

Comparison of Bowfin Diets in the Upper Barataria Estuary and Atchafalaya River Basins of the Lower Mississippi River

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Abstract: The life histories of many organisms are directly tied to floodplain inundation for access to spawning grounds, nurseries, and feeding, but many floodplain ecosystems have been altered by anthropogenic activities and are disconnected from associated rivers. The Atchafalaya River Basin (ARB) floodplain, Louisiana, is relatively intact, whereas the upper Barataria Estuary (UBE) has been separated from the Mississippi River by anthropogenic modifications and lacks an annual flood pulse. The lack of connection can alter trophic webs that include fish species such as bowfin (*Amia calva*). Therefore, bowfin diets in these two floodplain ecosystems were examined to determine if the difference in floodplain connectivity was associated to bowfin diets. Bowfin were collected by boat electrofishing in the ARB ($n = 89$) and UBE ($n = 143$) from March 2017 to August 2017. Mean percent empty stomachs was similar between basins, with 26% empty in the ARB and 30% in the UBE. Bowfin diets in both basins were composed primarily of crayfish and fish, but crayfish composed a higher proportion of bowfin diets in the ARB compared to the UBE. Overall, diets of bowfin were very similar between basins. However, fish consumed by bowfin in the ARB were primarily bowfin and sunfish (*Lepomis* spp.) whereas bay anchovy (*Anchoa mitchilli*) and unidentified fish were the preference of bowfin in the UBE. Bowfin in the UBE also had a more diverse diet which included insects, amphibians, and reptiles. This study provides a baseline to evaluate effects of floodplain inundation on trophic dynamics as coastal restoration activities progress and may be used as a tool to assist in evaluation of restoration measures.

Key words: floodplain, connectivity, anthropogenic, trophic

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The annual flood pulse is a major factor influencing aquatic biota in large river-floodplain ecosystems by providing seasonal access to spawning grounds, nurseries, and feeding areas (Junk et al. 1989, Wantzen et al. 2002, Alford and Walker 2013, Bonvillain et al. 2013b). As flooding occurs, nutrients that mineralized during dry periods are dissolved and suspended with sediments in river-floodplain systems and stimulate primary and secondary production (Bayley 1995, Baldwin and Mitchell 2000, Ou and Winemiller 2016). In addition, terrestrial-based food sources may become available on inundated floodplains and can support production of aquatic organisms during high water (Correa and Winemiller 2018).

The duration, magnitude, and timing of the annual flood pulse regulate productivity in river-floodplain systems and a change in the flood pulse can be considered a disruption (Bayley 1995, Alford and Walker 2013, Jardine et al. 2015). In short-duration floods, organic matter and nutrients may quickly flush into the main channel and be transported downstream away from the floodplain before becoming incorporated into the local food web, reducing primary production (Junk et al. 1989). An altered flood pulse may result in decreased larval fish production on large river floodplains due to a reduction in habitat quality and food resources

(Fontenot et al. 2001, Raibley et al. 2011). Therefore, years with a reduced flood pulse may have a reduced supply of energy and nutrients that can be transported through the food web in support of secondary production.

Many fish species forage on inundated floodplains during flood pulses and have adapted a life history that takes advantage of seasonally inundated floodplains (Wantzen et al. 2002, Agostinho-Luz et al. 2008, Correa and Winemiller 2018). The absence of a flood pulse prevents fish from foraging on the floodplain and reduces recruitment of prey items, which can affect food availability and growth (Agostinho-Luz et al. 2008, Sammons and Maceina 2009). Additionally, the lack of a flood pulse may result in decreased floodplain primary and secondary production and food availability for opportunistic feeding fish species such as bowfin (Bayley 1995, Jardine et al. 2015). Thus, long term hydrologic changes associated with disconnecting the main stem river from adjacent floodplains, such as the lack of a seasonal flood pulse, may alter faunal community structure and forage availability (Slipke and Maceina 2006, Bonvillain and Fontenot 2020).

Bowfin (*Amia calva*) are commonly found in swamps and backwater pools of rivers (Scott and Crossman 1973, Koch et al. 2009). During the spring and early summer, bowfin move into shallow

vegetated habitats for spawning and feeding when water temperatures approach 16°–19° C (Dugas et al. 1976, Davis 2006, Koch et al. 2009). Bowfin are typically top predators and are opportunistic feeders that consume prey based on presence and abundance, including insects, crustaceans, amphibians, and fish (Ross 2001, Manley 2012, Nawrocki et al. 2016). Prior to human modification, the lower Mississippi River would typically inundate its floodplain during the spring then recede, allowing the floodplain to dewater during early summer and most of the floodplain remained dry through the fall. However, channelization and flood protection levee construction have disconnected approximately 90% of the lower Mississippi River floodplain from the mainstem river (Eggleton et al. 2016). If disconnection from the Mississippi River and subsequent altered hydrology of the lower Mississippi Basin has changed faunal community structure in some areas, then it may also affect bowfin diets. Therefore, the objective of this project was to compare bowfin diets in a relatively unaltered floodplain system to diets of those in a highly altered system.

Study Area

The Atchafalaya River Basin (ARB) in south-central Louisiana (Figure 1) is the largest wetland-floodplain system in the United States (Lambou 1990, Snedden et al. 1999, Ford and Nyman 2011). The ARB contains cypress-tupelo swamps, bottomland hardwoods, backwater lakes, bayous, and human-made canals with a rich diversity of terrestrial and aquatic species (Bonvillain et al. 2013a, Piazza 2014). Anthropogenic alterations have changed the hydrology of the ARB, currently it receives approximately 30% of the combined volumes of the Mississippi and Red rivers (Bonvillain et al. 2015, Hahn and Jasinski 2015). Presently, the ARB floodplain is bound by two levees that are approximately 20–30 km apart. The U.S. Army Corps of Engineers (USACE) controls the amount of water diverted from the Mississippi River on a daily basis based on current river discharge. Because of the direct connection to the Mississippi River, the ARB receives an annual flood pulse that mimics the flood pulse of the Mississippi River, but human-made canals and associated spoil banks impede natural flow patterns on the Atchafalaya River floodplain (Hupp et al. 2008, Alford and Walker 2013).

The Barataria Estuary comprises the eastern half of the Barataria-Terrebonne National Estuary and is the southernmost western floodplain of the Mississippi River. The upper Barataria Estuary (UBE) is an extensive freshwater wetland that contains diverse habitats of cypress-tupelo swamps, bottomland hardwoods, backwater lakes, bayous, and human-made canals (Braud et al. 2006, Figure 1). Historically, annual spring floods of the Mississippi River inundated the UBE in a similar manner as the ARB; however, levees constructed along the Mississippi River after the Great Flood

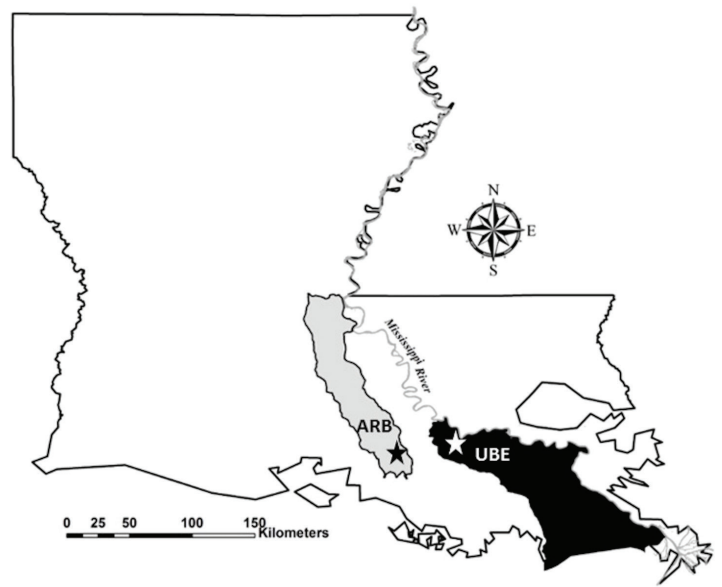


Figure 1. Location of the Atchafalaya River Basin (ARB; gray area) and the Barataria Estuary (UBE; black area). Stars indicate approximate area sampled in each basin. Only freshwater areas of the UBE were sampled.

of 1927 prevented the annual Mississippi River flood pulse from entering the system (Conner and Day 1987, Schramm et al. 2009). Therefore, inundation of the floodplain only occurs during heavy local precipitation events and does not always coincide with the spring spawning season (Sklar and Conner 1979).

Methods

Bowfin Processing, Collection, and Stomach Content Identification

Because bowfin are dispersed on the floodplain and difficult to collect when the ARB floodplain is inundated, sampling of bowfin began when the Atchafalaya River level decreased to 2.8 m at the USACE Butte La Rose gauge (03120) and the floodplain was dewatered (Bonvillain et al. 2013b). Thus, samples were collected in March, April, July, and August of 2017. Water levels in the UBE were also unusually high in May and June 2017 due to heavy local rainfall [Louisiana's Coastwide Reference Monitoring System (CRMS), 0217-H01 gauge].

Bowfin were collected via boat electrofishing (7.5 GPP electrofisher; Smith-Root, Inc., Vancouver, Washington, and fish were maintained in a live well until they were measured (TL mm) in the laboratory. Sex was determined via gross examination of gonads. Stomachs were removed and placed into individually labeled Hubco cloth sample bags (Hubco Inc., Hutchinson, Kansas, USA) and stored in 75% ethanol (Keevin et al. 2007, Manley 2012).

Stomach contents were examined using an illuminated magnification lens or a dissecting microscope. Individual items were identified to the lowest possible taxon, enumerated, and then grouped

as one of seven diet categories including, crayfish, shrimp, insect, amphibian, reptile, fish, and detritus (Toole 1971, Manley 2012).

Analyses

Diets were pooled across months and summarized using proportional composition by number in each diet category. Percent of empty stomachs were compared between basins using Chi square analysis (SAS Institute 2012). Diet overlap between the two basins was determined using the simplified Morisita's index (C) and was calculated as

$$C = (2\sum p_{ij}p_{ik}) / (\sum p_{ij}^2 + \sum p_{ik}^2);$$

where p_{ij} = the proportion of the prey item i used by predator from site j ; and p_{ik} = the proportion of the prey item i used by predator from site k (Garvey and Chips 2012). Morisita's index ranges between 0 and 1 and diet overlap increases as the index approaches 1.

A plot of prey-specific abundance versus frequency of occurrence was used to describe dominant and rare prey and compare the feeding strategy of bowfin between basins (Garvey and Chipps 2012). Prey-specific abundance ranges between 0 and 100 and is calculated as

$$(P_i) = (\sum S_i / \sum S_{ti})100;$$

where P_i is the specific abundance for a diet category; S_i is the total abundance of prey in that diet category; and S_{ti} is the total number of prey in bowfin stomachs that contain prey from diet category i . Based on the prey-specific abundance and frequency of occurrence values, prey can be classified as dominant or rare and feeding strategies can be classified as generalized or opportunistic (Garvey and Chips 2012). For example, prey that have a high (> 50%) prey-specific abundance and high frequency of occurrence are considered dominant prey items; whereas, prey that have a low (< 50%) prey-specific abundance and low frequency of occurrence are considered rare prey items. Prey that have a high prey-specific abundance and low frequency of occurrence indicates an opportunistic feeding pattern. Prey that have a low prey-specific abundance and high frequency of occurrence indicates a generalized feeding pattern.

Results

A total of 232 bowfin were collected from 16 March to 25 August 2017, 89 from the ARB (mean TL = 596 ± 6.1 [SE]) and 143 from the UBE (mean TL = 480 ± 8.2). More than 20 bowfin were collected every sample month, except in April in the ARB when only 2 bowfin were collected. Percent of empty stomachs was similar between fish in the ARB (25.8%) and the UBE (30.1%; $X^2 = 0.320$, $df = 1$, $P = 0.57$). Fish with empty stomachs were excluded from subsequent analysis.

A total of 135 diet items were identified in the stomachs of ARB bowfin, and a total of 294 diet items were identified in the stomachs of UBE bowfin (Table 1). The primary diet item eaten in both basins was crayfish, followed by fish. Fish eaten varied by basin, with bowfin and sunfish (*Lepomis* spp.) composing most of the diet in the ARB whereas bay anchovy (*Anchoa mitchilli*) and unidentified fish were the primary fish eaten by bowfin in the UBE. Not counting unidentified diet items, bowfin in the ARB consumed five diet items and those in the UBE consumed 10 (Table 1).

When grouped into broader categories, diets of bowfin in each basin were relatively similar, with fewer crayfish and more detritus found in bowfin diets in the UBE compared to those in the ARB (Table 2). However, the Morisita's diet overlap index between the basins was 0.978, indicating high overlap in the diets of bowfin between the basins. The plot of prey-specific abundance versus frequency of occurrence indicates that crayfish were a dominant component for bowfin in the ARB and shrimp, insects, reptiles, and amphibians were rare in bowfin diets in the UBE (Figure 2). No insects, reptiles, or amphibians were identified in the diets of bowfin collected in the ARB. Overall, diet patterns of bowfin in both basins indicated that bowfin exhibited an opportunistic feeding pattern, particularly in the UBE (Figure 2).

Table 1. Total number of diet items identified to lowest possible taxon within each diet category. Bowfin were collected in the Atchafalaya River Basin (ARB) and upper Barataria Estuary (UBE) from 16 March to 25 August 2017.

Diet item	Basin	
	ARB	UBE
Fish		
Amiidae		
<i>Amia calva</i>	10	0
Centrarchidae		
<i>Lepomis</i> spp.	20	11
Engraulidae		
<i>Anchoa mitchilli</i>	0	35
Unidentifiable fish	1	24
Insect		
Anisoptera	0	2
Dytiscidae	0	2
Unidentifiable insects	0	5
Shrimp		
Palaemonidae		
<i>Palaemonetes vulgaris</i>	7	19
Crayfish		
Cambaridae	86	152
Amphibian		
Ranidae	0	1
Reptile		
Squamata	0	6
Testudines	0	2
Detritus	11	35
Total stomach items	135	294

Table 2. Total number (proportion in parenthesis) of individual prey items identified in the stomachs of bowfin collected from the Atchafalaya River Basin (ARB; n = number of stomachs used for this analysis) and the upper Barataria Estuary (UBE). The frequency of occurrence (Frequency) is the percent of bowfin that had at least one representative from that diet category.

Category	ARB ($n = 67$)		UBE ($n = 99$)	
	Total (Proportion)	Frequency	Total (Proportion)	Frequency
Crayfish	86 (0.637)	85.1	152 (0.517)	43.4
Shrimp	7 (0.052)	4.5	19 (0.065)	12.1
Insect	–	–	9 (0.031)	9.1
Fish	31 (0.230)	13.4	70 (0.238)	24.2
Amphibian	–	–	1 (0.003)	1.0
Reptile	–	–	8 (0.027)	6.1
Detritus	11 (0.081)	16.4	35 (0.119)	35.4
Total	135		294	

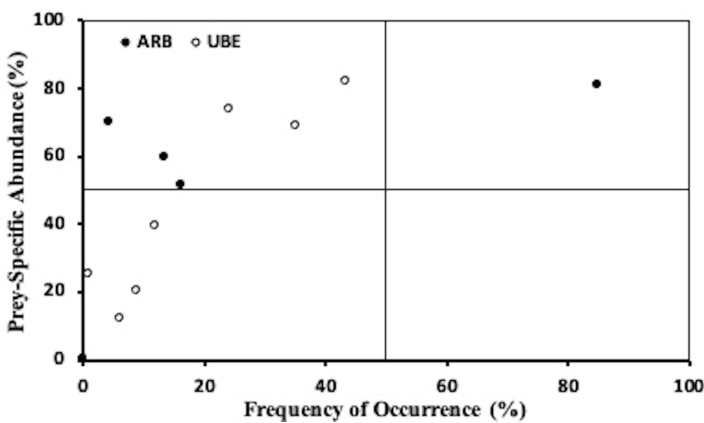


Figure 2. Plot of prey-specific abundance versus frequency of occurrence. The top right quadrant represents diet items that are a dominant diet component as they are frequently found in stomachs and are abundant.

Discussion

Bowfin are adapted to large river floodplain habitats and use the inundated floodplain for spawning and feeding (Dugas et al. 1976, Davis 2006, Koch et al. 2009). Although the UBE has been disconnected from the Mississippi River, bowfin diets had a high degree of overlap between the ARB and UBE. Crayfish composed the largest proportion of bowfin diet items in both basins, but crayfish appear to be more dominant in the diet of ARB bowfin. Similar patterns have been noted for other carnivorous fishes in the ARB and the UBE (Bonvillain and Fontenot 2020). Because the disconnection of the UBE from the Mississippi River has altered the timing and duration of the flood pulse in the UBE, crayfish production may be reduced (Ballinger 2018). Thus, crayfish may not have been a more dominant component of bowfin diets in the UBE because they may not have been as abundant as they are in the

ARB. The wider diversity of diet items in stomachs of UBE bowfin may indicate that the preferred diet of fish and crayfish (Nawrocki et al. 2016, VanMiddlesworth et al. 2017) may not be as available in the UBE as in the ARB. In addition to the dominant presence of crayfish in the diet of bowfin in the ARB, fish and shrimp consumption by bowfin in the ARB and fish consumption by bowfin in the UBE support the opportunistic feeding strategy reported for bowfin (Ross 2001, Nawrocki et al. 2016). The rare occurrence of insect, amphibians, and reptiles in the UBE and the absence of those categories from the ARB may be because we analyzed more individuals from the UBE compared to the ARB.

The disconnection of the UBE from the Mississippi River and subsequent absence or alteration of the flood pulse may limit floodplain dependent production of aquatic organisms that are adapted to an annual flood pulse (Junk et al. 1989, Fontenot et al. 2001, Agostinho-Luz et al. 2008, Raibley et al. 2011). In addition to affecting the hydrology of the UBE, modifications to the Mississippi River have exacerbated coastal land loss in Louisiana (Day et al. 2000, 2007, Martin 2002). Recent projects have reconnected the Mississippi River to the UBE by diverting river water into the surrounding coastal floodplains, including the Barataria Estuary, to reduce saltwater intrusion and slow coastal land loss (Meselhe et al. 2012, Teal et al. 2012, Wang et al. 2014). These diversions can be used to mimic the historic hydrologic regime in the UBE that could enhance production of bowfin and other flood-dependent species by providing seasonal access to spawning grounds, nurseries, and feeding areas (Junk et al. 1989, Wantzen et al. 2002, Alford and Walker 2013, Bonvillain et al. 2013b). Results of this study indicate that bowfin diets are highly similar in each basin, but crayfish are not as dominant of a component of bowfin diet in the UBE compared to the ARB. Also, bowfin in this study appear to have a mostly opportunistic feeding strategy. Therefore, an increase in any prey production, especially crayfish, in the UBE would likely be reflected in the bowfin diet.

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