Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia

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Abstract: Food habits of redbreast sunfish (*Lepomis auritus*), smallmouth bass (*Micropterus dolomieu*), and white sucker (*Catostomus commersoni*) populations in the Shenandoah River Basin, Virginia, were assessed during 2002 to identify dietary pathways and patterns potentially affecting mercury uptake. Aquatic insects (71% to 83%) were the principal food item of redbreast sunfish, while smallmouth bass mainly consumed aquatic insects (32% to 48%), crayfish (19% to 31%), and fish (22% to 29%). Principal food items of white sucker included aquatic insects (20% to 26%) and detritus (66% to 70%). Dipterans, ephemeropterans, and trichopterans were the main taxa of aquatic insects consumed by all species. As redbreast sunfish and smallmouth bass increased in size, redbreast sunfish diversified their diet, while smallmouth bass shifted from a diet mainly composed of aquatic insects to one primarily composed of crayfish and fish. Seasonal dietary shifts included decreased consumption of aquatic insects from spring to fall by smallmouth bass and white sucker and increased consumption of terrestrial insects during summer and fall and reduced consumption during winter by redbreast sunfish and smallmouth bass. Smallmouth bass in the South Fork of the Shenandoah River were more dependent on aquatic insects at larger sizes and for longer periods than smallmouth bass in the South River and North River, which consumed greater percentages of crayfish. Differences in forage fish composition were also noted among rivers for smallmouth bass. Results of this study have uncovered important dietary pathways and patterns potentially affecting mercury uptake by the selected fish species and provided the foundation necessary for future investigations concerning mercury dynamics in the aquatic food web of the Shenandoah River Basin and ultimately remediation efforts.

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Key words: food habits, mercury, redbreast sunfish, smallmouth bass, white sucker

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 59:325–335

Mercury accumulation in fish results from complex interactions among several environmental components, including mercury supply and methylation, trophic interactions, and fish bioenergetics (Rodgers 1996). Although some direct aqueous uptake is possible, fish mainly accumulate mercury through dietary pathways (Rodgers and Beamish 1981, Rodgers 1994, Hall et al. 1997). For instance, Harris and Snodgrass (1993) demonstrated that dietary pathways accounted for 90% or more of mercury uptake by yellow perch (*Perca flavescens*) and walleye (*Stizostedion vitreum*) using a bioenergetics-based approach. Hall et al. (1997) found that dietary pathways accounted for 85% or more of mercury uptake by finescale dace (*Phoxinus neogaeus*) in an oligotrophic lake in northwestern Ontario.

Although descriptions of redbreast sunfish (*Lepomis auritus*), smallmouth bass (*Micropterus dolomieu*), and white sucker (*Catostomus commersoni*) food habits exist (Surber 1941, Coomer et al. 1977, Elder and Carlson 1977, Lalancette 1977, Buynak et al. 1982, Austen and Orth 1985, Barwick and Hudson 1985, Johnson and Dropkin 1995), few reports exist for riverine populations inhabiting systems contaminated with mercury. Information on food habits is critical for the identification of important prey organisms and assessment of trophic interactions and fish bioenergetics. In addition, knowledge of prey selection enables mapping the flow of persistent chemical pollutants, such as mercury, through the aquatic food web.

The objective of this study was to assess the food habits of redbreast sunfish, smallmouth bass, and white sucker populations inhabiting the Shenandoah River Basin of north central Virginia to uncover dietary pathways and patterns potentially affecting mercury uptake by the selected fish species.

Methods

This study was conducted on the South River, South Fork of the Shenandoah River, and North River of the Shenandoah River Basin. Since the late 1970s, the Virginia Department of Health has restricted the consumption of fish caught in the South River and South Fork of the Shenandoah River due to mercury contamination from historical industrial practices in Waynesboro. Presently, there is no health advisory for consumption of fish caught in the North River. Average mercury levels in the muscle tissue of adult sized redbreast sunfish, smallmouth bass, and white sucker range from 0.57 to 1.30, 0.50 to 3.24, and 0.35 to 1.70 µg/g wet weight in the South River and 0.46 to 0.70, 0.66 to 1.77, and 0.60 to 0.83 µg/g wet weight in the South Fork of the Shenandoah River, respectively. Average mercury levels in the muscle tissue of adult sized redbreast sunfish, smallmouth bass, and white sucker are 0.11, 0.47, and 0.27 µg/g wet weight in the North River (VDEQ 2003).

Redbreast sunfish, smallmouth bass, and white sucker were collected seasonally (spring, summer, fall, and winter) in 2002 by use of boat and barge mounted pulsed direct current electrofishers. Fish were collected along the South River from Waynesboro to Grottoes, South Fork of the Shenandoah River from Port Republic to Front Royal, and North River from Bridgewater to Grottoes. Captured fish were immobilized using 40 mg/L clove oil solution and then euthanized. Total length (TL) and weight were recorded to the nearest millimeter (mm) and gram (g), respectively. Stomachs of redbreast sunfish and smallmouth bass and anterior fifth of intestinal tract of white sucker (Coomer et al. 1977) were removed by dissection and preserved in 10% formalin. Sagittal otoliths were removed for subsequent age analysis and sex was determined by visual examination of gonads.

Food items observed in the stomachs of redbreast sunfish and smallmouth bass and anterior fifth of intestinal tract of white sucker were identified to the lowest taxonomic level practical using a dissection scope. Following identification, food items were grouped taxonomically, blotted dry, weighed to the nearest 0.001 g wet weight, and preserved in 70% ethanol for archival purposes. Because of likely ontogenetic variations in diet, redbreast sunfish (<100, 100 to 150, and >150 mm TL) and smallmouth bass (<100, 100 to 199, 200 to 299, and >299 mm TL) were separated into size classes for diet analysis. White sucker were not separated into size classes due to difficulty collecting juveniles. Percent composition by weight was calculated for each food type. Non-biological items, such as fishing lures, were excluded from the diet analysis.

Results

Food habits of 1,209 fish were assessed, including 385 redbreast sunfish, 460 smallmouth bass, and 364 white sucker. Redbreast sunfish ranged from 35 to 226 mm TL with an average of 144 mm TL. Diet breadth of redbreast sunfish widened as fish size increased, with 26 food types identified overall. Of the 385 stomachs examined, 74% contained food items. However, this percentage declined sharply from 99% in spring to 8% in winter (Fig. 1). Aquatic insects, mainly dipterans (7.1% to 16.6%), ephemeropterans (18.6% to 26.2%), and trichopterans (8.0% to 20.7%), were the principal food item of redbreast sunfish, composing 70.6% to 83.2% of the diet (Table 1). Notable percentages of crayfish, gastropods, terrestrial coleopterans (mainly green June beetle *Cotinis nitida*), detritus, and vegetation were also consumed. Larger redbreast sunfish >150 mm TL consumed sizeable percentages of green June beetle in summer, particularly in the South River. Food habits were similar among rivers due to the common dependence on aquatic insects.

Smallmouth bass ranged from 46 to 476 mm TL with an average of 222 mm TL. Smallmouth bass had the widest diet breadth of the fish species studied, which widened as fish size increased including 30 food types overall. Of the 460 stomachs examined, 75% contained food items. Similar to the seasonal trend noted for redbreast sunfish, the percentage of smallmouth bass stomachs containing food items declined sharply from 93% in spring to 26% in winter. Aquatic insects (32.0% to

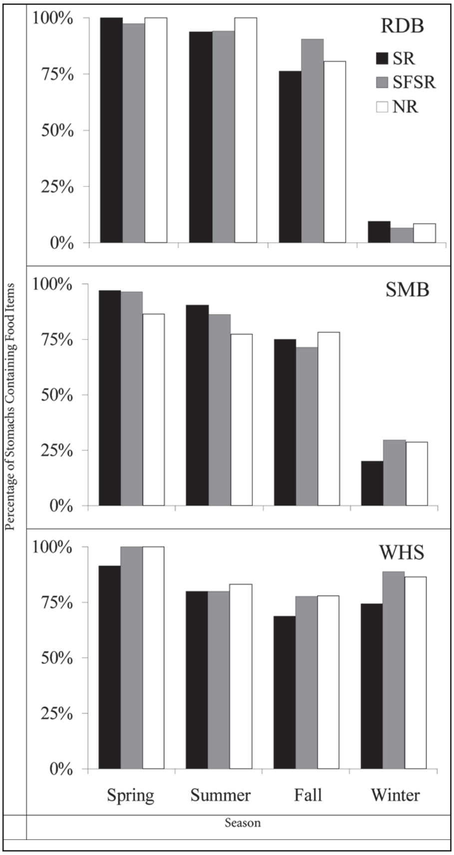

Figure 1. Percentages of redbreast sunfish (RDB) and smallmouth bass (SMB) stomachs and anterior fifth of white sucker (WHS) intestinal tracts containing food items in the South River (SR), South Fork of the Shenandoah River (SFSR), and North River (NR), Virginia, during 2002.

47.9%), crayfish (18.6% to 29.8%), and fish (22.1% to 29.1%) were the main food items of smallmouth bass, composing 86.6% to 95.6% of the diet (Table 2). Notable percentages of terrestrial insects, detritus, and vegetation were also consumed. As smallmouth bass increased in size they shifted from a diet mainly composed of aquatic insects to one primarily composed of crayfish and fish, which were generally not observed in the diet until sizes >100 mm TL were attained. Sizeable percentages of terrestrial insects, including coleopterans and hymenopterans, were consumed during summer in the North River and South River. The percentage of aquatic insects consumed decreased from spring to winter, while the percentage of crayfish consumed increased, particularly for smallmouth bass >200 mm TL. Smallmouth bass in the South Fork of the Shenandoah River were more dependent on aquatic insects at larger sizes and for longer periods than smallmouth bass in the North River or South River, while smallmouth bass in the North River and South River consumed greater percentages of crayfish. Differences in forage fish composition were also noted among rivers. Smallmouth bass in the South River primarily consumed centrarchids, cyprinids, and darters (*Etheostoma* spp.) while smallmouth bass in the South Fork of the Shenandoah River and North River mainly consumed centrarchids, cyprinids, and margined madtom (*Noturus insignis*).

White sucker ranged from 105 to 531 mm TL with an average of 395 mm TL. White sucker had the narrowest diet breadth of the fish species studied with only 18 food types identified overall. Of the 364 intestinal tracts examined, 84% contained food items. Unlike the seasonal pattern observed for redbreast sunfish and small-

Table 1. Percent composition by weight of food items consumed by redbreast sunfish in the South River, South Fork of the Shenandoah River, and North River, Virginia, during 2002.

Food item	South River	S. F. Shen. River	North River
Annelida	2.4	0.5	
Oligochaeta	2.4	0.5	
Aquatic insect	70.6	84.1	83.2
Coleoptera	4.9	0.9	4.1
Diptera	9.8	7.1	16.6
Ephemeroptera	22.6	26.2	18.6
Hemiptera	0.3	1.1	1.3
Lepidoptera	1.4	1.5	3.0
Megaloptera	0.4	0.6	
Odonata	3.1	5.1	3.9
Plecoptera	0.2	2.9	0.1
Trichoptera	8.0	20.7	18.2
Unidentified insect	19.9	18.0	17.5
Crustacea	3.6	0.9	2.3
Crayfish	2.3	0.9	2.1
Isopoda	1.0		0.2
Other Crustacea[a]	0.3		
Fish		0.9	0.3
Lepomis spp.		0.2	
Unidentified fish		0.7	0.3
Mollusca	3.9	1.7	3.9
Bivalvia	0.6		
Gastropoda	3.3	1.7	3.9
Terrestrial insect	8.0	1.9	6.1
Coleoptera	5.6	1.3	4.9
Hymenoptera	2.2	0.4	0.2
Other insect[b]	0.2	0.2	0.7
Unidentified insect			0.3
Detritus	8.6	6.1	2.6
Vegetation	1.9	3.9	1.6
Miscellaneous[c]	1.0		

a. Amphipoda and Cladocera
b. Araneae, Chilopoda, and Diplopoda
c. Banded water snake

Table 2. Percent composition by weight of food items consumed by smallmouth bass in the South River, South Fork of the Shenandoah River, and North River, Virginia, during 2002.

Food item	South River	S. F. Shen. River	North River
Annelida	2.3	0.7	0.3
Oligochaeta	2.3	0.7	0.3
Aquatic insect	32.0	47.9	38.1
Coleoptera	0.2		1.2
Diptera	5.3	2.1	1.7
Ephemeroptera	15.4	24.4	25.0
Hemiptera	1.0	2.5	1.3
Lepidoptera	0.3	0.1	
Megaloptera		3.9	0.7
Odonata	0.7	3.1	3.1
Plecoptera	0.9	1.9	
Trichoptera	3.0	5.4	2.6
Unidentified insect	5.2	4.5	2.5
Crustacea	30.2	18.6	31.5
Crayfish	29.8	18.6	31.3
Other Crustacea[a]	0.4		0.2
Fish	24.8	29.1	22.1
Redbreast sunfish		2.6	
Lepomis spp.	0.7	5.8	2.5
Smallmouth bass		1.2	0.7
Unidentified Centrarchidae	1.0	2.9	2.6
Comely shiner			1.8
Satinfin shiner		1.1	
Unidentified Cyprinidae	3.1	1.9	0.6
Margined madtom		5.1	1.5
Unidentified Ictaluridae	0.6		0.6
Fantail darter	1.8		
Etheostoma spp.	2.2		
Other fish[b]	0.8	1.0	0.8
Unidentified fish	14.6	7.5	11.0
Mollusca		0.5	0.2
Gastropoda		0.5	0.2
Terrestrial insect	2.6	0.1	4.1
Araneae	0.6		
Coleoptera	1.2	0.1	2.8
Hymenoptera	0.1		1.3
Unidentified insect	0.7		
Detritus	4.6	2.0	3.1
Vegetation	3.5	1.1	0.6

a. Cladocera and Isopoda
b. Pumpkinseed, rock bass, cutlips minnow, and *Nocomis* spp.

Table 3. Percent composition by weight of food items consumed by white sucker in the South River, South Fork of the Shenandoah River, and North River, Virginia, during 2002.

Food item	South River	S. F. Shen. River	North River
Aquatic insect	20.4	25.5	23.2
Diptera	8.8	4.2	10.0
Ephemeroptera	6.0	6.4	4.7
Odonata	0.5	1.4	1.3
Trichoptera	4.8	12.9	6.4
Other insect[a]	0.3	0.5	0.8
Unidentified insect		0.1	
Crustacea	3.1	0.7	2.0
Cladocera	2.6	0.1	1.3
Other Crustacea[b]	0.5	0.6	0.7
Mollusca	4.4	3.3	4.2
Bivalvia	3.8	2.4	3.5
Gastropoda	0.6	0.9	0.7
Other aquatic invertebrate[c]	0.3	0.2	0.1
Detritus	70.3	66.2	70.4
Vegetation	1.5	4.1	0.1

a. Coleoptera, Lepidoptera, and Megaloptera
b. Amphipoda and Ostracoda
c. Oligochaeta

mouth bass, the percentage of intestinal tracts containing food items was consistent among seasons. Detritus (66.2% to 70.4%) and aquatic insects (20.4% to 25.5%), mainly dipterans, ephemeropterans, and trichopterans, were the principal food items of white sucker, composing 90.7% to 93.6% of the diet (Table 3). Notable percentages of bivalves (mainly Asian clam *Corbicula fluminea*), cladocerans, and filamentous green algae were also consumed. Although food habits were similar among rivers, the percentage of aquatic insects consumed by white sucker in the South River and South Fork of the Shenandoah River decreased from spring to winter but remained consistent among seasons in the North River, while the percentage of bivalves consumed increased in fall and winter in the North River.

Discussion

Information on food habits is critical to the understanding of mercury uptake by fish. Smallmouth bass exhibited the most piscivory of the species assessed during this study, suggesting they occupy a higher trophic level than redbreast sunfish and white sucker and perhaps have greater mercury exposure through dietary pathways. Mueller and Serdar (2002) found that concentrations of mercury were highest in predaceous smallmouth bass, followed by omnivorous yellow perch and brown bullhead (*Ameiurus nebulosus*), zooplanktivorous kokanee (*Oncorhynchus nerka*), and benthivorous pumpkinseed (*Lepomis gibbosus*) in Lake Whatcom, Washington. This type of pattern has also been observed during the mercury-monitoring program in the Shenandoah River Basin (VDEQ 2003).

Observing large percentages of detritus in the diet of white sucker is characteristic (Elder and Carlson 1977, Lalancette 1977). For instance, Elder and Carlson (1977) found that detritus accounted for 70% of the diet by volume of white sucker in the South Platte River, Colorado. White sucker ingest detritus intentionally (i.e., the percentage of detritus consumed varies inversely with aquatic invertebrate abundance) and detritus is a nutritionally significant component of their diet (Ahlgren 1990*a*, 1990*b*). Snyder and Hendricks (1995) found a significant relationship between the concentration of mercury and relative amount of detritus consumed by the caddisfly (*Hydropsyche morose*) in the South River, suggesting that mercury uptake through detrital pathways may be of importance for aquatic organisms consuming substantial amounts of detritus such as white sucker.

As fish grow larger, they usually shift from one food type to another or select larger individuals of the same type. Dietary shifts within trophic categories and from one trophic category to another also occur with seasonal changes in food availability. Size-related and seasonal dietary shifts have the potential to affect mercury uptake by fish (MacCrimmon et al. 1983, Driscoll et al. 1994). For instance, MacCrimmon et al. (1983) found that when lake trout (*Salvelinus namaycush*) in Tadenac Lake, Canada, switched from a diet composed mainly of benthic macroinvertebrates to one primarily composed of smelt, they exhibited an abrupt increase in mercury. While Driscoll et al. (1994) found that concentrations of mercury in yellow perch in Adirondack lakes increased sharply after age-5, which corresponded to the size at which they became mainly piscivorous (200 mm).

Notable size related dietary shifts were observed for redbreast sunfish and smallmouth bass in this study with the latter being more pronounced. As smallmouth bass increased in size, they shifted from a diet mainly composed of aquatic insects to one primarily composed of crayfish and fish. Depending on mercury levels in prey organisms, dietary shifts such as that observed for smallmouth bass may have the potential to influence mercury uptake. Size-related dietary shifts have also been reported for white sucker (Stewart 1926, Lalancette 1977, Twomey et al. 1984), but could not be assessed in this study because of difficulty collecting juvenile fish.

Each of the fish species studied exhibited important seasonal dietary shifts. Decreased consumption of aquatic insects by smallmouth bass and white sucker from spring to fall may have been associated with a variation in the abundance of food items and their varying relative availabilities. However, it remains possible that the types and relative numbers of food items consumed were not representative of the types and numbers present due to influences such as preference. Redbreast sunfish and smallmouth bass consumed sizeable percentages of terrestrial coleopterans, mainly green June beetles, during summer, particularly in the South River. This finding uncovers an important link between floodplain and aquatic ecosystems with regard to mercury transport that may have been overlooked previously. The percentage of redbreast sunfish and smallmouth bass stomachs containing food items decreased sharply from spring through winter, suggesting a substantial reduction in consumption. Reduced consumption during winter was most likely caused by frigid water temperatures, which averaged 5.5, 4.5, and 4.0 C during the winter sampling period in the South River, South Fork of the Shenandoah River, and North River, respectively. Water temperatures <10 C reduce metabolic demands, causing redbreast sunfish and smallmouth bass to become inactive and seek shelter (Edwards et al. 1983, Aho et al. 1986), which was apparent during winter collections. Because dietary pathways account for the majority of mercury uptake by fish (Rodgers and Beamish 1981, Rodgers 1994, Hall et al. 1997), reduced consumption during winter may influence mercury uptake. In contrast, white sucker fed actively throughout the year, which was consistent with previous reports (Twomey et al. 1984).

For reasons relatively unknown, food habits may vary spatially between reaches, rivers, or basins (Surber 1941, Buynak et al. 1982, Austen and Orth 1985). Although food habits of redbreast sunfish and white sucker were similar among rivers, smallmouth bass exhibited notable differences in the composition and percentages of food items consumed among rivers. Factors influencing the observed differences may be associated with ecological differences among rivers, including difference in habitat and forage abundance, composition, and availability (Buynak et al. 1982, Austen and Orth 1985).

In summary, the results of this study have uncovered important dietary pathways and patterns potentially affecting mercury uptake by redbreast sunfish, smallmouth bass, and white sucker populations in the South River, South Fork of the Shenandoah River, and North River and provided the foundation necessary for future investigations concerning mercury dynamics in the aquatic food web of the Shenandoah River Basin and ultimately remediation efforts.

Acknowledgments

Funding for this study was provided by DuPont. Special thanks to Virginia Polytechnic Institute and State University Department of Fisheries and Wildlife Sciences, Virginia Department of Environmental Quality, and Virginia Department of Game and Inland Fisheries personnel who assisted with field and laboratory efforts. We also thank the South River Science Team for assistance with this study.

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