Seasonal Diet Composition of Black Bullhead (*Ameiurus melas*) in Lake Carl Etling, Oklahoma

Richard A. Snow
Oklahoma Department of Wildlife Conservation, Oklahoma Fishery Research Laboratory, Norman, OK 73072

Michael J. Porta
Oklahoma Department of Wildlife Conservation, Oklahoma Fishery Research Laboratory, Norman, OK 73072

Amie L. Robison
Oklahoma Department of Wildlife Conservation, Oklahoma Fishery Research Laboratory, Norman, OK 73072

Abstract: Black Bullhead (*Ameiurus melas*) is the most common of the three species of *Ameriurus* present in Oklahoma. They range across the state and inhabit any aquatic eco-system. However, little is known about their feeding habits. Food habits of Black Bullheads (95-318 mm total length) collected from June 2015 through May 2016 at Lake Carl Etling revealed a broad range of prey items. The total food volume of the 408 stomachs examined was comprised of sixteen different prey items (5 fish species, 5 crustacean species, 3 species of insects, and 3 plant species). No significant difference was found between seasons. Overall, fish had the highest index of relative importance (IRI; 88.5) with crustaceans having the lowest IRI (2.1), while insects and plants had similar IRI (5.8 and 5.5). Gizzard Shad were found to be the most frequent diet item consumed. Black Bullheads exhibit a mixed feeding strategy with varying degrees of specialization. Fish were most important prey item of Black Bullheads, while bullheads occasionally consumed crustaceans, insects or plants showing a higher between-phenotype component. It appears that Black Bullheads are highly piscivorous in Lake Carl Etling. Due to this finding, consideration of diet overlap and fish forage availability is critical when fisheries managers are considering management strategies for other top predators or when contemplating the introduction of a new species into an aquatic system containing Black Bullhead.

Introduction

Black Bullhead (*Ameiurus melas*) is one of three species of *Ameriurus* native to Oklahoma and has a wide distribution across the midwestern United States (Miller and Robison 2004; Mork et al. 2009). Their ability to survive under conditions of poor water quality with high nutrient concentrations has allowed Black Bullhead to adapt to virtually any aquatic ecosystem throughout their range (Pflieger 1997). As a result, many fisheries managers have considered Black Bullhead a pest species and most studies have been directed towards their removal (Houser and Grinstead 1961; Hanson et al. 1983) or studying how they negatively impact water quality (Braig and Johnson 2003; Fisher et al. 2013). However, few studies have examined their role in the ecosystem, particularly their trophic status in the aquatic communities.

The studies that have examined prey use by Black Bullheads are dated and have focused on prey preference. These studies have shown selectivity for a variety of macroinvertebrates (Raney and Webster 1940; Williams 1970) from a wide range of zones including limnetic, littoral, and benthic (Repsys et al. 1976).

Currently, there exists a lack of diet information in the literature and no studies to our knowledge describing feeding habits of Black Bullhead in Oklahoma. The objective of this study was to examine the diet composition of Black Bullhead in Lake Carl Etling in Oklahoma on the western extent of their natural range, and to describe their feeding patterns and the effect of season on diets.

Methods

Study Area

Lake Carl Etling is 64.3 ha at normal pool elevation, with approximately 8 km of shoreline. It was created in 1958 by impounding South Carrizo Creek, a tributary of the Cimarron River in the northwestern tip of Oklahoma's panhandle in Cimarron County.

Sampling

Black Bullheads were collected monthly from June 2015 through May 2016 using boat electrofishing to sample the entire shoreline. Fish were placed on ice immediately after capture, and processed at the Oklahoma Fisheries Research Lab in Norman, Oklahoma. Fish were measured for total length (nearest mm) and weight (nearest g). Stomachs were extracted, prey items were removed and identified, enumerated, and individual prey items weighed to the nearest gram. All prey items were identified to species when possible using scientific taxonomic keys to identify aquatic invertebrates (Merrit et al.2008), fish fillets and scales (Oats et al. 1993), clethra (Traynor et al. 2010), and fish dichotomous keys (Miller and Robison 2004) to identify fish prey items.

Analysis

One-way ANOVAs were performed to determine differences between TL and weight of Black Bullheads between seasons. Tukey HDS post-hoc tests were used when ANOVA indicated significant differences existed. Stomach samples were analyzed by percentage of empty stomachs, frequency of occurrence (O_i), percent composition by number (N_i), percent composition by weight (W_i), and index of relative importance (IRI) (Bowen 1996; Chipps and Garvey 2007). Different prey items were pooled into four categories (Fish, Crustacean, Insect, and Plant). Diet composition (excluding fish with empty stomachs) between seasons (Spring - from March 1 to May 31, Summer - from June 1 to August 31, Fall - from September 1 to November 30, and Winter - from December 1 to February 28) was assessed using a chi-square test (Sokal and Rohlf 1981; Bascinar and Saglam 2009). All statistical analyses were conducted at a significance level of $P \leq 0.05$.

The graphical model of Amundsen et al. (1996) was used to depict feeding strategy (specialized or generalized), relative prey importance (dominant or rare), and niche variation (individual versus population pattern based on the distribution of individual prey items) by plotting prey specific abundance against frequency of occurrence for each prey type. Prey specific abundance is calculated by taking in account only those predators in which the actual prey occurs ($Pi=(\Sigma S_i/\Sigma S_{ti}) \times 100$; where Pi is the prey-specific abundance of prey i, Si is the stomach content (volume, weight or number) comprised of prey i, and S_{ti} is the total stomach content in only those predators with prey i in their stomach (Amundsen et al. 1996).

Results

Of the 408 specimens collected between June 2015 through May 2016, 40% had empty stomachs (N = 162). Black Bullheads ranged in TL from 95-318 mm (mean = 201 mm), and from 10-525 g in weight (mean = 127 g). No significant difference was detected between total lengths ($F_{3, 405} = 0.44$, P = 0.72) and weights ($F_{3, 405} = 0.16$, P = 0.92) seasonally (Table 1). Diets of these fish were fairly diverse, including sixteen different prey items (5 fish, 5 crustaceans, 3 insects, and 3 plant species; Table 2).

Black Bullheads had empty stomachs most frequently in summer samples (O_i = 49.4), followed by fall (43.5), spring (33.0), and winter (28.9). Overall, fish had the highest IRI (88.5) with crustaceans having the lowest IRI (2.1), while insects and plants had similar IRI (5.8 and 5.5; Table 2). Of all prey items, Gizzard

Table 1. Total number, mean total length (±SE), and mean weight (±SE) of Black Bullheads captured during each season from Lake Carl Etling, Oklahoma.

Season	*N*	Total Length (mm)	Weight (g)
Winter	97	201 ± 5.5	126 ± 9
Spring	91	197 ± 5.6	124 ± 8.8
Summer	77	201 ± 6.1	132 ± 9.9
Fall	145	204 ± 4.6	128 ± 7.8

Shad had the highest O_i during summer, fall and winter. However, in the fall Bluegill had a higher IRI = 45.9 than Gizzard Shad (IRI = 39.4, Table 2). The two *Lepomis* species had a combined O_i 14.13 (spring) and 15.15 (winter) in diets, however in winter and summer O_i was three times less. During spring, unidentified fish had the highest O_i, N_i, and IRI of all prey species.

A Chi-square test revealed no significant differences among Black Bullhead stomach contents (the four diet categories) by season (χ^2 = 13.19, P = 0.15). Because no statistical difference occurred among seasons, all items were pooled into four main prey item groups (fish, crustaceans, insects and plant) for the entire year to graphically depict feeding strategy.

Analysis of feeding strategy, based on the Amundsen et al. method (1996), showed that Black Bullheads exhibit a mixed feeding strategy with varying degrees of specialization based on different prey groups (Figure 1). In terms of prey importance, fish were most important among individual bullheads based on habitat, but Black Bullheads also occasionally consumed crustaceans, insects or plants (having a higher between-phenotype component).

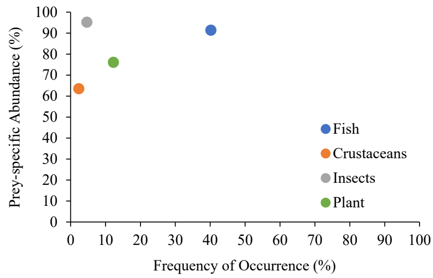
Discussion

Fish, but more specifically Gizzard Shad, were found most frequently in the diets of Black Bullheads from Lake Carl Etling. A transition from a Gizzard Shad dominated diet to alternate prey sources may be due to changes in environmental conditions, prey availability, or species habitat shifts, which could be a driving the seasonal presences of *Lepomis* species in diets of Black Bullheads. A preference for fish prey has not been documented in previous *Ameiurus* diet studies, instead Arthropoda and Crustacea were the most frequently consumed diet items in those studies (Raney and Webster 1940; Williams 1970). Repsys et al. (1976) suggested that prey consumed by Black Bullheads was based on habitat and availability of prey. The shoreline habitat in Lake Carl Etling is fairly homogenous consisting of inundated dead terrestrial vegetation and remnant debris from recent years of drought, large rock outcroppings, and a mixed sand/gravel substrate. Gizzard Shad are the most abundant fish species in Lake Carl Etling with electrofishing catch rates in the spring ranging from 216-341 fish/hr, and in the fall ranging from 1593-1752 fish/hr (ODWC unpublished data). Fish importance in the winter diet of Black Bullhead, particularly the Gizzard Shad component, is likely driven by the overall abundance of Gizzard Shad in Lake Carl Etling. High Gizzard Shad abundance is also likely driving total annual fish consumption values for Black Bullhead in this system.

A novel finding was the spike in unidentified fish that were found in spring diets of Black Bullhead. Lake Carl Etling is stocked annually in the fall with hatchery raised Rainbow Trout (*Oncorhynchus mykiss*) to create a winter time fishery. We speculate that during the winter months when surface water temperatures are low (ranging from 1.7 – 5.6 ºC; unpublished data 2016), Gizzard Shad movements are reduced, which has been shown to effect other *Clupeidae* winter movements (Hurst 2007). High densities of stocked trout and other resident predators in Lake Carl Etling are more effectively able to feed on Gizzard Shad in winter months. Furthermore, Lake Carl Etling freezes over for a brief period of time annually. This usually results in the observation of winter time Gizzard Shad kill. Gizzard Shad succumb once water temperatures decrease below 4 ºC (Porath 2006). Both events could result in lowering of density of Gizzard Shad shown in the decreased catch rates from fall to spring. Alternatively, when water warms to 21-26ºC (Cherry et al. 1977; Currie et al. 1998), the critical thermal maxima of Rainbow Trout, death occurs. While examining Black Bullhead stomach samples in early June 2015,

Table 2. Frequency of occurrence (O_i), percent composition by number (N_i), percent composition by weight (W_i), and index of relative importance (IRI) for seasonal diet composition of Black Bullheads collected from June 2015 through May 2016 from Lake Carl Etling,Oklahoma. Bold values indicates the overall annual combined group (fish, crustaceans, insects, plant and empty) values.

Diet Item	Winter				Spring				Summer				Fall			
	O_i	W_i	N_i	IRI	O_i	W_i	N_i	IRI	O_i	W_i	N_i	IRI	O_i	W_i	N_i	IRI
Fish	**39.6**	**89.5**	**47.1**	**88.5**												
Bluegill Sunfish (*Lepomis macrochirus*)	2.92	7.35	1.75	0.77	7.61	38.5	11.6	15.8	1.73	17.9	1.94	1.94	11.7	51.6	29	45.9
Green Sunfish (*Lepomis cyanellus*)	0.69	2.8	0.88	0.07	6.52	13.8	8.7	6.1	3.46	26.8	4.85	6.17	3.45	9.69	6.54	2.72
Gizzard Shad (*Dorosoma cepedianum*)	29.4	64.3	22.8	74	2.17	3.35	2.9	0.56	19.5	34.8	32	73.4	14.6	28.5	27.1	39.4
Common Carp (*Cyprinus carpio*)	0	0	0	0	0	0	0	0	2.6	0.21	1.94	0.32	0	0	0	0
Black Bullhead (*Ameiurus melas)*	2.06	1.16	0.88	0.12	1.09	9.23	1.45	0.48	9.16	12.6	7.77	10.5	2.07	1.93	2.8	0.48
Unidentifiable	8.76	7.25	3.95	2.83	26	19.1	40.6	64.5	1.3	0.18	0.97	0.08	3.62	3.51	5.61	1.61
Crustaceans	**2.3**	**0.87**	**8.5**	**0.21**												
Anostaca	0	0	0	0	1.52	1.25	2.9	0.26	0	0	0	0	0	0	0	0
Copepoda	0.82	0	8.77	0.21	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0	1.62	0.78	13.6	1.31	0	0	0	0
Ostracoda	0.1	0	0.44	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentifiable Crayfish Species	0	0	0	0	1.09	2.23	1.45	0.17	0	0	0	0	0	0	0	0
Unidentifiable	0	0	0	0	2.17	0.61	2.9	0.32	0	0	0	0	2.07	0.21	2.8	0.3
Insects	**4.4**	**3.9**	**33.3**	**5.8**												
Odonata	0	0	0	0	1.09	0.5	1.45	0.09	2.53	5.46	1.94	1.06	2.07	0.06	5.61	0.57
Orthoptera	0	0	0	0	0	0	0	0	1.3	0.03	1.94	0.14	0	0	0	0
Diptera	8.35	9.35	53.5	15.2	0	0	0	0	0	0	0	0	0	0	0	0
Unidentifiable	0	0	0	0	0	0	0	0	2.6	0.12	29.1	4.28	0.69	0.01	1.87	0.06
Plant	**12.5**	**5.7**	**11.1**	**5.5**												
Cladophora	16	7.77	7.02	6.83	1.41	0.2	4.35	0.27	1.3	0.62	0.97	0.12	1.72	1.5	2.8	0.36
Maize	0	0	0	0	0	0	0	0	0	0	0	0	0.52	0.3	0.93	0.03
Myriophyllum	0	0	0	0	9.78	10.5	13	9.59	3.57	0.49	2.91	0.68	9.93	2.74	15	8.55
Unidentifiable	0	0	0	0	4.73	0.7	8.7	1.85	0	0	0	0	0	0	0	0
Empty	**38.5**															
Empty	28.9				33				49.4				43.5			



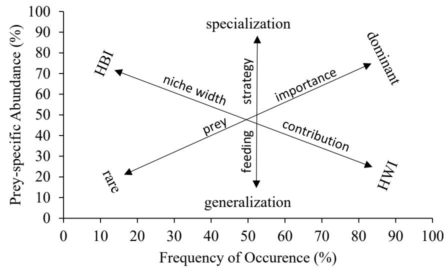


Figure 1a. Feeding strategy plot for Black Bullheads using methods described in Amundsen et al. (1996). Figure 1b. Graphic representation of feeding strategy, niche width contribution, and prey importance, as proposed by Amundsen et al. (1996; HBI = high between individuals; HWI = high within individuals).

observations of distinct fish organs (e.g. gill arches, pieces of intestines, stomachs, and pyloric caeca) were noted during analysis. However, it was not until May 2016 during an electrofishing survey that we developed a potential theory as to why we frequently observed unidentified fish parts in Black Bullhead diets during spring months. In May 2016, we sampled numerous Black Bullheads and Channel Catfish *Ictalurus punctatus* that were actively foraging on and were stuck within the body cavities of dead Rainbow Trout (Figure 2). Coinciding with the winter decline in Gizzard Shad abundance and an increase in dead or dying rainbow trout, we believe that Black Bullheads shifted to a scavenging foraging behavior, hence the observations of distinct fish organs in their diets during spring.

It appears that in certain aquatic systems Black Bullheads are highly piscivorous, but their impacts on other sport fish populations within the same system are unknown. Based on these results, it seems that Black Bullheads in Lake Carl Etling are likely competing with other top predators (Largemouth Bass *Micropterus salmoides*, Walleye *Sander vitreus*) based on the dominance of fish in their diets. This could be problematic if dietary overlap and resource availability is not considered in systems where Black Bullheads are established and a fisheries manager is trying to stock additional predators to create angling opportunities.

Although Black Bullheads are a native species in North America, they are considered invasive in Europe (Nowak et al. 2010; Rutkayova et al. 2013; Copp et al. 2016). Most studies have focused on species identification and factors affecting reproduction (Ruiz-Navarro et al 2015), but little is known about their impact on the native fishes. Similar to our results, Ruiz-Navarro et al. (2015) found through stable isotope analysis of a population of Black Bullheads in Europe that fish contributed to the long term assimilated diet, more so than macroinvertebrates. It appears that if Black Bullhead range continues to expand in Europe, the result could be negative for native predatory species based on competition, predation, or the

Figure 2. A photograph taken during an electrofishing survey in late May 2016 at Lake Carl Etling, Oklahoma showing a live Channel Catfish actively foraging on a recently deceased Rainbow Trout.

displacement of native fish species.

Results from this study show the importance of fish in the diets of Black Bullhead. Furthermore, it introduces the question of how to deal with Black Bullhead populations in situations where they are highly piscivorous and function similarly to a top predator in the system. Considerations of diet overlap and fish forage availability are critical when fisheries managers are considering management strategies for other top predators or when contemplating introduction of a new species into an aquatic system. Further research is needed on a larger scale (multiple systems) to determine the full impacts of Black Bullheads on sportfish populations.

Acknowledgments

The authors thank those individuals that assisted with monthly sampling and the lab portion of the project including Jory Bartnicki, Brandon Chen, Ty Harper, Michael Hollie, Chas Patterson, Shelby Jeter, Roger Kildow, Clayton Porter, Dakota Schoeling, and Jeff Tibbets. We thank K. Kuklinski (ODWC) and Dr. J. Long (Oklahoma State University) for reviewing an earlier draft of this manuscript. Financial support for this publication was provided by the Sport Fish Restoration Program grant [F-50-R-25] and [F-86-D-1] to the Oklahoma Department of Wildlife Conservation.

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Submitted August 7, 2017 Accepted November 17, 2017