Food Utilization by Riverine Smallmouth Bass in Relation to Minimum Length Limits

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Abstract: Food habits of smallmouth bass (*Micropterus dolomieui*) in the New River were studied to compare diet of fish in a minimum length limit regulated section (Virginia) with those in a non-length limit regulated section (West Virginia). Insects were the dominant food type by number for 152–228 mm smallmouth bass in both sections. Numerically, insects were also found to be common in smallmouth bass of several other size categories. Crayfish and fish, however, combined to form a large part of the diet of smallmouth bass greater than 228 mm. Crayfish were a more significant component of the diet of smallmouth bass in West Virginia than in Virginia in the fall 1982 sample. This may be a factor leading to low condition indices of Virginia smallmouth bass and may affect the success of the minimum length limit regulation.

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Minimum length limits often result in increased numbers of sublegal fish in reservoir and lake populations of largemouth bass (*Micropterus salmoides*) (Farabee 1974, Hickman and Congdon 1974, Johnson and Anderson 1974, Rasmussen and Michaelson 1974, Hoey and Redmond 1974), northern pike (*Esox lucius*), and walleye (*Stizostedion vitreum*) (Snow and Beard 1972, Kempinger and Carline 1978, Serns 1978, Davies et al. 1979). This increased abundance of fish is usually accompanied by a decrease in forage abundance and decreased growth and condition of the species being regulated.

Effects of minimum length limit regulations on smallmouth bass, however, have been variable in stream environments. Fleener (1974) showed increased growth

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for smallmouth bass in the Big Piney River, Missouri. Paragamian (1984) found no adverse impacts on growth and a decline in smallmouth bass standing stocks after implementation of minimum length limit regulations on smallmouth bass in the Maquoketa River, Iowa. On the Shenandoah River, Virginia, Kauffman (1983) found unchanged growth and on Huzzah and Curtois Creeks, Missouri, Fajen (1981) reported slight increases in smallmouth bass standing stocks and decreased growth and condition. In cases where numbers of sublegal fish increased it can be postulated that greater pressure was placed on the forage resource resulting in adverse effects on growth and condition. The abundance and quality of the forage, therefore, can influence the success of the regulation through the effect on growth and condition.

In the mid 1960s, a 305-mm minimum length limit was implemented for the Virginia section of the New River from Claytor Lake dam to the West Virginia border. This regulation was applied in the hope of maintaining quality smallmouth bass fishing in the presence of increasing angling pressure.

The present study was designed to determine if food habits of smallmouth bass differed between the 2 differently regulated sections of the New River. We expected that the increased density of sublegal fish following implementation of a length limit may have resulted in a decline in preferred food items. Consequently, if food is limiting, smallmouth bass in populations regulated by minimum length limits may rely on less preferred food items and, therefore, have poor growth rates or condition indices.

Methods

Two study sections on the New River were selected, 1 in Virginia and 1 in West Virginia. Study sections were described by Austen and Orth (1984). Both states maintain an 8 smallmouth bass per day creel limit.

Boat mounted electrofishing equipment (Coffelt Electronics, Englewood, Colo.) operated at 300 volt and 4-8 amps pulsed direct current (DC) was used to collect smallmouth bass. Electrode arrangements followed recommendations of Novotny and Priegel (1974). When electrofishing, the boat would be positioned perpendicular to shore with the electrodes towards shore. Electrofishing technique consisted of drifting downstream with the current using the motor for maneuvering around obstacles and proper positioning. Fall samples were taken in September and October 1982 and summer samples in June and July 1983. A spring 1983 sample was taken at the Virginia study section but no comparable sample was taken in West Virginia; hence, the data is not reported. All electrofishing sampling, with 1 exception, was done at night beginning at dusk and usually extending until 0200–0300 hours. The exception as the fall 1982 West Virginia sample which was conducted during daylight with personnel of the West Virginia Department of Natural Resources. This sample was done with a "parallel wire" device using alternating current and no voltage or amperage control.

An attempt was made to capture 10 smallmouth bass with food items in their stomachs in each of 3 categories: 152–228 mm, 229–304 mm, and >304 mm. Stomach contents were removed by use of plastic tubes following Dubets (1954), Lewis et al. (1974), and Van Den Avyle and Roussel (1980). Several tubes of different diameters were used (Tube-pak, Consolidated Plastics Co., Macedonia, Ohio, inside diameter sizes 11, 13, 16, 22, 24, 30, 36, and 41 mm). Contents were removed, preserved in alcohol, and taken to the laboratory. All items in each stomach were divided into the categories of fish, crayfish, hellgrammites (*Corydalus cornutus*), and other insects, and were counted. Insects were identified to order and fish and crayfish to the lowest taxonomic level feasible. Total lengths were measured for fish; carapace and total length for crayfish; and head capsule width and total length for hellgrammites. Chi-square analysis was used to test for differences in food habits (numbers of items per stomach) between sites. The numerical values of items per stomach were transformed to approximate volumetric values using volumes per item data from Surber (1941). Volumes used for individuals in each category were: crayfish 5.667 ml, fish and hellgrammites 1.0 ml, trichopterans 0.007 ml, ephemeropterans 0.03222 ml. No statistical tests were done on transformed data.

Results

At both study sections there was a general transition in smallmouth bass food habits from a numerical dominance of insects in young smallmouth bass to fish and crayfish in adults. Numerically, the diet of younger smallmouth bass was composed of a higher percentage of insects than the diet of adult smallmouth bass. By volume, crayfish were the most important food item in all size groups and in both sections. Relatively few hellgrammites were found in any of the samples (Tables 1 and 2).

The diet of 152–228 mm smallmouth bass in both sections was dominated numerically by insects. Approximately 82% to 94% of all items found in the stomachs were insects with ephemeropterans being the most abundant insect. Trichopterans, odonates, and terrestrial and unidentified insect parts comprised the remainder. Diet of 152–228 mm smallmouth bass, when analyzed by number of items per stomach, was significantly different ($P < 0.05$) between sections in the fall 1982 sample.

The occurrence of insects in the diet of 229–304 mm smallmouth bass was decreased over that of the smaller size category; this was especially true for the fall 1982 West Virginia sample. Crayfish dominated the diet of West Virginia smallmouth bass in this category with few insects being found. In this sample, Virginia smallmouth bass diet was composed of a larger percentage of insects and a relatively smaller volume content of crayfish than was found in West Virginia smallmouth bass. Again, hellgrammites were of minor numerical and volumetric importance. Diets of 229–304 mm smallmouth bass in the fall 1982 sample showed a greater utilization of insects and lower utilization of crayfish in Virginia than in West Virginia ($P < 0.01$).

Numbers of smallmouth bass > 304 mm were limited in all samples. In those that were collected, crayfish were dominant, with fish and some insects also being included.

Table 1. Mean number of items per stomach and percent composition of total diet (by number) of smallmouth bass collected from the New River, Virginia and West Virginia, 1982–1983. CRAY = crayfish, HELG = helgrammites, FISH = fish, INSC = insects. Chi-square statistic was used to test for differences. Sample sizes (*N*) and probabilities (P) were the same for both calculations.

Date / SMB TL (mm)	Food Item	Items Per Stomach Va.	(*N*)	W. Va.	(*N*)	Percent Composition Va.	W. Va.	*P*
Fall 1982								
152–228	cray	0.11	(9)	0.75	(12)	1.4	10.7	
	fish	0.44		0.42		5.8	5.9	
	helg	0.00		0.08		0.0	1.2	
	insc	7.11		5.75		92.7	82.1	<0.05
229–304	cray	0.38	(8)	0.80	(10)	15.8	42.1	
	fish	0.88		0.90		36.8	47.4	
	helg	0.00		0.10		0.0	5.3	
	insc	1.12		0.10		47.3	5.3	<0.01
>304	cray	1.00				60.0		
	fish	0.66				40.0		
	helg	0.00				0.0		
	insc	0.00				0.0		
Summer 1983								
152–228	cray	0.25	(12)	0.56	(16)	3.6	4.1	
	fish	0.25		0.25		3.6	1.8	
	helg	0.25		0.06		3.6	0.5	
	insc	6.08		12.68		89.0	93.5	>0.10
229–304	cray	0.75	(12)	1.00	(10)	10.6	8.5	
	fish	0.08		0.20		1.2	1.7	
	helg	0.00		0.10		0.0	0.8	
	insc	6.25		10.40		88.2	88.9	>0.10
>304	cray	2.00	(1)	1.00	(2)	66.6	100.0	
	fish	0.00		0.00		0.0	0.0	
	helg	0.00		0.00		0.0	0.0	
	insc	1.00		0.00		33.3	0.0	

At both sites *Orconectes* sp. was the dominant crayfish in the diet comprising 77% of all crayfish identified; the other crayfish were *Cambarus*. Average total lengths of crayfish found in stomachs were 48 mm (range 12–77 mm) and 40 mm (range 19–79 mm) in Virginia and West Virginia, respectively. Of the fish found in the stomachs of smallmouth bass there was no dominant species. Five of those identifiable were smallmouth bass (mean TL 77 mm, range 68–95 mm), 3 were other centrarchids, 3 *Notropis* sp. (mean TL 41 mm, range 37–48 mm), 3 *Etheostoma* sp. (mean TL 41 mm, range 35–45 mm), 2 chub (*Nocomis* sp.), and 1 *Campostoma anomalum* (112 mm TL). Average total length of fish found in the stomachs of smallmouth bass was 50 mm (range 24–78 mm TL) in West Virginia and 45 mm (range 34–112 mm TL) in Virginia.

A total of 11 hellgrammites were found in the stomachs. Average hellgrammite head capsule width found in West Virginia samples was 7.9 mm (range 2.4–11.3 mm, $N = 3$) and in Virginia was 8.75 mm (range 1.5–10.6 mm, $N = 8$). Regression of hellgrammite head capsule width (HCW) to total body length (TL) for 35 individuals collected by seine from the West Virginia section was:

$$TL = 10.17 + 3.95 \quad HCW \quad (r = 0.92),$$

and for 26 individuals from Virginia was:

$$TL = 10.64 + 6.25 \quad HCW \quad (r = 0.96).$$

Prey size, measured as a percentage of the fish's total length, was similar for both sections. For West Virginia, smallmouth bass with fish in their stomachs the prey total length averaged 20.9% that of the predator (range 10.8–31.9%., N = 15). Total length of crayfish found in the stomach of West Virginia smallmouth bass averaged 17.8% that of the predator (range 9.3–33.2%, N = 21). Total length of

Table 2. Average volume of food items found in stomachs of smallmouth bass collected from the New River, Virginia and West Virginia, 1982–1983. CRAY = crayfish, HELG = helgrammites, FISH = fish, INSC = insects.

Date	SMB TL (mm)	Food Item	Estimated Volume of Contents (ml)			
			Va.	(N)	W. Va.	(N)
Fall 1982	152–228	cray	0.62	(9)	4.25	(12)
		fish	0.44		0.42	
		helg			0.08	
		insc	0.23		0.18	
		total	1.29		4.93	
	229–304	cray	2.15	(8)	4.53	(10)
		fish	0.88		0.90	
		helg			0.10	
		insc	0.04		0.01	
		total	3.07		5.54	
	>304	cray	5.67	(3)		(0)
		fish	0.66			
		helg				
		insc				
		total	6.33			
Summer 1983	152–228	cray	1.42	(12)	3.17	(16)
		fish	0.25		0.25	
		helg	0.25		0.06	
		insc	0.20		0.41	
		total	2.12		3.89	
	229–304	cray	4.25	(12)	5.67	(10)
		fish	0.08		0.20	
		helg			0.10	
		insc	0.20		0.34	
		total	4.53		6.31	
	>304	cray	11.30	(1)	5.67	(2)
		fish				
		helg				
		insc	0.03			
			11.33		5.67	

Table 3. Percent empty stomachs from samples of smallmouth bass from the New River, Virginia and West Virginia, 1982–1983. Sample size (*N*) in parentheses.

Sample Date	Length Category (MM)	Site Va.	(*N*)	W. Va.	(*N*)
Fall 1982	152–228	47	(17)	13	(15)
	229–304	38	(13)	17	(27)
	>304	50	(36)		(0)
	average	44	(36)	15	(42)
Spring 1983	152–228	15	(13)		
	229–304	25	(12)		
	>304	0	(3)		
	average	18	(28)		
Summer 1983	152–228	15	(13)	30	(20)
	229–304	20	(10)	78	(9)
	>304	0	(1)	0	(1)
	average	17	(24)	43	(30)

ingested fish averaged 18% that of the Virginia smallmouth bass in which they were found (range 6.6–33.6%, $N = 27$) while crayfish averaged 16.9% (range 5.7–29%, $N = 9$).

The percentage of empty stomachs among smallmouth bass varied between samples and length categories (Table 3). Overall, the percentage of empty stomachs in the fall 1982 sample was greater in Virginia (44%) than in West Virginia (14.8%). This was the reverse of the summer sample in which West Virginia smallmouth bass exceeded that of Virginia fish. Among length categories, the highest percent empty stomachs was for 229–304 mm smallmouth bass from the summer 1983 West Virginia sample.

Discussion

Smallmouth bass utilized a significantly greater percentage of insects and less crayfish in the Virginia section than in the West Virginia section in the fall 1982 sample. In addition, average volume of crayfish found in the stomach of West Virginia smallmouth bass was greater than that of Virginia fish of all size classes.

Average size of crayfish ingested by smallmouth bass in both sections was similar and both were within or close to the range of preference (24–46 mm TL) exhibited by Missouri smallmouth bass (Probst et al. 1984). However, West Virginia smallmouth switched to a greater dependence on crayfish and fish at a smaller size than Virginia smallmouth bass. The West Virginia section, particularly near Bluestone Dam, has a very high abundance of insects (Voshell 1985). Even with this high abundance West Virginia smallmouth bass fed mainly on crayfish. In addition Virginia smallmouth bass generally fed more on insects and less on crayfish and fish and, therefore, would have a lower mean food particle size.

Dependence of smallmouth bass on fish and crayfish is well documented (Coble 1975, Kilambi et al. 1977, Miner 1978, Covington 1982). Smallmouth bass were both faster growing and in better condition in the Shenandoah River, where the diet consisted mostly of fish, than in either the Potomac or Cacapon rivers where the diet consisted of large numbers of small items (Surber 1941). Smallmouth bass in the Virginia section were also slower growing and had lower condition indices than West Virginia fish (Austen 1984). Virginia smallmouth bass reached legal length (305 mm) at age 5 whereas West Virginia smallmouth bass attained the same length at age 4. Relative weights (Wr) of Virginia smallmouth bass were significantly lower than West Virginia smallmouth bass for all length categories in July 1982 samples and for the 152–228 mm and 229–304 mm categories in July 1983. Virginia smallmouth bass also showed a decline in condition to mean Wr's near 70 during winter or early spring (Austen 1984).

Growth efficiency decreases with increasing size of fish if food particle size remains constant (Paloheimo and Dickie 1966). This has been shown for pellet fed Atlantic salmon (*Salmo salar*) raised in tanks (Wankowski and Thorpe 1979). Therefore, the smaller mean food particle size of Virginia smallmouth bass compared to West Virginia fish may be 1 factor contributing to the reduced growth and condition.

Several factors, however, may also influence the noted difference in food habits. First, sampling times for the fall 1982 collection in West Virginia were during daylight while collections in Virginia were at night. Evacuation rates for largemouth bass averaged 17.5 hours at 24°–25° C (Hunt 1960) and for bluegill (*Lepomis macrochirus*) averaged 17–19 hours at 21° C (Windell 1967). In general, bluegill digested natural food items at the same rate regardless of chemical composition (Windell 1967). These relatively slow evacuation rates suggest that the contents at any given time may be indicative of normal diet.

Second, habitat differences between sites may influence the type of prey and their availability to predators. Smallmouth bass diet often reflects what is most available in the area of their residence and are generally less selective than other species (Coble 1975, Covington 1982, Probst et al. 1984). Differences in food habits of smallmouth bass in two areas of the Susquehanna River were attributed to dissimilar abundances and availabilities of forage in the study areas (Buynak et al. 1982). Differences in river morphology between New River study sections include higher gradient and larger riffle sections in West Virginia. Crayfish are abundant in the West Virginia study section and are the target of a thriving bait industry (Nielsen and Orth 1984). The Virginia section has no bait industry and may have a less abundant crayfish population. Assuming no difference between sections in availability of crayfish to smallmouth bass the postulated abundance difference could account for food habit differences.

Percent empty stomachs (PES) may be used as a rough indicator of forage availability and was negatively, though not significantly, correlated with growth for largemouth bass (Zweiacker and Summerfelt 1973). West Virginia smallmouth bass exhibited lower PES values in the fall but were higher in the summer than were Virginia fish. Virginia smallmouth bass, because they are more dependent upon insects, would be expected to have higher PES values when insects are scarce and, conversely lower PES values when insect abundance increased. The higher PES values of West Virginia smallmouth bass in summer 1983 occurred even though annual growth increment and condition at time of the sample exceeded that of the Virginia fish (Austen 1984). Percent empty stomachs as a possible indicator of forage abundance, therefore, seems to be of questionable value with lotic smallmouth populations where type and size of food may be of equal or greater importance than numerical quantity.

Food habits of New River smallmouth bass were similar to those of several other lotic smallmouth bass populations. In almost all instances the diet of young-of-the-year smallmouth bass was predominantly insects or fish. Insects comprised 92%–99% of the total number of food items in the stomachs of young-of-the-year smallmouth bass in the Shenandoah River, Virginia (Miner 1978). By volume, insects dominated the diet in the spring. However, late summer (55% fish) and fall (66.8% fish) samples showed dramatic increases in the importance of fish. Similarly, Covington (1982) found that insects were relatively more important to immature smallmouth bass (< 254 mm TL) in the spring. By autumn these same fish fed almost exclusively on fish and crayfish. The diet of adult smallmouth bass in the Shenandoah River was dominated by crayfish during all seasons with insects being second in importance in the spring and fish being second during the summer and fall (Miner 1978). At all sizes New River smallmouth bass diet was mainly crayfish. Insects were found in the smaller size classes but there was no seasonal trend apparent.

In the few evaluations of length limit regulations on smallmouth bass populations, food supply has not often been considered. Both Kauffman (1983) and Paragamian (1984) estimated population statistics but included no analysis of food abundance. Conversely, several evaluations of length limits on largemouth bass, walleye, and northern pike have included some indication of the interaction between forage and the regulated species.

Farabee (1974) found high numbers of slow growing largemouth bass accompanied by sparse bluegill populations. This was attributed partially to heavy predation on young bluegills by largemouth bass. Increasing demands on a declining forage base resulted in poor growth in Worth Lake, Missouri, but was less consistent in Jamesport and Limpp Lakes, Missouri (Rasmussen and Michaelson 1974). Jamesport Lake showed declining bluegill populations and subsequently reduced largemouth bass growth. Introductions of threadfin shad, however, failed to alleviate the problem. In Limpp Lake, even with initially abundant forage, largemouth bass growth was reduced after 5 years. In these lakes the amount of time before reduced growth and overabundance of largemouth bass became severe was a function of basic fertility, forage availability, and presence of competing species (Rasmussen and Michaelson 1974). Kempinger and Carline (1978) noted that imposition of a length limit on northern pike was followed by a reduction in the panfish population. Snow and Beard (1972) reported that sparse and fluctuating panfish populations contributed to ineffectiveness of a minimum length limit on northern pike. Similarly, a minimum length limit on walleye harvest was followed by a 5-fold reduction in forage standing stock and consequent reduction in growth (Davies et al. 1979).

With lotic smallmouth bass populations the interrelationship between food availability and the success of minimum length limits may be more complicated than with largemouth bass in small reservoirs and ponds. Smallmouth bass utilize a different and more diverse forage base than largemouth bass. The presence of several competing species such as rock bass (*Ambloplites rupestris*) and flathead catfish (*Pylodictis olivaris*) also increases the demands on forage. Since smallmouth bass forage consists of crayfish and a variety of fish species as well as insects it is unlikely that attempts to manipulate panfish populations through length limit regulations on smallmouth bass would be successful. Further, length limits, by reinforcing size selective mortality of smallmouth bass and favoring buildup of sublegal fish densities, may lead to overexploitation of preferred forage items.

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