary consumers in Missouri River backwaters (Fisher et al. 2001). Ephemeropterans were a common prey for HRJPS during the warmer months from July to September, while very few were recovered from April to May or October to November. No HRJPS were captured in June 2003 and 2004; therefore, it is not possible to know if ephemeropterans were a common prey type during that time. Also, no HRJPS were captured from August to October 2004; therefore, it is not known if ephemeropterans found in the diets in 2003 accurately reflects their true importance to HRJPS. Gerrity et al. (2006) did not investigate seasonal trends in diets of HRJPS, but reported that ephemeropterans occurred in over 30% of the diet of HRJPS in the Missouri River above Fort Peck Reservoir. Trichopterans appear to be a more common prey item during the cooler months. Trichopterans are most likely available in greater numbers during spring and fall, or HRJPS are actively selecting for them during those times of the year. Only one isopod was found in the diets of HRJPS in April of 2003. Isopods were most likely not abundant or available to be preyed upon in 2003. However, isopods were more abundant and followed similar seasonal trends as trichopterans did in the diet of HRJPS with peaks in May and November of 2004. Fishes made up a substantial part of the diet by dry weight in 2003 but were only found in August and November. Age-0 prey fishes are likely most available in the Missouri River during late summer to fall. Only two unidentified fish were found in the diet of HRJPS in 2004, and seasonal trends could not be assessed.

Continued research is needed to further explore the food habits of age-0 pallid sturgeon. The youngest HRJPS in this study was age-1, and currently there is limited information on food habits of age-0 pallid sturgeon.

Shovelnose sturgeon

The shovelnose sturgeon has been described as and opportunistic feeder (Modde and Schmulbach 1977, Berry 2002). We found that larval benthic aquatic insects were prevalent in the diet of shovelnose sturgeon in the Missouri River downstream of Fort Randall Dam. The dominance of aquatic insects in the diet of shovelnose sturgeon has been previously reported for the Platte River (Shuman 2003), Mississippi River (Hoopes 1960, Helms 1974, Carlson et al. 1985), and the Missouri River (Held 1969, Modde and Schmulbach 1977, Carlson et al. 1985, Megargle 1997, Berry 2002, Gerrity et al. 2006).

Chironomids made up the majority of the diet composition by number and dry weight for shovelnose sturgeon in 2003 and 2004. In past studies of shovelnose sturgeon diets, chironomids have been the highest of all prey by frequency of occurrence (Held 1969, Shuman 2003, Gerrity et al. 2006), number (Held 1969, Shuman 2003), and dry weight or volume (Held 1969, Gerrity et al. 2006).

Seasonal trends were found in the diets of shovelnose sturgeon. In 2003 and 2004, the number of chironomids in the diet increased from April to June with a steady decline thereafter until an increase occurred again in the fall. In other shovelnose sturgeon diet studies in the Missouri River, chironomids were found in greatest numbers and weights in the summer months (Modde and Schmulbach 1977, Megargle 1997, Berry 2002). Shuman (2003) found that chironomid numbers in diets of shovelnose sturgeon increased from June to August and declined in September in the Platte River.

The frequency of occurrence for ephemeropterans in the diets of shovelnose sturgeon was substantial in 2003 and 2004 but did not make up a substantial portion of the dry weight. In terms of dry weight, ephemeropterans were highest among prey types from August to September in 2003 and in August 2004. Shuman (2003) reported higher numbers in July and August compared to June and September in the Platte River and Berry (2002) reported and increase of ephemeropterans in June through August and a decline thereafter in the Missouri River. However, Modde and Schmulbach (1977) reported ephemeropterans, specifically *Hexagenia* spp., in the highest numbers during February and March just prior to ice breakup.

The frequency of occurrence for trichopterans in the diet of shovelnose sturgeon was substantial in 2003 and 2004, but they composed a small portion by dry weight. Shovelnose sturgeon exhibited a seasonal trend of Trichoptera consumption with increases in the spring and fall. Both Modde and Schmulbach (1977) and Berry (2002) also reported the highest numbers and weights of the family Hydropsychidae in the spring with a decline through the summer months and again an increase in the fall months. However, Megargle (1997) found the highest numbers and weights of Trichoptera in the diet during July and September in 1993 and from May to July in 1994 with a decline in August for both years in the Missouri River in Montana. Shuman (2003) found the highest numbers of Trichoptera in the diet of shovelnose sturgeon during August in the Platte River.

Isopods were only found in substantial numbers in the diet of shovelnose sturgeon in the spring and fall in 2004. Modde and Schmulbach (1977) also found that isopods, specifically *Asellus* spp., were primarily preyed upon from January to April, rarely consumed from May to September, and again substantial in the diet through December. Both Trichoptera and Isopoda are likely more available or are preferred as prey for shovelnose sturgeon during the spring and fall.

Fishes were not found in the diets of shovelnose sturgeon in 2003 and rarely occurred in 2004. This is similar to other shovelnose sturgeon diet studies in the Platte

River (Shuman 2003), Mississippi River (Helms 1974), and the Missouri River (Modde and Schmulbach 1977, Megargle 1997, Berry 2002, Gerrity et al.2006).

Diet overlap

Diet overlap is generally considered biologically significant when the Schoener index value exceeds 0.60 (Wallace 1981). Thus, we suggest that diet overlap was low in 2003 (0.53) and quite low in 2004 (0.21) as HRJPS consumed a greater proportion of fish and Ephemeroptera, while shovelnose sturgeon consumed a greater proportion of Chironomidae. Gerrity et al. (2006) also reported low diet overlap between HRJPS (age-6 and age-7) and adult shovelnose sturgeon in the Missouri River above Fort Peck Dam. Adult pallid sturgeon typically have a greater proportion of fish in their diet (Coker 1930, Cross 1967, Carlson et al. 1985) than shovelnose sturgeon (Hoopes 1960, Held 1969, Helms 1974, Modde and Schmulbach 1977, Carlson et al. 1985, Megargle 1997, Shuman 2003).

Based on our results comparing HRJPS (age-1 to age-7) to adult shovelnose sturgeon and from past studies on diet overlap, shovelnose sturgeon should not be considered a surrogate species for pallid sturgeon based on food habits. While both sturgeon species appear to be opportunistic feeders, pallid sturgeon likely prefer larger prey such as cyprinids. Thus, the decline in abundance of native benthic cyprinids may partially explain the greater decline in pallid sturgeon compared to shovelnose sturgeon (Bramblett and White 2001, Gerrity et al. 2006).

Our data collection was not designed to assess competition between HRJPS and shovelnose sturgeon. We also did not measure prey availability; however, there is no evidence suggesting competition for available resources between the sturgeon species. Further research should be conducted on prey availability, for this type of data will be critical for bioenergetics modeling to estimate the growth potential of pallid sturgeon in this reach of the Missouri River.

The empirical food habits data we have collected are important but have limited value in terms of ecological food web depictions. Stable isotope analysis can be used as a tool to evaluate changes in river habitats, impacts of introduced exotic species, seasonal changes, and determination of energy origination points (Angradi 1994, Sierszen et al. 1996, Fisher et al. 2001). Using both dietary and isotopic approaches to create an energy transfer food web can in turn be supported by biological observations and chemical assessments (Fisher et al. 2001).

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