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Late summer and fall diet and condition of smallmouth bass, walleye, and channel catfish in the middle Columbia River, USA

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Executive Summary

American shad *Alosa sapidissima* in the middle Columbia River (MCR)—a high energy food available in the summer and fall—may be contributing to the enhanced condition of introduced predators. To test this hypothesis, we quantified the late summer and autumn diets of smallmouth bass *Micropterus dolomieu* (SMB), walleye *Sander vitreus* (WAL), and channel catfish *Ictalurus punctatus* (CHC) in the three lowermost reservoirs on the Columbia River (Bonneville [BON], The Dalles [TDA], and John Day [JDA]). The diet of SMB was similar among reservoirs, with crustaceans (0–84%) and fish (12–100%) being the dominant prey groups by percent mass. American shad and Cottidae were the dominant fish prey in the diet of SMB at most areas, and the contribution of juvenile shad ranged from 0%–33%. Fish were always the dominant prey item for WAL at all areas and at all times, ranging from 75–100% of their diet by mass. Juvenile American shad composed from 0–87% of the diet of walleye, depending on location and sample period. For CHC, the most common prey items consumed were crustaceans (18–67%) and other items (14–49%; mostly agricultural grains). Fish represented a relatively small component (3–10%) of their diet.

We evaluated the condition of SMB and WAL relative to their diet by determining relative weights (W_r), hepatosomatic indices (HSI), visceral lipid content, and gonadosomatic indices (GSI) for a subsample of our fish from three locations in the MCR. From late July to late November, mean W_r of SMB at each site ranged from about 0.9 to 1.0; mean HSI ranged from about 1.1 to 2.1 and generally increased over time; visceral lipid content ranged from about 6 to 14%; and GSI ranged from about 0.7 to 6.5% and always increased over time. The diet of SMB used for the condition analysis varied considerably, with crayfish and fish representing up to 80% of their diet depending on sample period and location. Cottids and juvenile shad (up to

63%) were the most common prey fishes consumed. For WAL, mean W_r ranged from about 0.86 to 0.97; mean HSI ranged from about 0.9 to 1.8 and generally increased over time at each site; mean visceral lipid content ranged from about 49% to 64% and generally decreased over time; and mean GSI ranged from about 0.4 to over 5.0 and generally increased over time. The diet of WAL used for condition analysis varied considerably among the sites with Cottidae, American shad, and unidentified fish being the most important prey groups. We were unable to discern any unequivocal influence of shad consumption on predator condition.

Collectively, our results are the first to describe the diets of SMB, WAL, and CHC in the MCR during late summer and fall. Generally, predators that ate a lot of fish were in better condition than those that ate mostly crayfish or other items. The notion that consumption of American shad may be significantly enhancing the condition of nonnative predators in the MCR—and perhaps improving their overwinter survival and making them more effective predators on juvenile salmonids—remains uncertain. Future work focused on predator diet and distribution over a wide range of shad runs and environmental conditions would help clarify the role of shad to the condition of SMB and WAL. Finally, even though we did not discuss CHC in detail here because they did not eat American shad, we think this fish warrants further study because the numbers of CHC we captured, their distribution, and their diet varied markedly from the results of earlier studies. Since it has been over twenty-five years since CHC were studied in detail, we recommend new, more detailed studies on these fish to determine their role in the CRB food web and the possibility of high salmonid consumption.

Introduction

Nonnative species pose a threat to native fauna and contribute to the decline of nearly half the species protected under the Endangered Species Act (ESA; Czech and Krausman 1997; Wilcove et al. 1998). From about 1892 to 1950, predators such as smallmouth bass *Micropterus dolomieu* (SMB), walleye *Sander vitreus* (WAL), and channel catfish *Ictalurus punctatus* (CHC) were introduced into the Columbia River Basin (CRB; Wydoski and Whitney 2003) to enhance sport fishing opportunities. With the construction of hydropower facilities and reservoirs in the CRB, these fishes have established self-sustaining populations and have become significant predators of ESA-listed salmonids (Poe et al. 1991).

Another introduced species, the anadromous American shad *Alosa sapidissima*, colonized the CRB soon after being introduced into the Sacramento River, California in 1871 (Petersen et al. 2003). From 1938 to 1957, few American shad crossed Bonneville Dam, but after construction of The Dalles Dam in 1957 (allowing passage over Celilo Falls, a historic passage barrier), their population increased, averaging almost 300,000 adult fish passing Bonneville Dam each year from 1958 to 1974 (Petersen et al. 2003). Fish ladders in the lower CRB, however, were not designed for American shad, and large numbers of these fish collected in the ladders due to inhibited passage (Monk et al. 1989). There was concern that aggregation of American shad in the ladders could impact passage of salmonids so the ladders at Bonneville Dam and John Day Dam were modified to improve passage of adult American shad. After these passage modifications, the number of adult shad passing Bonneville Dam increased six-fold, averaging nearly two million fish per year. Most American shad now spawn in the middle Columbia River (MCR; the Columbia River upstream of Bonneville Dam and downstream of McNary Dam), and

juvenile American shad are present in reservoirs of the MCR during the late summer through fall (Gadomski and Barfoot 1998; Petersen et al. 2003; Haskell et al. 2006).

Availability of a high energy food source such as juvenile American shad in the fall may bolster the growth and condition of introduced predators before the onset of winter and perhaps improve their overwinter survival (Sauter et al. 2004). Little is known, however, about the diet of introduced predators in the fall because almost all sampling from previous food habit studies was timed to correspond with the outmigration of juvenile salmonids (i.e., spring and summer; see Poe et al. 1991; Zimmerman 1999; Naughton et al. 2004). Until now, only northern pikeminnow *Ptychocheilus oregonensis* have been shown to consume significant quantities of juvenile American shad in the late summer (Poe et al. 1991; Petersen et al. 1994). This does not mean, however, that the introduced predators do not eat juvenile shad but instead probably reflects the consequences of sample timing and location. Juvenile American shad in the MCR move downstream in late summer (Haskell et al. 2006), and previous sampling for SMB, WAL, and CHC likely occurred at times and locations where the spatial overlap between these predators and juvenile shad was minimal. We suspect, however, that there is spatial and temporal overlap of juvenile American shad and introduced predators following summer because they both use mainstem shorelines, sloughs, and backwater habitats (Limburg 2001; Gadomski and Barfoot 1998; Petersen et al. 2003).

For this work, we documented the food habits of SMB, WAL, and CHC in the MCR from late-July through November. We specifically focused on the proportion of juvenile American shad in the diets of these predators and used this information to determine if fish that ate a lot of shad were in better condition than those that did not. We evaluated predator condition by calculating relative weights (W_r), hepatosomatic indices (HSI), visceral lipid

content, and gonadosomatic indices (GSI) of fish from late summer to late fall. Improved condition of predators in late fall may increase overwinter survival and enhance their reproductive success and predatory demand for ESA-listed salmonids the following spring (Sauter et al. 2004). Information from this study will guide management decisions for American shad and nonnative piscivores in the CRB.

Methods

Study area.—The MCR comprises the Bonneville Reservoir (BON), The Dalles Reservoir (TDA), and the John Day Reservoir (JDA), which are formed by large hydroelectric projects (Figure 1). The three reservoirs are 74, 39, and 123-km-long and range in mean elevation from 23–81 m. Within these three reservoirs, there are about 683 km of shoreline and 31,306 hectares of water surface area (Ward et al. 1995). Temperatures in the reservoirs range from about 4 to 27°C (Poe et al. 1991). The reservoirs are likely mesotrophic and polymictic, although partial stratification can occur during summer (Hjort et al. 1981; Poe et al. 1991).

Fish collection.—We collected SMB, WAL, and CHC at fixed sites within each reservoir by netting, set lining, angling, and electrofishing from 30 July to 29 November 2012. Specifically, fish were collected during four periods: 30 July through 31August; 4 September through 4 October; 8 October through 9 November; and 13 November through 30 November. The first period was generally a time of rearing for juvenile American shad and the second, third, and fourth periods correspond to times of rearing and outmigration (Gadomski and Barfoot 1998; Petersen et al. 2003; Haskell et al. 2006). Sites included near-dam areas (forebay and tailrace zones) and mid-reservoir areas away from dams and were similar to those being used by the northern pikeminnow management program (Ward et al. 1995; Beamesderfer et al. 1996; Figure 1). For netting, we sampled with gillnets (1.8-m-deep × 50-m-long, and containing panels of 3.8,

5.1, 6.4, 7.6, and 8.9 cm bar mesh) and trammel nets (50.0-m-long × 1.8-m-high, 30.5 cm outer mesh and 3.8 cm inner mesh). Depending on habitat at each location, we set nets in both nearshore and offshore areas and often restricted efforts to smaller sections of each area so that gear could be quickly reached and removed in response to changing weather. We targeted areas previously known from our earlier work to have high concentrations of introduced predators, which minimized the time needed for sampling. The mean (SD) gill net set was 3.8 (5.2) h and for trammel nets was 4.5 (6.0) h. For set lining, which mainly targeted CHC, we used 13–16 baited #2 to #4 hooks per line and fished them at various depths. We conducted hook and line angling for fish during the interim periods when other gear was deployed, targeting suitable habitat and using gear and artificial lures known to be productive in the MCR. We collected some fish via boat electrofishing when water temperatures were below 18°C, which occurred only after mid-October. For this, each sampling area was divided into several nearshore transects that were about 500 m long. The number of transects depended on the length of the site, and a standardized effort of 15 min of continuous output at 4 A was used for each transect. We randomly selected which transects were sampled each day. Finally, we also collected some channel catfish from the juvenile white sturgeon *Acipenser transmontanus* stock assessments conducted by the Washington and Oregon Departments of Fish and Wildlife. These sampling efforts used small mesh gill nets and we processed fish as described above shortly after they were caught.

Upon capture, all fish were anesthetized in a light solution of carbon dioxide (one tablet of Alka-Seltzer Gold© in 2.5 L of water). We measured fork length (FL) of all fish to the nearest mm and weight of most fish to the nearest g; some fish were not weighed due to mechanical difficulties in the field. We estimated the mass of unweighed fish using length-weight relations

derived from all measured fish. We removed stomach contents of SMB and WAL 150 mm and larger by gastric lavage with a modified Seaburg sampler (Seaburg 1957). Entire stomachs were removed from CHC by dissection. Individual samples were placed in labeled plastic bags and preserved in 80% alcohol.

Diet analysis.—We identified prey items under a dissecting microscope and the level of taxonomic resolution varied by prey type. Mollusks and annelids were identified to class, insects to order, crayfish, prawns, and shrimps to genus, and fish to genus or species. Other food items included vegetation and various other items. Individuals within each category were counted, placed together on a paper towel for 30 s, and the entire mass was weighed to the nearest 0.001 g. Partially digested prey fish were identified using diagnostic bones (Hansel et al. 1988) and we apportioned the mass of unidentified fish parts proportionally among the masses of identified taxa within a diet sample. Fish parts that could not be identified were simply classified as unidentified fish. For each prey category, we determined its contribution and importance to the diet by mean percent weight. We derived mean percent weight (MW_i) by calculating separate proportions of each diet category (by weight) per non-empty stomach and averaged the proportions within each group of predators. We also calculated percent occurrence and percent by number of common prey items for each predator; these data are not discussed in detail here and can be found in Appendix Tables A1–A7.

Influence of juvenile shad consumption on predator condition.—To determine the possible influence of juvenile shad consumption on the condition of SMB and WAL (the only fish that ate potentially relevant amounts of juvenile shad), we calculated relative weight (W_r), hepatosomatic index (HSI), visceral lipid content, and gonadosomatic index (GSI; for females only) for a subsample of fish at some locations during each of our sample periods. Specifically,

we used SMB collected from Bingen, Miller Island, and Arlington, and WAL from Arlington, the Blalock Islands, and Umatilla for this analysis. Our intent was to determine if indices of condition changed over time and differed between groups of fish from different areas relative to diet. To determine W_r, we used the standard weight (W_s) equations from Blackwell et al. (2000). Fork lengths were converted to total lengths (TL) using the equations in Carlander (1977) and Murphy et al. (1990). We calculated W_r by dividing the weight of each fish by W_s for a fish of the same length. We calculated mean W_r for the four sample periods described above at each location.

To evaluate temporal and spatial differences in HSI, visceral lipid content, and GSI, some SMB and WAL were sacrificed. We purposely sacrificed fish from each location about once per month but also used most incidental mortalities that occurred during sampling. In the end, we pooled all data into the four sample periods described above. After collection, fish were placed in a lethal dose (200 mg/L) of buffered MS-222, measured, weighed, labeled with an ID tag, and placed on ice for later analysis. At the end of each day, we re-weighed each carcass and then removed the liver and gonads and weighed them separately for calculation of HSI and GSI (i.e., 100 × liver or gonad weight/body weight). When finished, viscera (without gonads) was placed singly in a labeled plastic bag and frozen for later analysis.

At the laboratory, the viscera samples were slightly thawed and processed by either cutting them into small pieces with a knife or scissors (samples ≤ 50g) or individually homogenizing each sample by blending it in a commercial food processor (samples > than 50 g; Robot Coupe Blixer™, Model BX4V). Entire chopped samples and sub-sampled homogenates (ca. 25 g) were placed singly in airtight plastic bags and frozen at -20°C until analysis. Samples were delivered frozen to the Washington State University Wildlife Habitat Laboratory, where

they were analyzed for water content. We then used pre-determined regression equations of visceral water content against lipid content from our work in 2011 (Figure 2) to estimate the lipid content of each sample. For our analysis, we compared the mean ranks of metrics between like sample periods at each site and between sample periods within each site using nonparametric procedures (Kruskal-Wallis and Mann-Whitney tests). The level of significance for these tests was 0.05.

Results

Catch Data

We set 849 gillnets, 220 trammel nets, and 89 set lines during 2012. We also angled for 215 efforts and electrofished 29 transects. We captured 1,572 SMB, 390 WAL, and 516 CHC. Our catch of SMB was distributed widely throughout the MCR, with 51% caught from JDA, 24% from TDA, and 24% from BON. In contrast, we caught 87% of our WAL and 99% of our CHC from JDA, 7% and 1% from TDA, and 6% and 0% from BON.

Diets of Introduced Predators in the MCR

Smallmouth bass.—Of the 1,572 SMB collected (ranging in size from 152–513 mm), 78% had food in their stomachs representing six major prey types (Figure 3A; Appendix Tables 1–3). The diet of SMB was similar among the reservoirs, with crustaceans and fish being the most important prey groups by percent mass (Figure 3A). Crustaceans composed from 0–84% and fish from 12–100% of the diet by mass, depending on reservoir and sample period. The crustacean portion of the diet was dominated by crayfish at all areas, with amphipods (mainly *Corophium* spp.) and mysid shrimp (probably *Neomysis mercedis*) showing variable percentages by mass (0–37%; Appendix Tables 1–3). Cottidae were usually the most important fish prey in

the diet of SMB (0–14%; Appendix Tables 1–3), and the contribution of juvenile shad to the diet ranged from 0–33% (Appendix Tables 1–3).

The diet of SMB showed some differences over time but more so at BON and TDA than JDA (Figure 3A). At BON, the percent by mass of all fish items in the diet increased from 16% during period one to about 50% during period three (Figure 3A). At TDA, the percent by mass of fish in the diet increased from 12% during period one to 67% for period three, and then decreased to 25% for period four. At JDA the percent by mass of fish in the diet ranged from 16–34%. Increases in fish consumption at each site were accompanied by decreases in the consumption of crayfish. Juvenile shad were found in the diets of SMB at all areas, with the highest percentages by mass at BON and TDA during period three (9.5% and 33%; Figure 3A; Appendix Tables 1–3). Smallmouth bass consumed a smaller percentage of American shad in JDA than in other reservoirs.

Walleye.—Seventy-one percent of the 390 WAL (186–870 mm) captured contained prey items. Fish were always the most important prey item for WAL at all areas and at all times, ranging from 75–100% of their diet by mass (Figure 3B). American shad (0–87% of their diet by mass), Cyprinidae (0–60%), and salmonids (0–33%) were the most important prey fish for WAL at BON, whereas American shad (0–55%) and Cottidae (0–50%) were the most important prey fish at TDA and JDA—although sample sizes at TDA were small (Appendix Tables 4–6). American shad made up 31% of the diet of WAL in BON during the third sample period, 55% of their diet in TDA during the third period (N = 4), and from 9–27% of their diet in JDA during the second, third, and fourth sample periods (Figure 3B). Unidentified fish accounted for 0–33% of the diet of WAL in BON, 25–35% of their diet in TDA, and 20–32% of their diet at JDA. The diets of WAL were fairly consistent over time at each site (Figure 3B), with American shad

being consumed only during sample periods two through four. We note again that sample sizes for WAL at BON and TDA were relatively small, thus the diet information from these sites must be tempered accordingly.

Channel catfish.—Eighty-four percent of the 516 CHC (158–652 mm) collected contained food items. Because most (N = 510) CHC were collected from JDA, we restricted our analysis to this reservoir only. The most common prey items consumed by CHC were crustaceans (18–67% by mass) and vegetation (9–44%) comprised mostly of algae and agricultural grains (Figure 3C). Although fish represented a relatively small component (< 10% by mass) of the CHC diet, American shad (0–7%) and Cottidae (0–2%) were the most common identified prey fish consumed (Appendix Table 7). The percentage by mass of crustaceans in the diet of CHC was high and similar (ca. 60%) during sample periods one through three and decreased in period four (ca. 18%). In contrast, the importance of fish and agricultural grains was low and stable during periods one through three (ca. 0.6–8%) and both increased in period four (Appendix Table 7).

Condition of Smallmouth Bass at Selected Sample Sites

Relative weight.—Mean W_r for SMB at each site ranged from about 0.9 to 1.0, depending on site and sample period (Figure 4). The mean ranks of W_r for SMB at each site during sample period one did not differ significantly (Figure 4). During period two, the mean rank of W_r for fish at Arlington was significantly lower than values from Bingen and Miller Island (H = 16.84, P = 0.0002), but in period three the mean rank of W_r for fish at Miller Island was significantly higher than the other areas (H = 23.37, P < 0.0001). In period four, the mean rank of W_r for fish at Miller Island was significantly higher than the rank at Arlington, but not at Bingen (H = 11.14, P = 0.0038). At Bingen, the mean ranks of W_r did not change significantly over time (Figure 4).

At Miller Island, the mean ranks of W_r differed significantly only between periods two and four (H = 11.42, P = 0.0097) and, at Arlington, the ranks differed only between periods one and two and periods one and three (H = 13.63, P = 0.0034).

Hepatosomatic index.—The mean HSI for SMB at all sites ranged from about 1.1–2.1 and generally increased over time (Figure 4). There were no significant differences in the mean ranks of HSI for SMB at all sites during periods one, two, and four. During period three, the mean rank of HSI was significantly lower at Arlington compared to Miller Island (H = 6.28, P =0.043). At Bingen, the mean rank of HSI in sample period three was significantly greater than the rank in period one (H = 6.26, P = 0.043). At Miller Island, the mean ranks of HSI increased significantly during periods three and four, but only when compared to period one (H = 19.98, P = 0.0002). There were no significant differences in the mean ranks of HSI between any sample periods at Arlington.

Visceral lipid content.—The mean visceral lipid content of SMB ranged from about 6 to 14%, depending on sample period and location (Figure 4). The only significant difference in the mean ranks of lipid content for SMB at each site occurred during period four, where the rank of fish at Arlington was lower than that of fish at Miller Island (U = 3.00, P = 0.014). At Bingen and Miller Island, the mean rank of lipid content for SMB in period two was significantly higher than the value in period one (H = 6.753, P = 0.034); no other differences were apparent. At Arlington, the mean rank of lipid content for fish in period two was significantly higher than the ranks in periods one and four (H = 16.17, P = 0.001).

Gonadosomatic index. —Mean GSI of female SMB at the sites ranged from about 0.7 to 6.5% and always increased over time (Figure 4). The mean ranks of GSI for fish at each site never differed between the same sample periods. At Bingen, the mean rank of GSI for fish in

period three was significantly greater than the value in period one, but not period two (H = 10.11, *P* = 0.006). At Miller Island, the mean ranks of GSI for fish in periods three and four were significantly greater than the value during period one only (H = 23.39, *P* < 0.0001); no other differences were apparent. Finally, at Arlington, the mean rank of GSI for fish from period four was significantly greater than the values of fish from periods one and two, and the rank of GSI during period three was greater than that during period one (H = 23.20, *P* <0.0001).

Diet of SMB at sites used for condition analysis.—Of the 635 SMB collected at Bingen, Miller Island, and Arlington—which were a subset of the total number of fish we collected—81% had food in their stomachs representing seven major prey types (Figure 5). The diet of SMB varied considerably among locations, with crayfish always being the most important prey group at Arlington by percent mass (Figure 5) and crayfish and fish being most important at Bingen and Miller Island. For SMB from Bingen, crayfish represented about 60 to 70% of their diet during periods one and two, with fish contributing about 20 to 30% by mass (Figure 5). Cottidae were the most common prey fish consumed and some American shad were present during periods two and three, but the sample size was small in period three (and period four). Like Bingen, crayfish were the most important diet item by mass (ca. 70%) for SMB from Miller Island during periods one and two (Figure 5). Fish increased in importance during periods three (ca. 80%) and four (ca. 25%). The mass of American shad in the diets of SMB at Miller Island was highest during period three (63%) and was over four times greater than the mass for all other identified prey fishes consumed. The diet of smallmouth bass at Arlington was comprised almost exclusively of crayfish and other diet items (usually greater than 83% by mass); fish represented less than 17% of their diet during each period.

Condition of Walleye at Selected Sample Sites

Relative weight.— Mean W_r for WAL ranged from about 0.86 to 0.97 depending on site and sample period (Figure 6). The mean ranks of W_r for fish at each site never differed between the same sample periods. At Arlington, there were no significant differences in the mean ranks of W_r among the sample periods. At the Blalock Islands, the mean rank of W_r for WAL during sample period two was significantly lower than the value from period three (H = 11.51, P = 0.009); no other differences existed. Finally, at Umatilla, the mean rank of W_r for fish during period two was significantly lower than both period three and four (H = 12.04, P = 0.007).

Hepatosomatic index.—Mean values for HSI of WAL ranged from about 0.9 to 1.8 and generally increased over time at each site (Figure 6). During sample period three, the mean rank of HSI was significantly lower at Arlington than at the Blalock Islands or Umatilla (H = 11.11, P = 0.004); no other differences existed. At Arlington, the mean rank of HSI never differed between sample periods, but at the Blalock Islands, the value during period one was significantly lower than those during periods three and four (H = 15.96, P = 0.001). At Umatilla, the mean rank of HSI during period one was significantly lower than values from periods three and four, and the value from period two was also lower than that from period four (H = 24.09, P < 0.0001).

Visceral lipid content.—Mean visceral lipid content of WAL ranged from about 49% to 64% and generally decreased over time (Figure 6). There were no differences in the mean rank of lipid content between like sample periods at each site. The only differences in the mean ranks of lipid content within a site occurred at Umatilla, where the values for fish during periods one and two were significantly higher than those from periods three and four (H = 41.27, P < 0.0001).

Gonadosomatic index. —Mean GSI of female WAL ranged from about 0.4 to over 5.0 and generally increased over time (Figure 6). Sample sizes were often small and there were no significant differences in the mean ranks of GSI between like sample periods at each site or between time periods within a site.

Diet of WAL at sites used for condition analysis. —Of the 319 WAL collected at Arlington, the Blalock Islands, and Umatilla (again, a subset of the total collected), 72% had food in their stomachs representing seven major prey types (Figure 7). Fish were always the most important prey item for WAL at all areas and at all times, ranging from 67–100% of their diet by mass. The main species of fish consumed by WAL varied by location, with Cottidae generally being the most important prey group at Arlington and the Blalock Islands (Figure 7) and American shad being most important at Umatilla. For WAL collected at Arlington, Cottidae represented about 99% and 64% of their diet during periods one and two and then decreased to 22% and 29% of their diet during periods three and four; however, sample sizes were relatively small. In contrast, the mass of Cottidae in the diets of WAL from the Blalock Islands increased from 24% and 40% for periods one and two to 53% and 64% for periods three and four. American shad increased from less than 8% of their diet for periods one through three to over 33% of their diet for period four (the sample size during period four was relatively small). The diet of WAL at Umatilla was composed mainly of unidentified fish (41%), Cottidae (16%) and crustaceans (20%) during period one. Thereafter, their diet was composed of mostly unidentified fish (33–43%) and American shad (27–49%; Figure 7).

Discussion

This report describes results from the second full year of a study describing the diet of SMB, WAL, and CHC from three reservoirs in the MCR during late summer and fall. We were

most interested in the contribution of juvenile American shad to their diets and the possible influence of this high calorie diet item on predator condition prior to the onset of winter. Our results indicate that only SMB and WAL consumed relevant amounts (up to 63% by mass for SMB and 49% for WAL) of American shad and that the importance of this specific diet item varied by sample period and location. Although SMB and WAL showed increases in W_r, HSI and GSI during sample period three when they consumed relatively large amounts of American shad, it was difficult to conclude that such increases were due to an effect specific to the presence of American shad in their diets. Discerning an effect specific to American shad was difficult because we could not discount the importance of other prey items, the relations between condition indices and diet composition were varied, we sometimes had small sample sizes, and we do not know if there were other site-specific factors that may have influenced our results. Despite this, the diet and condition information collected during this study is new, indicate that juvenile American shad can be an important prey item for SMB and WAL at certain times and locations, and should be useful for future discussions regarding the management of introduced predators and American shad in the MCR. We should note that our study occurred during two high water years (2011 and 2012; from 125–137% of 10 year average flows) with disparate numbers of adult American shad migrating above Bonneville Dam (33% and 86% of the ten year average for 2011 and 2012). Conducting this type of work under normal or low flow conditions and varied run sizes of adult American shad (which should result in varied juvenile fish numbers) would help clarify questions related to the influence of juvenile American shad on predator condition.

The diets of SMB and WAL in our study were similar to those from our previous year of work (Rose et al. 2012) and to fish in the lower and mid-Columbia River during the spring and

summer. For example, our study, Poe et al. (1991), and Zimmerman (1999) found that crayfish and Cottidae were important prey for SMB, and fish were the dominant prey item for WAL. The variety of food types in many CHC stomachs, such as agricultural grains, terrestrial and aquatic vegetation, algae, detritus, insects, crayfish, and mollusks, suggests omnivorous feeding and scavenging behavior during summer and fall, which is similar to the results of others (Bailey and Harrison 1948; Davis 1959; Tyus and Nikirk 1990). Our results contrast with those of Poe et al. (1991) who reported that CHC ate considerable quantities of fish, mostly salmonids and Cottidae, during spring. The differences between the studies probably reflect seasonal changes in the distribution of CHC. Most of our work was conducted during summer and fall when CHC were more abundant in the lower portion of JDA, whereas Poe et al. (1991) noted that the abundance of CHC was higher in the upper portion of JDA where they take advantage of spring outmigrations of juvenile salmonids and consume more fish. Indeed, the few CHC that we captured at Umatilla during fall showed higher proportions of fish in their diets relative to other areas.

We noticed that mysid shrimp (probably *Neomysis mercedis*) were a common prey item for SMB and CHC, which contrasts with other fish food habits literature for the MCR (summarized by Stanford et al. 2006). It is also noteworthy that smaller SMB and CHC consumed considerable amounts of *Corophium* (probably mostly *C. salmonis*). Both of these normally estuarine species have expanded their range into upstream reservoirs of the Columbia and Snake rivers and are now integral parts of the Columbia River food web (Haskell and Stanford 2006). The upstream range expansion of *Corophium* may negatively affect the Columbia River food web because they have a lower nutritional value than the native invertebrates they displace (De La Noue and Choubert 1985; Rondorf 1990). On the other hand,

Corophium are an important food source for juvenile salmonids (Haskell and Stanford 2006). Clearly, as native species expand their range and more exotic species become established, the food web and the dynamics and role of predation in the CRB ecosystem will require continued study.

Juvenile American shad were probably abundant in the MCR beginning in mid-August (Haskell et al. 2013) and overlapped spatially with introduced predators in both the littoral zone and offshore habitats (Haskell et al. 2013; Limburg 2001; Gadomski and Barfoot 1998; Petersen et al. 2003). However, American shad were not consumed in any relevant quantities until October, when they were probably, on average, larger than 60 mm FL (Haskell et al. 2013). Others have reported similar seasonal patterns in which gizzard shad (*Dorosoma cepedianum*) and anadromous herring (*Alosa* sp.) were not consumed by largemouth bass (*Micropterus salmoides*) until about two months after they were available to the predator (Storck 1986; Michaletz 1997; Yako and Mather 2000), suggesting that the dietary change of largemouth bass to these prey fishes corresponded to a larger body size of the prey. This sized-based dietary switch may also explain why juvenile American shad were not consumed by SMB or WAL until October in our study. In the MCR, size of juvenile American shad is highly dependent on water temperature, with fish reaching 60 mm or greater by September in warm water years and October in cool water years (Haskell et al. 2013; Parsley et al. 2011). This may explain why consumption of juvenile American shad by SMB and WAL was highest in October.

Despite the spatial overlap between American shad and SMB and WAL during mid-October through November, they were not consumed consistently by these predators and their importance as a diet item differed between locations and sample periods. For example, consumption of American shad by SMB occurred almost exclusively downstream of John Day

Dam, particularly in the area around Miller Island. In contrast, WAL consumed American shad throughout most of their MCR range, although the sample size was small at some sites and sample periods. That SMB and WAL ate substantial amounts of American shad at some distinct locations was probably not coincidental. For example, the high predation of American shad by SMB at Miller Island occurred when we routinely observed large schools of juvenile American shad rearing. Also, we noted an increase in shad consumption and relative abundance of WAL at Umatilla where American shad likely became concentrated near the spillway and other passage routes of McNary Dam. Thus, consumption of American shad by SMB and WAL may depend on local prey aggregations and spatial overlap as well as the overall absolute abundance of juvenile American shad.

As previously mentioned, a focus of our work was to determine whether introduced predators that consumed juvenile American shad in the fall were in better condition than fish that did not eat a lot of shad. For this idea to have merit, we had to see two things: (1) marked increases in the consumption of shad relative to other prey items; and (2) increases in condition of predators concomitant with this change in diet. To evaluate predator condition, we chose a variety of indices that provided insight into the general health of these fish over time. For example, HSI is a sensitive indicator of short-term energy intake, responds to various metabolic demands, and can be useful for predicting growth (Heidinger and Crawford 1977; Bulow et al. 1978; Allen and Wootton 1982; Adams and McLean 1985). Also, the viscera are a primary lipid storage depot for fish, and animals with more stored energy are expected to have greater survival and reproductive success (Kaufman et al. 2007; Berg and Bremset 1998; Henderson and Nepszy 1994; Gardiner and Geddes 1980). Despite the usefulness of these indices for assessing the condition of our target predators, it was difficult to discern consistent and significant differences

in predator condition between fish that ate a lot of shad compared to fish that did not. Although we showed that American shad can be an important diet item for SMB and WAL at certain times and locations, the influence of this prey item alone on the condition of these predators remains uncertain.

At the sites where we evaluated both predator condition and diet, we showed that the consumption of American shad by SMB was highest during period three at Bingen and Miller Island—but the sample size from Bingen was only three fish. We also noted that few American shad (or other fishes) were consumed by SMB at Arlington. Evaluating changes in condition relative to site, sample period, and diet illustrates the difficulty of discerning a specific "shad effect". First, although the highest values of W_r for SMB were from fish at Miller Island during a time when they were eating a lot of shad, on average the differences between groups only amounted to about 10% at most. For HSI, SMB at Miller Island had values during periods three and four that were higher than any other group. However, such differences were not always statistically significant. Further, although visceral lipid content for SMB was always highest at Miller Island, the values during periods three and four did not differ significantly from the value during period two nor did they differ from the values of fish from other sites. And finally, for GSI, the shad-eating fish at Miller Island showed no unique trends over time compared to other groups. Thus, in the end, our data suggests that the condition of SMB was generally better in groups that ate a lot of fish—not just American shad—compared to SMB that ate mostly crayfish. This may be due to the nutritional quality of fish versus crayfish and their relative digestibility, but more work is needed to evaluate this.

Because WAL primarily consumed fish, it was even more difficult to draw a clear connection between shad consumption and predator condition. In fact, the only between site

differences in condition occurred during period three for WAL at Arlington, which had lower HSI values than other sites. Even though WAL from Umatilla consumed more American shad than any other group, they did not consistently show increases in values of W_r, HSI, lipid content, and GSI unique to the increase in American shad in their diets. For example, although we detected significant changes in W_r and HSI for WAL at Umatilla during a time when they were eating a lot of American shad, WAL at the Blalock Islands showed a similar trend (for HSI only) during a time when they were eating large quantities of cottids and American shad. In addition, of all the groups, WAL from Umatilla showed the greatest decline in visceral lipid content over time—which contrasts with the notion of American shad providing a significant nutritional subsidy. However, the trend of decreasing lipid content for each population was concomitant with an increasing trend in GSI. This could indicate that the WAL populations from our study were at different stages of sexual maturity and that each group put different amounts of their visceral lipid reserves towards gonad development (e.g., capital breeding; see Henderson and Nepszy 1994). In the end, although American shad were occasionally an important prey item for WAL, determining the influence of American shad on WAL condition was difficult because differences in paired-site comparisons were rare and the importance of other fishes (mainly cottids) varied. In retrospect, determining the influence of a single prey type on predator condition may be untenable via simple field studies alone and will probably require some detailed laboratory studies combined with more intensive multi-year field sampling.

Through diet analysis and condition assessments, we have shown that prey with high lipid contents such as American shad and cottids were seasonally important diet items for SMB and WAL in some areas of the MCR. Generally, predators that ate a lot of fish were in better condition than those that ate mostly crayfish or other items. We were unable to determine

unequivocally whether the consumption of juvenile American shad was more beneficial to the condition of SMB and WAL than other fishes—particularly cottids. The notion that consumption of American shad may be significantly enhancing the condition of nonnative predators in the MCR—and perhaps improving their overwinter survival and making them more effective predators on juvenile salmonids—thus remains uncertain. Future work focused on predator diet and distribution analyses over a wide range of shad runs and environmental conditions would help clarify the role of shad to the condition of SMB and WAL. Finally, even though we did not discuss CHC in detail here because they did not eat American shad, we think this fish warrants further study because the numbers of CHC we captured, their distribution, and their diet varied markedly from the results of Poe et al. (1991). Since it has been over twenty-five years since data were collected for Poe et al. (1991), we recommend new, more detailed studies on CHC to determine their role in the CRB food web and the possibility of high salmonid consumption.

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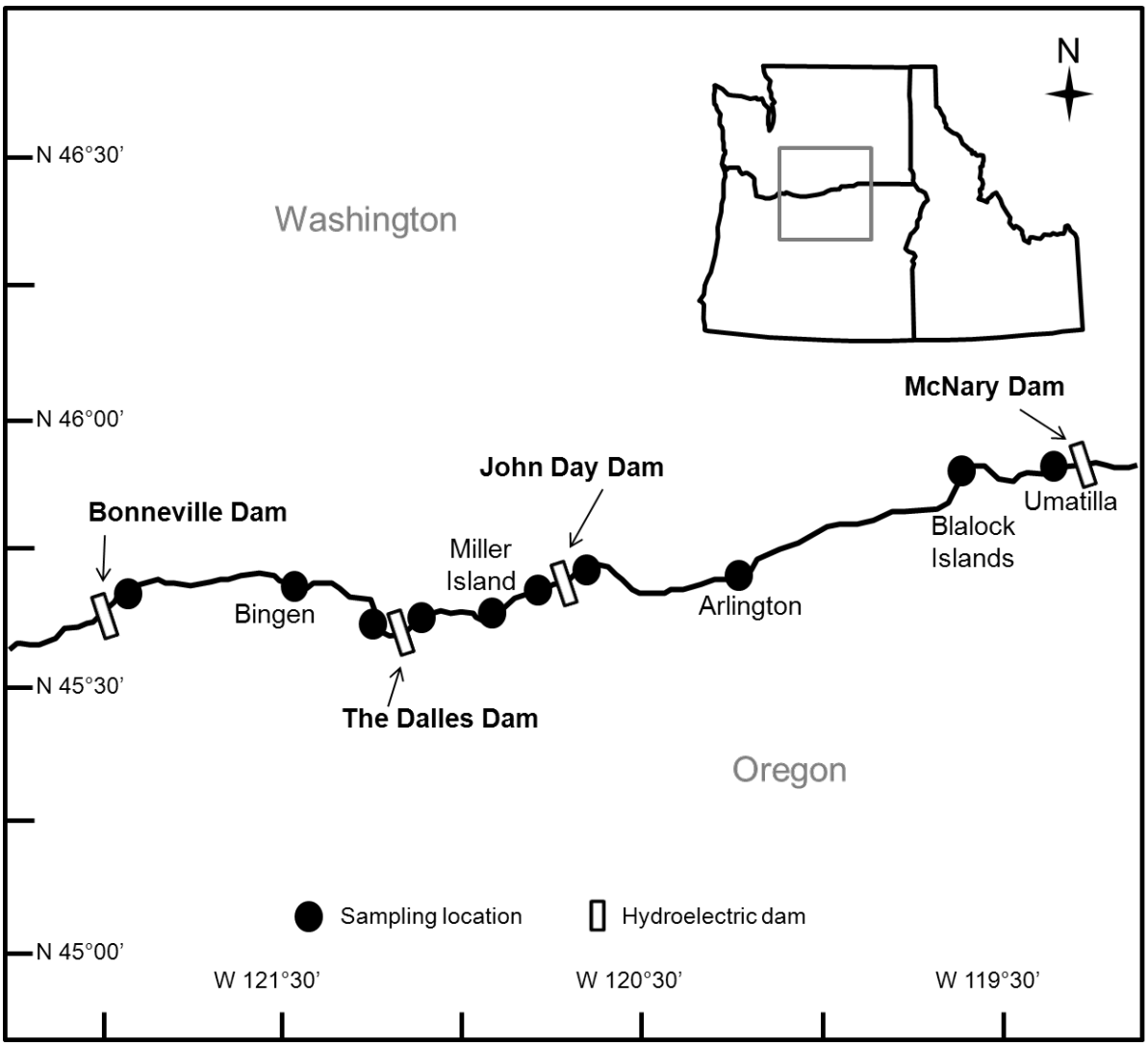

FIGURE 1.—Map of the middle Columbia River showing the four lowermost dams and sampling locations during 2012. Sampling locations are shown as black circles and dams as rectangles.

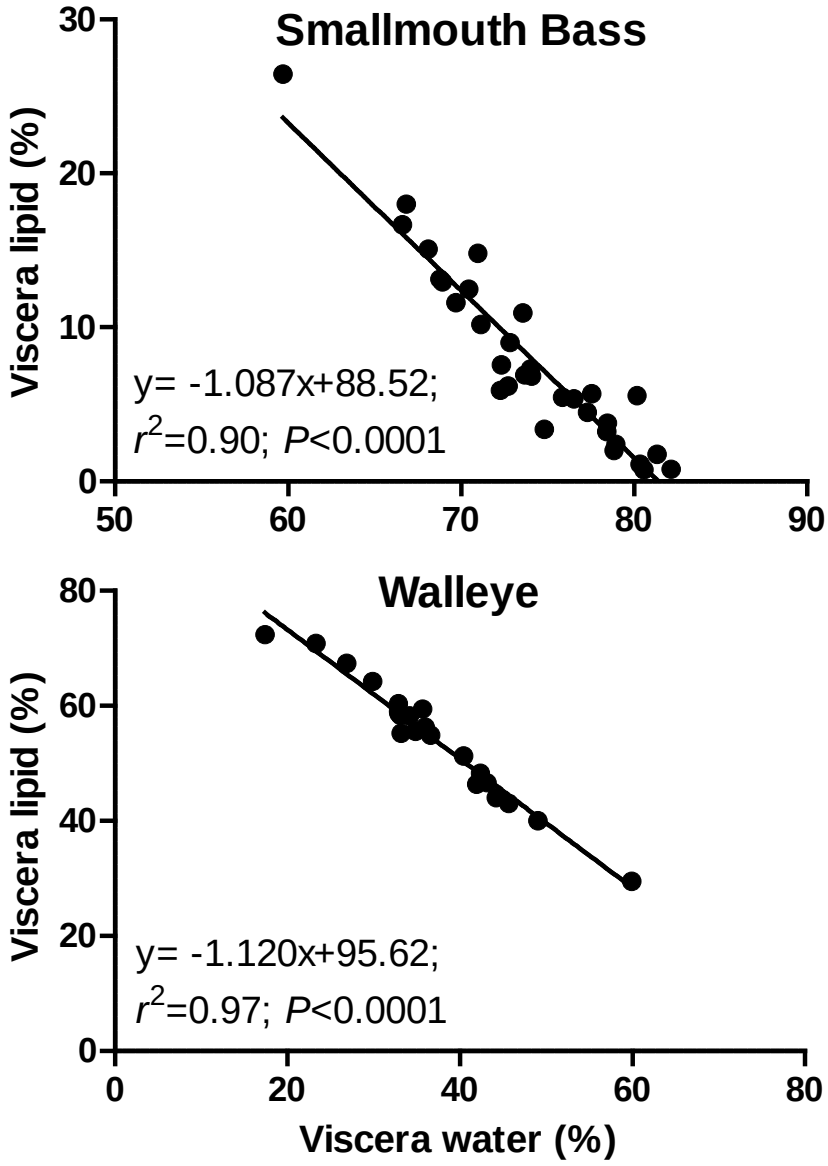

FIGURE 2.—Relation of lipid to water content in the viscera of smallmouth bass and walleye from the Columbia River during 2011.

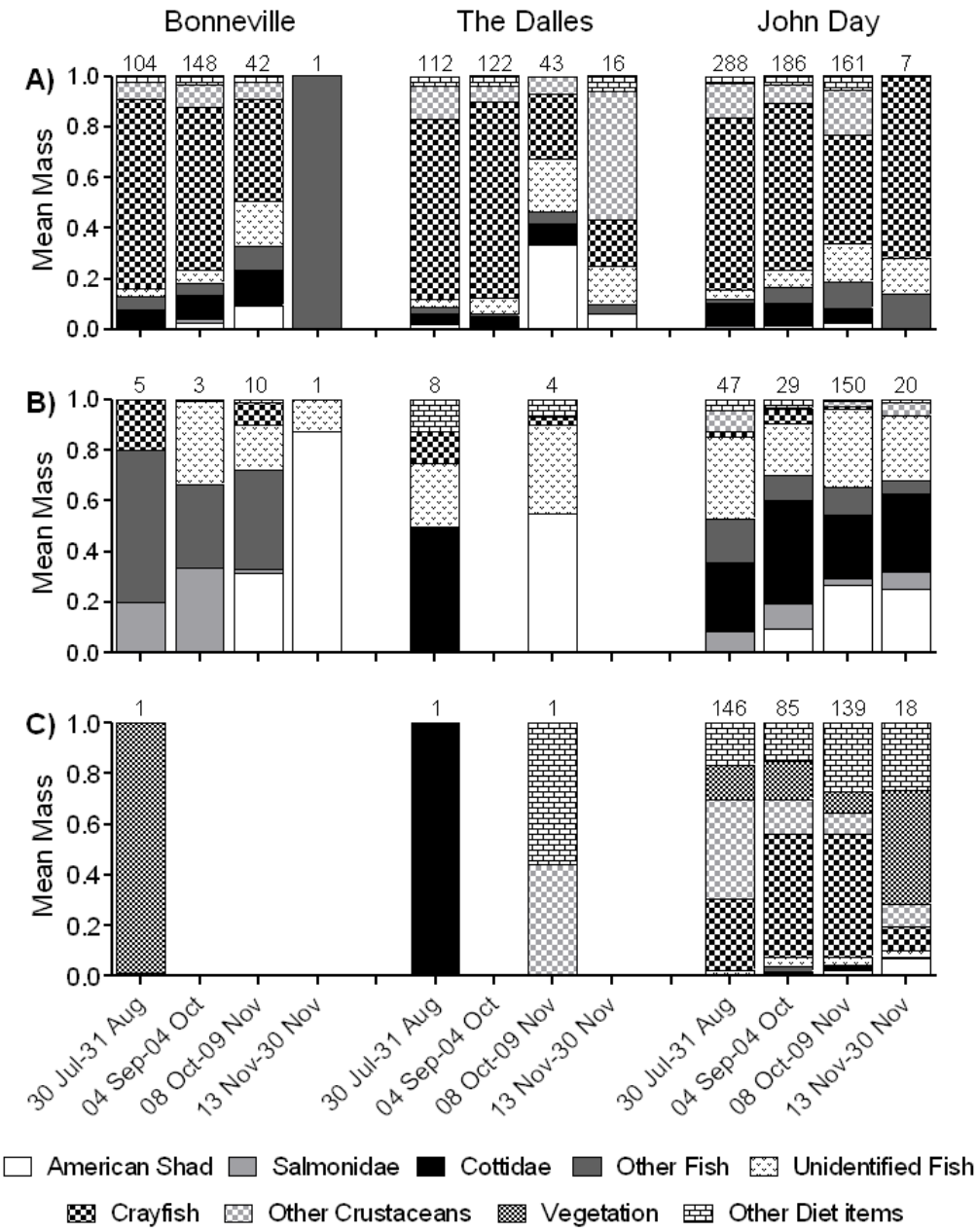

FIGURE 3.—Composition (mean percent mass) of smallmouth bass (A), walleye (B), and channel catfish (C) diets in three middle Columbia River Reservoirs for four sampling periods during 2012. Numbers above bars show sample sizes.

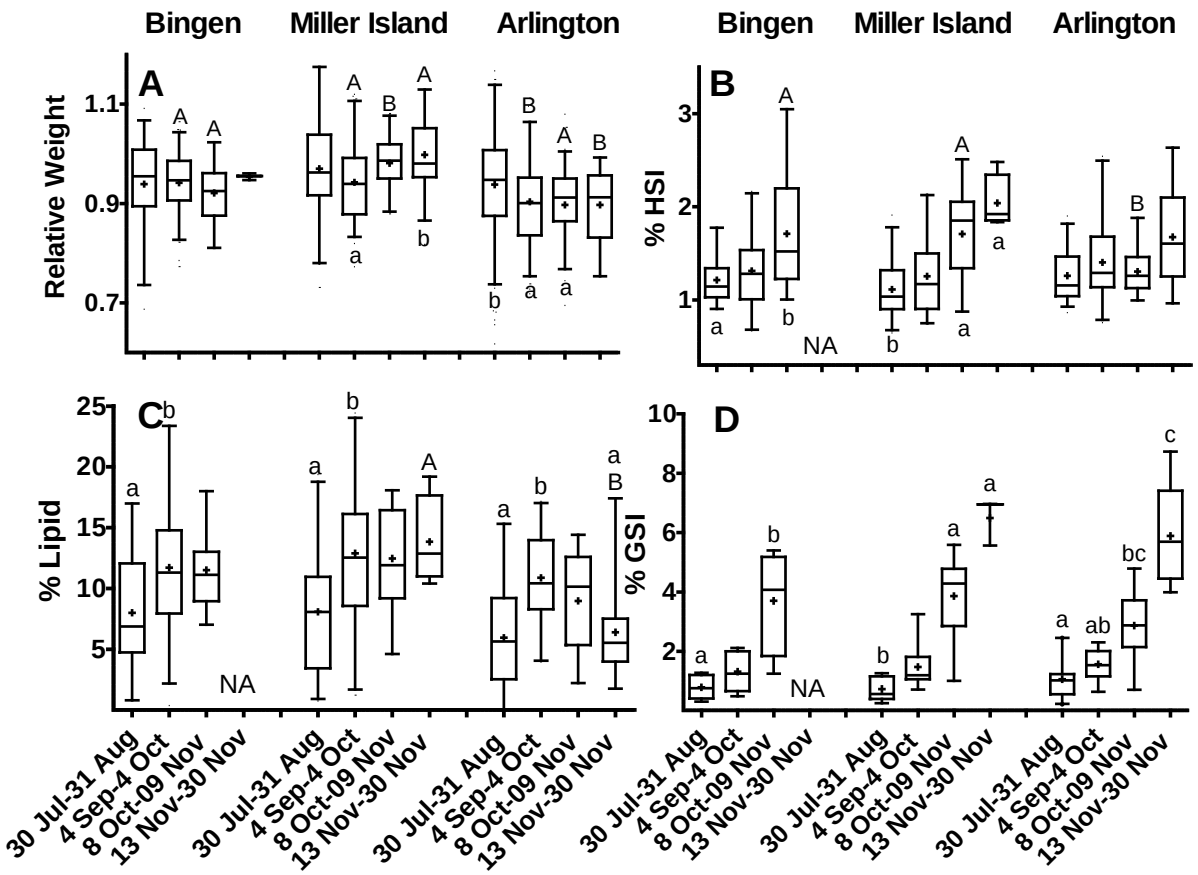

FIGURE 4.—Spatial and temporal variation in relative weight, hepatosomatic index (HSI), visceral lipid content, and gonadosomatic index (GSI) of smallmouth bass from three locations in the middle Columbia River. The upper and lower boundaries of the box are the 25th and 75th quartiles, the horizontal line is the median, + is the mean, and the whiskers are the 5th and 95th percentiles. Different uppercase letters above bars indicate that the mean ranks of metrics during like sample periods between sites were significantly different. Different lowercase letters above (or below) bars indicate that the mean ranks of metrics between sample periods within a site were significantly different. Bars without letters indicate no differences in any pair-wise comparisons. Sample sizes ranged from 3 to 136 fish; NA= data not available.

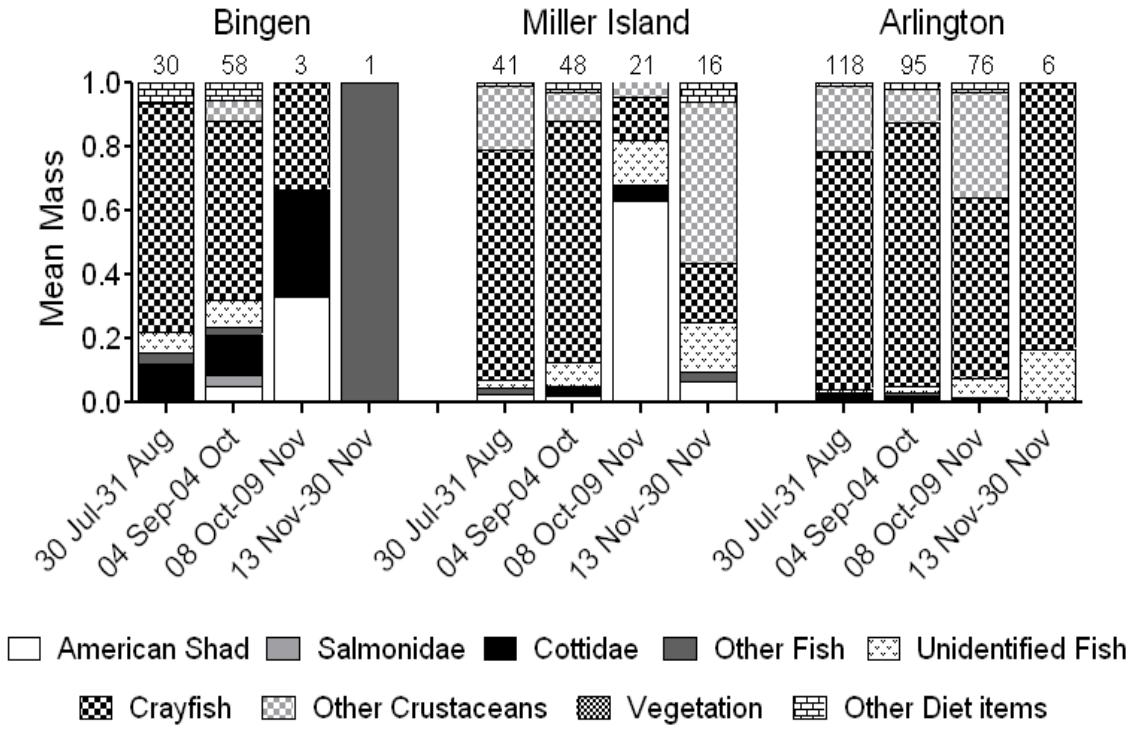

FIGURE 5.—Composition (mean percent mass) of smallmouth bass diets from three locations in the middle Columbia River during 2012. Numbers above bars show sample sizes.

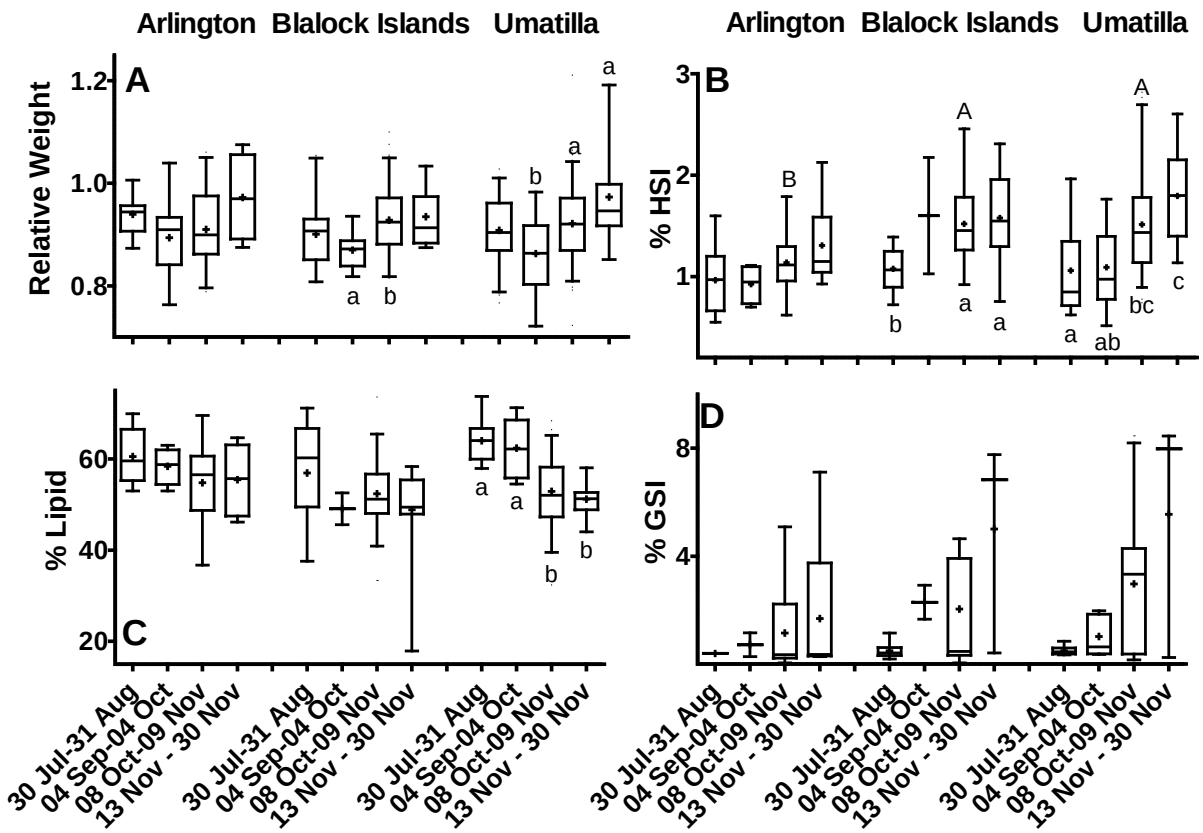

FIGURE 6.—Spatial and temporal variation in relative condition, hepatosomatic index (HSI), visceral lipid content, and gonadosomatic index (GSI) of walleye from three locations in the middle Columbia River. The upper and lower boundaries of the box are the 25th and 75th quartiles, the horizontal line is the median, + is the mean, and the whiskers are the 5th and 95th percentiles. Different uppercase letters above (or below) bars indicate that the mean ranks of metrics between like sample periods at each site were significantly different. Different lowercase letters indicate that the mean ranks of metrics between sample periods within a site were significantly different. Bars without letters indicate no differences in any pair-wise comparisons. Sample sizes ranged from 2 to 88 fish.

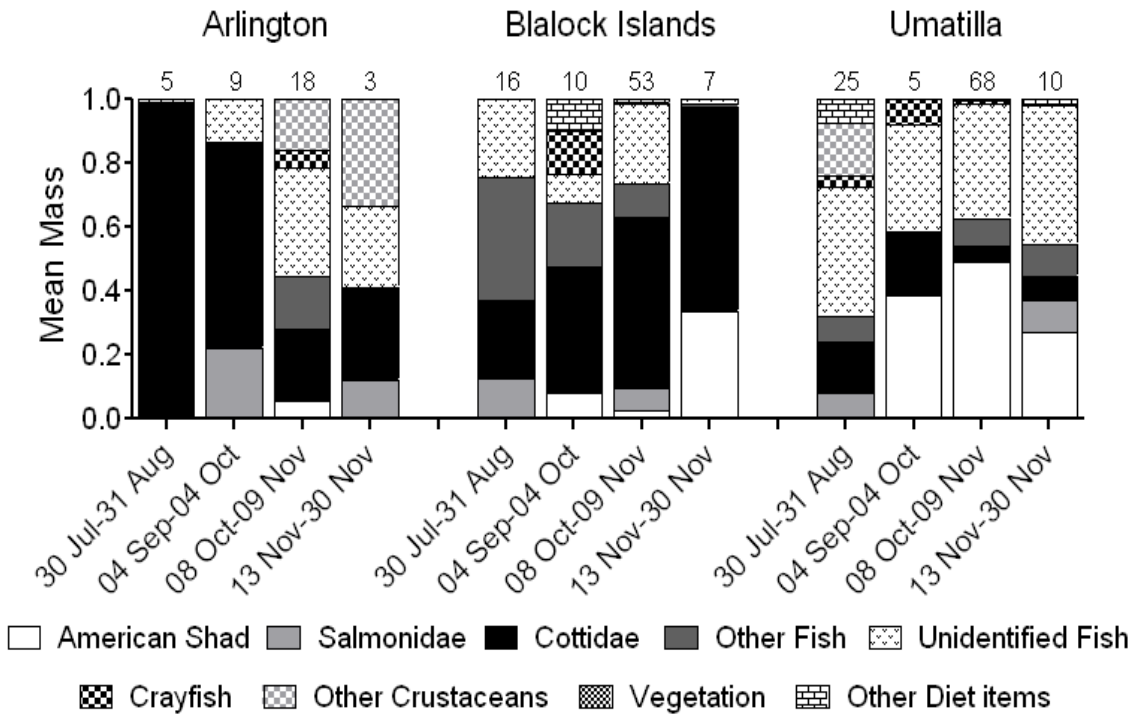

FIGURE 7.—Composition (mean percent mass) of walleye diets for three locations in the middle Columbia River during 2012. Numbers above the bars show the sample size.

Appendix

TABLE A1—Frequency of occurrence (O), mean percent by number (N), and mean percent by mass (M) of prey items consumed by smallmouth bass during four periods in Bonneville Reservoir, Columbia River, 2012. All diet items representing less than one percent of the three indices omitted from the table. Bold category indices reflect all diet items.

	30 Jul–31 Aug			4 Sep–4 Oct			8 Oct–9 Nov			13 Nov–30 Nov		
	N = 104			*N* = 148			*N* = 42			*N* = 1		
Diet item	O	N	M	O	N	M	O	N	M	O	N	M
Fishes	**27.9**	**12.5**	**16.3**	**35.1**	**19.4**	**23.5**	**59.5**	**49.1**	**50.5**	**100**	**100**	**100**
Catostomidae	1.0	0.3	0.0	1.4	1.0	0.8	4.8	3.6	3.6	0.0	0.0	0.0
Centrarchidae	2.9	1.2	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Clupeidae	0.0	0.0	0.0	3.4	2.0	2.6	9.5	8.9	9.5	0.0	0.0	0.0
Cottidae	12.5	4.4	7.7	15.5	7.6	9.7	14.3	10.3	13.8	0.0	0.0	0.0
Cyprinidae	3.8	2.5	3.2	5.4	2.2	3.3	7.1	5.9	5.9	100	100	100
Petromyzontidae	0.0	0.0	0.0	0.0	0.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Salmonidae	0.0	0.0	0.0	2.0	1.2	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	8.7	4.1	3.3	10.1	5.1	5.1	28.6	20.4	17.7	0.0	0.0	0.0
Crustaceans	**92.3**	**82.3**	**81.2**	**87.2**	**73.4**	**72.9**	**54.8**	**46.5**	**47.1**	**0.0**	**0.0**	**0.0**
Amphipoda	18.3	9.9	3.2	9.5	5.2	2.9	9.5	4.6	2.1	0.0	0.0	0.0
Decapoda	86.5	66.8	74.8	77.0	60.4	64.0	45.2	36.3	40.2	0.0	0.0	0.0
Mysida	14.4	5.6	3.2	10.1	6.6	4.4	4.8	3.2	2.4	0.0	0.0	0.0
Other or unidentified	0.0	0.0	0.0	2.0	1.2	1.6	2.4	2.4	2.4	0.0	0.0	0.0
Mollusks	**1.0**	**0.5**	**0.2**	**0.0**	**0.0**	**0.0**	**4.8**	**2.0**	**0.0**	**0.0**	**0.0**	**0.0**
Insects	**8.7**	**3.2**	**1.0**	**12.8**	**6.3**	**2.8**	**2.4**	**2.4**	**2.4**	**0.0**	**0.0**	**0.0**
Other	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Unidentified	**1.9**	**1.5**	**1.3**	**1.4**	**0.8**	**0.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

TABLE A2—Percent frequency of occurrence (O), mean percent by number (N), and mean percent by mass (M) of prey items consumed by smallmouth bass during four periods in The Dalles Reservoir, Columbia River, 2012. All diet items representing less than one percent of the three indices omitted from the table. Bold category indices reflect all diet items.

	30 Jul–31 Aug			4 Sep–4 Oct			8 Oct–9 Nov			13 Nov–30 Nov		
	N = 112			*N* = 122			*N* = 43			*N* = 16		
Diet item	O	N	M	O	N	M	O	N	M	O	N	M
Fishes	**23.2**	**11.8**	**12.0**	**23.0**	**13.3**	**12.5**	**76.7**	**63.0**	**67.3**	**25.0**	**25.0**	**24.9**
Catostomidae	0.9	0.2	0.0	0.0	0.0	0.0	2.3	2.3	2.3	6.3	3.1	3.4
Centrarchidae	1.8	0.7	1.2	0.0	0.0	0.0	2.3	2.3	2.3	0.0	0.0	0.0
Clupeidae	2.7	1.5	2.1	0.8	0.8	0.8	37.2	25.4	33.1	6.3	6.3	6.2
Cottidae	8.0	2.8	4.1	9.0	4.9	4.5	11.6	4.6	8.6	0.0	0.0	0.0
Cyprinidae	5.4	2.3	1.5	0.8	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Salmonidae	0.0	0.0	0.0	0.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	11.6	4.3	3.1	12.3	6.5	6.4	53.5	28.4	21.0	18.8	15.6	15.3
Crustaceans	**90.2**	**76.4**	**84.1**	**87.7**	**80.2**	**83.6**	**46.5**	**34.6**	**32.6**	**68.8**	**68.7**	**68.8**
Amphipoda	17.0	8.9	4.8	4.9	2.2	1.7	4.7	4.7	4.7	50.0	40.6	37.3
Decapoda	79.5	54.1	70.8	82.0	71.5	77.1	39.5	27.6	25.7	18.8	15.6	18.5
Mysida	22.3	11.1	6.6	6.6	3.7	2.2	2.3	0.8	0.0	0.0	0.0	0.0
Other or unidentified	4.5	2.3	1.9	3.3	2.7	2.6	2.3	1.5	2.2	18.8	12.5	13.0
Mollusks	**1.8**	**0.4**	**0.1**	**2.5**	**0.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Insects	**25.9**	**10.8**	**3.0**	**11.5**	**4.0**	**1.8**	**2.3**	**1.2**	**0.1**	**6.3**	**6.3**	**6.3**
Other	**0.9**	**0.1**	**0.0**	**1.6**	**0.9**	**0.9**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Unidentified	**0.9**	**0.5**	**0.8**	**1.6**	**1.2**	**1.2**	**2.3**	**1.2**	**0.0**	**0.0**	**0.0**	**0.0**

TABLE A3—Frequency of occurrence (O), mean percent by number (N), and mean percent by mass (M) of prey items consumed by smallmouth bass during four periods in John Day Reservoir, Columbia River, 2012. All diet items representing less than one percent of the three indices omitted from the table. Bold category indices reflect combined diet items.

	30 Jul–31 Aug			4 Sep–4 Oct			8 Oct–9 Nov			13 Nov–30 Nov		
	N = 289			*N* = 186			*N* = 161			*N* = 7		
Diet item	O	N	M	O	N	M	O	N	M	O	N	M
Fishes	**24.2**	**11.4**	**15.5**	**30.1**	**16.7**	**23.1**	**39.8**	**31.4**	**34.0**	**28.6**	**19.1**	**28.4**
Catostomidae	0.7	0.4	0.3	2.7	1.2	1.3	2.5	1.7	1.8	0.0	0.0	0.0
Centrarchidae	1.4	0.6	0.8	1.6	1.3	1.5	3.1	2.1	1.9	0.0	0.0	0.0
Clupeidae	0.7	0.1	0.3	2.2	0.6	1.7	3.1	2.3	2.3	0.0	0.0	0.0
Cottidae	12.8	5.3	8.7	14.0	6.3	8.8	8.7	5.6	6.1	0.0	0.0	0.0
Cyprinidae	1.0	0.2	0.1	2.7	1.7	2.5	3.7	2.8	2.8	0.0	0.0	0.0
Percidae	0.3	0.3	0.3	1.1	0.5	0.8	5.0	3.0	4.1	14.3	4.8	14.1
Petromyzontidae	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Salmonidae	1.7	0.8	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	7.6	3.6	3.8	11.3	5.1	6.5	19.3	13.9	15.0	14.3	14.3	14.3
Crustaceans	**93.4**	**79.3**	**81.8**	**86.0**	**74.5**	**73.2**	**71.4**	**60.8**	**60.3**	**71.4**	**71.4**	**71.4**
Amphipoda	29.4	15.8	8.2	20.4	11.9	3.6	13.7	8.0	5.8	0.0	0.0	0.0
Decapoda	80.6	55.7	68.0	74.2	55.9	65.9	54.7	40.5	42.9	71.4	71.4	71.4
Mysida	15.6	6.7	4.4	10.2	5.6	3.0	13.0	9.2	8.5	0.0	0.0	0.0
Other or unidentified	2.4	1.1	1.2	1.6	1.1	0.7	3.1	3.1	3.1	0.0	0.0	0.0
Mollusks	**1.0**	**0.2**	**0.0**	**1.1**	**0.1**	**0.0**	**3.1**	**1.1**	**0.3**	**0.0**	**0.0**	**0.0**
Insects	**20.4**	**8.0**	**1.9**	**14.0**	**6.8**	**3.0**	**5.0**	**2.6**	**1.8**	**14.3**	**9.5**	**0.2**
Other	**1.4**	**0.5**	**0.2**	**3.2**	**1.8**	**0.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Unidentified	**1.4**	**0.6**	**0.6**	**1.1**	**0.1**	**0.1**	**5.0**	**4.1**	**3.6**	**0.0**	**0.0**	**0.0**

TABLE A4—Frequency of occurrence (O), mean percent by number (N), and mean percent by mass (M) of prey items consumed by walleye during four periods in Bonneville Reservoir, Columbia River, 2012. All diet items representing less than one percent of the three indices omitted from the table. Bold category indices reflect all diet items.

	30 Jul–31 Aug			4 Sep–4 Oct			8 Oct–9 Nov			13 Nov–30 Nov		
	N = 5			*N* = 3			*N* = 10			*N* = 1		
Diet item	O	N	M	O	N	M	O	N	M	O	N	M
Fishes	**80.0**	**73.3**	**80.0**	**100**	**83.3**	**99.5**	**90.0**	**85.0**	**90.0**	**100**	**100**	**100**
Catostomidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Centrarchidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Clupeidae	0.0	0.0	0.0	0.0	0.0	0.0	60.0	26.7	31.3	100	40.0	87.1
Cottidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyprinidae	60.0	53.3	60.0	33.3	33.3	33.3	50.0	30.0	39.1	0.0	0.0	0.0
Salmonidae	20.0	20.0	20.0	33.3	33.3	33.3	10.0	3.3	1.8	0.0	0.0	0.0
Unidentified	0.0	0.0	0.0	33.3	16.7	32.9	40.0	25.0	17.8	100	60.0	12.9
Crustaceans	**40.0**	**26.7**	**20.0**	**33.3**	**16.7**	**0.5**	**10.0**	**5.0**	**8.8**	**0.0**	**0.0**	**0.0**
Amphipoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Decapoda	40.0	26.7	20.0	33.3	16.7	0.5	10.0	5.0	8.8	0.0	0.0	0.0
Mysida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other or unidentified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mollusks	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Insects	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**10.0**	**5.0**	**0.0**	**0.0**	**0.0**	**0.0**
Other	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**10.0**	**5.0**	**1.2**	**0.0**	**0.0**	**0.0**
Unidentified	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

TABLE A5—Frequency of occurrence (O), mean percent by number (N), and mean percent by mass (M) of prey items consumed by walleye during four periods in The Dalles Reservoir, Columbia River, 2012. All diet items representing less than one percent of the three indices omitted from the table. Bold category indices reflect all diet items.

	30 Jul–31 Aug			4 Sep–4 Oct			8 Oct–9 Nov			13 Nov–30 Nov		
	N = 8			*N* = 0			*N* = 4			*N* = 0		
Diet item	O	N	M	O	N	M	O	N	M	O	N	M
Fishes	**75.0**	**60.4**	**74.8**	**–**	**–**	**–**	**100**	**87.6**	**90.0**	**–**	**–**	**–**
Catostomidae	0.0	0.0	0.0	–	–	–	0.0	0.0	0.0	–	–	–
Centrarchidae	0.0	0.0	0.0	–	–	–	0.0	0.0	0.0	–	–	–
Clupeidae	0.0	0.0	0.0	–	–	–	75.0	38.8	54.8	–	–	–
Cottidae	50.0	35.4	49.6	–	–	–	0.0	0.0	0.0	–	–	–
Cyprinidae	0.0	0.0	0.0	–	–	–	0.0	0.0	0.0	–	–	–
Salmonidae	0.0	0.0	0.0	–	–	–	0.0	0.0	0.0	–	–	–
Unidentified	37.5	25.0	25.2	–	–	–	100	48.8	35.2	–	–	–
Crustaceans	**37.5**	**23.0**	**12.6**	**–**	**–**	**–**	**25.0**	**6.2**	**3.2**	**–**	**–**	**–**
Amphipoda	0.0	0.0	0.0	–	–	–	0.0	0.0	0.0	–	–	–
Decapoda	25.0	16.7	12.6	–	–	–	25.0	6.2	3.2	–	–	–
Mysida	12.5	6.3	0.0	–	–	–	0.0	0.0	0.0	–	–	–
Other or unidentified	0.0	0.0	0.0	–	–	–	0.0	0.0	0.0	–	–	–
Mollusks	**12.5**	**4.2**	**0.1**	**–**	**–**	**–**	**0.0**	**0.0**	**0.0**	**–**	**–**	**–**
Insects	**12.5**	**6.2**	**0.0**	**–**	**–**	**–**	**0.0**	**0.0**	**0.0**	**–**	**–**	**–**
Other	**12.5**	**6.2**	**12.5**	**–**	**–**	**–**	**0.0**	**0.0**	**0.0**	**–**	**–**	**–**
Unidentified	**0.0**	**0.0**	**0.0**	**–**	**–**	**–**	**25.0**	**6.2**	**6.8**	**–**	**–**	**–**

TABLE A6—Frequency of occurrence (O), mean percent by number (N), and mean percent by mass (M) of prey items consumed by walleye during four periods in John Day Reservoir, Columbia River, 2012. All diet items representing less than one percent of the three indices omitted from the table. Bold category indices reflect all diet items.

	30 Jul–31 Aug			4 Sep–4 Oct			8 Oct–9 Nov			13 Nov–30 Nov		
	N = 47			*N* = 29			*N* = 150			*N* = 20		
Diet item	O	N	M	O	N	M	O	N	M	O	N	M
Fishes	**87.2**	**74.0**	**85.4**	**93.1**	**81.1**	**90.5**	**98.0**	**92.3**	**96.2**	**95.0**	**0.0**	**93.9**
Catostomidae	14.9	10.7	11.8	0.0	0.0	0.0	3.3	2.6	3.1	5.0	5.0	5.0
Centrarchidae	0.0	0.0	0.0	3.4	3.4	3.4	2.7	1.4	1.9	0.0	0.0	0.0
Clupeidae	0.0	0.0	0.0	10.3	5.4	9.3	36.7	19.7	26.8	30.0	17.2	25.3
Cottidae	29.8	22.1	27.3	41.1	30.1	40.6	29.3	20.2	25.0	35.0	22.2	30.6
Cyprinidae	6.4	5.3	5.6	3.4	3.5	3.4	6.7	3.7	3.7	0.0	0.0	0.0
Ictaluridae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	1.7	0.3
Percidae	0.0	0.0	0.0	3.4	3.5	3.5	5.3	2.9	2.2	0.0	0.0	0.0
Salmonidae	8.5	7.5	8.5	10.3	8.6	10.1	4.0	2.4	2.5	15.0	8.5	6.8
Unidentified	42.6	28.4	32.2	44.8	26.6	20.2	59.3	39.4	31.0	50.0	35.0	25.9
Crustaceans	**25.5**	**15.9**	**10.5**	**17.2**	**13.5**	**6.0**	**6.0**	**4.6**	**3.1**	**5.0**	**5.0**	**5.0**
Amphipoda	8.5	4.8	2.1	6.9	6.6	0.1	2.0	1.7	0.0	0.0	0.0	0.0
Decapoda	6.4	3.2	1.7	10.3	6.9	5.9	2.0	0.4	1.1	0.0	0.0	0.0
Mysida	2.1	0.4	0.0	0.0	0.0	0.0	4.0	2.2	1.5	5.0	5.0	5.0
Other or unidentified	8.5	7.5	6.7	0.0	0.0	0.0	0.7	0.3	0.5	0.0	0.0	0.0
Mollusks	**4.3**	**2.1**	**0.1**	**0.0**	**0.0**	**0.0**	**2.7**	**1.1**	**0.5**	**10.0**	**2.9**	**1.1**
Insects	**10.6**	**5.5**	**1.9**	**10.3**	**4.3**	**2.4**	**3.3**	**1.4**	**0.1**	**0.0**	**0.0**	**0.0**
Other	**2.1**	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**5.0**	**2.5**	**0.0**
Unidentified	**2.1**	**2.1**	**2.1**	**3.4**	**1.1**	**1.1**	**1.3**	**0.6**	**0.1**	**0.0**	**0.0**	**0.0**

TABLE A7—Frequency of occurrence (O), mean percent by number (N), and mean percent by mass (M) of prey items consumed by channel catfish during four periods in John Day Reservoir, Columbia River, 2012. All diet items representing less than one percent of the three indices omitted from the table. Bold category indices reflect all diet items.

	30 Jul–31 Aug			4 Sep–4 Oct			8 Oct–9 Nov			13 Nov–30 Nov		
	N = 146			*N* = 85			*N* = 139			*N* = 18		
Diet item	O	N	M	O	N	M	O	N	M	O	N	M
Fishes	**13.0**	**1.6**	**2.5**	**17.6**	**6.3**	**7.4**	**17.3**	**6.6**	**7.7**	**27.8**	**10.3**	**10.3**
Catostomidae	0.0	0.0	0.0	1.2	0.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Clupeidae	0.0	0.0	0.0	1.2	0.2	0.1	3.6	1.9	2.3	11.1	8.3	7.1
Cottidae	1.4	0.2	0. 3	4.7	1.3	1.9	2.2	0.9	1.4	0.0	0.0	0.0
Cyprinidae	0.7	0.2	0.0	1.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Percidae	0.0	0.0	0.0	1.2	0.3	0.9	0.0	0.0	0.0	5.6	1.8	0.3
Petromyzontidae	1.4	0.0	0.1	1.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Gasterosteidae	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7	0.7	0.0	0.0	0.0
Salmonidae	0.7	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	8.9	1.2	1.8	9.4	3.8	3.4	11.5	3.1	3.3	11.1	0.2	2.9
Crustaceans	**91.8**	**73.0**	**67.0**	**83.5**	**60.4**	**62.5**	**80.6**	**53.6**	**56.7**	**61.1**	**30.9**	**18.4**
Amphipoda	68.5	47.4	32.3	30.6	14.5	8.1	20.1	6.7	3.0	5.6	0.9	0.0
Decapoda	54.8	16.5	28.0	69.4	33.2	48.6	61.2	35.8	48.4	11.1	5.6	9.2
Mysida	58.2	9.1	6.7	27.1	12.6	5.5	26.6	10.0	4.0	50.0	24.4	9.2
Other or unidentified	0.7	0.0	0.0	1.2	0.1	0.3	1.4	1.1	1.2	0.0	0.0	0.0
Mollusks	**31.5**	**0.7**	**0.3**	**15.3**	**2.0**	**1.0**	**10.1**	**2.5**	**10.7**	**0.0**	**0.0**	**3.2**
Insects	**25.3**	**3.6**	**2.7**	**28.2**	**10.8**	**2.6**	**32.4**	**19.0**	**0.3**	**16.7**	**3.6**	**0.0**
Other	**49.3**	**13.6**	**14.1**	**41.2**	**11.4**	**15.9**	**28.1**	**8.5**	**9.3**	**66.7**	**47.5**	**48.5**
Algae and vegetation	27.4	3.8	6.7	34.1	9.1	14.4	21.6	5.6	7.9	5.6	0.2	0.4

Agricultural grains	24.0	8.7	7.3	3.5	1.5	0.6	2.2	1.3	0.7	61.1	44.5	44.0
Worms and leeches	5.5	1.1	0.1	2.4	0.6	0.7	1.4	0.4	0.2	5.6	2.8	4.0
Unidentified	**34.9**	**7.5**	**13.4**	**31.8**	**9.1**	**10.6**	**38.8**	**9.8**	**15.3**	**38.9**	**7.7**	**19.6**