DIET OVERLAP OF STRIPED BASS X WHITE BASS HYBRIDS AND LARGEMOUTH BASS IN SOONER LAKE, OKLAHOMA

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Abstract: In 1980 and 1981, stomach contents were removed from 224 striped bass *(Morone saxatilis)* × white bass *(M. chrysops)* hybrids and 149 largemouth bass *(Micropterus salmoides)* collected from Sooner Lake, Oklahoma. Relative abundances of forage fishes were also estimated and food electivity and overlap of diet were determined seasonally. Gizzard shad *(Dorosoma cepedianum)* was the most important food of all hybrids except those <301-mm; insects and inland silversides *(Menidia beryllina)* were seasonally important. Gizzard shad, insects, and sunfishes *(Lepomis* spp.*)* and crappies *(Pomoxis* spp.*)* were the most important foods of largemouth bass. Insects and inland silversides were the major constituents of the diet of largemouth bass ≤151 mm. Electivity values showed gizzard shad were generally preferred by both hybrids and largemouth bass whereas silversides, sunfishes, and crappies were consistently underutilized in relation to their abundance. Overlap in diets, which was limited except for the largest individuals of the two fish types, was probably not significant considering the diversity and abundance of forage and the ability of both fishes to utilize a wide range of prey items.

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Striped bass × white bass hybrids were first produced in South Carolina in 1965 (Logan 1968) and in subsequent years have provided substantial recreational fisheries throughout the southeastern United States (Bishop 1968, Williams 1971, Ware 1975, Crandall 1979). The fish has become a popular species for stocking programs because of rapid growth and good fighting ability (Williams 1971). In addition to providing excellent angling opportunities, the hybrid may serve as a biological control for underutilized populations of gizzard shad and threadfin shad *(D. pentenense)* (Bishop 1968, Williams 1971, Ware 1975). In general, hybrid growth rates have been found to be exceptional during the 1st 2 years of life, but seemed to decrease in subsequent years (Bishop 1968, Williams 1971, Ware 1975, Crandall 1979).

Hybrids were stocked in Sooner Lake, a 2185 ha power plant cooling water reservoir in north-central Oklahoma, in 1977, 1978, and 1980. These fish were reported to feed primarily on gizzard shad (64% of items in stomach) and grow at rates similar to hybrids elsewhere (Hicks 1978, 1979). Little attention has been

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given to possible feeding interactions between native predators, such as the largemouth bass, and *Morone* hybrids. In Sooner Lake these fishes were studied in the same enviroment to determine if food habits overlapped. This information, along with data on relative abundance of prey, is helpful for proper management of the fishery.

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METHODS

Hybrids and largemouth bass in Sooner Lake were caught from April 1980 through May 1981. Experimental gill nets (61 × 2 m, 19- to 102-mm bar mesh), trap nets (Crowe 1950), and hoopnets (Houser 1960), were set nightly for 12 hours from April 1980 to July 1980, and from October 1980 to May 1981. Gill netting was discontinued in the late summer due to low catches and advanced digestion of stomach contents. Night-time shoreline electrofishing using a boat-mounted pulsed-DC unit was conducted during June and December of 1980 and February through May of 1981. Shoreline seining (9.1 m, 6-mm mesh straight seine) was done throughout July, August, and November 1980. Total lengths (nearest millimeter) and weights (nearest gram) were recorded and scales were collected from hybrids and largemouth bass. All fish over 100 mm were identified to species, measured and weighed. Other fish were subsampled, identified to species and relative weights determined. Stomach contents were removed from hybrids and largemouth bass by using hollow glass tubes inserted through the fish's mouth and preserved in 70% ethanol following the procedure outlined by Van Den Avyle and Roussel (1980). Food items were separated, identified to the lowest taxon practical, weighed to the nearest gram, and volumes determined to the nearest milliliter in a graduated cylinder. We calculated frequency of occurrence (F) and percentages of total volume (V), total weight (W), total number (N), and mean volume percent per stomach. In addition, we calculated the Index of Relative Importance (IRI) of Pinkas et al. (1971) to give a dimensionless, rankable value that combines the important features of frequency of occurrence, number, and volume in the equation: $IRI = (N + V)F$.

Electivity indices were calculated by using the linear index of Strauss (1979): $L = r_i + p_i$, where r_i is the relative abundance of food item i in the gut and p_i is the relative abundance of food item i in the environment. The Schoener (1970) overlap index was used to compare food habits among length groups between species. Wallace (1981) found that using mean volume percent data in this equation gave the most reliable results: $\alpha = 1 - 0.5(\Sigma | p_{xi} - p_{yi} |)$, where p_{xi} is the relative abundance of food item i in the stomach contents of species x and p_{yi} is the relative abundance of food item i in the stomach contents of species y.

RESULTS AND DISCUSSION

Prey Abundance

Relative abundance of forage species was estimated from mean catch-per-unit-effort (c/f) with several gears, as well as percent of total number and weight by gear (Table 1). Catches of gizzard shad in gill nets increased progressively from spring through winter of 1980, with spring 1981 catches about equal to winter catches. The c/f in gill nets for sunfishes and crappies was generally low and declined slightly through 1980 but increased in winter 1980 and early spring 1981. Electrofishing catches showed similar trends with the c/f of gizzard shad increasing from 15 in summer to 37 in winter. Sunfishes and crappies followed the opposite pattern; c/f decreased from 16 in summer to 10 in winter. Inland silversides were not caught in gill nets, and only a few were collected by electrofishing (c/f of 6 in winter and 0 in spring 1981). Seine catches on the other hand were dominated by silversides in late summer and fall of 1980. The overwhelming c/f of silversides in seines in relation to c/f of other fishes probably better reflect this species' abundance.

Food Habits

Of the 224 hybrids and 149 largemouth bass examined, 86 (38%) and 91 (61%) of the stomachs, respectively, contained food. Breakdown by age class and length group showed little difference for hybrids except in July 1980 when 13% of the age II, 301 - 450-mm long fish contained food, compared with 75% of the age III, 451 - 600-mm fish. Among largemouth bass, only age IV fish, 451 - 600 mm long, contained food more often than did other age or size groups.

Since positive separation of age zero hybrids from white bass in the ≤150-mm and 151 - 300-mm length groups was difficult, only a few hybrids <300 mm collected in late July 1980 were included in these analyses. Insects were the most important food item according to both IRI and mean volume percent (Table 2). Unidentified fish remains made up the rest of the stomach contents of small hybrids. Another group of small hybrids was collected in August. These fish were feeding exclusively on juvenile threadfin shad. Although the mean lengths of the fish in July and August were essentially the same, diets were distinctly different. This shift in diet may have been an artifact of sampling or due to the sudden availability of suitable forage fish.

The 301 - 450-mm length group of hybrids consisted of age II fish during the spring and summer of 1980. Only 1 hybrid in this intermediate length group was collected after July 1980. In spring 1980, gizzard shad were the most important food item as determined by both IRI and mean volume percent (Table 2). Insects made up a small portion of the diet in the spring (1% by volume) and ranked 2nd by IRI. Sunfishes and crappies were absent from stomachs during the spring, but were ranked 2nd (IRI of 1166) in the summer. Gizzard shad fell to 4th rank (IRI of 744) in the summer, but were the only food item in the single fish in this length class captured in spring 1981.

Because of the decreased growth rates of the age III fish in the 451 - 600-mm length group, mean lengths of the rapidly growing age II fish were similar by early fall of 1980. Larger sample sizes for the 451 - 600-mm length group (N = 61)

Table 1. Seasonal catch-per-unit-effort (c/f) and percent total weight of forage fishes captured by three gears in Sooner Lake during 1980 and 1981.

	Gear					
	Gill net		Electrofishing		Seine	
	c/12 hr.	% Wt.	c/30 min.	% Wt.	c/100 ft. haul	% Wt.
			Spring 1980			
Gizzard Shad	0	0				
Sunfish & crappie	2	2				
Inland silverside	0	0				
			Summer 1980			
Gizzard shad	1	0	15	11	2	3
Sunfish & crappie	2	3	16	38	1	19
Inland silverside	0	0	0	0	341	67
			Fall 1980			
Gizzard shad	2	1			0	0
Sunfish & crappie	1	1			0	0
Inland silverside	0	0			1272	100
			Winter 1980-81			
Gizzard shad	6	14	37	27		
Sunfish & crappie	3	11	10	12		
Inland silverside	0	0	6	1		
			Spring 1981			
Gizzard shad	6	2	18	8		
Sunfish & crappie	1	3	48	42		
Inland silverside	0	0	0	0		

Table 2. Seasonal analysis of hybrid stomach contents from Sooner Lake during 1980 and 1981, presented by length group.

Season and food item	Method and length group					
	% Freq.	% No.	% Vol. (wt.)	% Vol.[a]	IRI	Rank
			151-300 mm, N=8			
Summer 1980						
Insects	100	98	75	89	17320	1
Unidentified fish remains	25	2[b]	25	7	670	2
			301-450 mm, N=17			
Spring 1980						
Gizzard shad	67	57	98	67	10425	1
Insects	17	29	1	17	491	2
Unidentified fish remains	17	14	1	17	252	3
Summer 1980						
Unidentified fish remains	60	37	39	55	4572	1
Sunfish & crappie	20	25	33	20	1166	2
Insects	30	25	3	10	846	3
Gizzard shad	20	13	25	15	744	4
Spring 1981						
Gizzard shad	100	100	100	100	20000	1
			451-600 mm, N=61			
Spring 1980						
Insects	57	90	28	22	7655	1
Gizzard shad	29	3	48	25	1455	2
Sunfish & crappie	43	4	9	32	558	3
Unidentified fish remains	29	3	15	19	516	4

Table 2. Continued.

Season and food item	Method and length group					
	% Freq.	% No.	% Vol. (wt.)	% Vol.[a]	IRI	Rank
			451-600 mm, N=61			
Summer 1980						
Gizzard shad	56	64	79	56	7917	1
Unidentified fish remains	44	44	21	44	2913	2
Fall 1980						
Gizzard shad	48	22	42	45	3056	1
Sunfish & crappie	19	8	47	15	1051	2
Unidentified fish remains	43	18	5	24	991	3
Inland silverside	14	46	5	7	732	4
Spring 1981						
Gizzard shad	58	35	82	54	6792	1
Insects	17	41	0	10	689	2
Unidentified fish remains	23	12	5	26	385	3
Sunfish & crappie	13	4	12	9	213	4
Inland silverside	4	2	1	1	9	5

[a] Denotes mean volume percent.
[b] Estimated numbers.

probably allow a better understanding of the diet of adult hybrids. Diet was apparently not the cause of the slowdown in growth rate of hybrids during the 3rd year of life as food habits of age II and III fish were essentially the same. Except in spring 1980, gizzard shad were the most important food (Table 2). In the early spring, mayfly larvae were the preferred forage, based on IRI rankings. Measurements by volume, however, indicated that gizzard shad were more abundant in stomachs (48%). The hybrids may have been feeding opportunistically on insects or suitable forage fish were not readily available to this length group in early spring 1980. Again in spring 1981, insects were an important food item, ranking 2nd after gizzard shad. Sunfishes and crappies were relatively unimportant in the spring (ranked 3rd) and summer 1980 (not present), but became the second most important item in the fall 1980 and were 2nd in percent volume in spring 1981. Inland silversides were a minor portion of the hybrid diet during most of the year, with none found in spring and summer 1980 and only 5% and 1% by volume in the following fall and spring, respectively.

No largemouth bass were collected during spring and fall 1980. During the summer 1980 and spring 1981 insects were the most important food item in fish ≤150 mm (Table 3). Various fish constituted the rest of the food in other seasons. Silversides ranked second in both summer and winter 1980.

Largemouth bass in the 151 - 300-mm length group also preferred insects during much of the year. Insects were ranked 1st by IRI in both summer 1980 and spring 1981 (Table 3). Gizzard shad made up 58% by volume in summer 1980, were not present during the winter, and ranked only 5th by IRI in spring 1981. Inland silversides were important in both summer and winter (15 and 68% by volume, respectively). Sunfishes and crappies were relatively unimportant in the diets of these largemouth bass; they ranked 6th in both summer 1980 and spring 1981, and were absent in winter.

In contrast to fish in the smaller length groups, largemouth bass 310 - 450-mm long relied heavily on gizzard shad, sunfishes and crappies. Although insects still ranked 2nd by IRI in spring and summer 1980, fish made up 97% and 94% by volume, respectively, in those seasons (Table 3). Gizzard shad ranked 1st in 3 of the 4 seasons, and sunfishes and crappies ranked 1st in summer 1980. Sunfishes and crappies made up a greater percent volume than did gizzard shad in spring 1981, 78% to 14%, respectively. Silversides were found only in the spring 1981 samples, ranking 3rd by IRI but making up only 5% by volume.

Gizzard shad were generally dominant in the stomach contents of the largest largemouth bass, 451 - 600-mm long. Other fish were the only item found in summer 1980 (1 large white bass in 1 largemouth bass stomach). Otherwise, gizzard shad made up 100% and 89% by volume, respectively, in winter and spring 1981. All other forage fish were of negligible importance.

Electivity

Seasonal electivity values for hybrids and largemouth bass of various lengths were computed for the 3 major components of the diet; gizzard shad, sunfishes and crappies, and inland silversides (Table 4). A value of −1 indicates a complete avoidance or inaccessiblity of abundant prey and +1 a selection for a rare prey item. Values near zero indicate that prey items were consumed in proportion to their adundance in the environment.

Table 3. Seasonal analysis of largemouth bass stomach contents from Sooner Lake during 1980 and 1981, presented by length group.

Season and food item	Method and length group					
	% Freq.	% No.	% Vol. (wt.)	% Vol.[a]	IRI	Rank
			≤150 mm, N=11			
Summer 1980						
Insects	100	54	40	63	9560	1
Inland silverside	50	22	20	13	2110	2
Gizzard shad	50	11	20	13	1555	3
Other[b]	50	11	20	13	1555	4
Winter 1980						
Unidentified fish remains	50	50[c]	67	50	5850	1
Inland silverside	50	50	33	50	4150	2
Spring 1981						
Insects	71	97	50	60	10489	1
Unidentified fish remains	43	3	50	34	2273	2
			151-300 mm, N=47			
Summer 1980						
Insects	43	31	2	24	1411	1
Gizzard shad	14	6	68	10	905	2
Other fish[b]	21	40	2	16	888	3
Inland silverside	14	6	15	14	296	4
Unidentified fish remains	21	9	1	17	187	5
Sunfish & crappie	7	3	22	7	179	6
Crayfish	7	3	0	7	22	7
Winter 1980-81						
Inland silverside	50	40	68	50	5410	1
Unidentified fish remains	50	40	27	38	3365	2
Insects	25	20	5	13	613	3

Table 3. Continued.

Season and food item	Method and length group					
	% Freq.	% No.	% Vol. (wt.)	% Vol.[a]	IRI	Rank
Spring 1981						
Insects	31	60	3	29	1956	1
Unidentified fish remains	24	13	4	23	393	2
Crayfish	7	4	45	7	333	3
Threadfin shad	10	6	27	10	330	4
Gizzard shad	10	6	15	10	209	5
Sunfish & crappie	14	7	4	14	161	6
			301-450 mm, N=24			
Spring 1980						
Gizzard shad	100	50	97	99	14670	1
Insects	50	50	3	1	2265	2
Summer 1980						
Sunfish & crappie	46	32	44	43	3502	1
Insects	39	32	3	20	1309	2
Gizzard shad	15	11	45	16	862	3
Unidentified fish remains	23	16	5	3	325	4
Crayfish	15	11	2	13	197	5
Winter 1980-81						
Gizzard shad	67	67	97	67	10905	1
Crayfish	33	33	3	33	1215	2
Spring 1981						
Gizzard shad	50	40	14	50	2715	1
Sunfish & crappie	25	20	78	25	2448	2
Inland silverside	25	20	5	17	630	3
Unidentified fish remains	25	20	3	8	565	4

Table 3. Continued.

Season and food item	Method and length group					
	% Freq.	% No.	% Vol. (wt.)	% Vol.[a]	IRI	Rank
			451-600 mm, N=100			
Summer 1980						
Other fish[b]	100	100	100	100	20000	1
Winter 1980-81						
Gizzard shad	100	100	100	100	20000	1
Spring 1980						
Gizzard shad	67	50	89	48	9251	1
Sunfish & crappie	17	13	4	2	281	2
Other fish	17	13	4	17	281	3
Inland silverside	17	13	3	17	254	4
Unidentified fish remains	17	13	0	17	215	5

[a] Denotes mean volume percent.
[b] Includes various minnow and white bass.
[c] Estimated numbers.

Table 4. Seasonal electivity values (L)[a] for hybrids and largemouth bass taken from Sooner lake during 1980 and 1981. Values range from −1.0 to 1.0 with positive numbers indicating preference while negative numbers indicate prey avoidance or inaccessibility.

Season and food item	Fish and length group					
	Largemouth bass				Hybrids	
	≤150 mm	151-300 mm	301-450 mm	451-600 mm	301-450 mm	451-600 mm
Spring 1980						
Gizzard shad			−1.0		0.9	0.4
Sunfish & crappie			−1.0		−1.0	−0.7
Summer 1980						
Gizzard shad	0.0	0.4	0.3	−1.2	0.2	0.3
Sunfish & crappie	−1.0	−0.6	−0.4	−1.0	−0.6	−1.0
Inland silverside	0.2	0.5	−1.0	−1.0	−1.0	−1.0
Fall 1980						
Gizzard shad						−0.1
Sunfish & crappie						0.0
Inland silverside						0.0
Winter 1980-81						
Gizzard shad	−1.0	−1.0	0.1	0.2		
Sunfish & crappie	−1.0	−1.0	−1.0	−1.0		
Inland silverside	0.3	0.7	−1.0	−1.0		
Spring 1981						
Gizzard shad		−1.0	−1.0	0.3	0.1	0.3
Sunfish & crappie		−0.9	−0.7	−0.9	−1.0	−0.1
Inland silverside		−1.0	−0.6	−0.7	−1.0	−1.0

[a] $L = r_i - p_i$ (Strauss 1979)

Hybrids preferred gizzard shad in spring 1980; L values were 0.9 and 0.4 for 301 - 450-mm and 451 - 600-mm fish, respectively. Electivity values for summer 1980 were not strong, 0.2 and 0.3, respectively. Low L values for gizzard shad in fall 1980 and spring 1981 showed a continuation of this trend. Sunfishes and crappies were usually avoided or unavailable to hybrids with electivity values in spring and summer 1980 ranging from −0.6 to −1.0. During fall 1980 and spring 1981, however, hybrids neither selected for nor against sunfishes and crappies. Inland silversides were strongly selected against in summer 1980 and spring 1981. Only larger hybrids in the fall of 1980 selected silversides in proportion to their abundance. Largemouth bass electivity values were variable. Gizzard shad were strongly selected against in spring 1980 (L of −1.0) and spring 1981 (L of −1.0) by 301 - 450-mm long largemouth bass, but were slightly selected for in summer 1980 and winter 1980 - 81 (L of 0.3 and 0.1, respectively). Gizzard shad were preferred slightly only 3 other times, summer 1980 by 151 - 300 mm bass (L of 0.4), and both winter 1980 - 81 and spring 1981 by 451 - 600-mm bass (L of 0.2 and 0.1, respectively). Sunfishes and crappies were avoided by largemouth bass or unavailable to them; L values ranged from −0.4 to −1.0 during each season. Silversides were preferred by the 2 smaller length groups of largemouth bass in both summer and winter 1980, but avoided by other sizes in all other seasons.

Diet Overlap

Overlap indices, which were used to determine the degree to which hybrids and largemouth bass were using the same food resources, were shown as a matrix of overlap values for the 4 length groups of largemouth bass and the 3 length groups of hybrids (Table 5). Values of over 0.6 may indicate interaction between the paired length groups (Zaret and Rand 1971). There was no consistent overlap among fishes 301 - 450 mm through the 3 seasons, values of 0.7 for spring 1980, summer 1980, and spring 1981, respectively. The 451 - 600-mm length group hybrids' diet also overlapped with the 3 larger largemouth bass length groups in spring 1981. The 301 - 450-mm length groups of both fishes were relying primarily on gizzard shad. The 151 - 300-mm largemouth bass were relying on insects which were the second most important item in the 451 - 600-mm hybrids' spring diet. Food of smaller fish did not overlap significantly.

CONCLUSIONS

As a result of the bias of estimates of relative abundance in a given year, catches in several gears were combined to determine the values to be used in the electivity equation. We calculated relative abundance of forage items in the hybrid's environment by combining percent total weight from catches in gill nets and seines in the fall. For largemouth bass, a combination of catches by electrofishing and seining in the summer and winter was used. These combinations provided an estimate of relative abundance for each forage species on catches that were most meaningful in view of the habits and habitat of the predator.

Electivities are only as accurate as the estimates of relative abundance in stomach and environment used to calculate them. In this study, the estimates made by grouping catches from several gears probably reduced error, but did not eliminate it. For example, hybrids 301 - 450 mm long fed heavily on gizzard shad

Table 5. Seasonal overlap (α^a) in food of hybrids and largemouth bass of various lengths taken from Sooner Lake during 1980 and 1981.

Season	Hybrid length group	Largemouth bass ≤150 mm	151-300 mm	301-450 mm	451-600 mm
Spring 1980	301-450 mm			0.7	0.3
Summer 1980	151-300 mm		0.4	0.3	0.0
	301-450 mm	0.2	0.4	0.6	0.0
	451-600 mm	0.1	0.2	0.2	0.0
Spring 1981	301-450 mm	0.0	0.3	0.7	0.5
	451-600 mm	0.4	0.7	0.7	0.7

[a] $\alpha = 1 - 0.5 \left(\sum_{i=1}^{n} | p_{xi} - p_{yi} | \right)$, (Schoener 1971).

in the spring of 1980 even though no shad were captured in our sampling. These limitations must be resolved before indices can be compared and tested for significant differences. In addition, analysis of mouth gape of predators and body depth of prey may give clues to the availability of certain sized prey to the various sizes of hybrids and largemouth bass that affect electivity. Despite some diet overlap, especially among the larger fish, negative feeding interactions should be limited in this reservoir because of the diverse forage base and the ability of both fishes to convert to alternate prey when preferred items are scarce.

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