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Juvenile Pallid Sturgeon are Piscivorous: A Call for Conserving Native Cyprinids

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Abstract.—We examined the diets of age-6 and age-7 hatchery-reared juvenile pallid sturgeon *Scaphirhynchus albus* (mean fork length [FL] = 538 ± 13 mm [90% confidence interval]; mean weight = 518 ± 49 g) and indigenous shovelnose sturgeon *S. platorynchus* (mean FL = 525 ± 12 mm; mean weight = 683 ± 41 g) sampled in 2003 and 2004 from the Missouri River above Fort Peck Reservoir, Montana. Diet overlap between juvenile pallid sturgeon and shovelnose sturgeon was low. Fish were the primary prey of juvenile pallid sturgeon, and aquatic insects were the primary prey of shovelnose sturgeon. Sturgeon chub *Macrhybopsis gelida* and sicklefin chub *M. meeki*, two species that have declined throughout much of the Missouri River, comprised 79% of the number of identifiable fish in juvenile pallid sturgeon stomachs. The prevalence of sicklefin chub and sturgeon chub as a food resource of juvenile pallid sturgeon indicates that recovery and management of native cyprinids is a potentially important step in the recovery of pallid sturgeon.

Pallid sturgeon *Scaphirhynchus albus* were listed as endangered in 1990 (Dryer and Sandvol 1993) and the abundance of shovelnose sturgeon *S. platorynchus* has declined over the past 100 years (Keenlyne 1997). Aquatic insects are the primary prey of shovelnose sturgeon (Barnickol and Starrett 1951; Hoopes 1960; Held 1969; Helms 1974; Modde and Schmulbach 1977; Gardner and Berg 1980; Megargle 1996; Shuman 2003), but little information exists on the food habits of pallid sturgeon. Coker (1930) and Cross (1967) both noted that fish were in the diets of adult pallid sturgeon. Aquatic insects comprised the majority of the diets of pallid sturgeon, shovelnose sturgeon, and hybrids between the two species; however, hybrids consumed more fish than shovelnose sturgeon, and pallid sturgeon consumed more fish than shovelnose sturgeon and hybrids (Carlson et al. 1985). These studies, however, focused on the diet of adult pallid sturgeon and had low sample sizes. We are unaware of any published studies on the diet of juvenile pallid sturgeon. Small pallid sturgeon (i.e., <5 kg) used larger substrate than large pallid sturgeon in Lake Sharpe (a main-stem Missouri River reservoir), South Dakota (Erickson 1992), which led Bramblett and White (2001) to speculate that small pallid sturgeon include more aquatic insects than fish in their diet. Bramblett and White (2001) also speculated that severed trophic links might partially explain why pallid sturgeon have declined more than shovelnose sturgeon (because pallid sturgeon are on a higher trophic level). An understanding of the diet of juvenile pallid sturgeon may provide information critical to the recovery of the species.

The Missouri River above Fort Peck Reservoir (river kilometers [rkm] 3,000–3,302, measuring from the confluence of the Missouri and Mississippi rivers) is one of seven recovery priority management areas in the U.S. Fish and Wildlife Service (USFWS) Pallid Sturgeon Recovery Plan based on recent records of pallid sturgeon occurrence and probability that the area still provides suitable habitat for the restoration and recovery of the species (Dryer and Sandvol 1993). Limited storage by upstream dams and several unregulated tributaries make this reach the least hydrologically altered portion of the Missouri River (Scott et al. 1997). As a result, this reach maintains many of the normal characteristics of a free-flowing river (e.g., islands, sandbars, side channels, backwaters). The Montana Department of Fish, Wildlife and Parks (MTFWP) stocked 732 age-1 hatchery-reared juvenile pallid sturgeon in this reach in 1998 to augment the wild pallid sturgeon population. These hatchery-reared fish provided a unique opportunity to study the ecology of juvenile pallid sturgeon because limited recruitment of pallid sturgeon throughout their range limits abundance of such fish. Our objective was to describe the diets of these juvenile pallid sturgeon (1997 year-class) and sympatric indigenous shovelnose sturgeon of

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similar sizes in 2003 and 2004 to compare potential differences in trophic status. Shovelnose sturgeon mature at and grow to smaller sizes than pallid sturgeon. Thus, some of the shovelnose sturgeon sampled were probably not juveniles. We predicted that juvenile pallid sturgeon would be more piscivorous than shovelnose sturgeon, but still contain aquatic insects as the majority of their diet.

Methods

Juvenile pallid sturgeon and shovelnose sturgeon were collected from May through September in 2003 and from March through October in 2004 with setlines, rod and reel, and trammel nets in the Missouri River above Fort Peck Reservoir (rkm 3,004–3,138). All gears were deployed throughout the 134-km study area; however, most sampling effort was focused on areas where juvenile pallid sturgeon and shovelnose sturgeon were known to commonly occur (according to MTFWP biologists who had extensive experience in the study area). All gears were deployed during daylight hours (0700–2100 hours), and setlines and rod and reel gear were also deployed at night (2100–0700 hours). Setlines were 8 m long with six to eight number 2 circle hooks spaced 91 cm apart. Setlines deployed during daylight were checked every 2–3 h, whereas setlines deployed at night were checked in the morning after 10–12 h. Rod and reel gear consisted of 1.8-m rods, 2.7- to 5.4-kg-test monofilament or multifilament fishing line, and number 2 or 4 circle hooks. Both setlines and rod and reel gear were baited with earthworms *Lumbriscus terrestris*. Trammel nets (45.8 m long and 1.8 m deep with a 2.5-cm-mesh inner panel and 25.4-cm-mesh outer panels) were drifted perpendicular to the current for 5–10 min. Fork length (FL; mm) and weight (g) of all fish sampled were measured.

Stomach contents of juvenile pallid sturgeon and shovelnose sturgeon were obtained by gastric lavage modified from Brosse et al. (2002). Fish were held ventral side up and an intramedic polyethylene tube (1.57 mm inner diameter, 2.08 mm outer diameter) was inserted through the mouth until it reached the stomach. Tubing was attached to a 7.58-L pressurized garden sprayer filled with water. After the tubing reached the stomach, the fish was placed dorsal side up and water from the garden sprayer was slowly pumped into the stomach to flush out food items. The lavage process lasted no longer than 15–20 s for each fish to prevent water from entering the swim bladder. Stomach contents were washed into a 500-μm-mesh sieve and then placed in a plastic bag and frozen. After the lavage process was completed, fish were placed in a holding tank for 10–15 min to allow recovery and then released in the vicinity of capture.

Stomach contents were examined in the laboratory under a dissecting microscope. Fish were identified to species and insects to order except Diptera, which were all chironomids. Wet weight of each taxonomic group from each sample was measured to the nearest milligram. Frequency of occurrence and percent composition by wet weight were calculated for each taxon (Bowen 1996). Individual fish were the experimental unit; however, some individuals in the sample (fish that were radio-tagged for another study) were captured and lavaged two or three times during the study, and it is possible that other untagged fish were captured and lavaged more than once. If we knew the diet of an individual had been examined more than once (i.e., recaptured radio-tagged fish only), the total wet weight of each prey taxon was averaged for all samples collected from that individual to preclude pseudoreplication.

Pianka's index of niche overlap was calculated to determine the amount of diet overlap between juvenile pallid sturgeon and shovelnose sturgeon as follows:

$$O_{jk} = \frac{\sum_{i}^{n} p_{ij} p_{ik}}{\sqrt{\sum_{i}^{n} p_{ij}^2 \sum_{i}^{n} p_{ik}^2}},$$

where O_{jk} is Pianka's measure of overlap, p_{ij} is the proportion that diet item i is of the total resources used by species j, p_{ik} is the proportion that diet item i is of the total resources used by species k, and n is the total number of diet items (Pianka 1973). Complete niche overlap is indicated by a value of 1.0 and no niche overlap is indicated by a value of 0 (Pianka and Pianka 1976). The index value was then bootstrapped 5,000 times (Efron and Tibshirani 1993) to reduce bias and provide an estimate of variability (Mueller and Altenberg 1985; Smith 1985). Bootstrapping was conducted by calculating an overlap value using randomly selected fish with replacement from each species separately. The number of fish sampled from each species with replacement in each bootstrap replication was equal to the sample size of each species (50 juvenile pallid sturgeon and 155 shovelnose sturgeon).

Results

In 2003 and 2004, the diets of 50 juvenile pallid sturgeon (mean FL = 538 ± 13 mm [90% confidence interval]; mean weight = 518 ± 49 g) and 155 shovelnose sturgeon (mean FL = 525 ± 12 mm; mean weight = 683 ± 41 g) were sampled. Twenty-nine juvenile pallid sturgeon and 154 shovelnose sturgeon were captured with trammel nets, 13 juvenile pallid sturgeon and 1 shovelnose sturgeon were captured with setlines, and eight juvenile pallid sturgeon were captured by angling. Empty stomachs were observed in 30% of the juvenile pallid sturgeon and 26% of the shovelnose sturgeon that were lavaged (Figure 1). Interestingly, 94% of the juvenile pallid sturgeon stomachs lavaged during the spring were empty, whereas only 23% were empty during the summer and autumn. Additionally, 36% of the shovelnose sturgeon stomachs were empty during spring and 24% were empty during summer and autumn.

Diet overlap between juvenile pallid sturgeon and shovelnose sturgeon was low (mean Pianka's overlap index value = 0.0269 ± 0.0003). Fish (percent occurrence = 54%; percent composition by wet weight = 90%) comprised the majority of the juvenile pallid sturgeon diet, whereas Chironomidae larvae (percent occurrence = 70%; percent composition by wet weight = 67%) were the primary prey of shovelnose sturgeon (Figures 1 and 2). Fish remains were found in 1% of the shovelnose sturgeon diets, whereas 30% of the juvenile pallid sturgeon ate Chironomidae (Figure 1). Sturgeon chub *Macrhybopsis gelida* and sicklefin chub *M. meeki* comprised 79% of the number of identifiable fish (N = 19) in juvenile pallid sturgeon stomach contents, while channel catfish *Ictalurus punctatus*, flathead chub *Platygobio gracilis*, sand shiner *Notropis stramineus*, and shorthead redhorse *Moxostoma macrolepidotum* comprised the other 21%. Ephemeroptera, Trichoptera, Chironomidae, and detritus each occurred in at least 10% of the juvenile pallid sturgeon diets (Figure 1); however, no prey other than fish comprised more than 10% of the diet by wet weight (Figure 2). Ephemeroptera and detritus occurred in at least 10% of the shovelnose sturgeon diets (Figure 1), while fish eggs and Ephemeroptera each made up more than 10% of the diet by wet weight (Figure 2).

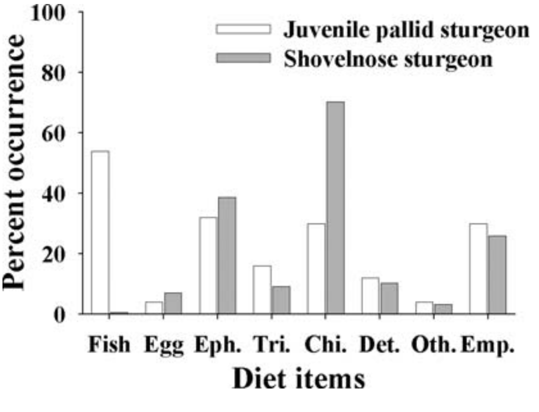

FIGURE 1.—Percent occurrence of fish, fish eggs, Ephemeroptera (Eph.), Trichoptera (Tri.), Chironomidae (Chi.), detritus (Det.), other prey (Oth.), and empty stomachs (Emp.) for juvenile pallid sturgeon (N = 50) and shovelnose sturgeon (N = 155) sampled in the Missouri River above Fort Peck Reservoir, Montana (rkm 3,004–3,138), in 2003 and 2004.

Discussion

Fish were an important diet component of juvenile pallid sturgeon, and aquatic insects were the primary prey of shovelnose sturgeon. These are the first reported food habits data for juvenile pallid sturgeon in the wild. Low niche overlap values confirmed that juvenile pallid sturgeon and shovelnose sturgeon used different food resources. These results are similar to those reported for adult pallid sturgeon (Coker 1930; Cross 1967; Carlson et al. 1985) and for shovelnose sturgeon (Barnickol and Starrett 1951; Hoopes 1960; Held 1969; Helms 1974; Modde and Schmulbach 1977; Gardner and Berg 1980; Carlson et al. 1985; Megargle 1996; Shuman 2003). The results of this study support neither our prediction nor the speculation of Bramblett and White (2001) that small pallid sturgeon consume more aquatic insects than fish. Pallid sturgeon have been associated with sicklefin chub in both habitat use and distribution (Bailey and Cross 1954). The consumption of sicklefin chub and sturgeon chub by juvenile pallid sturgeon substantiates claims by Bramblett and White (2001) and Snook et al. (2002) that pallid sturgeon habitat use may be influenced by the presence of potential cyprinid prey. This finding also supports speculation by Bramblett and White (2001) that severed trophic links may partially explain why pallid sturgeon have declined more than shovelnose sturgeon. The distinct differences in diet between juvenile pallid sturgeon and shovelnose sturgeon further illustrate that shovelnose sturgeon are not a surrogate for pallid sturgeon.

Although the gastric lavage technique used in this study was probably not 100% efficient, it was the only way to examine stomach contents from a live endangered species such as a pallid sturgeon. Mean gastric lavage recovery rate of known quantities of prey fed to Siberian sturgeon *Acipenser baeri* was only 67.5%, and recovery rate was greater for shrimp and fish (78.2%) than for chironomids and earthworms (51.4%; Brosse et al. 2002). Although we did not quantify recovery rate in this study, it is likely that gastric lavage efficiency for different prey types was not different between two morphologically similar species such as pallid sturgeon and shovelnose sturgeon. Thus, our conclusions that fish comprised the majority of the juvenile pallid sturgeon diet and aquatic insects

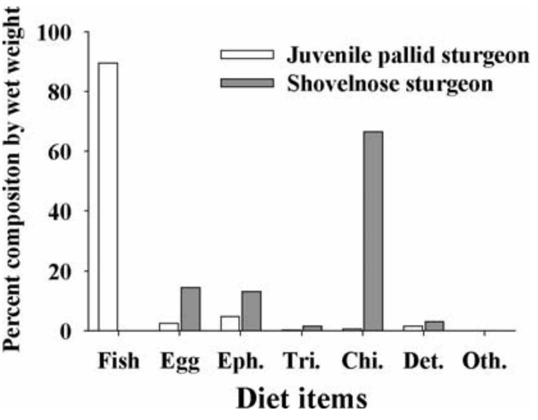

FIGURE 2.—Percent composition by wet weight of fish, fish eggs, Ephemeroptera (Eph.), Trichoptera (Tri.), Chironomidae (Chi.), detritus (Det.), and other prey (Oth.) in the diets of juvenile pallid sturgeon ($N = 50$) and shovelnose sturgeon ($N = 155$) sampled in the Missouri River above Fort Peck Reservoir, Montana (rkm 3,004–3,138), in 2003 and 2004.

comprised the majority of the shovelnose sturgeon diet were probably not affected by the use of gastric lavage. However, percent composition by wet weight of some prey taxa was probably underestimated for both juvenile pallid sturgeon and shovelnose sturgeon because no corrections were made for digestion of the stomach contents. Digestion of stomach contents by juvenile pallid sturgeon captured on overnight setlines may have also slightly biased frequency of occurrence and percent composition by wet weight of some prey taxa. Brosse et al. (2002) recovered stomach contents from all Siberian sturgeon lavaged. Therefore, it is likely that the fish we classified as empty were indeed empty. The higher percentage of empty stomachs in juvenile pallid sturgeon than shovelnose sturgeon in spring suggests that shovelnose sturgeon are actively feeding more than juvenile pallid sturgeon, or that food is limiting to juvenile pallid sturgeon during this period.

Sicklefin chub and sturgeon chub were important prey items for juvenile pallid sturgeon in our study area. Populations of both species have declined in the Missouri River in Nebraska (Hesse 1994), and a review by Galat et al. (2005) concluded that population declines of sturgeon chub and sicklefin chub have occurred throughout much of the Missouri River. As a result, both of these cyprinids are listed as imperiled in many states along the Missouri River (Galat et al. 2005). Conversely, stable or increasing population levels of sicklefin chub and sturgeon chub were reported in the lower Missouri River in Missouri (Pflieger and Grace 1987; Grady and Milligan 1998). These two species are also fairly abundant in deep main-channel habitat of the upper Missouri River in Montana and North Dakota (Grisak 1996; Young et al. 1997; Everett 1999; Gardner 2004; Welker and Scarnecchia 2004). Although the lower Missouri River lacks many of the normal characteristics of a free-flowing river (e.g., islands, sandbars, side channels, backwaters), Dieterman and Galat (2004) suggested that the presence of sicklefin chub in this area was primarily because of the long distance (i.e., >300 km) from the nearest upstream impoundment. Similarly, catches of sicklefin chub and sturgeon chub were higher in areas least impacted by Fort Peck Dam in the upper Missouri River between Fort Peck Reservoir and Lake Sakakawea, suggesting that a more naturally fluctuating hydrograph and high sediment load should be preserved to produce sustainable populations of these species (Welker and Scarnecchia 2004).

No evidence exists that pallid sturgeon are naturally recruiting in the upper Missouri River (i.e., Montana, North Dakota, and South Dakota). The wild pallid sturgeon populations that exist in the upper Missouri River consist of a few old individuals that will probably be deceased by the time habitat issues that limit recruitment are discovered and resolved. Thus, the survival, growth, and maturation of hatchery-reared juvenile pallid sturgeon are essential to the long-term recovery of the species in this area. Our research has provided an understanding of the diet of juvenile pallid sturgeon that has been lacking. Sicklefin chub and sturgeon chub, two species that have been negatively affected by anthropogenic habitat alterations in many areas of the Missouri River, were the primary prey of juvenile pallid sturgeon in one of the least-altered sections of the Missouri River. Reduced availability of these prey in the upper Missouri River may reduce survival, growth, and maturation rates in hatchery-reared juvenile pallid sturgeon. Thus, the use of sicklefin chub and sturgeon chub by juvenile pallid sturgeon as a food resource indicates that recovery and management of native cyprinids in the upper Missouri River is an important step to the long-term recovery of pallid sturgeon.

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