BONNEVILLE POWER ADMINISTRATION

Environment, Fish & Wildlife Publication

Understanding the influence of predation by introduced fishes on juvenile salmonids in the Columbia River Basin: closing some knowledge gaps

Document ID #

http://www.efw.bpa.gov/IntegratedFWP/reportcenter.asp#

2012

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

Interim Report of Research 2011

Prepared by:

Brien P. Rose[1], Gabriel S. Hansen[1], Michele H. Weaver[2], David E. Ayers[1], Erick S. Van Dyke[2], and Matthew G. Mesa[1]

[1]U.S. Geological Survey

Columbia River Research Laboratory

Cook WA

and

[2]Oregon Department of Fish and Wildlife

Ocean Salmon and Columbia River Program

Clackamas OR

Prepared for:

U.S. Department of Energy

Bonneville Power Administration

Environment, Fish, and Wildlife Department

Project Number 2008-719-00

Contract Number 00054182

Reporting Period: September 2011 to August 2012

12 December 2012

Abstract

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 increased growth and enhanced condition of nonnative piscivores. To test this hypothesis we quantified the late summer and autumn diets of smallmouth bass *Micropterus dolomieu*, walleye *Sander vitreus*, and channel catfish *Ictalurus punctatus* in the three lowermost reservoirs on the Columbia River (Bonneville [BON], The Dalles [TDA], and John Day [JDA]). The diet of smallmouth bass (SMB) was fairly similar among reservoirs, with crustaceans (52–82%) and fish (13–38%) being the dominant prey groups by percent mass. *Cottidae* were usually the dominant fish prey in the diet of SMB at all areas and the contribution of juvenile shad ranged from 0–8.2%. Fish (mostly *Cyprinidae* and *Cottidae*) were always the dominant prey item for walleye (WAL) at all areas and at all times, ranging from 70–100% of their diet by mass. Juvenile American shad composed from 10–27% (by mass) of the diet of walleye, depending on area and month. For channel catfish (CHC), the most common prey items consumed were crustaceans (20%–80% by mass) and unidentified items (30%–80%). Fish represented a relatively small component (< 4%) of their diet. We also evaluated the condition of SMB and WAL by determining relative weights (W_r) and hepatosomatic indices (HSI). Mean W_r for SMB greater than 300 mm ranged from 0.89 to 0.94 depending on area and month and showed a significant increase from August to September for fish in BON only. Overall, mean W_r of WAL was similar at all areas, ranging from 0.89–0.91, and increased significantly from September to mid-October and November for fish in TDA only. Overall, mean HSI of SMB ranged from 1.18 to 1.48, did not differ between fish in different reservoirs, and increased significantly from September to mid-October and November for fish from the lower JDA only. Mean HSI of WAL was significantly higher in October and

November (0.95±0.24) than in August (0.73±0.22). Collectively, our results are the first to describe the diets of SMB, WAL, and CHC over a large spatial area in the MCR during late summer and fall. Only SMB and WAL consumed relevant amounts (up to 27% by mass for walleye) of American shad, however the influence of this diet item on their condition was not discernible because these fish showed only slight increases in condition indices that did not always correspond to a dietary shift that included an increase in shad consumption, and we could not discount the importance of other prey items. Our results should be useful for future discussions regarding predation and shad management in the Columbia River.

Introduction

Nonnative species pose a threat to native fauna and are a factor contributing 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, nonnative piscivores, such as smallmouth bass *Micropterus dolomieu*, walleye *Sander vitreus*, and channel catfish *Ictalurus punctatus*, 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, in some cases, on 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; Figure 1). 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 nonnative piscivores prior to the onset of winter and perhaps improve their overwinter survival. Little is known, however, about the diet of nonnative piscivores 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 nonnative piscivores 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 smallmouth bass (SMB), walleye (WAL), and channel catfish (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 nonnative predators following summer because they both use mainstem shorelines as well as sloughs and backwater habitats (Limburg 2001; Gadomski and Barfoot 1998; Petersen et al. 2003).

Others have hypothesized that nonnative predators consume juvenile American shad in the fall and that consumption of this high energy food source improves their growth and condition, increasing overwinter survival (Sauter et al. 2004). As a first step towards testing this hypothesis, we documented the food habits of SMB, WAL, and CHC in the MCR from August through mid-November. We specifically focused on the proportion of juvenile American shad in

the diets of these predators during this time and used this information to determine if consumption of this specific diet item improved their condition. We evaluated predator condition by calculating relative weights (W_r) and hepatosomatic indices (HSI) of fish in each month. Improved condition in late fall may result in increased overwinter survival and a greater predatory demand for ESA-listed salmonids the following spring and summer. Information from this study will guide management decisions for American shad in the CRB.

Methods

Study area—The MCR comprises three reservoirs formed by large hydroelectric projects (Figure 1), including Bonneville Dam (BON; rkm 234), The Dalles Dam (TDA; rkm 308), and John Day Dam (JDA; rkm 347). 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 1 August to 10 November 2011. 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 (see Ward et al. 1995; Beamesderfer et al. 1996). For netting, we sampled with gillnets (1.8-m-deep, either 24 or 50-m-long, and containing panels of 3.8, 5.1, 6.4, 7.6, and 8.9 cm bar mesh), fyke nets (1.8 × 0.9-m double throated box with 2.6 cm #126 mesh), trammel nets (50.0-m-long × 1.8-m-high, 30.5 cm outer mesh and 3.8 cm inner mesh), and 0.8 m hoop nets (4.3-m-long with 2.6

cm #15 mesh). Depending on habitat availability at each location, we set nets in both nearshore and offshore areas and often constrained netting 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 to have high concentrations of nonnative piscivores, which minimized the time needed to catch an adequate sample. We also collected some fish from the juvenile white sturgeon *Acipenser transmontanus* stock assessments conducted by the Washington and Oregon Departments of Fish and Wildlife. For set lining, which mainly targeted CHC, we used 13–16 baited #4 to 3/0 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. For angling, effort was defined as a continuous period of sampling that lasted until we needed to process fish or retrieve nets. Finally, we collected some fish via boat electrofishing when water temperatures were below 18°C, which occurred only after early to 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.

Upon capture, all fish were anesthetized with either 200 mg/L MS-222 for fish that were sacrificed or one tablet of Alka-Seltzer Gold© in 2.5 L of water for fish that were released. 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 with outliers removed (Motulsky and Brown 2006). 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 70% 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 unidentified items. Individuals within each category were counted, placed on a paper towel for 30 s, and 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 in the absence of identified taxa were simply classified as unidentified fish prey.

For each prey category, we determined its frequency of occurrence and its average contribution to the diet by calculating mean percent number and weight for three sample periods in each reservoir. The first sample period was 1 August through 1 September, the second was from 6 September through 6 October, and the third period was from 10 October through 10 November. The first period was generally a time of nearshore rearing for juvenile American shad and the second and third periods corresponded to times of rearing and outmigration (Gadomski and Barfoot 1998; Petersen et al. 2003; Haskell et al. 2006).

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) and hepatosomatic index (HSI) of these fish relative to location and sample period. 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 over 200 mm by W_s for a fish of the same length. We calculated mean W_r for the three sample periods described above and for each reservoir. Mean W_r of subadult SMB (< 300 mm) and adult SMB (≥ 300 mm; Scott and Crossman 1973) and adult WAL were compared between consecutive sample periods within each reservoir with analysis of variance (ANOVA) followed by the Bonferroni procedure. We also tested if mean W_r for each group was significantly different than W_s (i.e., 1.00) with one sample *t*-tests.

To evaluate temporal and spatial differences in HSI, a subsample of SMB and WAL from specific areas were sacrificed. For our temporal assessment, we collected fish from a restricted area in the middle of JDA reservoir; SMB were collected during all three sample periods and WAL were collected during periods one and three only. For our spatial assessment, we sampled SMB only from each reservoir during the third sample period. Our intent was to determine if HSI changed over time and differed between fish in different reservoirs relative to diet. After collection, fish were placed in a lethal dose (200 mg/L) of buffered MS-222, measured and weighed, placed singly in a labeled plastic bag, and placed on ice for transport to our laboratory where they were frozen for later analysis. At the laboratory, the carcasses were slightly thawed, and we removed the viscera (without gonads) and a whole skinless fillet from the left side of each fish (for analysis of their proximate composition; data not available for this report). The liver was removed from the viscera and weighed for calculation of HSI (i.e., 100 × liver weight/body weight. We compared mean arcsine transformed HSI for each species between sample periods and reservoirs using ANOVA as described above. The level of significance for all tests was 0.05 and we present data as untransformed.

Results

Catch Data

We set 457 gillnets, 222 trammel nets, 88 fyke nets, 98 set lines, and 22 hoop nets. We also angled for 242 efforts and electrofished 227 transects; effort for all gear types was similar between reservoirs (data not shown). We captured 1,589 SMB, 143 WAL, and 260 CHC. Our catch of SMB was distributed widely throughout the MCR, with 44% caught from JDA, 31% from TDA, and 25% from BON. In contrast, catches of WAL and CHC were predominantly at JDA. We caught 61% of our WAL and 97% of our CHC from JDA, 28% and 2% from TDA, and 11% and 1% from BON.

Diets of Nonnative Piscivores in the MCR

Smallmouth bass—Of the 1,589 SMB collected (ranging in size from 150–484 mm), 79% had food in their stomachs representing six major prey types (Appendix Tables 1–3). The diet of SMB was fairly similar among the reservoirs, with crustaceans and fish being the most important prey groups by percent mass (Figure 2). Crustaceans composed from 52–82% and fish from 13–38% 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 (1–27%; Appendix Tables 1–3). *Cottidae* were usually the most important fish prey in the diet at all areas (Appendix Tables 1–3), and the contribution of juvenile shad to the diet ranged from 0–8.2% (Figure 2).

The diet of SMB showed some differences over time, but more so at BON and TDA than JDA (Figure 2). At BON, the percent by mass of all fish items in the diet increased from 14% during period 2 to 38% during period 3 (Figure 2). At TDA, the percent by mass of fish in the

diet increased from about 20% to almost 32% from period 2 to 3. At, JDA the percent by mass of fish in the diet ranged from 17–22%. Increases in fish consumption were accompanied by decreases in the consumption of crustaceans. Juvenile shad were found in the diets of SMB during all sample periods but was highest during sample period 3, ranging from 2–8%. Crustaceans were the most important prey item for SMB of all sizes during sample period 1 and 2 (Figure 3). However, SMB larger than 300 mm showed a marked increase in fish consumption during sample period 3 at BON and TDA (Figure 3). Smallmouth bass of all sizes consumed a smaller percent mass of American shad in JDA than fish from other reservoirs.

Walleye.—Two-thirds of the 143 WAL (208–740 mm) we captured contained prey items. Fish were always the most important prey item for WAL at all areas and at all times, ranging from 70–100% of their diet by mass (Figure 4). At BON, *Cyprinidae* were the most important prey fish, and *Cottidae* were the most important at TDA and JDA (Appendix Tables 4–6). American shad made up 27% (by mass) of the diet of WAL in BON during the third sample period, 11% of their diet in TDA during the second period, and 10% and 16% of their diet in JDA during the second and third sample periods (Figure 4). However, unidentified fish, which made up 16–34% (by mass) of the diet of WAL in BON, 18–93% of their diet in TDA, and 32–40% of their diet at JDA, indicate that the diet of WAL is somewhat ambiguous.

Channel catfish—Eighty-four percent of the 260 CHC (158–652 mm) collected contained food items. The most common prey items consumed by channel catfish in all areas were crustaceans (from 16% to 74% by mass) and all other items but fish (30% to 83% by mass; Figure 5). Fish represented a relatively small component (< 4% by mass) of the CHC diet, except for TDA during period 2 (29% by mass; Appendix Tables 7–9). *Cyprinidae*, American shad, and salmonids were the only identifiable prey fish consumed (Appendix Tables 7–9). In JDA, where

enough fish were collected to allow for temporal comparisons, the percentage by mass of crustaceans decreased over time while the percentage by mass of fish, mollusks, insects, and other items increased (Appendix Table 9).

Temporal changes in predator condition

Relative weight—Mean W_r for subadult SMB was highest in BON (0.98 ± 0.01 for all periods combined) and TDA (0.98 ± 0.01) and lowest at JDA (0.94 ± 0.01; Figure 6). At BON and JDA, W_r was similar during the first two sample periods and decreased significantly in period 3 (Figure 6). At TDA, W_r increased significantly from sample period 1 to 2 and was stable thereafter (Figure 6). Relative weights were equal to or less than W_s for all comparisons.

Mean W_r for adult SMB was highest at BON (0.94 ± 0.09), lowest at JDA (0.89 ± 0.09), and intermediate at TDA (0.92 ± 0.09; Figure 6). At BON, W_r increased significantly from sample period 1 to 2 and was stable thereafter (Figure 6). At TDA and JDA, mean W_r of adult SMB increased 4% to 5% between each of the sample periods, but results did not differ significantly. Relative weights were significantly lower than W_s for all sample periods.

Overall, mean W_r of WAL was similar at all areas, ranging from 0.89–0.91 (Figure 7). At all areas, mean W_r of WAL did not differ between sample periods 1 and 2 but increased significantly (14%) at TDA from sample period 2 to 3 (Figure 7). At JDA, mean W_r of WAL increased 6% from sample period 2 to 3, but this increase was not significant. Relative weights were equal to W_s for sample period two at BON and less than W_s for all other comparisons.

Hepatosomatic index—Overall, mean HSI of SMB was highest at BON (1.48 ± 0.49), lowest at JDA (1.18 ± 0.29), intermediate at TDA (1.27 ± 0.56) and did not differ significantly (Figure 8). Mean HSI of SMB in the lower MCR was highest for sample period three (1.18 ± 0.29), lowest for period two (0.91 ± 0.26), and intermediate for period one (1.01 ± 0.21); the

increase between sample period 2 and 3 was significant (Figure 8). Mean HSI for WAL was significantly higher in sample period 3 (0.95 ± 0.24) than 1 (0.73 ± 0.22; Figure 9).

Discussion

This is the first study to describe the diet of smallmouth bass, walleye, and channel catfish over a large spatial area 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. Although our results indicate that only SMB and WAL consumed relevant amounts (up to 27% by mass for WAL) of American shad, the influence of this specific diet item on their condition was not unequivocally discernible. This was because SMB and WAL showed only slight (but sometimes significant) increases in our indicators of condition, such increases did not always correspond to a dietary shift that included an increase in shad consumption, and we could not discount the importance of other prey items. Regardless, the diet information collected during our study is new and important and should be useful for future discussions regarding predation or American shad management. We should note that our study was conducted during a high water year with a relatively small (in terms of number) run of adult American shad above BON that probably reduced and delayed out-migrating juvenile shad compared to normal flow years. Our second field season, which is currently ongoing and being conducted under a normal flow year, may 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 of fish in the lower and mid-Columbia River during the spring and summer. For example, both Poe et al. (1991) and Zimmerman (1999) found that crayfish and *Cottidae* were important prey for SMB, and fish were the dominate prey item for WAL. The variety of foods in many CHC stomachs, such as

agricultural grains, terrestrial and aquatic vegetation, detritus, insects, crayfish, mollusks, and occasionally salmon eggs, 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*, in the tailrace area of JDA during spring. We also noticed that mysid shrimp were an common prey item for smaller SMB (150–200 mm) and CHC, which contrasts with other fish food habits literature for the MCR (summarized by Stanford et al. 2006). Stanford et al. (2006) concluded that mysid shrimp were not a major component of the Columbia River food web, but we suspect that exotic species such as mysid shrimp, the Siberian prawn *Exopalaemon modestus*, the New Zealand mud snail *Potamopyrgus antipodarum*, and the rusty crayfish *Oronectes rusticus* are increasing in the CRB, which could alter the food web and warrants further study. It is also noteworthy that smaller SMB and CHC consumed considerable amounts of *Corophium* (probably mostly *C. salmonis*). The upstream range expansion of *Corophium* may negatively affect the food base in the CRB 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* is an important food source for juvenile salmonids (Haskell et al. 2006). Clearly, as species expand their range and more exotics become established, the food web and the dynamics and role of predation in the CRB ecosystem will require continued study.

As previously mentioned, a major focus of our work was to determine if nonnative piscivores consume juvenile American shad in the fall and whether the consumption of this high energy food source improves their condition prior to winter. 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) significant increases in condition of predators concomitant with this change in diet. For larger (> 250 mm) SMB, we did see increases in shad consumption of up to 28% (by mass) for fish at BON and TDA in sample periods 2 and 3. However, the only significant increase in W_r we observed was from sample period 1 to 2 at BON—when shad consumption was relatively low. For HSI, which is one of the more sensitive indicators of growth and nutritional status for fish (Heidinger and Crawford 1977; Bulow et al. 1978; Allen and Wootton 1982; Adams and McLean 1985), we observed a significant increase in HSI of SMB from sample period 2 to 3—but for fish captured at JDA only. Since SMB at JDA ate very small quantities of American shad, it is unlikely that the increase in HSI was a result of increased shad consumption. Finally, we saw no significant differences in HSI from SMB in the different reservoirs, indicating that SMB that ate shad (i.e., those from BON and TDA) had a nutritional status similar to that of fish that ate very small quantities of shad (i.e., fish from JDA). For WAL, the story was much the same—although they did show some increases (up to 26% by mass) in shad consumption during periods 2 and 3, such increases were not concomitant with increases in condition. Statements about the relation between shad consumption and predator condition may become more conclusive after our second field season. Our second field season is currently occurring under a more normal water year and may have a greater abundance of juvenile shad. Hence, we may see juvenile American shad become more important in our targeted predator diets. We hope that data collected this year will help clarify questions related to nonnative predator diets, shad consumption, and predator condition.

Acknowledgements

We thank Heather Down, Matt Gardner, Hayden Howell, Will Hurst, Peter McHugh, Matt Powell, Leif Rinearson, Kevin Rybacki, Travis Schneider, Pamela Tyhurst, and Joe Warren for

field assistance and Lisa Weiland for technical assistance. Reviews by Helena Christiansen, Hal Hansel, and Matt Gardner improved the manuscript. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

References

Adams, S. M., and R. B. McLean. 1985. Estimation of the largemouth bass, *Micropterus salmoides* Lace´pe`de, growth using the liver-somatic index physiological variables. Journal of Fish Biology 26:111–126.

Allen, J. R. M., and R. J. Wootton. 1982. Effect of food on the growth of carcass liver and ovary in female *Gasterosteus aculeatus* L. Journal of Fish Biology 21:537–547.

Bailey, R. M., and H. M. Harrison, Jr. 1948. Food habits of the southern channel catfish (*Ictalurus lacustrisp unctatus*) in the Des Moines River, Iowa. Transactions of the American Fisheries Society 75:110–138.

Beamesderfer, R. C. P., D. L. Ward, and A. A. Nigro. 1996. Evaluation of the biological basis for a predator control program on northern pikeminnow (*Ptychocheilus oregonensis*) in the Columbia and Snake rivers. Canadian Journal of Fisheries and Aquatic Sciences 53:2898–2908.

Blackwell, B. G., M. L. Brown, and D. W. Willis. 2000. Relative weight (Wr) status and current use in fisheries assessment and management. Reviews in Fisheries Science 8:1–44.

Bulow, F. J., C. B. Coburn, Jr., and C. S. Cobb. 1978. Comparisons of two bluegill populations by means of the RNA–DNA ratio and liver-somatic index. Transactions of the American Fisheries Society 107:799–803.

Carlander, K. D. 1977. Life history data on Centrarchid fishes of the United States and Canada, Volume 2. The Iowa State University Press, Ames, Iowa.

Czech B., and P. R. Krausman. 1997. Distribution and causation of species endangerment in the United States. Science 277:1116–1117.

Davis, J. 1959. Management of channel catfish in Kansas. Miscellaneous Publication of the Museum of Natural History, University of Kansas 21:1–56.

De La Noue, J., and G. Choubert. 1985. Apparent digestibility of invertebrate biomass by rainbow trout. Aquaculture 50:103–112.

Gadomski, D. M., and C. A. Barfoot. 1998. Diel and distributional abundance patterns of fish embryos and larvae in the lower Columbia and Deschutes rivers. Environmental Biology of Fishes 51:353–368.

Hansel, H. C., S. D. Duke, P. T. Lofy, and G. A. Gray. 1988. Use of diagnostic bones to identify and estimate original lengths of ingested prey fishes. Transactions of the American Fisheries Society 117:55–62.

Haskell, C. A., K. F. Tiffan, and D. W. Rondorf. 2006. Food habits of juvenile American shad and dynamics of zooplankton in the lower Columbia River. Northwest Science 80:47–64.

Heidinger, S. D., and S. D. Crawford. 1977. Effects of temperature and feeding rate on the liver-somatic index of the largemouth bass, *Micropterus salmoides*. Journal of the Fisheries Research Board of Canada 34:633–638.

Hjort, R. C., B. C. Mundy, and P. L. Hulett. 1981. Habitat requirements for resident fishes in the reservoirs of the lower Columbia River. Final Report to the U.S. Army Corps of Engineers, Portland, Oregon.

Limburg, K. E. 2001. Through the gauntlet again: demographics restructuring of American shad by migration. Ecology 82:1584–1596.

Motulsky, H. J., and R. E. Brown. 2006. Detecting outliers when fitting data with nonlinear regression—a new method based on robust nonlinear regression and the false discovery rate. BMC Bioinformatics 7:123-142.

Monk, B., D. Weaver, C. Thompson, and F. Ossiander. 1989. Effects of flow and weir design on the passage behavior of American shad and salmonids in an experimental fish ladder. North American Journal of Fisheries Management 9:60–67.

Murphy, B. R., M. L. Brown, and T. A. Springer. 1990. Evaluation of the relative weight index (W_R), with new application to walleye. North American Journal of Fisheries Management 10:85–97.

Naughton, G. P., D. H. Bennett, and K. B. Newman. 2004. Predation on juvenile salmonids by smallmouth bass in the Lower Granite Reservoir system, Snake River. North American Journal of Fisheries Management 24:534–544.

Petersen, J. H., R. A. Hinrichsen, D. M. Gadomski, D. H. Feil, and D. W. Rondorf. 2003. American shad in the Columbia River. American Fisheries Society Symposium 35:141–155.

Petersen, J. H., D. M. Gadomski, and T. P. Poe. 1994. Differential predation by northern squawfish (*Ptychocheilus oregonensis*) on live and dead juvenile salmonids in the Bonneville Dam tailrace (Columbia River). Canadian Journal of Fisheries and Aquatic Sciences 51:1197–1204.

Poe, T. P., H. C. Hansel, S. Vigg, D. E. Palmer, and L. A. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:405–420.

Rondorf, D. W., G. A. Gray, and R. B. Fairley. 1990. Feeding ecology of subyearling Chinook in riverine and reservoir habitats of the Columbia River. Transactions of the American Fisheries Society 119:16–24.

Sauter, S., R. Schrock, J. Petersen, and A. Maule. 2004 Assessment of smolt condition: biological and environmental interactions; the impact of prey and predators on juvenile salmonids. Final Report, Project No. 198740100, 50 electronic pages, (BPA Report DOE/BP-00004740-1).

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Bulletin of the Fisheries Research Board of Canada 184:1–966.

Seaburg, K. G. 1957. A stomach sampler for live fish. The Progressive Fish Culturist 19:137–139.

Stanford, J. A., C. A. Frissell, and C. C. Coutant. 2006. The status of freshwater habitats. Pages 173–248 *in* R. N. Williams (editor). Return to the River: Restoring Salmon to the Columbia River. Elsevier Academic Press, Amsterdam, Netherlands.

Tyus, M. H., and N. J. Nikirk. 1990. Abundance, growth, and diet of channel catfish, *ittalurus punctatus*, in the Green and Yampa rivers, Colorado and Utah. The Southwestern Naturalist 35:188–198.

Wilcove, D. S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. BioScience 48:607–615.

Zimmerman, M. P. 1999. Food habits of smallmouth bass, walleyes, and northern pikeminnow in the lower Columbia River Basin during outmigration of juvenile anadromous salmonids. Transactions of the American Fisheries Society 128:1,036–1,054.

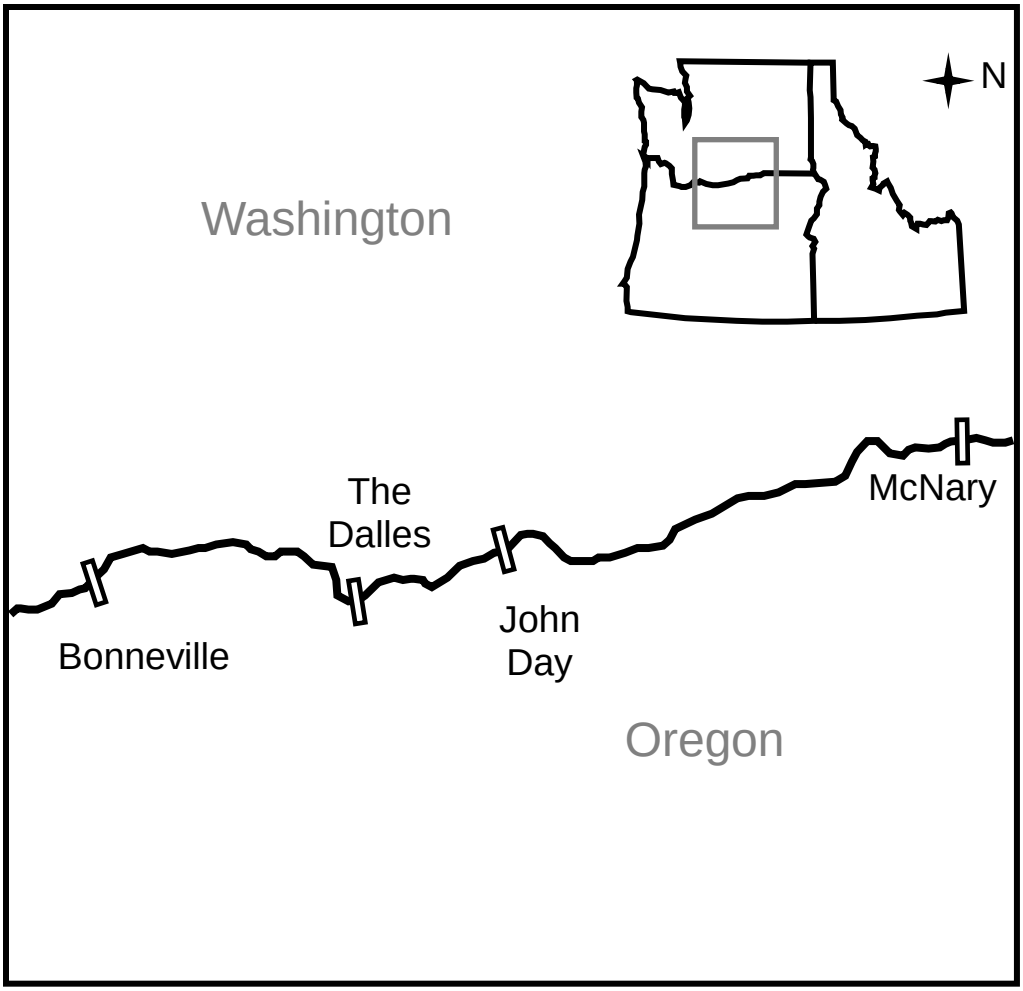

FIGURE 1.—Map of the middle Columbia River (MCR) showing the four lowermost dams and the three reservoirs that were sampled during 2011.

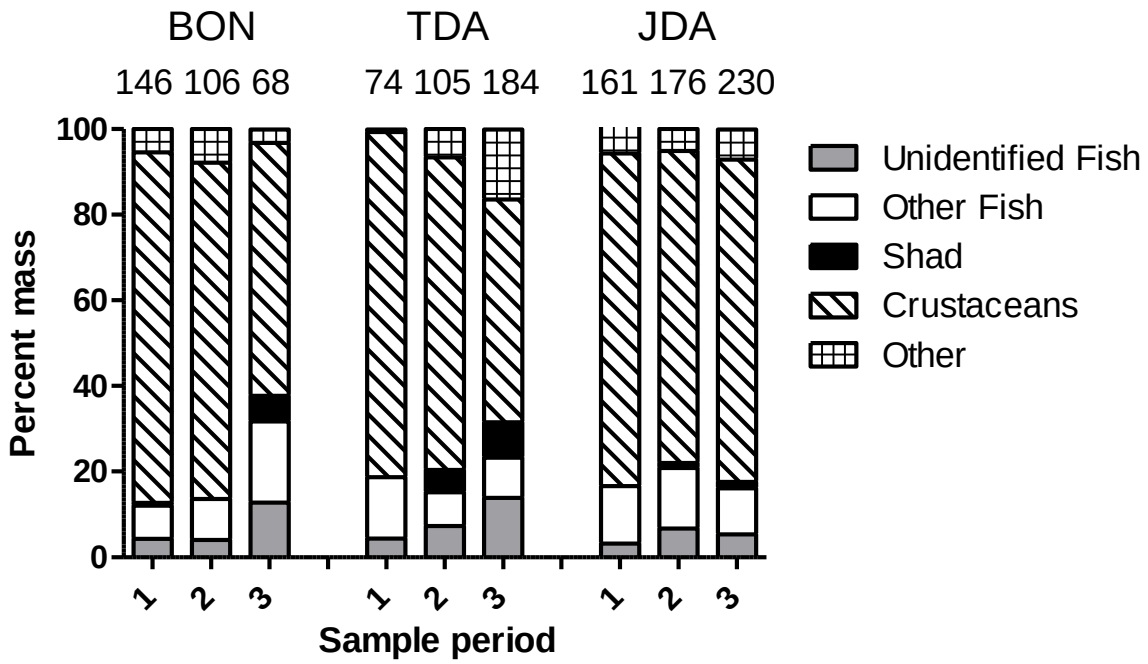

FIGURE 2.—Composition (mean percent mass) of smallmouth bass diets in the three mid-Columbia River Reservoirs (MCR) for three sampling periods during 2011. BON = Bonneville reservoir, TDA = The Dalles reservoir, and JDA = John Day reservoir. Sample period 1 was 1 Aug – 1 Sept, period 2 was 6 Sept – 6 Oct, and period 3 was 10 Oct – 10 Nov.

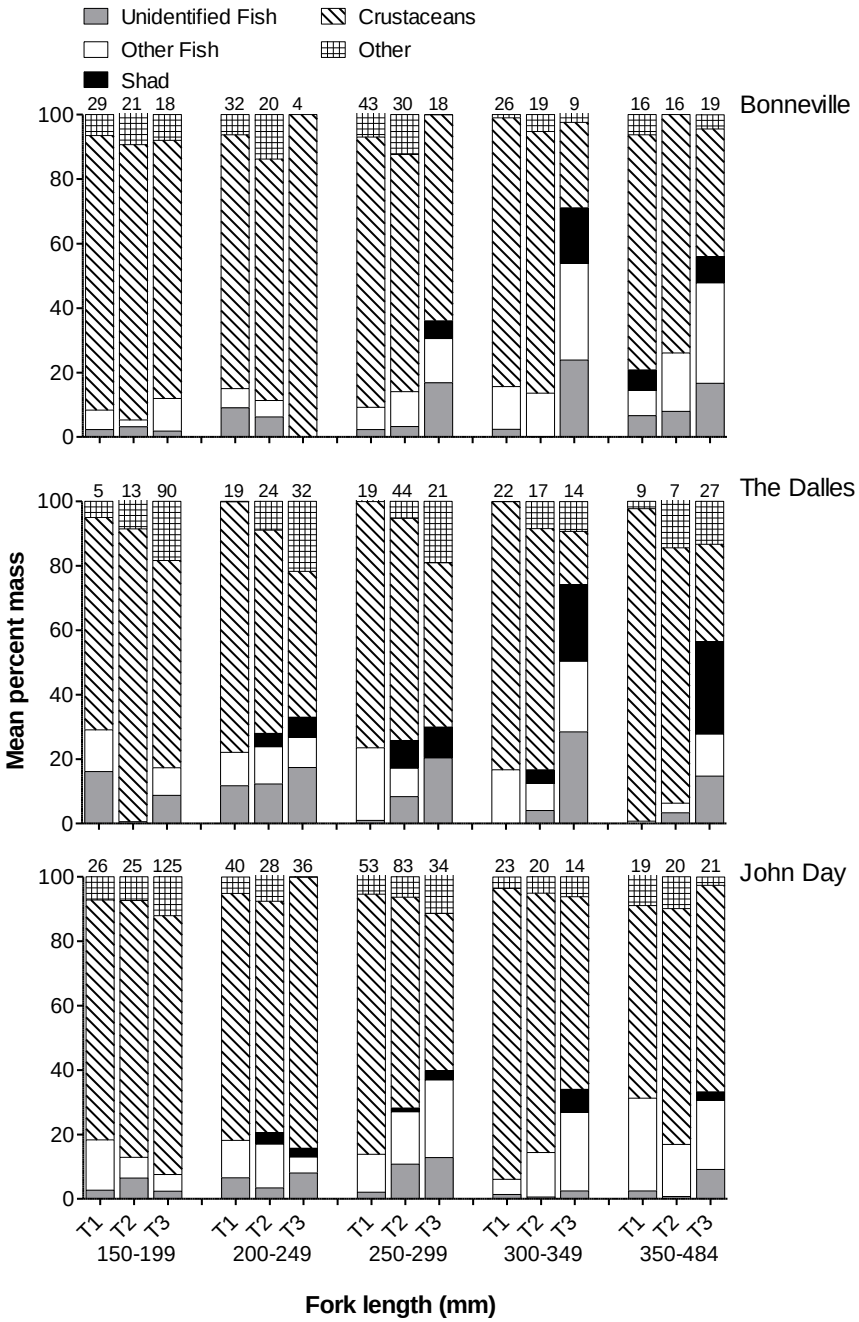

FIGURE 3.—Diet composition (mean percent mass) of various size classes of smallmouth bass from three reservoirs in the middle Columbia River. Sample periods were 1 Aug - 1 Sept (T1), 6 Sept - 6 Oct (T2), and 10 Oct - 10 Nov (T3). Numbers above each bar are the sample size.

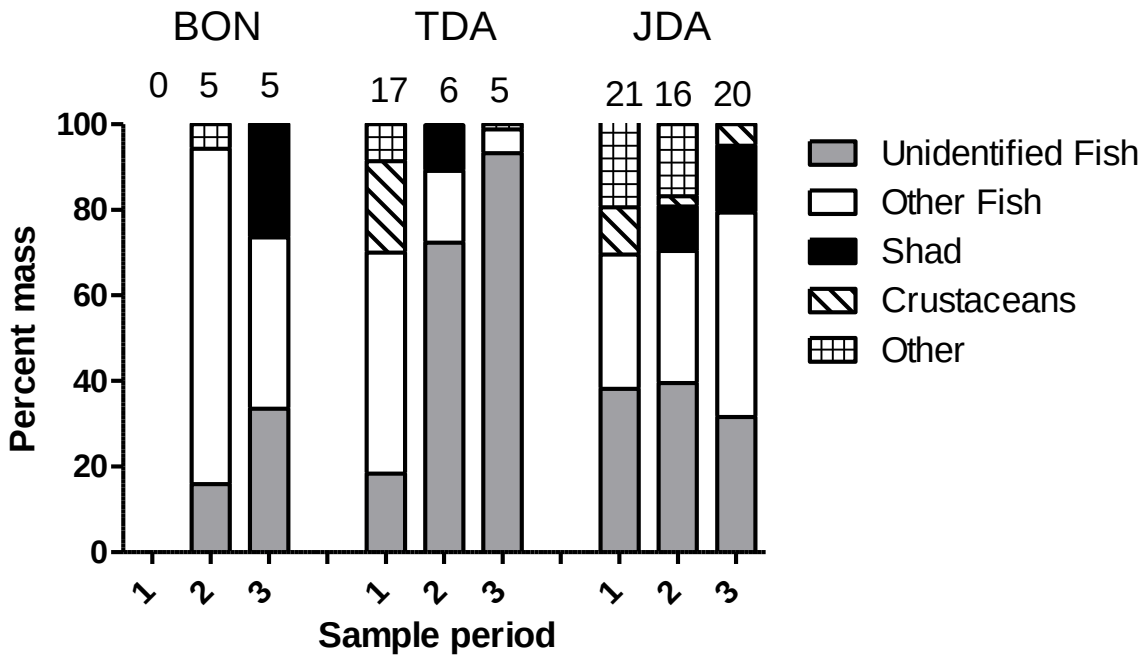

FIGURE 4.—Composition (mean percent mass) of walleye diets in the three mid-Columbia River Reservoirs (MCR) for three sampling periods during 2011. BON = Bonneville reservoir, TDA = The Dalles reservoir, and JDA = John Day reservoir. Sample period 1 was 1 Aug – 1 Sept, period 2 was 6 Sept – 6 Oct, and period 3 was 10 Oct – 10 Nov.

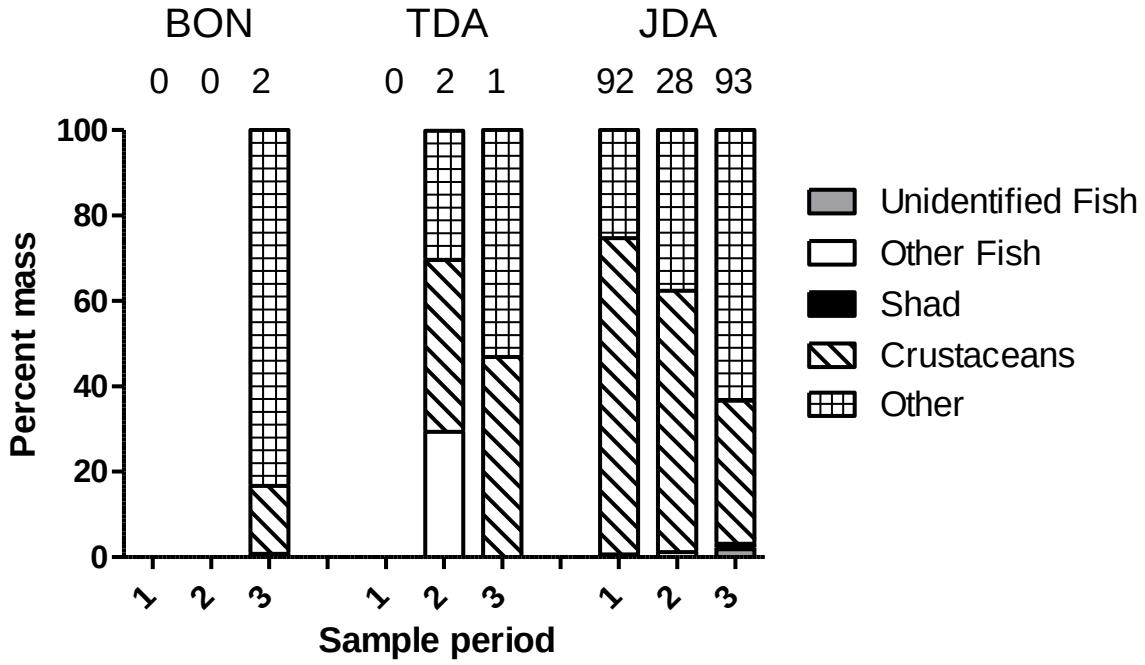

FIGURE 5.—Composition (mean percent mass) of channel catfish diets in the three mid-Columbia River Reservoirs (MCR) for three sampling periods during 2011. BON = Bonneville reservoir, TDA = The Dalles reservoir, and JDA = John Day reservoir. Sample period 1 was 1 Aug – 1 Sept, period 2 was 6 Sept – 6 Oct, and period 3 was 10 Oct – 10 Nov.

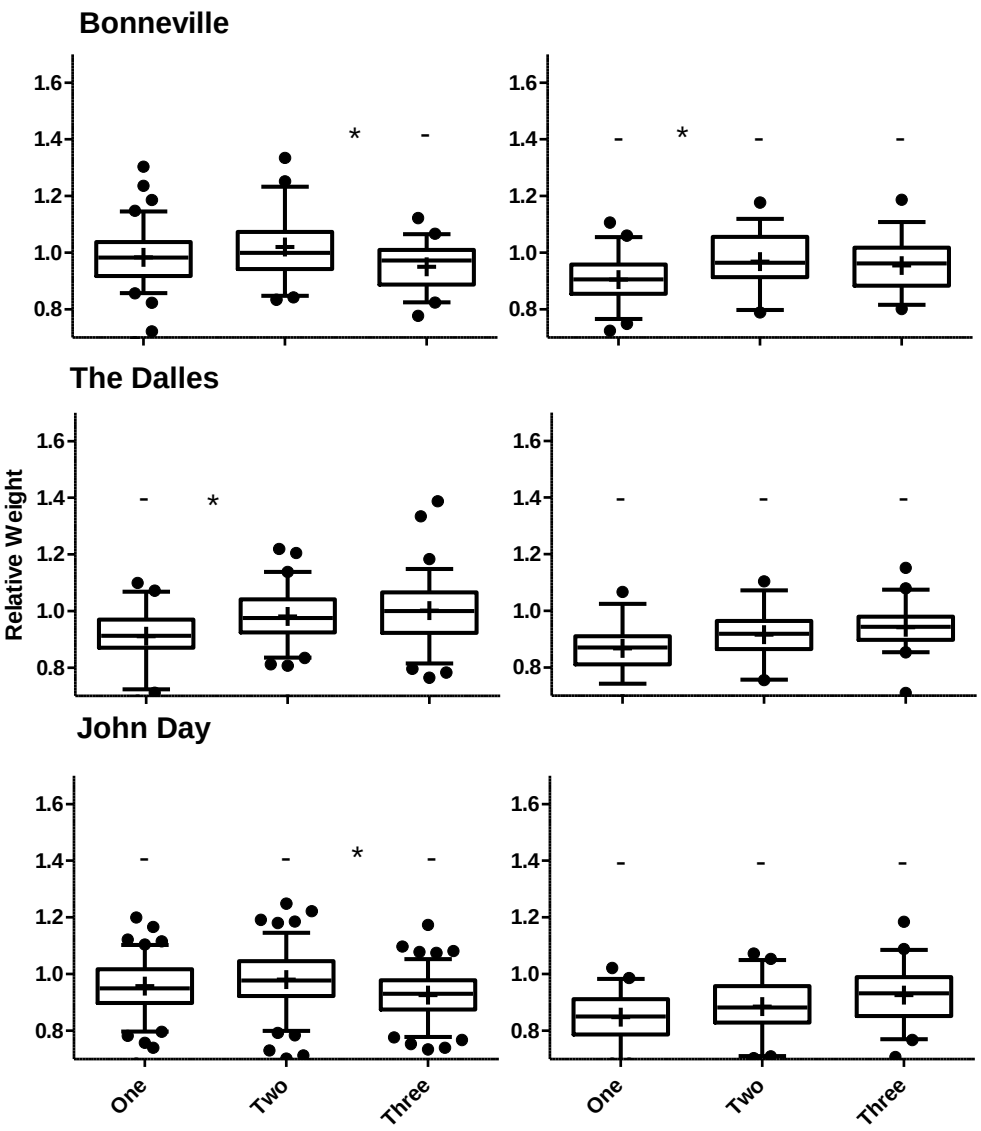

FIGURE 6.—Relative weight of subadult (<300mm; left graphs) and adult (>300mm; right graphs) smallmouth bass for three sample periods. Periods were 1 Aug - 1 Sept, 6 Sept - 6 Oct, and 10 Oct - 10 Nov. The upper and lower boundaries of the box are the 25th and 75th quartiles, the horizontal line is the median, + is the mean, the whiskers are the 5th and 95th confidence intervals, and outliers are dots. Minus symbols indicate that W_r was significantly less than standard weight and asterisks indicate that values from consecutive periods were significantly different ($P < 0.05$). Sample sizes ranged from 29 to 115.

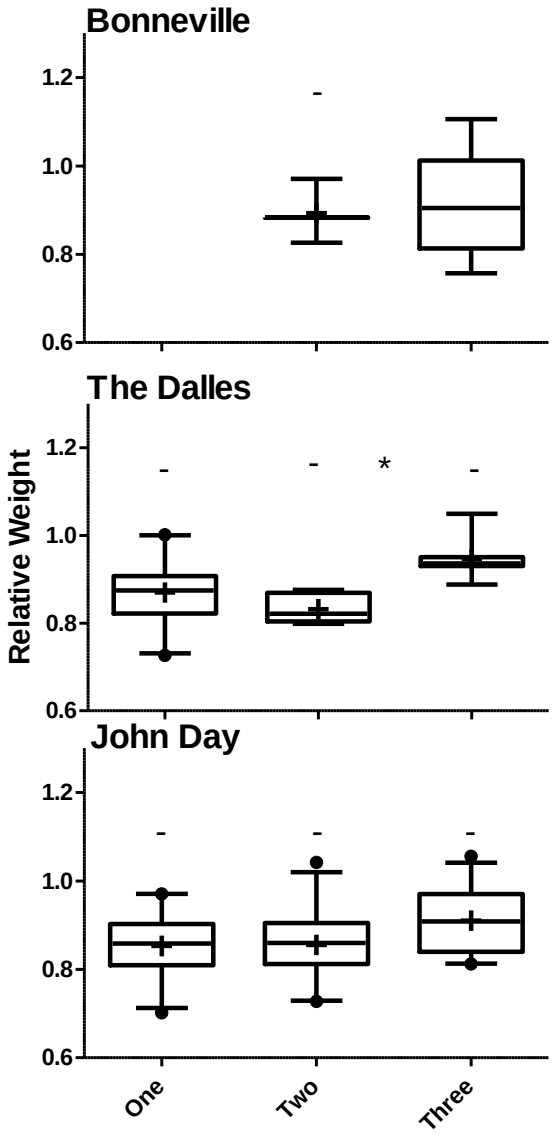

FIGURE 7.—Relative weight of walleyes for three sample periods. Periods were 1 Aug - 1 Sept, 6 Sept - 6 Oct, and 10 Oct - 10 Nov. The upper and lower boundaries of the box are the 25th and 75th quartiles, the horizontal line is the median, + is the mean, the whiskers are the 5th and 95th confidence intervals, and outliers are dots. Minus symbols indicate that W_r was significantly less than standard weight and asterisks indicate that values from consecutive periods were significantly different ($P < 0.05$). Sample sizes ranged from 3 to 28.

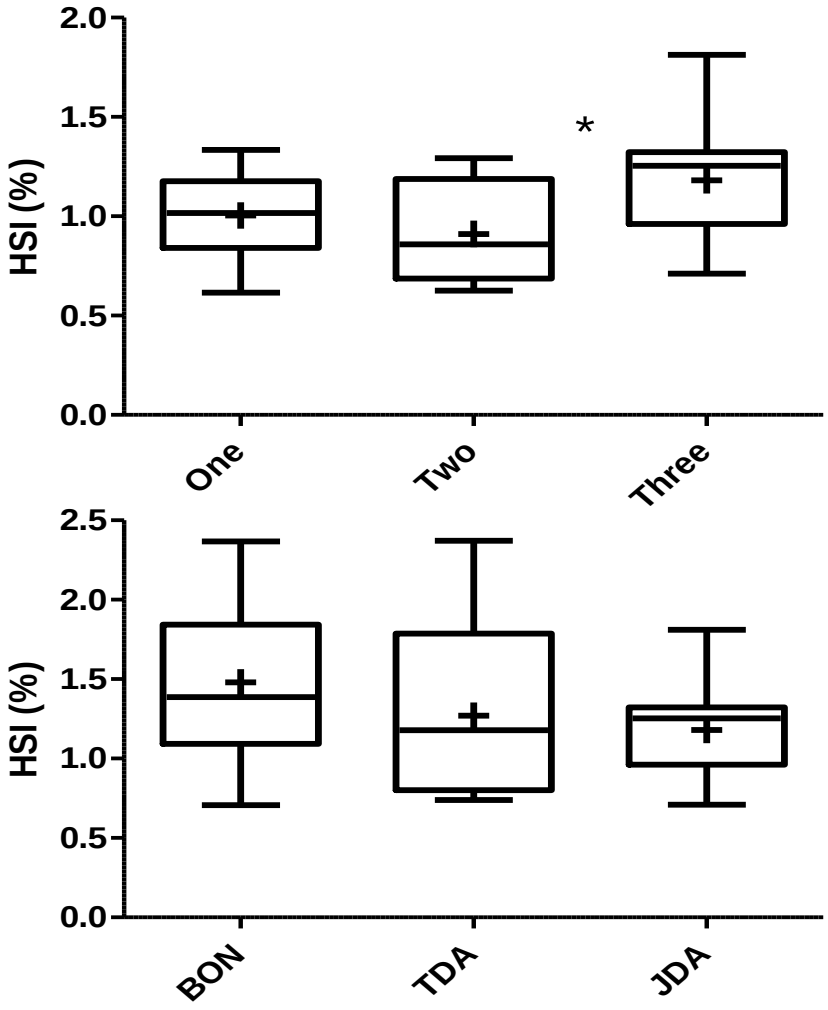

FIGURE 8.—Temporal (top panel) and spatial (lower panel) variation in hepatosomatic index (HSI) of smallmouth bass from the middle Columbia River. The three sample periods were 1 Aug – 1 Sept, 6 Sept - 6 Oct, and 10 Oct - 10 Nov; only fish from the lower middle area of JDA were used. The spatial comparisons used fish collected from each reservoir during sample period three only; BON = Bonneville reservoir, TDA = The Dalles reservoir, and JDA = John Day reservoir. 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 confidence

intervals. An asterisk indicates that values from consecutive samples were significantly different ($P < 0.05$). Sample sizes ranged from 8 to 16.

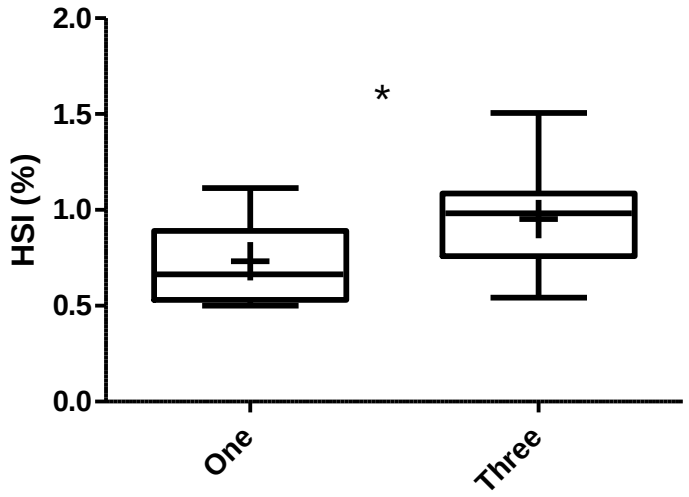

FIGURE 9.—Temporal variation in hepatosomatic index (HSI) of walleyes from the lower middle area of John Day reservoir. The two sample periods were 1 Aug - 1 Sept and 10 Oct – 10 Nov. The upper and lower boundaries of the box are the 25th and 75th quartiles, the horizontal line is the median, + is the mean, and the whiskers are the 5th and 95th confidence intervals. All values fall within the 5th and 95th confidence intervals. An asterisk indicates that values were significantly different ($P < 0.05$). Sample sizes were 16 for period 1 and 18 for period 3.

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 three periods in Bonneville Reservoir, Columbia River, 2011. Counts of samples that contained a diet item were 146, 106, and 68 for periods 1, 2, and 3.

	1 Aug–1 Sep			6 Sep–6 Oct			10 Oct –10 Nov		
Diet item	O	N	M	O	N	M	O	N	M
Fishes	**30.8**	**12.4**	**12.7**	**22.6**	**11.5**	**13.6**	**50.0**	**32.5**	**37.7**
Catostomidae	0.7	0.7	0.7	0.0	0.0	0.0	4.4	1.4	2.2
Centrarchidae	0.0	0.0	0.0	0.9	0.2	0.4	0.0	0.0	0.0
Clupeidae	0.7	0.7	0.7	0.0	0.0	0.0	8.8	4.5	6.0
Cottidae	8.9	3.3	6.1	9.4	3.4	5.7	11.8	5.6	8.4
Cyprinidae	3.4	1.1	0.9	3.8	2.8	3.5	8.8	4.6	8.1
Salmonidae	1.4	0.3	0.2	0.0	0.0	0.0	1.5	0.2	0.3
Unidentified	19.9	6.4	4.3	11.3	5.1	4.0	32.4	16.2	12.8
Crustaceans	**93.8**	**79.7**	**81.8**	**90.6**	**77.2**	**78.5**	**82.4**	**59.6**	**59.1**
Amphipoda	21.2	10.9	5.8	15.1	6.5	2.0	13.2	8.3	5.6
Decapoda	82.2	58.6	69.1	83.0	63.2	71.1	73.5	49.4	51.9
Mysida	15.8	9.6	6.8	11.3	6.6	4.5	2.9	1.5	1.2
Other or unidentified	2.7	0.6	0.0	0.9	0.9	0.9	1.5	0.5	0.5
Mollusks	**3.4**	**0.7**	**0.6**	**2.8**	**0.6**	**0.0**	**4.4**	**2.4**	**0.9**
Insects	**10.3**	**3.1**	**2.4**	**4.7**	**2.3**	**2.5**	**8.8**	**2.7**	**0.8**
Other	**3.4**	**1.3**	**0.6**	**9.4**	**4.1**	**1.1**	**1.5**	**0.4**	**0.0**
Unidentified	**7.5**	**2.8**	**1.9**	**11.3**	**4.4**	**4.3**	**8.8**	**2.4**	**1.4**

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 three periods in The Dalles Reservoir, Columbia River, 2011. Counts of samples that contained a diet item were 74, 105, and 184 for periods 1, 2, and 3.

	1 Aug–1 Sep			6 Sep–6 Oct			10 Oct–10 Nov		
Diet item	O	N	M	O	N	M	O	N	M
Fishes	**32.4**	**14.9**	**18.7**	**36.2**	**17.6**	**20.4**	**39.7**	**28.3**	**31.5**
Catostomidae	2.7	1.1	0.9	0.0	0.0	0.0	1.1	0.6	0.6
Centrarchidae	5.4	2.0	2.9	0.0	0.0	0.0	1.6	1.1	1.1
Clupeidae	0.0	0.0	0.0	7.6	4.0	5.2	9.2	6.4	8.2
Cottidae	13.5	5.5	8.8	13.3	4.4	6.9	4.9	1.8	3.8
Cyprinidae	5.4	2.3	1.8	0.0	0.0	0.0	4.9	3.2	3.4
Salmonidae	1.4	0.2	0.0	1.0	1.0	1.0	0.5	0.5	0.5
Unidentified	12.2	3.8	4.4	19.0	8.2	7.3	24.5	14.6	13.9
Crustaceans	**94.6**	**80.5**	**80.6**	**89.5**	**67.5**	**73.0**	**62.5**	**51.6**	**52.0**
Amphipoda	23.0	10.3	3.2	9.5	3.9	0.7	26.1	16.2	12.9
Decapoda	81.1	60.3	69.0	83.8	56.5	67.9	37.0	26.1	28.7
Mysida	16.2	9.4	8.4	12.4	6.0	3.4	13.0	8.4	9.3
Other or unidentified	2.7	0.5	0.0	1.9	1.1	1.0	1.6	1.1	1.1
Mollusks	**4.1**	**0.6**	**0.0**	**3.8**	**1.3**	**0.2**	**0.5**	**0.3**	**0.0**
Insects	**12.2**	**3.3**	**0.3**	**14.3**	**6.5**	**1.6**	**6.5**	**3.7**	**2.5**
Other	**1.4**	**0.3**	**0.0**	**6.7**	**2.7**	**1.0**	**4.3**	**2.0**	**1.0**
Unidentified	**2.7**	**0.4**	**0.3**	**12.4**	**4.4**	**3.8**	**20.1**	**14.0**	**12.9**

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 three periods in John Day Reservoir, Columbia River, 2011. Counts of samples that contained a diet item were 161, 176, and 230 for periods 1, 2, and 3.

Diet item	1 Aug–1 Sep			6 Sep–6 Oct			10 Oct–10 Nov		
	O	N	M	O	N	M	O	N	% M
Fishes	**26.7**	**11.5**	**16.6**	**35.8**	**18.2**	**22.0**	**22.2**	**14.4**	**17.6**
Catostomidae	2.5	1.5	2.3	0.6	0.0	0.4	1.7	0.8	1.3
Centrarchidae	0.6	0.6	0.6	1.1	0.3	0.3	1.7	0.9	1.2
Clupeidae	0.0	0.0	0.0	1.1	0.9	1.1	2.2	1.3	1.5
Cottidae	12.4	3.5	7.7	15.3	8.2	12.0	6.5	3.1	5.0
Cyprinidae	2.5	0.9	1.0	2.3	0.6	0.6	2.6	1.3	2.1
Gasterosteidae	0.6	0.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Ictaluridae	0.0	0.0	0.0	0.6	0.2	0.5	0.0	0.0	0.0
Percidae	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.5	0.8
Salmonidae	2.5	0.4	1.2	1.1	0.2	0.3	0.9	0.2	0.3
Unidentified	9.3	3.8	3.2	19.3	7.8	6.7	11.7	6.4	5.4
Crustaceans	**88.8**	**74.9**	**77.7**	**85.8**	**73.3**	**72.9**	**83.5**	**76.0**	**75.3**
Amphipoda	19.3	10.8	3.8	25.0	10.1	4.2	40.9	31.1	26.5
Decapoda	78.9	57.8	69.3	68.2	47.4	56.9	42.6	30.6	34.7
Mysida	11.8	5.7	4.5	22.7	13.9	10.0	19.1	12.8	12.3
Other or unidentified	2.5	0.6	0.1	3.4	1.9	1.7	5.2	1.5	1.7
Mollusks	**2.5**	**0.9**	**0.6**	**1.7**	**0.6**	**0.5**	**0.9**	**0.6**	**0.0**
Insects	**20.5**	**7.7**	**3.1**	**13.6**	**3.3**	**0.3**	**5.7**	**3.0**	**1.5**
Other	**5.6**	**2.1**	**0.9**	**4.0**	**1.2**	**0.1**	**1.3**	**0.7**	**0.2**
Unidentified	**10.6**	**2.9**	**1.2**	**9.1**	**3.3**	**4.2**	**11.7**	**5.4**	**5.3**

TABLE A4—Frequency of occurrence (O), mean percent by number (N), and mean percent by mass (M) of prey items consumed by walleye during three periods in Bonneville Reservoir, Columbia River, 2011. Counts of samples that contained a diet item were 0, 5, and 5 for periods 1, 2, and 3.

	1 Aug–1 Sep			6 Sep–6 Oct			10 Oct–10 Nov		
Diet item	O	N	M	O	N	M	O	N	M
Fishes	–	–	–	**100.0**	**77.0**	**94.3**	**100.0**	**98.2**	**100.0**
Clupeidae	–	–	–	0.0	0.0	0.0	40.0	17.7	26.5
Cyprinidae	–	–	–	80.0	34.7	78.4	60.0	33.3	40.0
Unidentified	–	–	–	80.0	42.3	15.9	80.0	47.1	33.5
Crustaceans	–	–	–	**20.0**	**4.0**	**0.0**	**20.0**	**1.8**	**0.0**
Mollusks	–	–	–	**20.0**	**10.0**	**0.1**	0.0	0.0	0.0
Insects	–	–	–	0.0	0.0	0.0	0.0	0.0	0.0
Other	–	–	–	**40.0**	**9.0**	**5.6**	0.0	0.0	0.0
Unidentified	–	–	–	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 three periods in The Dalles Reservoir, Columbia River, 2011. Counts of samples that contained a diet item were 17, 6, and 5 for periods 1, 2, and 3.

	1 Aug–1 Sep			6 Sep–6 Oct			10 Oct–10 Nov		
Diet item	O	N	M	O	N	M	O	N	M
Fishes	**76.5**	**44.7**	**70.0**	**100.0**	**86.1**	**99.8**	**100.0**	**83.3**	**98.8**
Centrarchidae	0.0	0.0	0.0	16.7	16.7	16.7	0.0	0.0	0.0
Clupeidae	0.0	0.0	0.0	16.7	8.3	10.7	0.0	0.0	0.0
Cottidae	52.9	19.8	46.1	0.0	0.0	0.0	0.0	0.0	0.0
Cyprinidae	0.0	0.0	0.0	0.0	0.0	0.0	20.0	5.0	5.4
Salmonidae	5.9	2.9	5.5	0.0	0.0	0.0	20.0	5.0	0.0
Unidentified	41.2	21.9	18.4	83.3	61.1	72.4	100.0	73.3	93.3
Crustaceans	**58.8**	**47.2**	**21.4**	**33.3**	**13.9**	**0.2**	0.0	0.0	0.0
Amphipoda	41.2	25.8	8.1	16.7	4.2	0.1	0.0	0.0	0.0
Decapoda	35.3	19.6	13.2	33.3	9.7	0.1	0.0	0.0	0.0
Mysida	5.9	1.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Other or unidentified	5.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mollusks	**5.9**	**2.9**	**2.4**	0.0	0.0	0.0	**20.0**	**5.0**	**1.0**
Insects	**5.9**	**2.9**	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0
Other	**11.8**	**2.2**	**6.2**	0.0	0.0	0.0	**20.0**	**5.0**	**0.0**
Unidentified	0.0	0.0	0.0	0.0	0.0	0.0	**20.0**	**6.7**	**0.2**

TABLE A6—Frequency of occurrence (O), mean percent by number (N), and mean percent by mass (M) of prey items consumed by walleye during three periods in John Day Reservoir, Columbia River, 2011. Counts of samples that contained a diet item were 21, 16, and 20 for periods 1, 2, and 3.

	1 Aug–1 Sep			6 Sep–6 Oct			10 Oct–10 Nov		
Diet item	O	N	M	O	N	M	O	N	M
Fishes	**81.0**	**52.9**	**69.5**	**81.3**	**61.8**	**80.8**	**95.0**	**87.9**	**95.0**
Clupeidae	0.0	0.0	0.0	12.5	6.5	10.4	20.0	14.2	15.6
Cottidae	33.3	12.1	24.6	31.3	19.3	31.0	40.0	22.5	37.8
Cyprinidae	0.0	0.0	0.0	0.0	0.0	0.0	10.0	6.3	5.0
Salmonidae	9.5	7.1	6.7	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	52.4	33.6	38.2	56.3	36.0	39.5	60.0	40.0	31.6
Crustaceans	**38.1**	**24.2**	**11.1**	**31.3**	**13.3**	**2.4**	**15.0**	**8.8**	**5.0**
Amphipoda	28.6	19.9	8.8	18.8	6.0	0.0	5.0	2.5	0.0
Decapoda	14.3	4.1	1.9	12.5	6.3	2.3	0.0	0.0	0.0
Mysida	4.8	0.2	0.4	6.3	1.0	0.0	10.0	6.3	5.0
Mollusks	**9.5**	**2.4**	**1.5**	0.0	0.0	0.0	0.0	0.0	0.0
Insects	**23.8**	**4.7**	**3.5**	**12.5**	**8.9**	**0.1**	**5.0**	**1.7**	**0.0**
Other	**4.8**	**3.2**	**4.6**	**12.5**	**5.8**	**4.2**	0.0	0.0	0.0
Unidentified	**19.0**	**12.7**	**9.9**	**18.8**	**10.3**	**12.5**	**5.0**	**1.7**	**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 three periods in Bonneville Reservoir, Columbia River, 2011. Counts of samples that contained a diet item were 0, 0, and 2 for periods 1, 2, and 3.

Diet item	1 Aug–1 Sep			6 Sep–6 Oct			10 Oct–10 Nov		
	O	N	M	O	N	M	O	N	M
Fishes	–	–	–	–	–	–	**50.0**	**10.0**	**0.8**
Unidentified	–	–	–	–	–	–	50.0	10.0	0.8
Crustaceans	–	–	–	–	–	–	**100.0**	**35.0**	**15.9**
Decapoda	–	–	–	–	–	–	50.0	10.0	3.4
Mysida	–	–	–	–	–	–	50.0	25.0	12.4
Mollusks	–	–	–	–	–	–	**50.0**	**10.0**	**1.1**
Bivalvia	–	–	–	–	–	–	50.0	10.0	1.1
Insects	–	–	–	–	–	–	**0.0**	**0.0**	**0.0**
Other	–	–	–	–	–	–	**50.0**	**10.0**	**6.6**
Worms and leeches	–	–	–	–	–	–	50.0	10.0	6.6
Unidentified	–	–	–	–	–	–	**100.0**	**35.0**	**75.6**

TABLE A8—Frequency of occurrence (O), mean percent by number (N), and mean percent by mass (M) of prey items consumed by channel catfish during three periods in The Dalles Reservoir, Columbia River, 2011. Counts of samples that contained a diet item were 0, 2, and 1 for periods 1, 2, and 3.

Diet item	1 Aug–1 Sep			6 Sep–6 Oct			10 Oct–10 Nov		
	O	N	M	O	N	M	O	N	M
Fishes	–	–	–	**50.0**	**3.6**	**29.4**	**0.0**	**0.0**	**0.0**
Cyprinidae	–	–	–	50.0	3.6	29.4	0.0	0.0	0.0
Crustaceans	–	–	–	**100.0**	**55.0**	**40.2**	**100.0**	**25.0**	**46.9**
Amphipods	–	–	–	50.0	7.1	0.0	0.0	0.0	0.0
Decapoda	–	–	–	100.0	47.9	40.2	100.0	25.0	46.9
Mollusks	–	–	–	**100.0**	**17.1**	**3.7**	**100.0**	**25.0**	**36.4**
Bivalvia	–	–	–	50.0	3.6	3.5	100.0	25.0	36.4
Gastropoda	–	–	–	100.0	13.6	0.2	0.0	0.0	0.0
Insects	–	–	–	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Other	–	–	–	**50.0**	**10.7**	**0.1**	**100.0**	**25.0**	**1.2**
Aquatic vegetation	–	–	–	50.0	3.6	0.0	0.0	0.0	0.0
Worms and leeches	–	–	–	50.0	7.1	0.1	100.0	25.0	1.2
Unidentified	–	–	–	**100.0**	**13.6**	**26.5**	**100.0**	**25.0**	**15.6**

TABLE A9—Frequency of occurrence (O), mean percent by number (N), and mean percent by mass (M) of prey items consumed by channel catfish during three periods in John Day Reservoir, Columbia River, 2011. Counts of samples that contained a diet item were 92, 28, and 93 for periods 1, 2, and 3.

Diet item	1 Aug–1 Sep			6 Sep–6 Oct			10 Oct–10 Nov		
	O	N	M	O	N	M	O	N	M
Fishes	**4.3**	**0.3**	**0.6**	**10.7**	**1.9**	**1.2**	**15.1**	**4.5**	**3.1**
Clupeidae	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.7	1.1
Cyprinidae	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.2	0.1
Salmonidae	1.1	0.0	0.0	3.6	0.9	1.2	0.0	0.0	0.0
Unidentified	3.3	0.3	0.6	7.1	1.0	0.0	12.9	3.7	1.9
Crustaceans	**96.7**	**85.1**	**74.1**	**100.0**	**65.5**	**61.2**	**75.3**	**43.4**	**33.5**
Amphipoda	88.0	69.3	49.2	67.9	25.7	6.1	30.1	11.8	4.3
Decapoda	41.3	5.4	15.5	71.4	18.1	47.1	40.9	14.0	22.4
Mysida	76.1	10.2	9.4	64.3	21.7	8.0	36.6	16.0	5.5
Other	1.1	0.2	0.0	0.0	0.0	0.0	4.3	1.7	1.4
Mollusks	**62.0**	**0.9**	**0.4**	**17.9**	**1.3**	**0.8**	**17.2**	**2.1**	**1.2**
Insects	**39.1**	**1.4**	**0.4**	**42.9**	**7.3**	**1.0**	**34.4**	**10.6**	**3.8**
Other	**60.9**	**6.4**	**7.1**	**82.1**	**14.3**	**7.8**	**54.8**	**17.5**	**7.4**
Agricultural grains	27.2	5.2	4.1	3.6	0.0	0.0	11.8	4.7	0.8
Aquatic vegetation	29.3	0.3	1.8	50.0	6.9	5.3	24.7	3.1	3.9
Arachnidae	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.3	0.0
Terrestrial vegetation	20.7	0.6	1.1	10.7	1.7	0.0	8.6	2.1	0.2
Worms and leeches	14.1	0.4	0.0	25.0	5.4	2.5	20.4	6.6	2.5
Zooplankton	1.1	0.0	0.0	3.6	0.3	0.0	3.2	0.9	0.0
Unidentified	**90.2**	**5.9**	**17.4**	**78.6**	**9.7**	**28.0**	**80.6**	**21.8**	**51.0**