FfLife history and trophic ecology of gars (Lepisosteidae) in two Mississippi River floodplains with comparisons to other Louisiana populations

A Thesis

Submitted to the Graduate Faculty
of Nicholls State University
in Partial Fulfillment
of the Requirements for the Degree
Master of Science in Marine and Environmental Biology

by
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B.S., Wisconsin Lutheran College, 2017

Summer 2022

Certificate

This is to certify that the thesis entitled "Life history and trophic ecology of gars (Lepisosteidae) in two Mississippi River floodplains with comparisons to other Louisiana populations" submitted for the award of Master of Science to Nicholls State University is a record of authentic, original research conducted by Mr. Derek Sallmann under our supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship, or other similar titles.

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Abstract

Connectivity of large rivers with their floodplains can benefit riverine fishes by providing access to food, additional habitat, and spawning areas. However, due to anthropogenic modifications, floodplain habitats are often disconnected from their associated rivers, potentially limiting ecosystem function. Two restoration projects addressing this issue were initiated in 2020-2021 at floodplain sites in the Lower Mississippi River Basin: Loch Leven (LL) in Mississippi, and Richard K. Yancey Wildlife Management Area (RKY) in Louisiana. Age and growth rates of top predators such as gars (Lepisosteidae) at these sites may serve as indicators of ecosystem health due to their high trophic position and frequent reliance on floodplains for spawning. From June 2020-December 2021, 572 gars (Alligator Gar *Atractosteus spatula*, Longnose Gar *Lepisosteus osseus*, Shortnose Gar *L. platostomus*, Spotted Gar *L. oculatus*) were captured at LL and RKY using gill nets and cast nets, with a subsample from each site retained for analysis of life history, growth, and trophic ecology. Based on sagittal otoliths, several old individuals were identified, including a 56-year-old Alligator Gar, 23-year-old Longnose Gar, 34-year-old Spotted Gar, and the oldest known Shortnose Gar, at 49 years. Trophic position (based on $\delta^{15}N$) was highest in Alligator Gar (3.55 ± SE 0.16, n = 6), followed by Longnose Gar (3.21 ± 0.03, n = 76), Shortnose Gar (3.02 ± 0.02, n = 153), and Spotted Gar (2.92 ± 0.03, n = 107). To investigate differences in growth of gars between Mississippi River floodplains and other ecosystems, Spotted Gar data from LL and RKY were combined into a Mississippi River floodplain group and then compared to Spotted Gar populations from the Atchafalaya River Basin, Upper Barataria Estuary, and a Near-coastal Marsh. Analysis of variance (ANOVA, α = 0.05) indicated that Spotted Gar trophic position and mean length at age of multiple age classes were significantly higher at Mississippi River floodplain sites compared to the Atchafalaya River

Basin, Upper Barataria Estuary, and Near-coastal Marsh. Parameters from von Bertalanffy growth models also suggested that Mississippi River floodplain gars reach a larger maximum size than gars from other Louisiana populations, and ANCOVA (analysis of covariance) indicated Mississippi River floodplain Spotted Gars exhibited significantly higher growth rates. This study created a baseline of life history values for four gar species which can be compared to other systems. Although abundant in some areas of the United States, gar species have been extirpated or are imperiled in several parts of their range. This study's age and growth models suggest that Mississippi River floodplains support faster growth and larger size in gars and may be similarly beneficial to other species. These valuable freshwater ecosystems should be conserved, and other comparable sites should be restored.

Acknowledgements

First of all, I would first like thank God for being with me on the journey to move to another state and for the opportunity to work with gar, which are truly incredible creatures. I feel privileged to have seen and work with some gar that are larger than I am.

I would like to thank Dr. Solomon David for giving me the opportunity to work in the lab and for all the advice, laughs, and gar puns over the years. I thank Mr. Scott Lemmons and TNC, Raynie Harlan and LDWF, the National Fish and Wildlife Foundation, Lower Mississippi River Conservation Committee, Aquatic Ecology and Astacology Lab, Coastal Behavior Ecology Lab, and Bayousphere Research Lab, as well as Shelby, Rick, and Hannah for helping with fieldwork. Without them, our work would not be possible. Additionally thank you to Dr. Alec Lackmann for using his expertise to age our gar and Derek Ogle, Dr. Clay, and Dr. Willis for their help with statistics. Thank you to my committee members, Dr. Tina Whitaker and Dr. Bryan Piazza, for their feedback and comments. I have appreciated getting to work with them and learn from them.

Thank you to Dr. Robert Anderson for helping to guide me on my journey in Marine Biology and for always being supportive and positive.

I would like to thank Gar Lab members Anthea Fredrickson, Sarah Fontana, KristieRae Ellis, Audrey Baetz, and Dinah Cador for for sharing their knowledge, and for the fieldwork we’ve done together. Thank you to the NSU graduate students for their assistance in the lab and field, Dr. John Lyons for his guidance, and Manu Kumar Gundappa for his gar illustrations.

Thank you to my mom and dad, grandma, grandpa, and brother Ryan for believing in me, talking to me on the phone while I’m away, and for always being there when I need them.

Lastly, I would like to thank my girlfriend Claire for supporting me, going on adventures with me, and sharing in my love of wildlife.

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Introduction

The flood pulse is an important component of riverine ecosystems - a periodic discharge of water that may overflow into floodplains (Junk et al. 1989; Bayley 1995; Silva 2020). Floodplains are areas that are periodically inundated by lateral river overflow, precipitation, or groundwater, causing biota to respond and adapt, producing new communities (Junk et al. 1989). Floodplains serve an important role in providing additional habitat, food, and spawning areas for riverine fish species (Junk et al. 1989; Bayley 1995; Ropke et al. 2015). Fishes with access to floodplain habitats may also have higher growth rates and access to more prey while also encountering fewer predators (Rypel 2012). However, due to anthropogenic modification such as levees, fish are often disconnected from these habitats, limiting access to these benefits (Pander et al. 2019).

The Mississippi River has been heavily modified with levees that have disconnected the river from much of its original floodplains (Klimas 1989; Baker et al. 1991). Large sections of levees were created under the Flood Control Act of 15 May 1928, which initiated the Mississippi River and Tributaries (MR&T) project, authorizing the construction of 6094.60 km of embankments and floodwalls with nearly 3566.30 km on the main stem of the Mississippi River (DeHaan et al. 2012). River modifications have also affected the length and intensity of the flood pulse, which may negatively affect fish species (Baker et al. 1991; Pander et al. 2019). For example, Spotted Gars *Lepisosteus oculatus* in Louisiana have been found to increase movements as a result of higher temperature and water level rise, signaling them to move into floodplains for spawning (Snedden et al. 1999). If floodplains are not inundated for the appropriate duration, Spotted Gar spawning may not be successful. Jeffres et al. (2008) also found that juvenile Chinook Salmon *Oncorhynchus tshawytscha* grew faster in enclosures, simulating floodplain habitats compared to riverine habitats. If access to floodplain habitats becomes inhibited, juvenile Chinook Salmon may have slower growth rates.

Acknowledging the importance of floodplain connectivity, efforts have been made by multiple organizations to restore connectivity between rivers and their floodplains (Pander et al. 2019). In the Lower Mississippi River basin, two sites are being used for connectivity restoration projects. At Loch Leven (LL), Mississippi, The Nature Conservancy (TNC) built a water control structure (WCS) to moderate the flood pulse and manage water as it moves in and out of the floodplain. At the Richard K. Yancey Wildlife Management Area (RKY) in Louisiana, the Louisiana Department of Wildlife and Fisheries (LDWF) and Lower Mississippi River Conservation Committee (LMRCC) removed and replaced culverts and a weir to increase aquatic connectivity. Although restoration is important, monitoring is also critical to evaluate if changes are having a positive effect on fish communities.

Life history of floodplain fishes may provide insights into the effects of restoration and highlight differences in populations of fish between sites (Crampton 2008; David et al. 2015). Spatial variation in size, sex ratio, and age among species populations can provide information about floodplain habitat use. For example, age, sex, and size of fishes using the floodplain may indicate where mature females are spawning (Johnson and Noltie 1996). Accurate age estimates of fishes may also provide information about life history traits such as recruitment, mortality, and growth (Hilborn and Walters 1992; Ferrara 2001; Daugherty et al. 2020). Comparisons of population demographics between sites can also inform species management (Olden et al. 2006). Life history of American Paddlefish *Polyodon spathula* has been used to advise stewardship and stocking (Zigler 2009) and life history of Largemouth Bass *Micropterus salmoides* and Shoal Bass *M. cataractae* has been used to advise fisheries management (Sammons et al. 2019). Aging of "rough fish," species historically seen as low-value by fisheries managers and anglers (Burr 1931; Johnston 1961; Rypel et al. 2021), can also provide novel understanding of the life history of previously understudied species (Lackmann et al. 2019). Lackmann et al. (2019) found that Bigmouth Buffalo *Ictiobus cyprinellus* can live up to 112 years, quadrupling previous longevity estimates, which may have impacts on future management decisions. Sauer et al. (2021) also found that Bigmouth Buffalo seemed resistant to aging and may exhibit immune system improvements with age.

Monitoring species diversity and abundance in floodplain ecosystems is another way to measure success of aquatic connectivity projects and is important to ensure the effects are beneficial to target species (Stoffels et al. 2014). Monitoring can also help fisheries managers develop effective strategies for future restoration (e.g., adding a water control structure versus removing barriers to fish passage). Diverse communities of native fishes, including "rough fishes" such as gars and suckers, may be more beneficial to the environment than having high numbers of traditionally more desirable game species, such as Largemouth Bass *Micropterus salmoides* and Bluegill *Lepomis macrochirus* (Scarnecchia 1992; Lyons et al. 2001). The presence of juvenile fishes in multiple habitat types can also indicate successful use of floodplains by different life stages of riverine fishes (Junk et al. 2014).

Trophic Ecology is another concept for investigating resource use by comparing feeding positions of organisms (Vander Zanden and Rasmussen 1999; Nawrocki et al. 2020). To calculate trophic position, isotopic ratios of nitrogen ($\delta^{15}N$) can be used to estimate an organism's position on the food web (Minagawa and Wade 1984, Peterson and Fry 1987; Keppeler 2019). Lewis et al. (2001) also used stable isotopes to construct food webs in the Orinoco floodplain in Venezuela, and Tilcock (2019) used isotopes to track floodplain rearing of juvenile Chinook Salmon. Changes in isotopic signatures over time may indicate trophic position in floodplains and provide information about habitat use (Fry 2002).

Indicator species can also be used to assess the efficacy of restoration. In the Lower Mississippi River basin, gars (Lepisosteidae) can serve as indicator species because of their role as top predators and reliance on floodplains for spawning (Ferrara 2001; David et al. 2018). Species at higher trophic positions such as gars may be more likely to experience negative effects of food web disruption (Petchey et al. 2004), therefore, the continued presence of apex predators such as gars may serve as evidence of food web stability. Four species of gars are native to the lower Mississippi River Basin: Alligator Gar *Atractosteus spatula*, Spotted Gar *Lepisosteus oculatus*, Longnose Gar *L. osseus*, and Shortnose Gar *L. platostomus*. Historically, gars have been persecuted for their purported consumption of game fish, and management techniques were implemented to reduce or eliminate gar populations (Scarnecchia 1992). Recently, more attention has been placed on gars and other "rough fishes", and management practices have started to shift to include these species in their management strategies (Scarnecchia 1992; David et al. 2018; Smith et al. 2019; Rypel et al. 2021).

One species of gar that has garnered particular attention is also the largest: Alligator Gar. Alligator Gar migrate into floodplain habitats during spring months to spawn (Buckmeier et al. 2013; Van der Most and Hudson 2018). In 2008, the Alligator Gar was listed as "vulnerable" by the American Fisheries Society (Jelks et al. 2008), when populations declined mostly due to hydrologic alterations (Allen et al. 2014; Robertson et al. 2018). Allen et al. (2014) found that there is limited suitable habitat for Alligator Gar spawning left in the Mississippi River corridor, suggesting that suitable habitats on floodplains are critical for the continued survival of the species. Unregulated bowfishing has also removed large adults from the population, potentially leading to decline (Scarnecchia and Schooley 2020). Alligator Gars are also slow to mature (normally 5-10 years for females), making them especially vulnerable to extirpation (Ferrara 2001, Buckmeier et al. 2016).

The purpose of this study is to assess the impacts of restoration activities by TNC and LDWF/LMRCC on the fish communities, using gars as indicator species. If significant differences are found in fish diversity, abundance, age, growth, or trophic position in the floodplains, then it will reinforce the idea that restoration may impact riverine fish species. Gars spawning in restored areas can also be used as an indicator of success in future restoration projects if creating spawning habitat is a goal of fisheries managers.

I hypothesized that gar populations at LL and RKY would be similar in life history, given the two sites' close proximity to each other. As gars move in and out of floodplains, some likely move back into the main channel of the Mississippi River which may lead to similar populations, even if they inhabit different floodplains during the high-water season. For comparisons with other populations, I hypothesized that Spotted Gar populations from ecosystems that receive a regular flood pulse would have similar life history characteristics and trophic ecology compared to Spotted Gar populations from systems that do not receive a consistent flood pulse.

OBJECTIVES

1. Compare gar populations at Loch Leven and Richard K. Yancey restoration sites

2. Compare life history and population demographics (age, sex, and growth) of gars within and between LL and RKY sites

3. Use Stable Isotope Analysis to explore patterns in trophic ecology of gars within and between LL and RKY

4. Compare Mississippi River Floodplain gar populations with other Louisiana aquatic ecosystems, using Spotted Gar as a model species.

Methods

Loch Leven

This study focused on gar populations within two Mississippi River floodplain restoration sites known as Loch Leven (LL) and the Richard K. Yancey Wildlife Management Area (RKY) (Figure 1). Loch Leven is a privately owned 2,470-hectare floodplain in Wilkinson, Mississippi, that became part of the Wetlands Reserve Program in the early 2000s. The optional program helps landowners with wetland restoration and conservation by providing technical and financial support (Forshay et al. 2005). In the 1840s, the construction of a ring levee disconnected the Mississippi River and the LL floodplain for about 180 years, with the only connection being a 1.0 m diameter pipe. In some years, extremely high water did top the levee and enter the floodplain, resulting in irregular inundation. Land use data from 2012 (Conservation Biology Institute 2022) showed that LL is composed of approximately 27.3% Soybean (7.1 km^2), < 0.1% Idle Cropland (< 0.1 km^2), 55.5% Grassland Herbaceous/Pasture/Hay (14.4 km^2), 4.6% open water (1.2 km^2), < 0.1% Developed Land (< 0.1 km^2), 0.8% Barren Land (0.2 km^2), 3% Winter Wheat (0.1 km^2), and 11.4% Herbaceous or Woody Wetland (3.0 km^2). To reconnect the Mississippi River with LL, The Nature Conservancy (TNC) completed installation of a 2.5 m wide by 3.0 m high Water Control Structure (WCS) in November of 2020, which allows manual control of water coming into and leaving the floodplain, unless water levels top the WCS (Ellis 2021). In the spring of 2021, the levee bordering the WCS failed, which required draining water off the floodplain for reconstruction in summer 2021. The LL floodplain is bordered by Lake Mary, an oxbow lake, on the north, east, and south side, and by the Mississippi River on the west. During low water, fish are concentrated in an approximately 42 ha reservoir on the northeast edge of the floodplain known as “Blue Lake”.

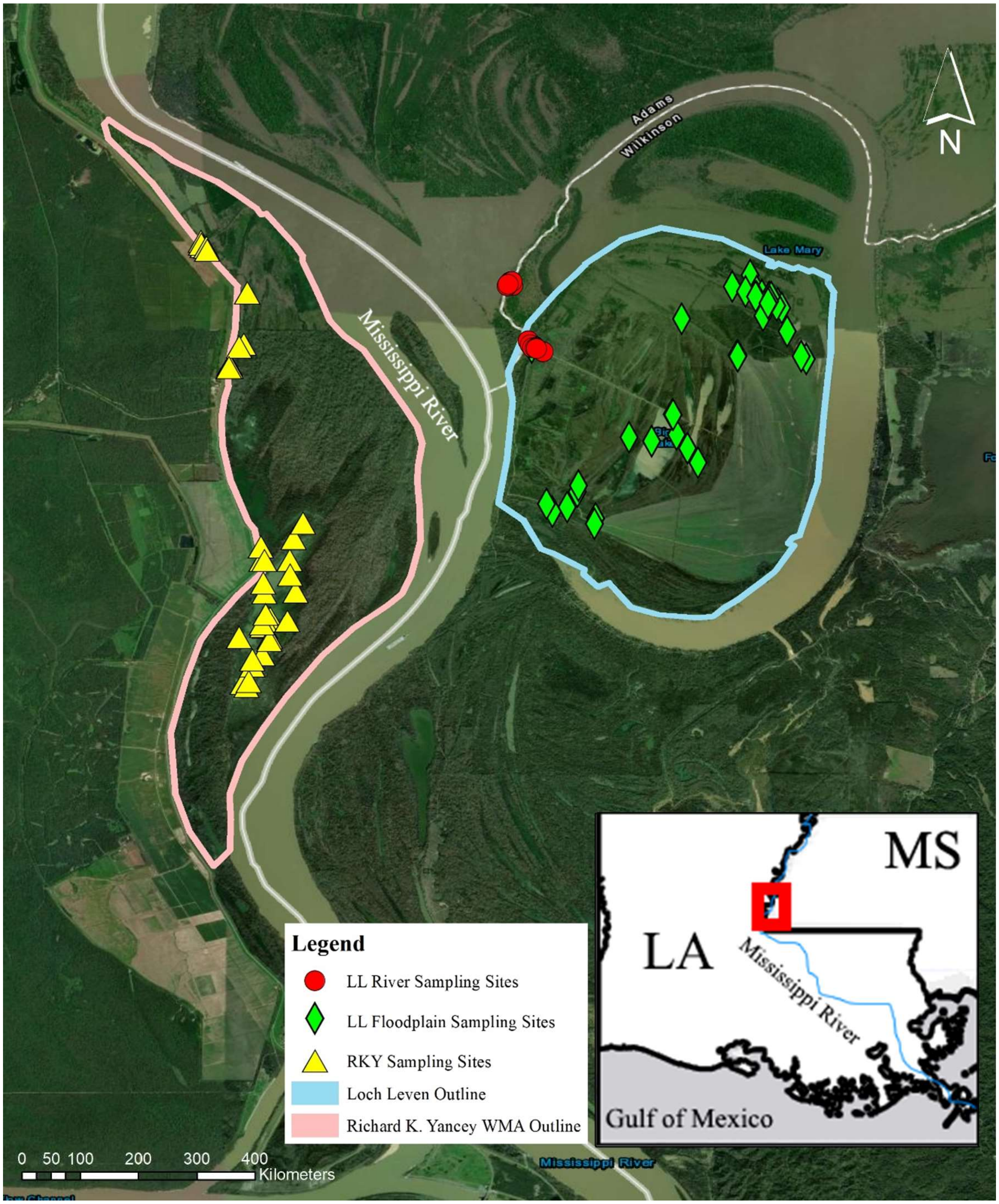

Figure 1. Sampling areas representing the Loch Leven floodplain in Wilkinson, Mississippi, and the Richard K. Yancey Wildlife Management Area floodplain in Vidalia, Louisiana. Both sites are inundated by the Mississippi River. Outline of Louisiana in inset map adapted from Natasha Sinegina (CC by 4.0) https://creativecommons.org/licenses/by/4.0/.

Richard K. Yancey Wildlife Management Area

Richard K. Yancey Wildlife Management Area in Vidalia, Louisiana is an approximately 28,681 ha wildlife management area that is relatively flat with poor drainage, containing a series of small lakes and bayous. Levees and an artificial sand ridge are the only sources of elevation, with Louisiana Highway 15 and a levee bisecting the management area. The study area at RKY is approximately 2,1577 ha and is east of Highway 15 and west of the Mississippi River. Within the study area, culverts and a weir are being removed and replaced by the Louisiana Department of Wildlife and Fisheries (LDWF) to re-establish connectivity between the Mississippi River and its floodplains. The culverts are intended to enhance fish passage within the management area and the weir is intended to retain water on the floodplain for a longer duration. Currently, at low water, a series of three lakes at RKY called the Blackhawk Scar Lakes remain inundated year-round but are only seasonally connected after the weir that once held water in the lakes became too degraded to function (LMRCC 2020). A series of barrow pit culverts also remain inundated with water year-round. Land use data from 2012 (Conservation Biology Institute 2022) showed that the study area is composed of approximately 0.2% Soybean (< 0.1 km^2), 0.1% Idle Cropland (> 0.1 km^2), 7.9% Grassland Herbaceous/Pasture/Hay (1.7 km^2), 5.1% open water (1.1 km^2), 0.7% Developed Land (0.2 km^2), 0.3% Barren Land (0.1 km^2), < 0.1% Winter Wheat (< 0.1 km^2), and 85.8% Herbaceous or Woody Wetland (18.5 km^2). The restoration goals at RKY are to provide stable and connected lake habitat within the Blackhawk Scar Lakes for fish and other wildlife, to allow improved access for anglers to these areas, and to enhance fish passage through culverts by allowing increased access to floodplain areas (LMRCC 2020). Studies at both sites occurred as restoration activities were being implemented from summer 2020 – winter 2021.

Fish Data Collection

Gill nets (21.3 m long, 1.2 m depth, 5.0 and 7.0 cm m bar mesh; 45.7m long, 1.2 m depth 9.0 cm bar mesh; 15.2 m long, 1.2 m depth, 13.0 cm bar mesh, 45.7 m long, 3.0 m depth, 13.0 cm bar mesh), jug lines (6), and cast nets (1.8 m diameter; 1.3 cm bar mesh) were used to collect fishes at LL and RKY depending on water levels and site access. Sampling events occurred between 0600 and 1900 hours. All fishes collected were identified to species, measured for total length (TL, mm), and a representative photograph of each species was taken at both LL and RKY Sites. All gars (Lepisosteidae) were identified and measured (total length, standard length, snout length, and head length), and a subsample of gars were euthanized, placed on ice, and taken back to the lab for life history analysis. A fin clip (approximately 2.5 x 2.5 cm) was also taken from the caudal fin of each gar for stable isotope analysis of carbon and nitrogen (Figure 2). Dissolved oxygen (mg/L), pH, Secchi disk depth (cm), flow (m/s), and air and water temperature (°C) were also recorded at each sample site during each visit.

Life History and Population Demographics

Euthanized gars were frozen until dissection. Gars were thawed, cut open ventrally (vent to isthmus), and sex was determined by presence/absence of ovaries, testes, and characteristics of gamete release pathways (Ferrara and Irwin 2001). Sagittal otoliths were removed from each fish, rinsed with deionized water, and dried (Figure 3). Otoliths were sent to Alec Lackmann at the University of Minnesota Duluth to be thin-sectioned for aging based on King et al. (2018) and Lackmann et al. (2019). Age and length of gars were compared between sites using ANOVA, and sex ratio was compared using a proportions test to see if populations were significantly different than 1:1. Von Bertalanffy growth curves were also created in the statistical program "R" to model growth of gars (Fabens 1965) in the Mississippi River. Young-of-year

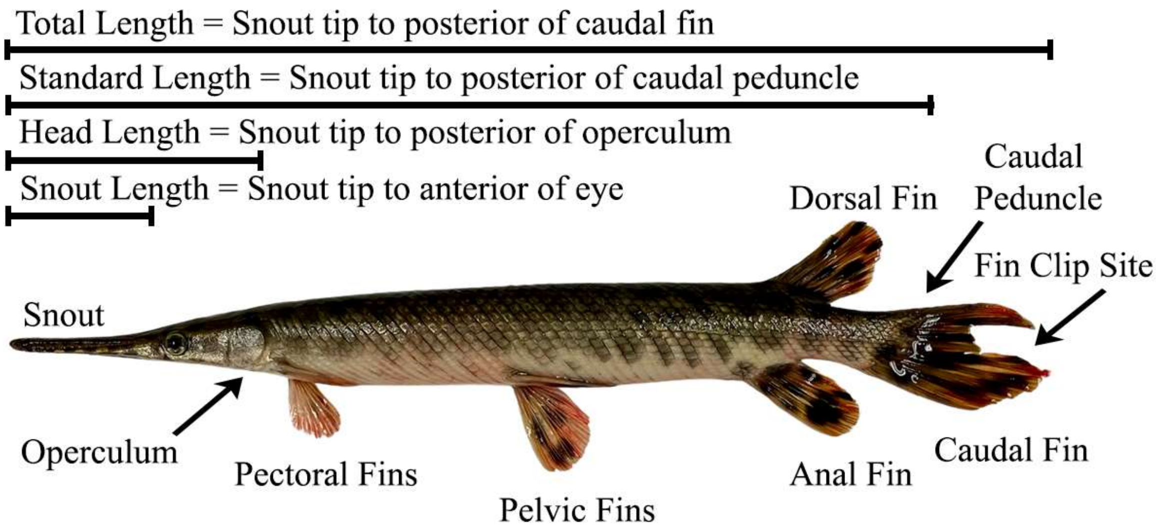

Figure 2. Description of gar measurements, anatomy, and location of fin clip sample on a Spotted Gar. Photo by Solomon R. David.

Figure 3. Sagittal otoliths from a Shortnose Gar with scale in cm. Photo by Solomon R. David.

gars with undetermined sex were included in both male and female growth curves. The typical von Bertalanffy (VB) growth equation was used to estimate growth parameters for gar populations:

$$L_t = L_\infty (1 - e^{-K(t - t0)})$$

Model parameters L_t is length at age t, L_∞ is the asymptote of the average length-at-ages (Francis 1988), K is a growth coefficient (Ricker 1975), and t_0 is a modeling artifact, meant to adjust for the initial size of the fish at age 0. For analysis, 95% confidence intervals were used to compare L_∞ and K values between gar populations. Due to a lack of young individuals at RKY, the length and age at hatch of 30 Spotted Gar from Fontana (2020) were included in Spotted Gar von Bertalanffy models for LL and RKY. Von Bertalanffy growth curves were not fit for male Alligator Gar due to sample size. Female Alligator Gar (n = 3) data were supplemented with young Alligator Gar (< 4 years old) from a Near-coastal Marsh (NCM) site in Chauvin, Louisiana (n = 3) to create a model for Louisiana populations of female Alligator Gar.

Stable Isotope Analysis

Fin clips were taken from the distal area of the caudal fin of each gar collected for stable isotope analysis ($\delta^{13}C$ and $\delta^{15}N$) and were used in place of muscle tissue (Fredrickson et al. 2022). A subsample of primary consumers (Grass Shrimp *Palaemonetes paludosus*) was also taken for baseline isotope analysis. Tissue from gars and baseline organisms were frozen after collection and individually placed in a drying oven at 60°C for at least 24 hours for fin clips and over 48 hours for baseline samples. Baseline organisms of the same species were combined into multiple samples (depending on the number collected) by site visit before being ground into a fine powder using a mortar and pestle and weighed. Gar fin clips were ground using a mortar and pestle and weighed individually. Sample weight for baseline organisms and gar fin clips was between 1.00 mg and 4.00 mg. Each sample was placed in an Eppendorf tube and sent to the Cornell Isotope Lab for stable isotope analysis using a Finnigan MAT Delta Plus IRMS coupled to an elemental analyzer (Carlo Erba NC2500). Isotope values are listed per mil (‰) deviation from the International Atomic Agency standards (atmospheric nitrogen for $\delta^{15}N$ and Vienna Pee-Dee Belemnite for $\delta^{13}C$) and calculated using the following equation:

$$[(R_{sample} - R_{standard}) / R_{standard}] \times 1000 = d_{sample\text{-}standard}$$

Due to the possibility of $\delta^{15}N$ enrichment, it is necessary to correct $\delta^{15}N$ values using baseline organisms (Cabana and Rasmussen 1996; Vander Zanden and Rasmussen 2001). Baseline nitrogen values were used to determine the trophic position of gars, along with a trophic fractionation constant of 3.4, and a value of 2 used to represent the trophic position of primary consumers in the following equation (Vander Zanden and Rasmussen 2001; Post 2002):

$$\text{Trophic Position of consumer} = [\delta^{15}N \text{ Consumer} - \delta^{15}N \text{ Primary Consumer})/3.4] + 2$$

Trophic position of gars was compared by site and by species using ANOVA, followed by a Tukey's post hoc analysis when necessary. Young-of-year (YOY) gar trophic position from LL was also compared between species using ANOVA and Tukey's post hoc analysis.

Additional Comparisons

To make additional comparisons with other populations of gars in Louisiana, Spotted Gars from Little Bayou Sorrel in the Atchafalaya River Basin (ARB), Bayou Chevreuil in the Upper Barataria Estuary (UBE) and a near-coastal Marsh (NCM) in Chauvin, LA were collected (Figure 4). Gars from ARB and UBE were collected in 2019 using a 7.6 GPP boat electrofisher. A subsample of yearling gars was also collected from UBE in spring 2022. Spotted Gars were collected from NCM using 5.0 cm and 7.0 cm gill nets from 2019 – 2021. Spotted Gars from LL and RKY were combined into a Mississippi River Floodplain (MRFP) group and compared to

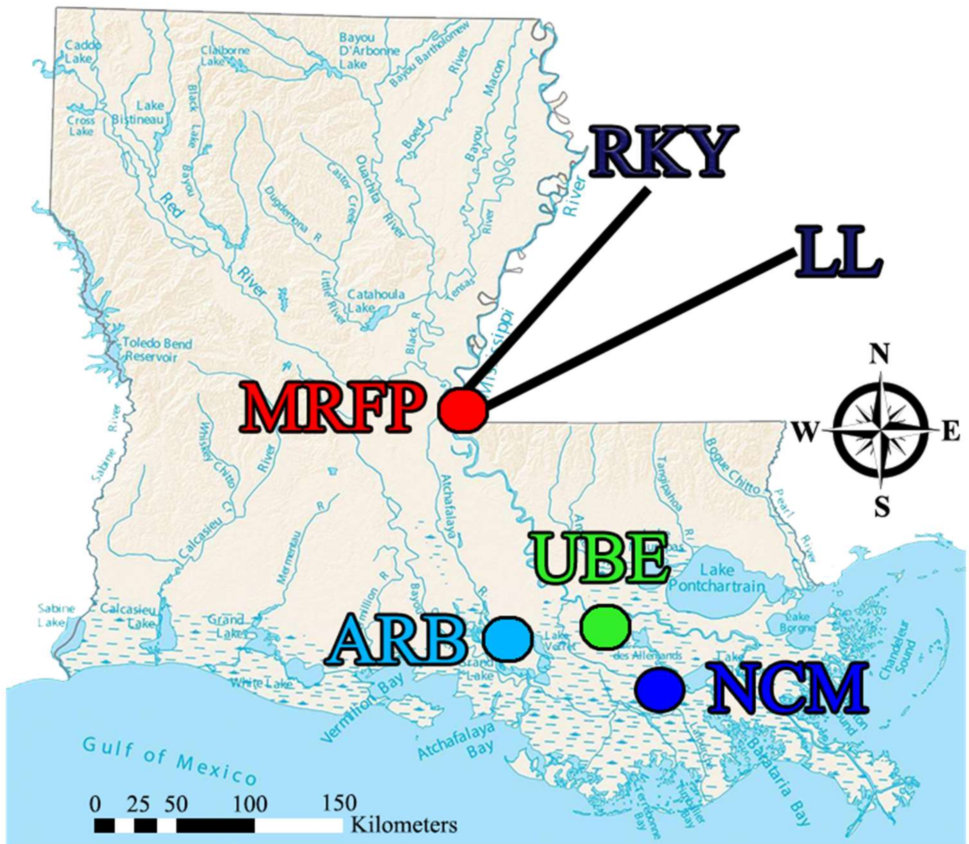

Figure 4. Sampling locations for Spotted Gar populations. Loch Leven (LL), Mississippi, and Richard K. Yancey Wildlife Management Area (RKY), Louisiana, Spotted Gars were combined into a Mississippi River Floodplain (MRFP) group and compared to Spotted Gars from a Near-coastal Marsh (NCM) near Chauvin, LA, Little Bayou Sorrel in the Atchafalaya River Basin (ARB), and Bayou Chevreuil in the Upper Barataria Estuary (UBE). Map adapted from GISGeography 2022.

gar populations from the other sites. Mean age and length of populations was compared using ANOVA and Tukey's post hoc test. Young-of-year gars were not collected for ARB and NCM Spotted Gar populations.

Von Bertalanffy Growth parameters were also estimated using the typical von Bertalanffy growth equation and compared using 95% Confidence intervals. Due to a lack of young individuals collected at ARB and NCM sites, the length and age at hatch of 30 Spotted Gar from Fontana (2020) were included in all Spotted Gar von Bertalanffy models. Young-of-year gars with undetermined sex were included in both male and female growth curves. Mean length at age of Spotted Gars to age 10 was compared using ANOVA and followed by a Tukey's post hoc test if more than two values were compared. Analysis of covariance (ANCOVA) was used to compare the growth rates of Spotted Gars from hatch to three years of age, which also included the lengths at hatch of 30 Spotted Gar from Fontana (2020). Trophic position values were compared using ANOVA and Tukey's post hoc test. Snails were used as baselines for trophic position calculations (Apple Snails *Pomacea maculata* were collected from the UBE, Amber Snails from family Succineidae were collected from the ARB, and Ramshorn Snails (family Planorbidae) were collected from the MRFP). Isotope samples were not processed from NCM Spotted Gars.

Results

Abundance and Length of Gars

A total of 572 gars were captured in the Loch Leven (LL) and Richard K. Yancey Wildlife Management Area (RKY) sites from 2020-2021. Six sampling trips took place in the Loch Leven (LL) floodplain in 2020, resulting in the collection of 214 gars (Table 1). In 2021, five sampling trips occurred, resulting in the capture of 275 gars. From 2020-2021, five sampling trips occurred at the Richard K. Yancey Wildlife Management Area, resulting in the collected of 83 gars (Table 2). The greatest number of gars were collected on July 9th at LL, where young-of-the-year (YOY) Shortnose Gar and Spotted Gar were abundant, resulting in a total of 167 gars collected from one sampling trip. During the two-year sampling period, YOY of all four gar species were collected at Loch Leven (Table 3). Although, no YOY gars were collected at RKY, young-of-the-year Spotted Gars were observed at the site during spring of 2021 (Audrey Baetz personal communication). Shortnose Gars were the most abundant species found at both LL and RKY sites, followed by Spotted Gars, Longnose Gars, and Alligator Gars (Figure 5). One large Alligator Gar was collected in Loch Leven on August 6th, 2021 measuring 2450.00 mm in total length. Over two years, only nine Alligator Gars were caught at LL, and only one individual was caught at RKY. Mean length of Longnose Gars was significantly larger at LL, compared to RKY ($P < .05$), and mean lengths of the other gar species were not significantly different between sites (Figure 6). All other fish species collected are reported in Appendix A.

Age and Sex of Gars

The oldest gar found during this study was a 56-year-old female Alligator Gar from LL. The oldest Shortnose Gar (a 49-year-old male) and oldest Longnose Gar (a 23-year-old male) were both found at LL. The oldest Spotted Gar was a 34-year-old female collected at RKY.

Table 1. Using gill nets and cast nets, a total of 214 gars were collected from Loch Leven between June 11th 2020 and November 13th 2020, and a total of 275 gars were collected from Loch Leven between April 30th 2021 and December 9th 2021.

Common Name	Family	Species Name	Loch Leven			2020			Total
			June 11th	June 18th	July 9th	July 21st	Sept. 17th	Nov. 13th	
Alligator Gar	Lepisosteidae	*Atractosteus spatula*	-	-	-	2	1†	-	3
Longnose Gar	Lepisosteidae	*Lepisosteus osseus*	19	13	15	4	4	6	61
Shortnose Gar	Lepisosteidae	*Lepisosteus platostomus*	17	11	14	15	10	29	96
Spotted Gar	Lepisosteidae	*Lepisosteus oculatus*	6	7	9	9	9	14	54
Total			**42**	**31**	**38**	**30**	**23**	**49**	**214**

†Escaped prior to landing

Common Name	Family	Species Name	Loch Leven		2021			
			April 30th	June 6th	July 9th	Aug. 5th-6th	Dec. 9th	Total
Alligator Gar	Lepisosteidae	*Atractosteus spatula*	-	-	-	4	2	6
Longnose Gar	Lepisosteidae	*Lepisosteus osseus*	3	3	-	2	7	15
Shortnose Gar	Lepisosteidae	*Lepisosteus platostomus*	1	7	146	25	39	218
Spotted Gar	Lepisosteidae	*Lepisosteus oculatus*	-	4	21	4	7	36
Total			**4**	**14**	**167**	**35**	**55**	**275**

Table 2. A total of 83 gars were collected from Richard K. Yancey WMA between October 16th 2020 and October 22nd 2021 using gill nets and cast nets.

Common Name	Family	Species Name	Richard K. Yancey WMA		2020-2021			
			Oct. 16th	Nov. 18th	June 16th	July 28th	Oct. 22nd	Total
Alligator Gar	Lepisosteidae	*Atractosteus spatula*	-	-	1	-	-	1
Longnose Gar	Lepisosteidae	*Lepisosteus osseus*	2	5	2	1	-	10
Shortnose Gar	Lepisosteidae	*Lepisosteus platostomus*	1	22	1	-	4	28
Spotted Gar	Lepisosteidae	*Lepisosteus oculatus*	8	8	11	9	8	44
Total			**11**	**35**	**15**	**10**	**12**	**83**

Table 3. Mean (±SD) total length (mm) and range of total lengths (mm) of gars collected from LL and RKY sites between 11 June 2020 and December 2021. Total Length abbreviated as TL.

Species		Location	n	Mean TL (mm)	Range (mm)
Longnose Gar	Adult	LL	64	1001.15 ± 146.78*	630.00 – 1330.00
		RKY	10	824.90 ± 185.22	582.00 – 1230.00
		Both	74	977.61 ± 164.05	582.00 – 1330.00
	YOY	LL	2	318.00 ± 46.00	272.00 – 364.00
Shortnose Gar	Adult	LL	177	677.67 ± 53.73	550.0 – 893.00
		RKY	28	665.18 ± 37.42	586.00 – 735.00
		Both	205	687.14 ± 73.99	550.00 – 893.00
	YOY	LL	51	366.28 ± 79.72	191.00 – 505.00
Spotted Gar	Adult	LL	58	636.53 ± 70.27	512.00 – 875.00
		RKY	44	628.20 ± 98.42	426.00 – 871.00
		Both	102	676.48 ± 51.57	512.00 – 875.00
	YOY	LL	19	238.26 ± 71.28	162.00 – 498.00
Alligator Gar	Adult	LL	6	1623.50 ± 532.06	911.00 – 2450.00
		RKY	1	625.00	625.00
		Both	7	1480.86 ± 603.93	625.00 – 2450.00
	YOY	LL	2	31.45 ± 0.92	308.00 – 321.00

*Represents significant difference between LL and RKY sites

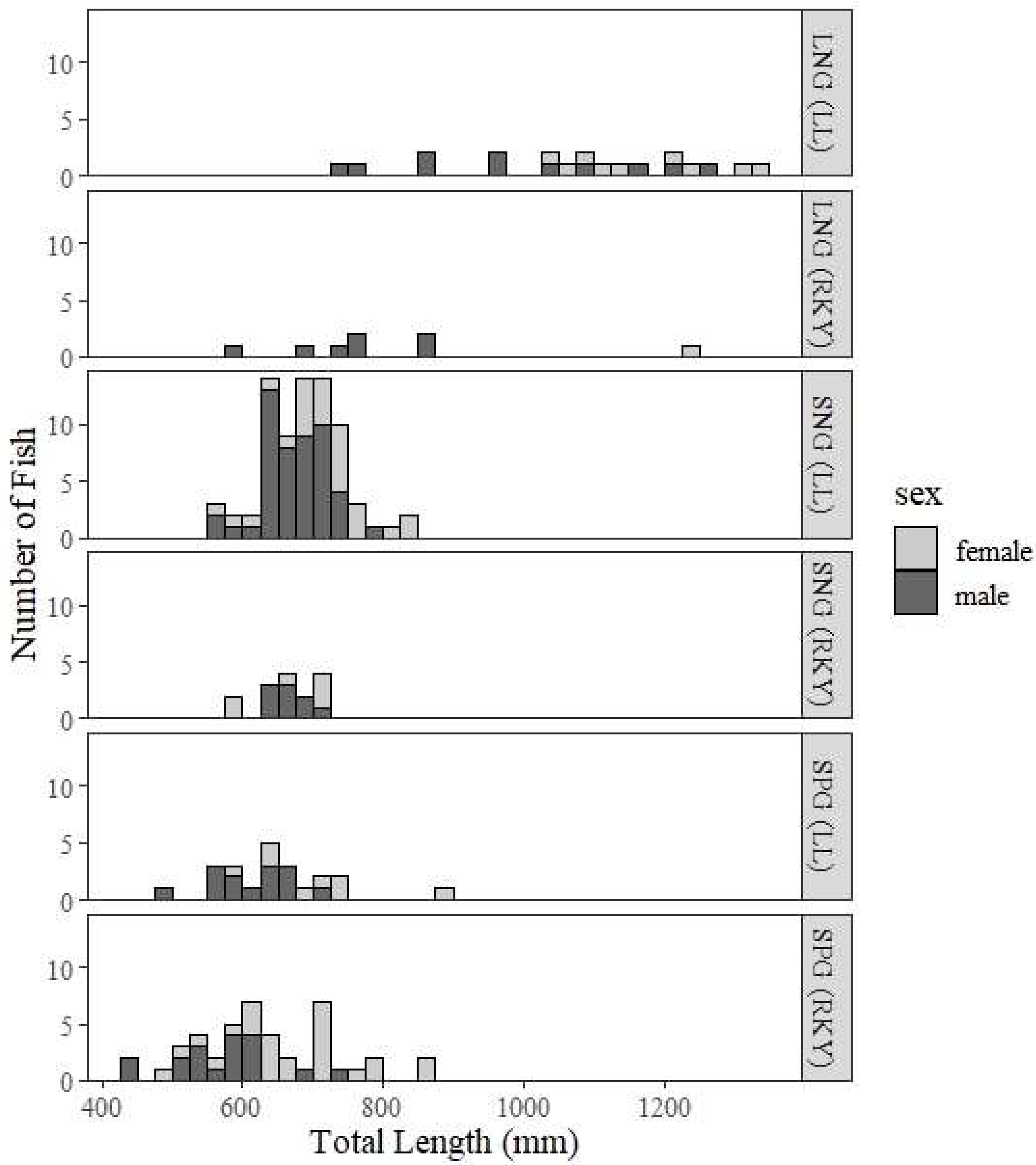

Figure 5. Lengths of adult gars collected at Loch Leven, MS (LL), and Richard K. Yancey Wildlife Management Area, LA (RKY). Gar species have the following abbreviation: Spotted Gar (SPG), Longnose Gar (LNG) and Shortnose Gar (SNG). Alligator Gars (ALG) were not included due to low sample size.

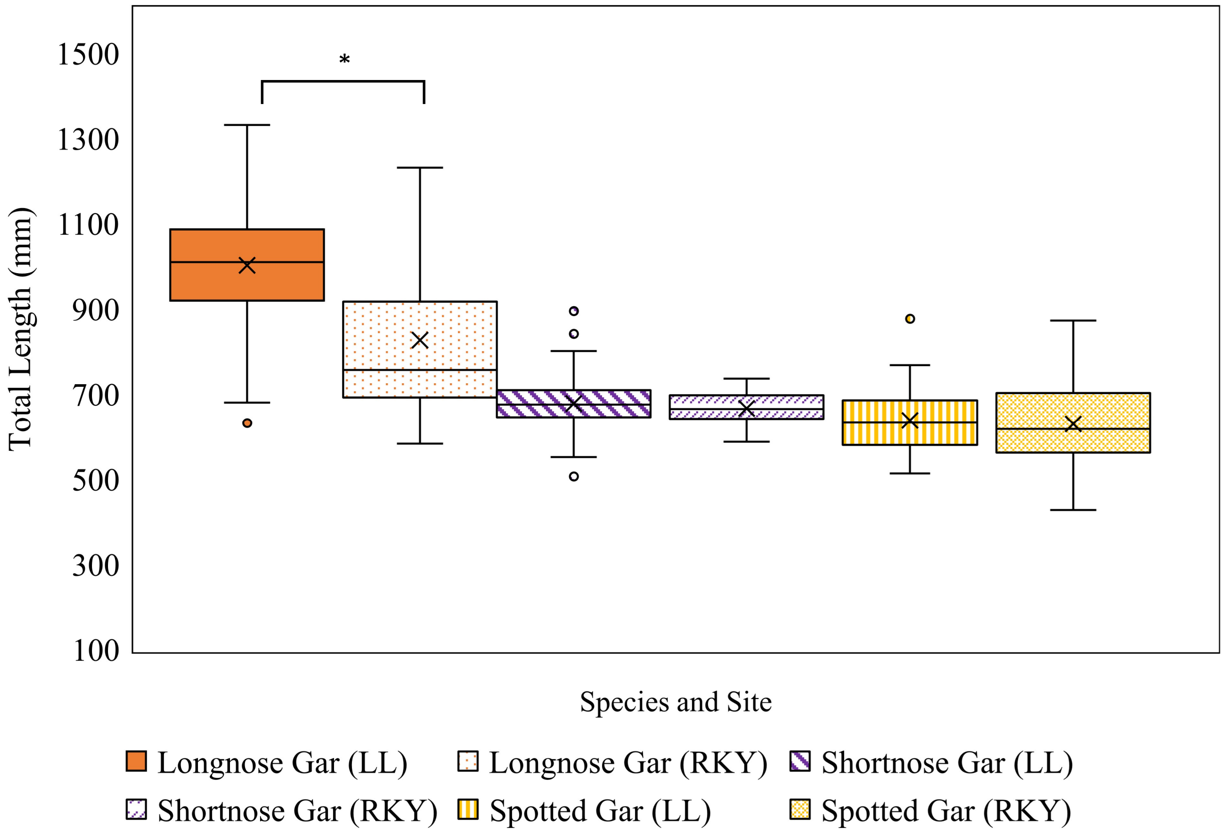

Figure 6. Box and whisker plots of gar total length from Loch Leven (LL), MS, and Richard K. Yancey WMA (RKY), LA. Alligator Gar were not included due to low sample size. Asterisk indicates significant differences in mean length between Longnose Gars from LL (n = 64) and RKY (n = 10). Mean length of Shortnose Gar at LL (n = 177) and RKY (n = 28) and Spotted Gar from LL (n = 58) and RKY (n = 44) were not significantly different. The "X" is indicative of mean total length (mm).

Composite images of thin-sectioned sagittal otoliths for the oldest individual from each species are shown in Figure 7. At RKY, only Shortnose Gar displayed significant differences in mean age based on sex (♀ = 4.00 years ± SD 1.53, n = 6, ♂ = 5.78 ± SD 1.40, n = 9) and only female Spotted Gars (669.54 mm ± 92.53, n = 26) were significantly longer than males (568.50 mm ± 72.64, n = 18) (Table 4). At LL, mean lengths of Longnose, Shortnose, and Spotted Gar females were all significantly longer than mean lengths of males, and no species were significantly different in age based on sex (Table 5). In the combined Mississippi River Floodplain group (Gars from RKY and LL), mean total length for females of all gar species was significantly longer compared to males of the same species (Table 6). Ages between males and females were not significantly different. Shortnose Gars at LL and Shortnose Gars in the combined MRFP group had significantly different sex ratios with more males than females in both groups. Sex ratios of gar species between and within LL and RKY sites were not significantly different.

Water Quality and River Stage

Temperature (°C), conductivity (µS/cm), dissolved oxygen (mg/L), percent dissolved oxygen (%), and Secchi depth were taken at each gillnet site when possible. Water quality values are denoted in Tables 7 and 8. Mean and standard deviation were calculated if multiple readings were taken at different locations within the same site. Sampling locations were divided into two sections. Richard K. Yancey WMA was separated by sites in the Blackhawk Scar Lakes and their floodplains, and "Culvert" sites that encompassed sampling locations in barrow-pit culverts. Loch Leven was separated into "Floodplain" sites that included sampling locations in the Loch Leven floodplain and "Blue Lake". Sampling locations at the WCS and the "Narrows", a tributary connecting Lake Mary to the Mississippi River were considered "Riverine" sites. During 2021, the Mississippi River had an abnormally high flood pulse. Mississippi River gage

Figure 7. Composite images of thin-sectioned sagittal otoliths from the oldest aged gars in the Mississippi River Floodplain (Loch Leven, MS and Richard K. Yancey, LA sites combined) from four species, Alligator Gar, Longnose Gar, Shortnose Gar, and Spotted Gar. Images by Alec Lackmann.

Table 4. Male and female sex ratio, mean age (years) ± SD, age range, and mean total length (TL, mm) ± SD of aged and sexed subsample of gars from Richard K. Yancey WMA. Asterisks indicate a significant difference between mean age or total length between males and females of a species in age or total length column. Significance was not tested if only one observation occurred in a group.

Species	Sex	n	M/F Ratio	Age (Years)	Age (Range)	Mean TL (mm)
Alligator Gar	♂	1		1.00	1.00	625.00
	♀	0		-	-	-
	Both	1	-	1.00	1.00	625 ± 625
Longnose Gar	♂	7		1.86 ± 0.35	1.00-2.00	749.86 ± 89.67
	♀	1		11.00 ± 0.00	11.00	1230.00 ± 0.00
	Both	8	7.00	3.00 ± 3.04	1.00-11.00	809.88 ± 179.58
Shortnose Gar	♂	9		5.78 ± 1.40*	4.00-7.00	668.33 ± 28.54
	♀	6		4.00 ± 1.53	2.00-6.00	661.83 ± 55.31
	Both	15	1.50	5.07 ± 1.69	2.00-7.00	665.73 ± 41.50
Spotted Gar	♂	18		5.44 ± 5.01	1.00-19.00	568.50 ± 72.64*
	♀	26		7.88 ± 7.31	2.00-34.00	669.54 ± 92.53
	Both	44	0.69	6.89 ± 6.58	1.00-34.00	628.20 ± 98.42

Table 5. Male and female sex ratio, mean age (years) ± SD, age range, and mean total length (TL, mm) ± SD of aged and sexed subsample of gars from Loch Leven, MS. Asterisks indicate a sex ratio that is significantly different from 1:1 based on a proportions test in ♂/♀ ratio column, or a significant difference between mean age or total length between males and females of a species in age or total length column.

Species	Sex	n	M/F Ratio	Age (Years)	Age (Range)	Mean TL (mm)
Alligator Gar	♂	3		4.67 ± 2.36	3.00-8.00	1210.33 ± 368.87
	♀	3		27.67 ± 20.37	9.00-56.00	2036.67 ± 297.81
	Both	6	1	16.17 ± 18.51	3.00-56.00	1623.50 ± 532.06
	YOY	2		0.25 ± 0.00	0.25	314.50 ± 6.50
Longnose Gar	♂	11		7.09 ± 6.10	1.00-23.00	992.45 ± 168.86*
	♀	9		6.89 ± 3.70	4.00-12.00	1136.78 ± 166.74
	Both	20	1.22	7.20 ± 5.00	1.00-23.00	1072.25 ± 167.58
	YOY	2		0.25 ± 0.00	0.25	318.00 ± 48.00
Shortnose Gar	♂	49		7.65 ± 6.61	2.00-49.00	673.37 ± 45.29*
	♀	26		6.04 ± 1.89	3.00-10.00	712.00 ± 65.49
	Both	75	1.88*	7.09 ± 5.51	2.00-49.00	686.76 ± 56.26
	YOY	51		0.25 ± 0.00	0.25	366.27 ± 75.38
Spotted Gar	♂	14		4.29 ± 2.68	1.00-10.00	609.86 ± 55.88*
	♀	8		6.25 ± 3.15	2.00-12.00	701.25 ± 82.32
	Both	22	1.75	6.26 ± 5.72	1.00-12.00	633.17 ± 92.92
	YOY	24		0.25 ± 0.00	0.25	231.42 ± 39.60

Table 6. Male and female sex ratio, mean age (years) ± SD, age range, and mean total length (TL, mm) ± SD of aged and sexed subsample of Mississippi River Floodplain gars. Asterisks indicate a sex ratio that is significantly different from 1:1 based on a proportions test in ♂/♀ ratio column, or a significant difference between mean age or total length between males and females of a species in age or total length column.

Species	Sex	n	M/F Ratio	Age (Years)	Age (Range)	Mean TL (mm)
Alligator Gar	♂	1		1.00	1.00	625.00
	♀	0		-	-	-
	Both	1	-	1.00	1.00	625.00 ± 625.00
Longnose Gar	♂	7		1.86 ± 0.35	1.00-2.00	749.86 ± 89.67
	♀	1		11.00 ± 0.00	11.00	1230.00 ± 0.00
	Both	8	7.00	3.00 ± 3.04	1.00-11.00	809.88 ± 179.58
Shortnose Gar	♂	9		5.78 ± 1.40*	2.00-49.00	668.33 ± 28.54
	♀	6		4.00 ± 1.53	2.00-6.00	661.83 ± 55.31
	Both	15	1.50	5.07 ± 1.69	2.00-49.00	665.73 ± 41.50
Spotted Gar	♂	18		5.44 ± 5.01	1.00-19.00	568.50 ± 72.64*
	♀	26		7.88 ± 7.31	2.00-34.00	669.54 ± 92.53
	Both	44	0.69	6.89 ± 6.58	1.00-34.00	628.20 ± 98.42

Table 7. Water quality parameters taken in proximity to the Blackhawk Scar Lakes (BSL) and floodplain at Richard K. Yancey WMA, LA, and parameters taken at the "Culvert" sites during sampling from 2020-2021. Mean and standard deviation were compiled if parameters were taken from multiple locations within a site.

2020-2021 Parameters		October 16th	November 18th	June 16th	July 28th	October 22nd
Temperature (°C)	BSL	20.85	16.42 ± 0.36	29.63 ± 1.06	30.24 ± 0.26	24.99 ± 0.36
	Culverts	-	-	31.49 ± 0.04	33.32 ± 0.52	24.10 ± 0.18
Conductance (µS/cm)	BSL	-	0.45 ± 0.01	0.35 ± 0.01	0.40 ± 0.01	0.55 ± 0.03
	Culverts	-	-	0.39 ± 0.01	0.42 ± 0.00	0.35 ± 0.00
Dissolved Oxygen (mg/L)	BSL	6.64	9.40 ± 0.27	12.13 ± 1.57	4.48 ± 2.07	8.66 ± 0.76
	Culverts	-	-	3.89 ± 0.13	3.20 ± 0.84	6.23 ± 0.98
Percent Dissolved Oxygen (%)	BSL	74.30	96.2 ± 2.73	158.33 ± 19.26	61.34 ± 28.61	106.23 ± 9.15
	Culverts	-	-	52.90 ± 2.00	44.68 ± 12.48	74.13 ± 11.90
Secchi Depth (cm)	BSL	15.0	-	81.98 ± 6.70	47.2 ± 17.34	17.33 ± 2.05
	Culverts	-	-	85.19 ± 5.19	39.83 ± 2.03	27.33 ± 3.86

Table 8. Water quality parameters taken in and around the Floodplain (FP) and Riverine (R) sites at Loch Leven, MS in 2020 and 2021. Mean and standard deviation were compiled if parameters were taken from multiple locations within a site.

2020 Parameters	Site	June 11th	June 18th	July 9th	July 21st	Sept. 17th	Nov. 13th
Temperature (°C)	FP	28.87 ± 0.53	29.29 ± 0.55	29.54 ± 1.42	30.44 ± 1.70	28.37 ± 0.30	21.70 ± 0.12
	R	-	-	29.48	31.19	-	21.90
Conductance (µS/cm)	FP	343.00 ± 0.82	348.17 ± 6.77	397.25 ± 33.58	451.00 ± 39.15	352.00 ± 1.73	302.00 ± 0.00
	R	-	-	381.00	344.00	-	185.00
DO (mg/L)	FP	11.69 ± 0.79	8.44 ± 1.28	5.91 ± 1.55	3.99 ± 1.12	4.78 ± 0.20	8.65 ± 0.41
	R	-	-	5.15	6.77	-	9.47
DO (%)	FP	134.87 ± 14.51	113.02 ± 14.74	78.61 ± 21.26	53.70 ± 16.05	61.67 ± 2.59	98.57 ± 4.54
	R	-	-	67.7	92.1	-	103.60
Secchi Depth (cm)	FP	-	82.5 ± 24.42	28.60 ± 18.57	29.33 ± 9.45	26.67 ± 2.52	15.00 ± 0.00
	R	-	-	30.00	27.00	-	20.00

2021 Parameters	Site	April 30th	June 10th	July 9th	August 5th/6th	December 9th
Temperature (°C)	FP	21.71	24.37 ± 0.07	28.81 ± 0.62	28.34 ± 1.32	14.76 ± 0.11
	R	21.32	29.77 ± 0.12	-	28.38	15.71
Conductance (µS/cm)	FP	0.31	0.38 ± 0.00	0.33 ± 0.04	0.30 ± 0.02	0.25 ± 0.00
	FP	0.32	0.31 ± 0.00	-	0.3	0.15
Dissolved Oxygen (mg/L)	R	5.70	6.15 ± 0.38	3.51 ± 1.04	4.69 ± 2.08	15.09 ± 50.07
	FP	5.42	5.68 ± 0.07	-	6.09	10.7
Percent Dissolved Oxygen (%)	R	65.50	73.45 ± 4.45	45.66 ± 13.05	61.16 ± 28.56	149.18 ± 50.07
	FP	61.10	74.87 ± 0.90	-	78.6	108.00
Secchi Depth (cm)	R	37.00	21.5 ± 2.50	41.83 ± 19.28	12.9 ± 9.60	20.00 ± 1.67
	FP	30.00	67.83 ± 1.55	-	3.00	16.00

height (m) at Natchez, Mississippi (USGS Gauge 07290880), peaked in April of 2021, exceeding 17.5 m in height. River height at Natchez in 2020 also peaked in April, reaching over 16 m in height. The floodplain at LL begins to inundate through the WCS at approximately 9.45 m (Figure 8) and the RKY floodplain begins to inundate around 10.8 m (Figure 9).

Gar Growth Between LL and RKY Sites

Standard von Bertalanffy growth models were created for LL male and female Spotted Gars (Figure 10A) and RKY male and female Spotted Gars (Figure 10B). Von Bertalanffy growth metrics for Spotted Gars were compared between males and females and between LL and RKY (Figure 11A and B). The L_∞ parameter was not significantly different between Spotted Gars of the same sex at LL and RKY sites, however male Spotted Gar L_∞ at RKY (616.61 mm, 95% CI [588.20 to 670.36], n = 18) was significantly smaller than female L_∞ at RKY (743.43 mm [696.57 to 789.94], n = 25) (Table 9). The K parameter was significantly different between LL (♂ = 1.78 [1.61 to 1.99], ♀ = 1.55 [1.33 to 1.77]) and RKY (♂ = 1.01 [0.70 to 1.24], ♀ = 0.60 [0.32 to 0.80]) sites for both sexes. The t_0 parameter was not significantly different between sexes or sites, likely due to the inclusion of "length at hatch" fish to both groups.

Von Bertalanffy growth metrics for gar communities varied significantly, depending upon species, and sometimes sex. Female Alligator Gar (n = 8) had a significantly different L_∞ (2222.27 mm [1396.31 to 2503.45]) compared to any other species (Figure 12). Longnose Gar L_∞ did not differ between females (1283.95 mm [1227.27 to 1534.92], n = 12) and males (1136.03 mm [981.90 to 1241.30], n = 20) but male and female Longnose Gar L_∞ differed significantly from all other species (Figure 13). Female Shortnose Gar L_∞ (760.71 mm [715.18 to 838.98], n = 83) was significantly larger (Figure 14) compared to males (692.01 mm [673. 80 to 710.31], n = 108). Spotted Gar male (49-year-old outlier not included in growth curves) L_∞

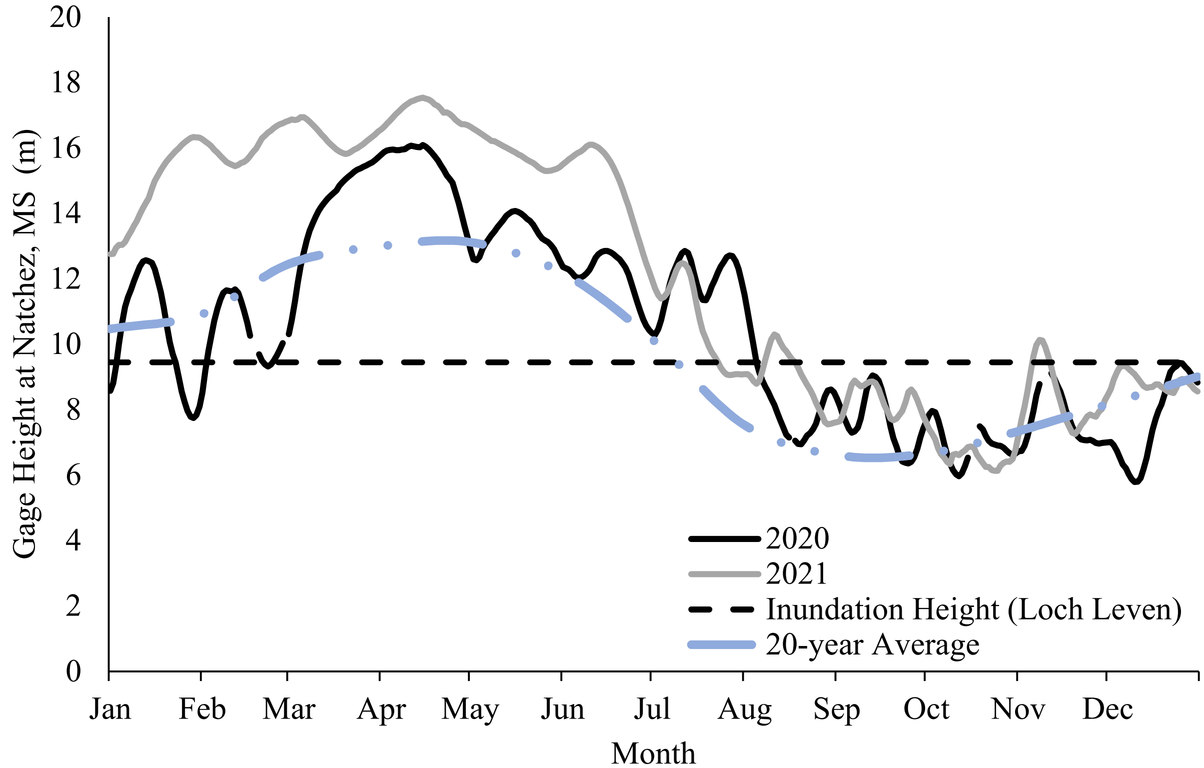

Figure 8. Mississippi River gage height (m) at Natchez, Mississippi (USGS Gauge 07290880). The Loch Leven, MS floodplain begins to inundate through the water control structure at the level of the dashed line (9.45 m). A 20-year average of the Mississippi River flood pulse is also shown.

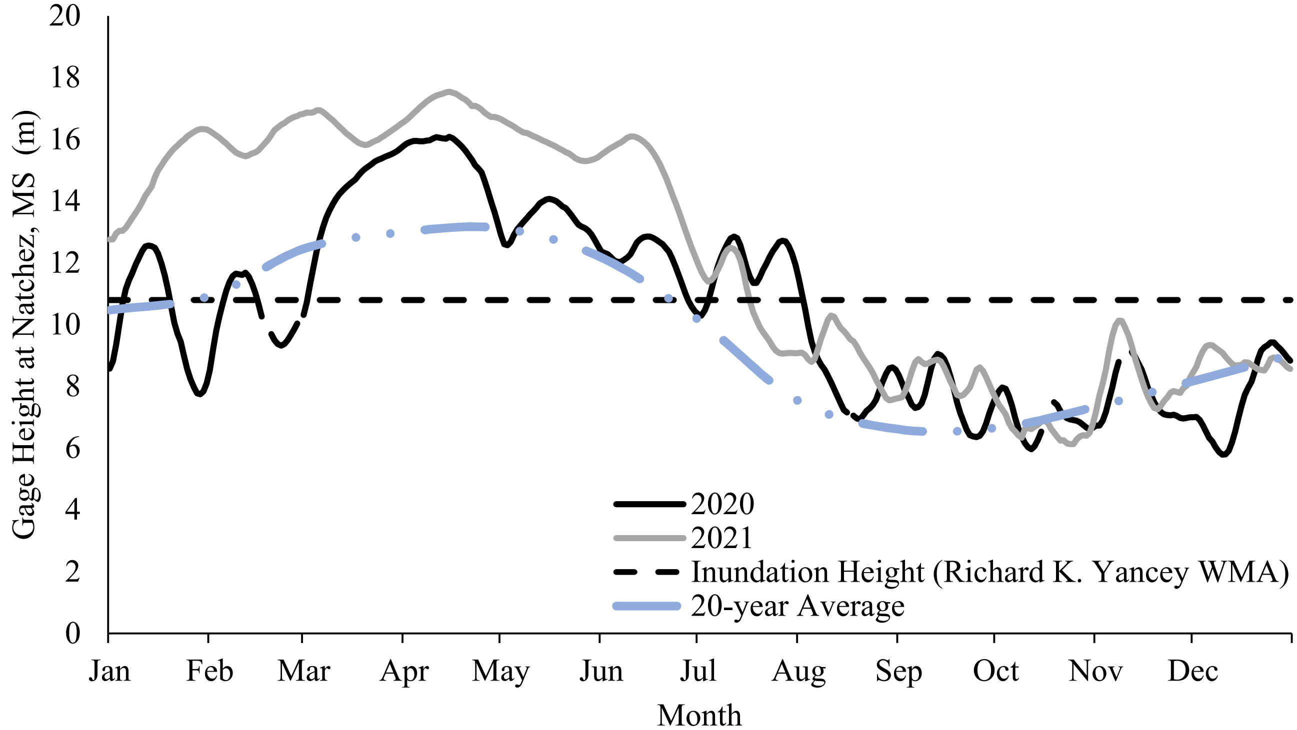

Figure 9. Mississippi River gage height (m) at Natchez, Mississippi (USGS Gauge 07290880). The Richard K. Yancey WMA, LA floodplain begins to inundate around the level of the dashed line (10.8m). A 20-year average of the Mississippi River flood pulse is also shown.

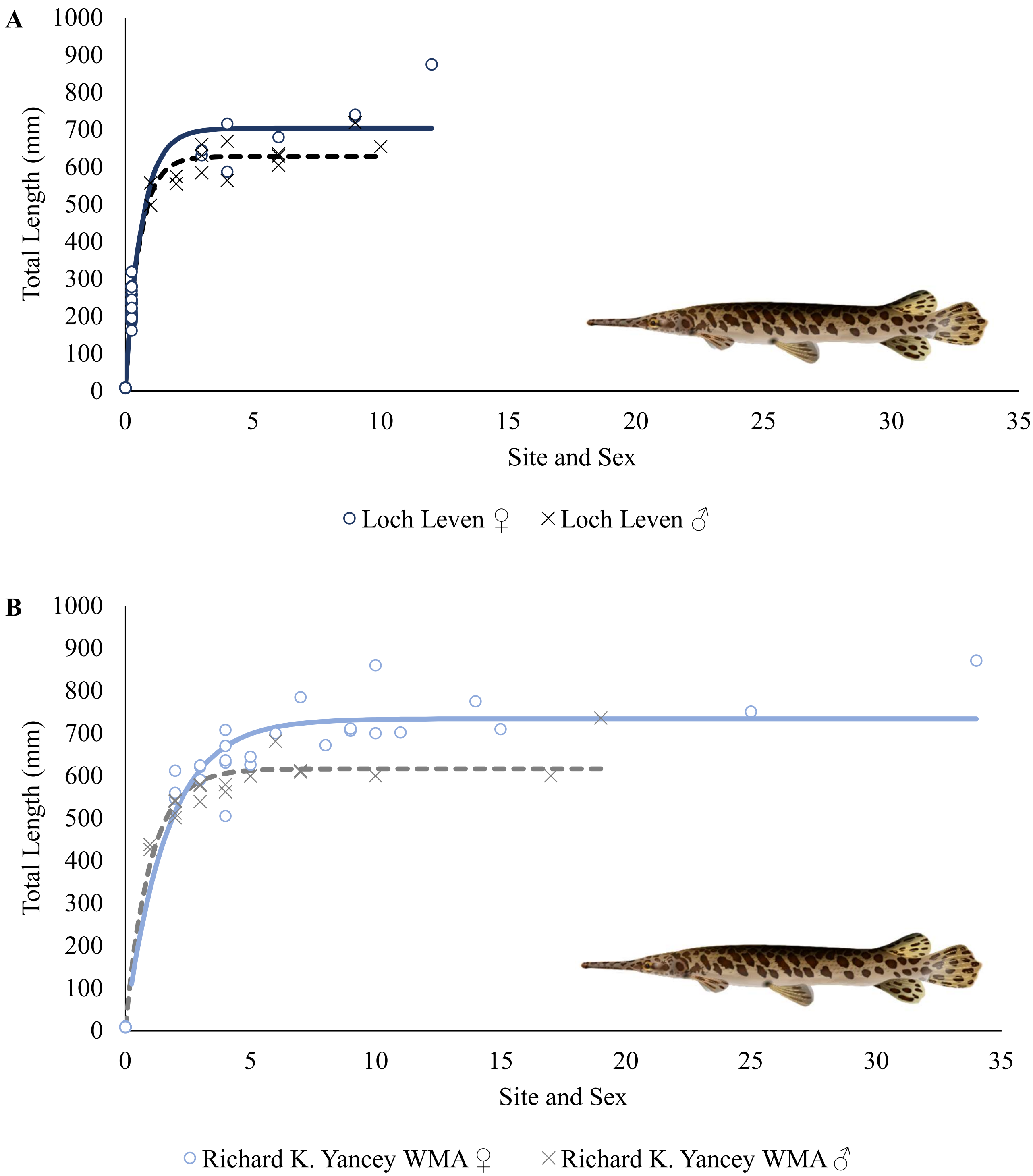

Figure 10. Standard von Bertalanffy growth curves fitted for female (n = 8, Young-of-year = 24) and male (n = 14, Young-of-year = 24) Spotted Gars at Loch Leven, MS (A), and female (n =25) and male (n = 18) Spotted Gars at Richard K. Yancey WMA, LA (B).

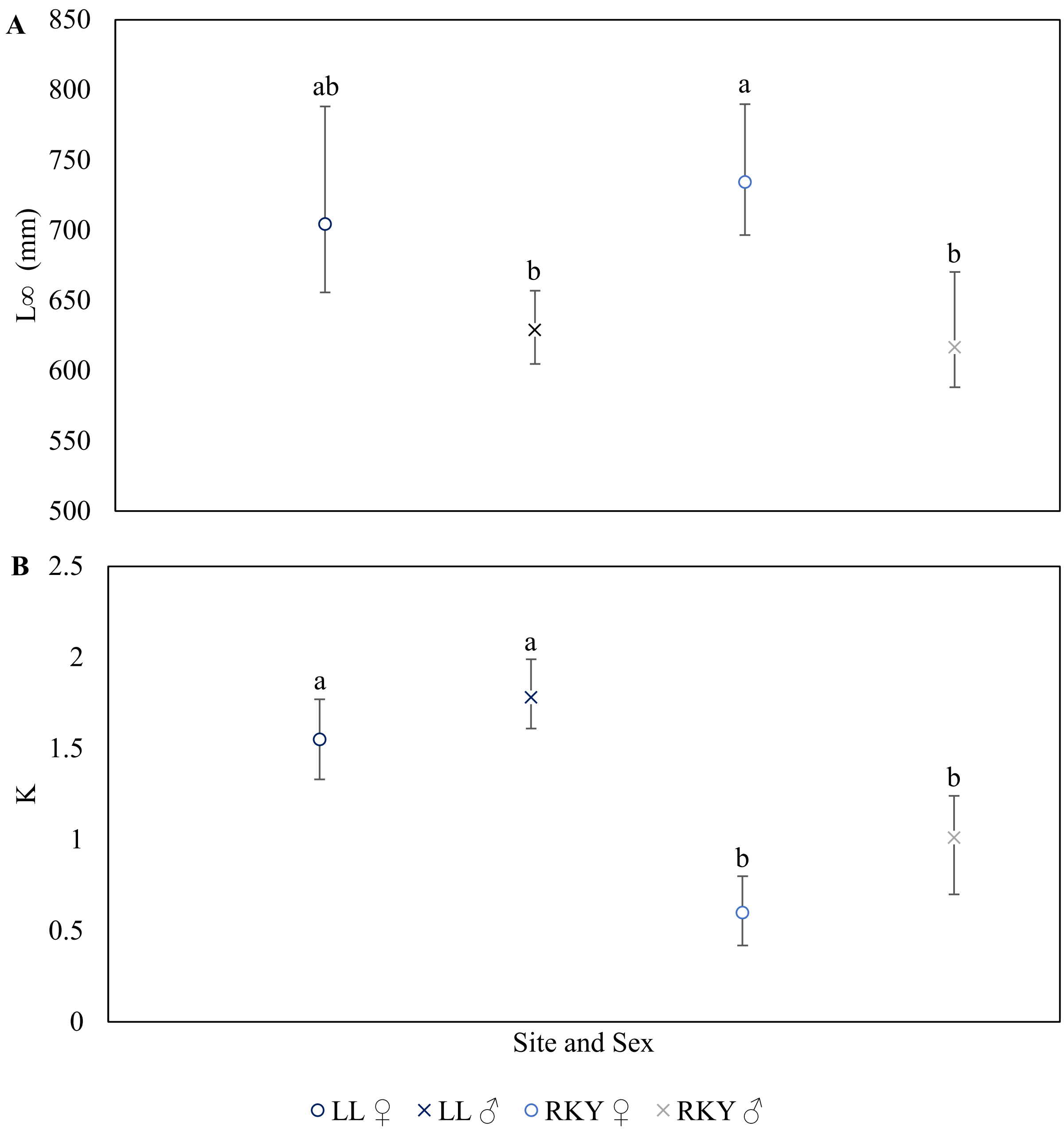

Figure 11. Asymptotic length parameter L_∞ (A) and growth coefficient K (B) of female (n = 8, Young-of-year = 24) and male (n = 14, Young-of-year = 24) Spotted Gars at Loch Leven, MS (A), and female (n =25) and male (n = 18) Spotted Gars at Richard K. Yancey WMA, LA (B). Letters indicate significant differences between sites based on 95% Confidence Intervals.

Table 9. Von Bertalanffy Growth metrics with 95% CI values from standard von Bertalanffy growth curves fitted for male and female Spotted Gars at Loch Leven, MS and Richard K. Yancey WMA, LA. The 95% CI was not included for t_0 because there was not a significant difference between site or sex. Letters indicate significant differences between sites and apply to each metric. Young-of-year gars collected at a site displayed in parentheses.

Site	Sex	n	L_∞ (mm)	K	t_0
Loch Leven	♀	8 (24)	704.49 (655.72-788.13)^{AB}	1.55 (1.33-1.77)^{A}	-0.01
	♂	14 (24)	628.81 (604.82-657.05)^{B}	1.78 (1.61-1.99)^{A}	-0.01
Richard K. Yancey WMA	♀	25	743.43 (696.57-789.94)^{A}	0.60 (0.32-0.80)^{B}	-0.02
	♂	18	616.61 (588.2-670.36)^{B}	1.01 (0.70-1.24)^{B}	-0.01

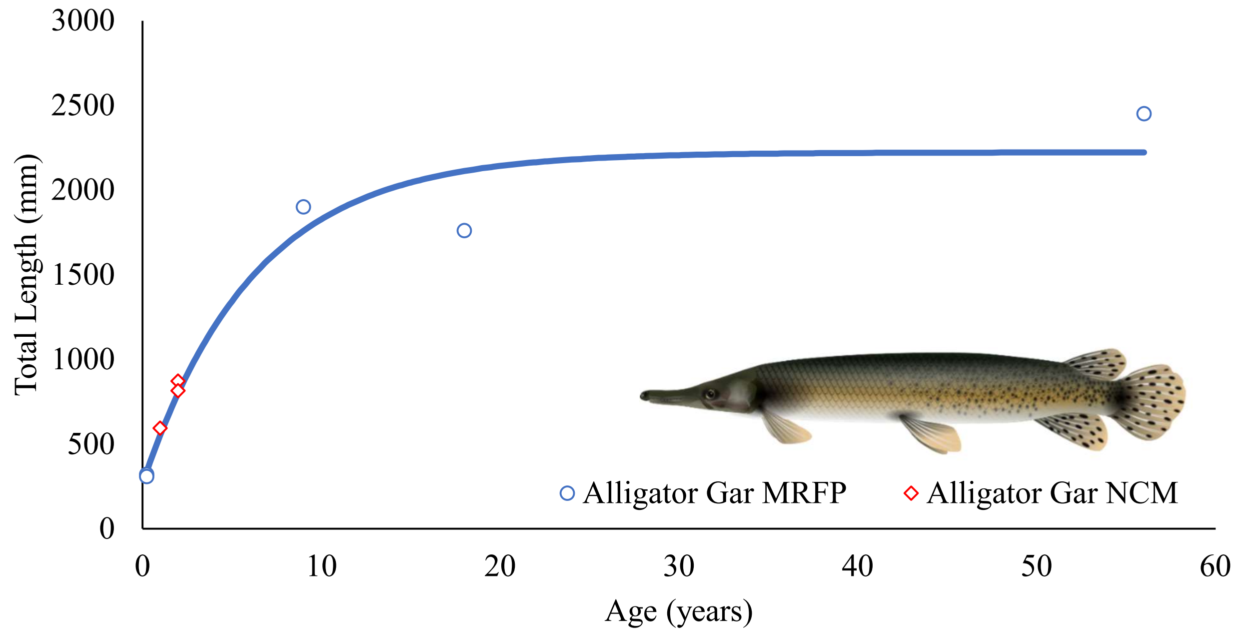

Figure 12. Standard von Bertalanffy growth curve ($L_{\infty} = 2222.27$ mm, K = 0.16) fit for female Alligator Gar from the Mississippi River Floodplain (MRFP, n = 3 adults, n = 2 young-of-year) and a Near-coastal Marsh (NCM, n = 3). The oldest female was 56 years old. Males were not included due to a lack of older individuals.

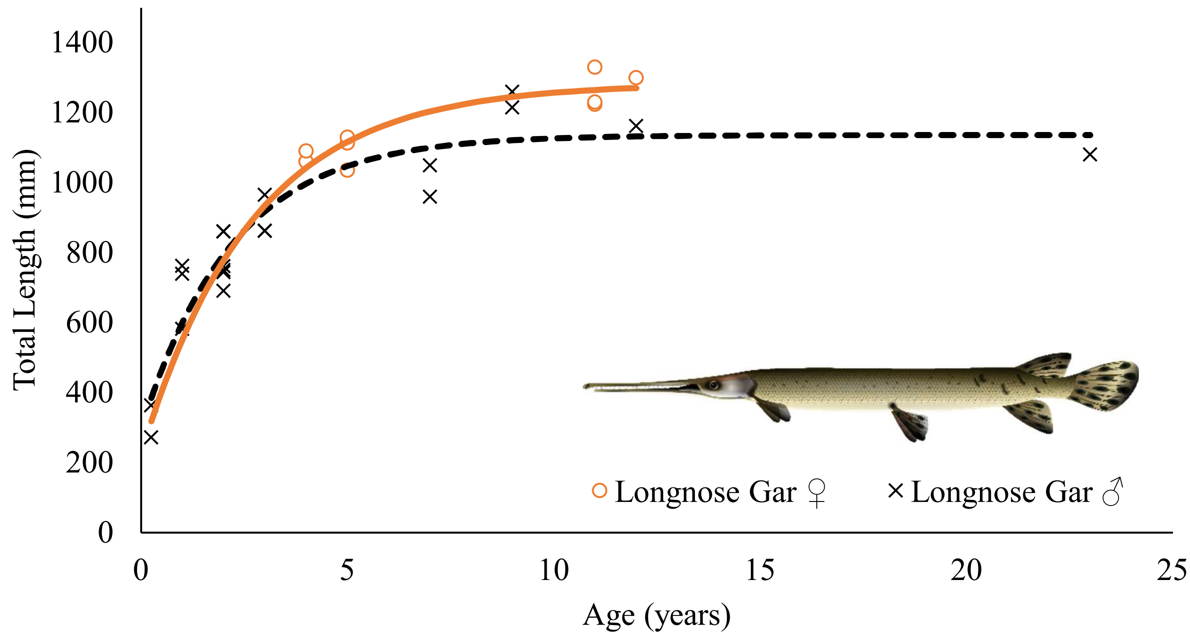

Figure 13. Standard von Bertalanffy growth curves fit for female (L_{∞} = 1283.95 mm, K = 0.37, n = 12) and male (L_{∞} = 1136.03 mm, K = 0.45, n = 20) Longnose Gar from Mississippi River Floodplain communities. The oldest individual was a 23-year-old male.

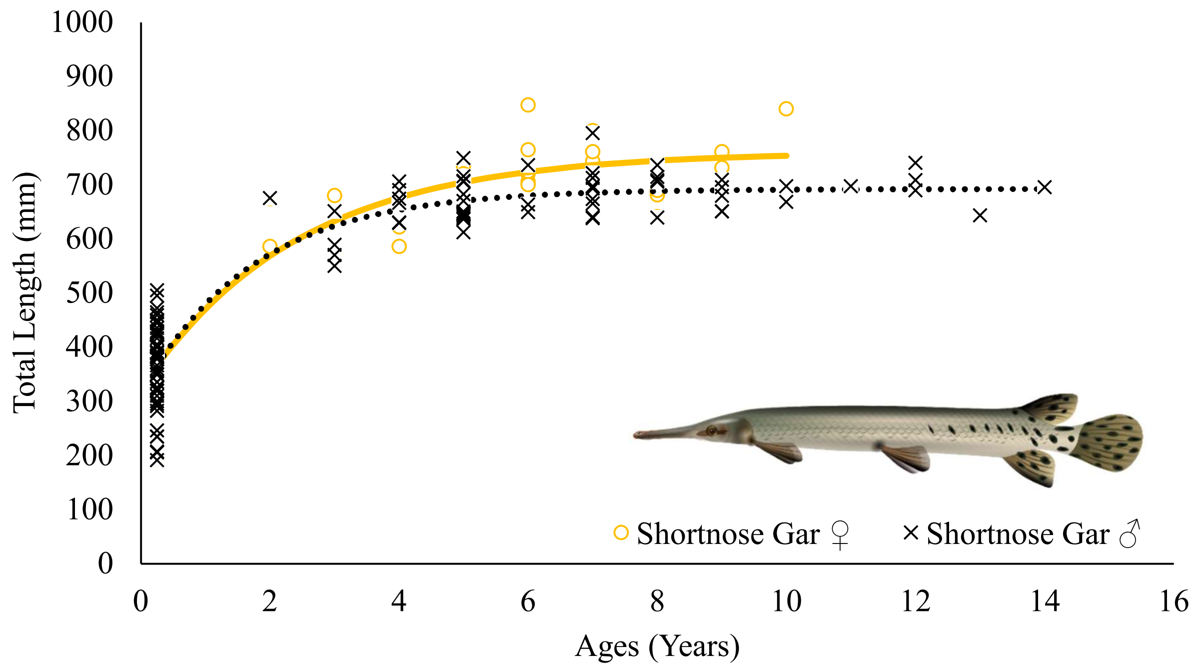

Figure 14. Standard von Bertalanffy growth curves fit for Shortnose Gar females ($L_\infty = 760.71$ mm, K = 0.41, n = 83) and males ($L_\infty = 692.01$ mm, K = 0.57, n = 108) from Mississippi River Floodplain communities. The oldest individual, a 49-year-old male was not included as it was an extreme outlier. The second oldest individual was a 14-year-old male.

(627.76 mm [603.99 to 667.76], n = 58) was significantly smaller than other species (Figure 15). Von Bertalanffy curves for multiple species displayed differences in growth between sex and species (Figures 16 and 17). Parameter K values were different between male Spotted Gars (0.99 [0.72 to 1.85]) and female Alligator Gars (0.16 [0.05 to 0.32]), female Longnose Gars (0.37 [0.06 to 0.47]) and female Spotted Gars (0.45 [0.72 to 1.85]) (Figure 18). Estimated t_0 parameters were not significantly different (Table 10).

Trophic Ecology of Gars

Trophic position of gars was compared by site (Figure 19) and by species within sites (Figures 20 and 21). At RKY, there was not a significant difference in trophic position based on "Culvert" or Blackhawk Scar Lake Sites, therefore trophic position values were combined into a "Richard K. Yancey" group. Comparisons by species within sites are also listed in one figure (Figure 22, Table 11). Gars from both study sites (LL and RKY) were also combined by species to determine overall species trophic position among, regardless of site (Figure 23). Alligator Gars on the LL Floodplain occupied the highest mean trophic position of any gar species (3.55 ± SE 0.16, n = 6). *Lepisosteus* gars had significantly lower trophic positions in floodplain habitats at LL, compared to Riverine habitats. Trophic position of gars at RKY was above the trophic position of gars of the same species in the LL Floodplain and below the trophic position of gars of the same species at RKY, but the difference was not always significant. Trophic position of Longnose Gars at RKY (3.13 ± 0.06, n = 8) was similar to Longnose gars on the Floodplain (3.06 ± 0.06, n = 16) and in Riverine habitats (3.27 ± 0.03, n = 52). Shortnose Gars at RKY (3.01 ± 0.04, n = 20) were significantly lower in trophic position compared to Riverine Shortnose Gars (3.20 ± 0.03, n = 62) and significantly higher than those in the LL Floodplain (2.86 ± 0.03, n = 71). Spotted Gars at RKY (3.00 ± 0.03, n = 44) had a lower trophic position compared to

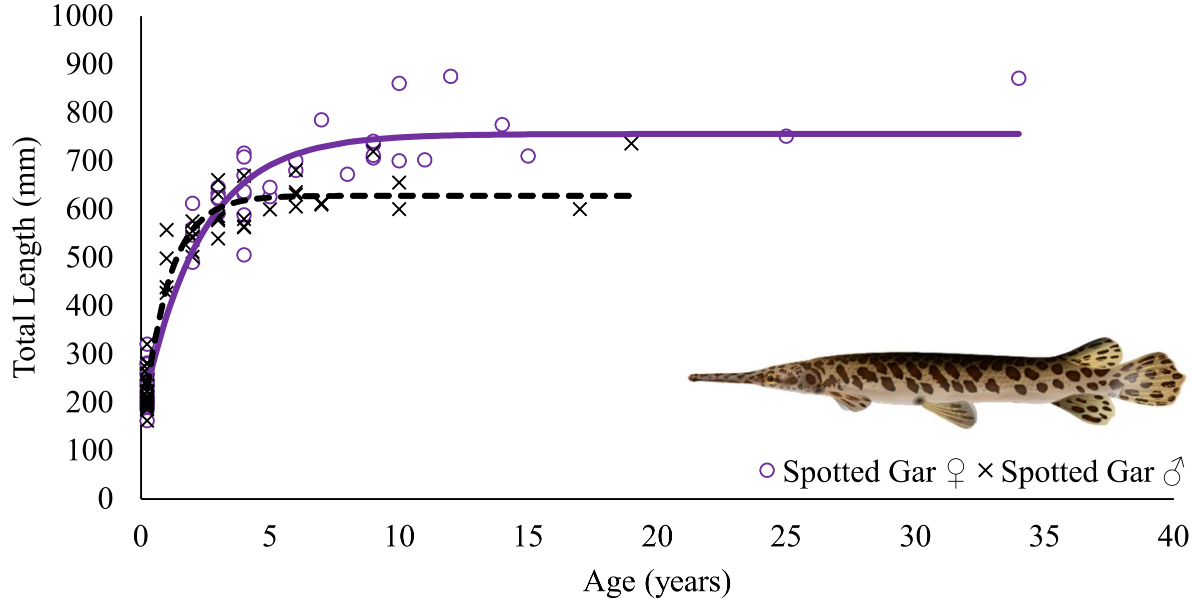

Figure 15. Standard von Bertalanffy growth curves fit for female ($L_{\infty} =$ 755.67 mm, K = 0.45, n = 58) and male ($L_{\infty} =$ 627.76 mm, K = 0.99, n = 56) Spotted Gars from Mississippi River Floodplain communities. The oldest individual was a 34-year-old female.

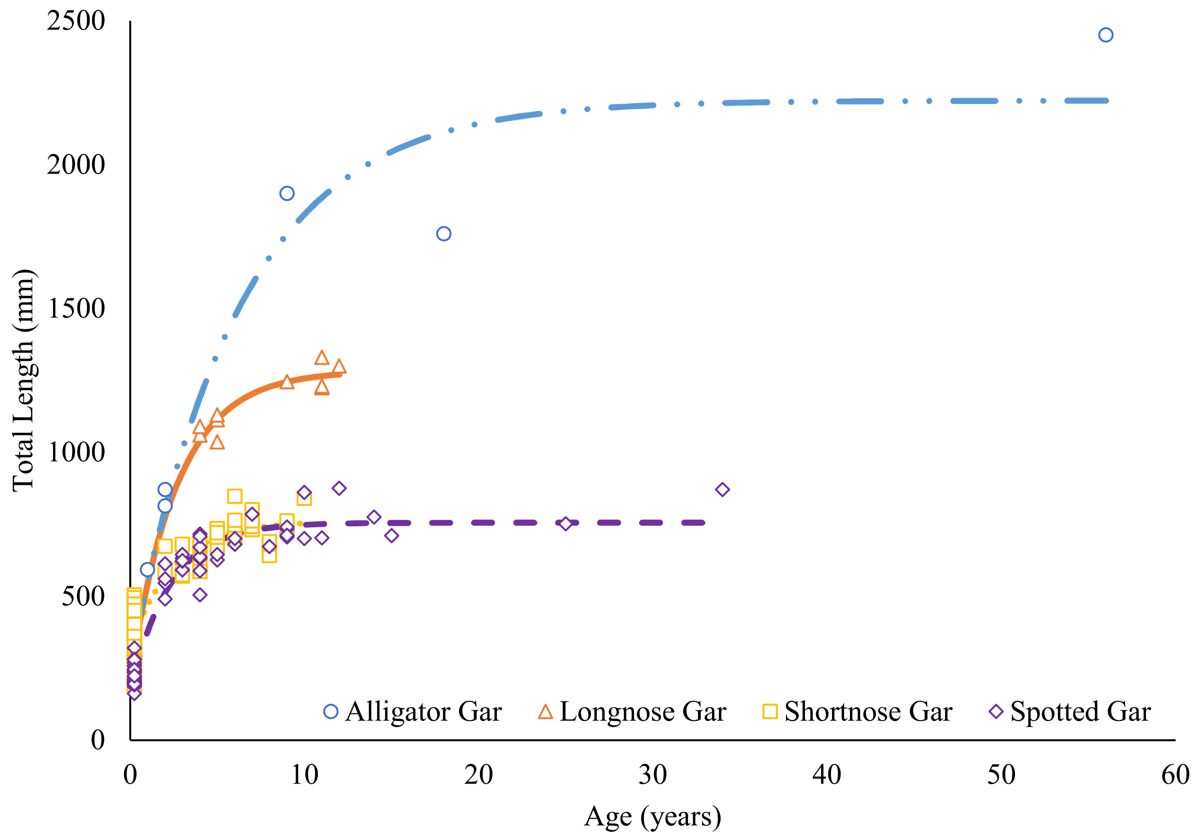

Figure 16. Standard von Bertalanffy growth curves fit for female Alligator Gar ($L_{\infty} = 2222.27$ mm, K = 0.16, n = 5), Longnose Gar ($L_{\infty} = 1283.95$ mm, K = 0.37, n = 12), Shortnose Gar ($L_{\infty} = 760.71$ mm, K = 0.41, n = 83), and Spotted Gar ($L_{\infty} = 755.67$ mm, K = 0.45, n = 58) from Mississippi River Floodplain communities. An additional three female Alligator Gar from a Near-coastal Marsh in Chauvin, LA were added to fill in gaps in the dataset for a total of 8.

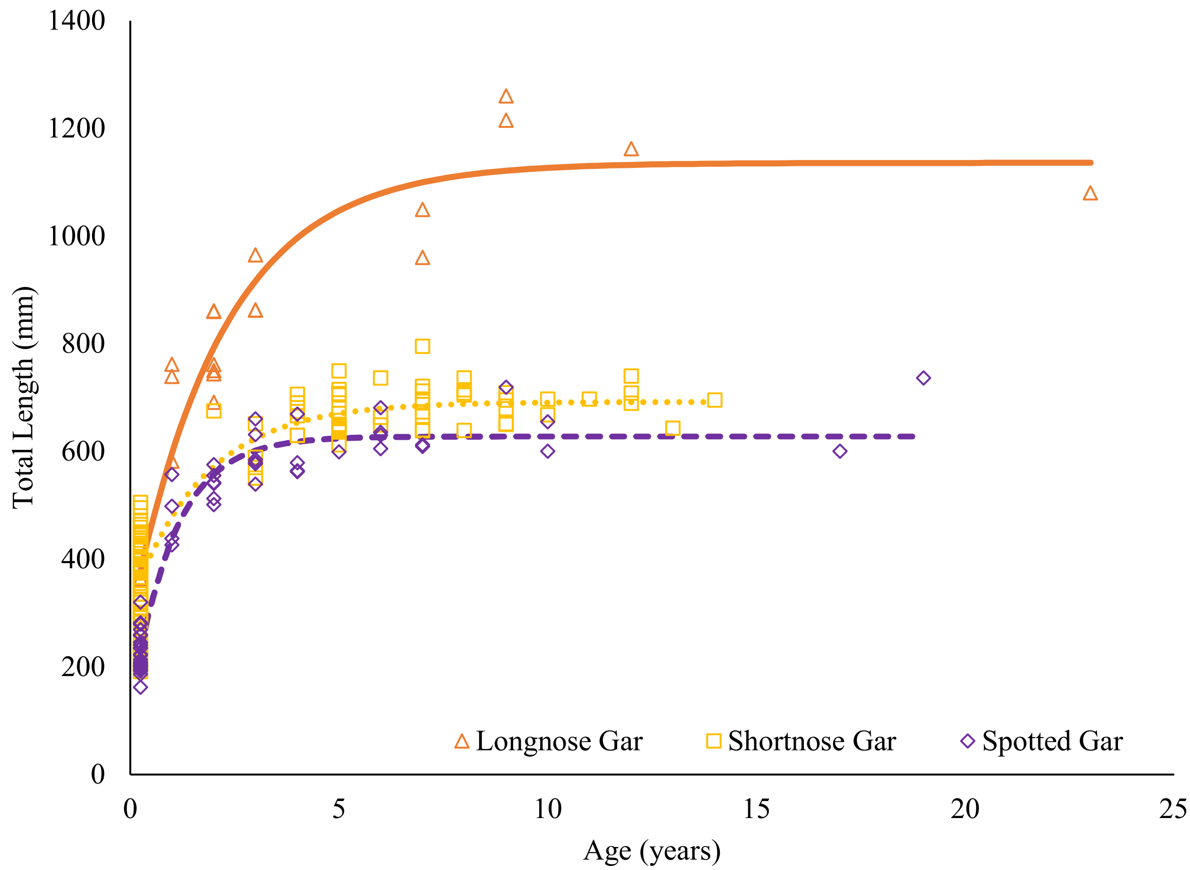

Figure 17. Standard von Bertalanffy growth curves fit for male Longnose Gar (L_∞ = 1136.03 mm, K = 0.45, n = 20), Shortnose Gar (L_∞ = 692.01 mm, K = 0.57, n = 108), and Spotted Gar (L_∞ = 627.76 mm, K = 0.99, n = 56) from Mississippi River Floodplain communities.

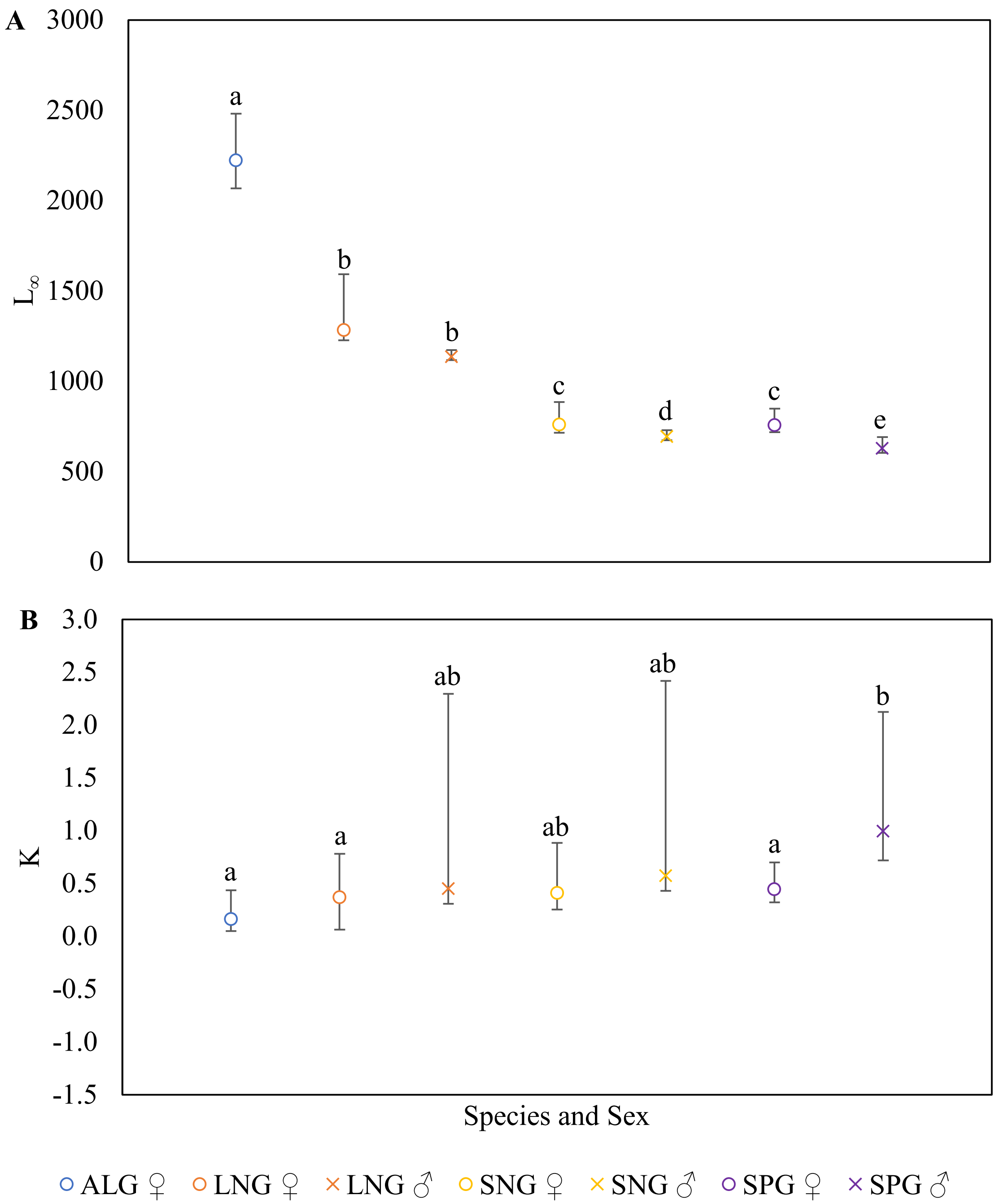

Figure 18. Asymptotic length parameter L_∞ (A) and growth coefficient K (B) values from standard von Bertalanffy growth curves fitted for female (n = 5) Alligator Gar (ALG), female (n = 12) and male (n = 20) Longnose Gar (LNG), female (n = 83) and male (n = 108) Shortnose Gar (SNG), and female (n = 58) and male (n = 56) Spotted Gar (SPG) collected in Mississippi River Floodplains. Different letters denote significant differences based on 95% confidence intervals. An additional three female Alligator Gar from a Near-coastal Marsh in Chauvin, LA were added to fill in gaps in the dataset for a total of 8.

Table 10. Growth metrics with 95% CI values (in parentheses) from standard von Bertalanffy growth curves fit by sex for Alligator Gar, Longnose Gar, Shortnose Gar, and Spotted Gar collected in Mississippi River Floodplains. An additional three female Alligator Gars were added from a Near-coastal Marsh (NCM) to fill in gaps in the dataset (in parentheses, n = 3). Letters indicate significant differences between sites, and apply to each metric individually. The 95% CI is not included for t_0, there was no significant differences between sex or species.

Species	Sex	n	L_∞ (mm)	K	t_0
Alligator Gar	♀	5 (3)	2222.27 (1396.31-2503.45)^{A}	0.16 (0.05-0.32)^{A}	-0.80
	♂	-	-	-	-
Longnose Gar	♀	12	1283.95 (1227.27-1534.92)^{B}	0.37 (0.06-0.47)^{A}	-0.52
	♂	20	1136.03 (981.90-1241.30)^{B}	0.45 (0.25-0.90)^{AB}	-0.67
Shortnose Gar	♀	83	760.71 (715.18-838.98)^{C}	0.41 (0.25-0.73)^{AB}	-1.35
	♂	108	692.01 (673.80-710.31)^{D}	0.57 (0.43-2.27)^{AB}	-1.07
Spotted Gar	♀	58	755.67 (717.82-810.05)^{C}	0.45 (0.32-0.58)^{A}	-0.58
	♂	56	627.76 (603.99-667.76)^{E}	0.99 (0.72-1.85)^{B}	-0.22

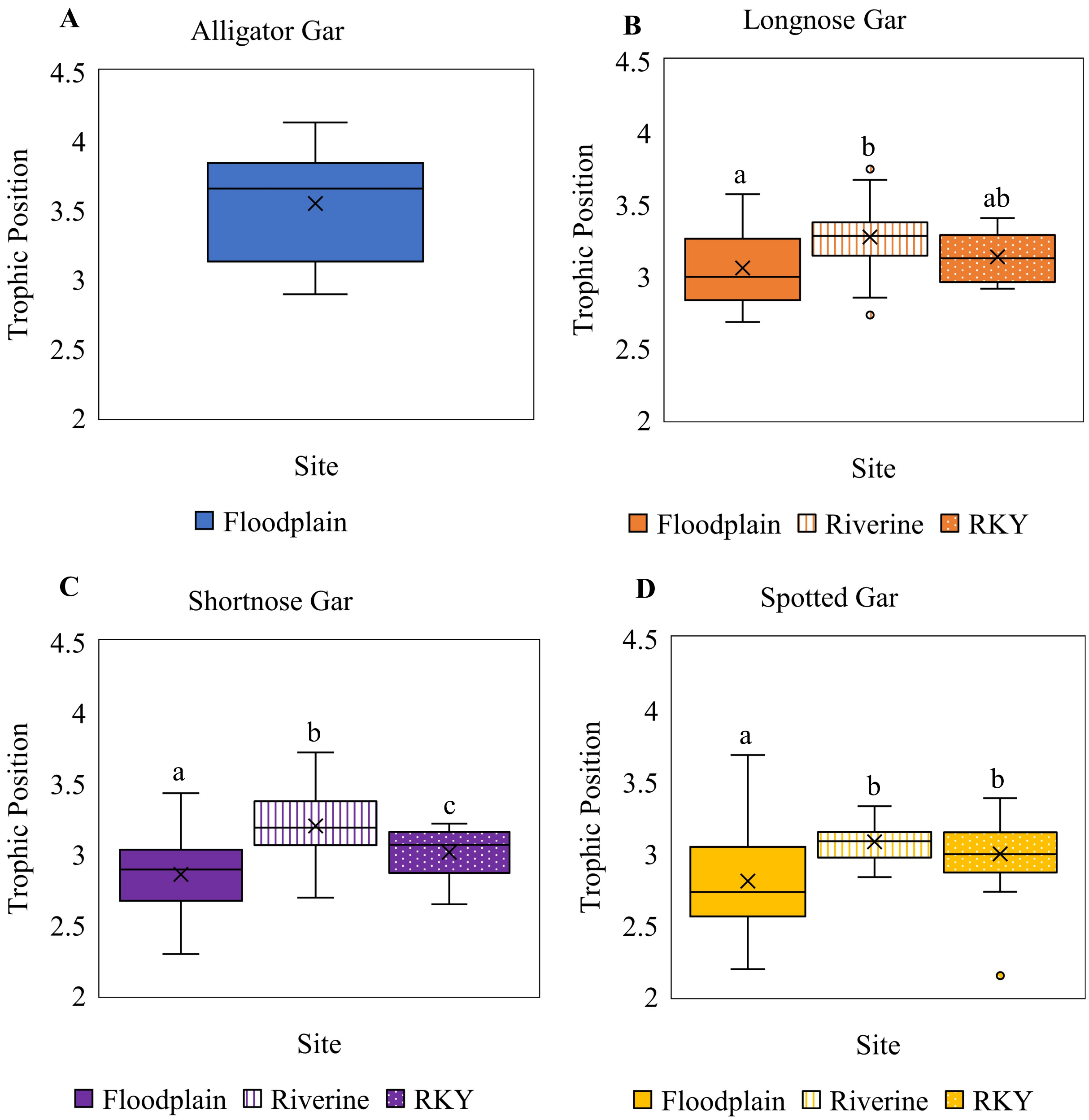

Figure 19. Box and whisker plots of Alligator (A), Longnose (B), Shortnose (C), and Spotted (D) Gar trophic position from Loch Leven, MS "Floodplain" and "Riverine" sites, and Richard K. Yancey WMA, LA (RKY). Different letters indicate significant differences among groups based on ANOVA and Tukey's post hoc test, and the "X" indicates the mean. Number of gars per site and species were Alligator Gar (n = 6), Longnose Gar Floodplain (n = 16), River (n = 52), RKY (n = 8), Shortnose Gar Floodplain (n = 71), River (n = 62), RKY (n = 20), and Spotted Gar Floodplain (n = 51), River (n = 12), and RKY (n = 44).

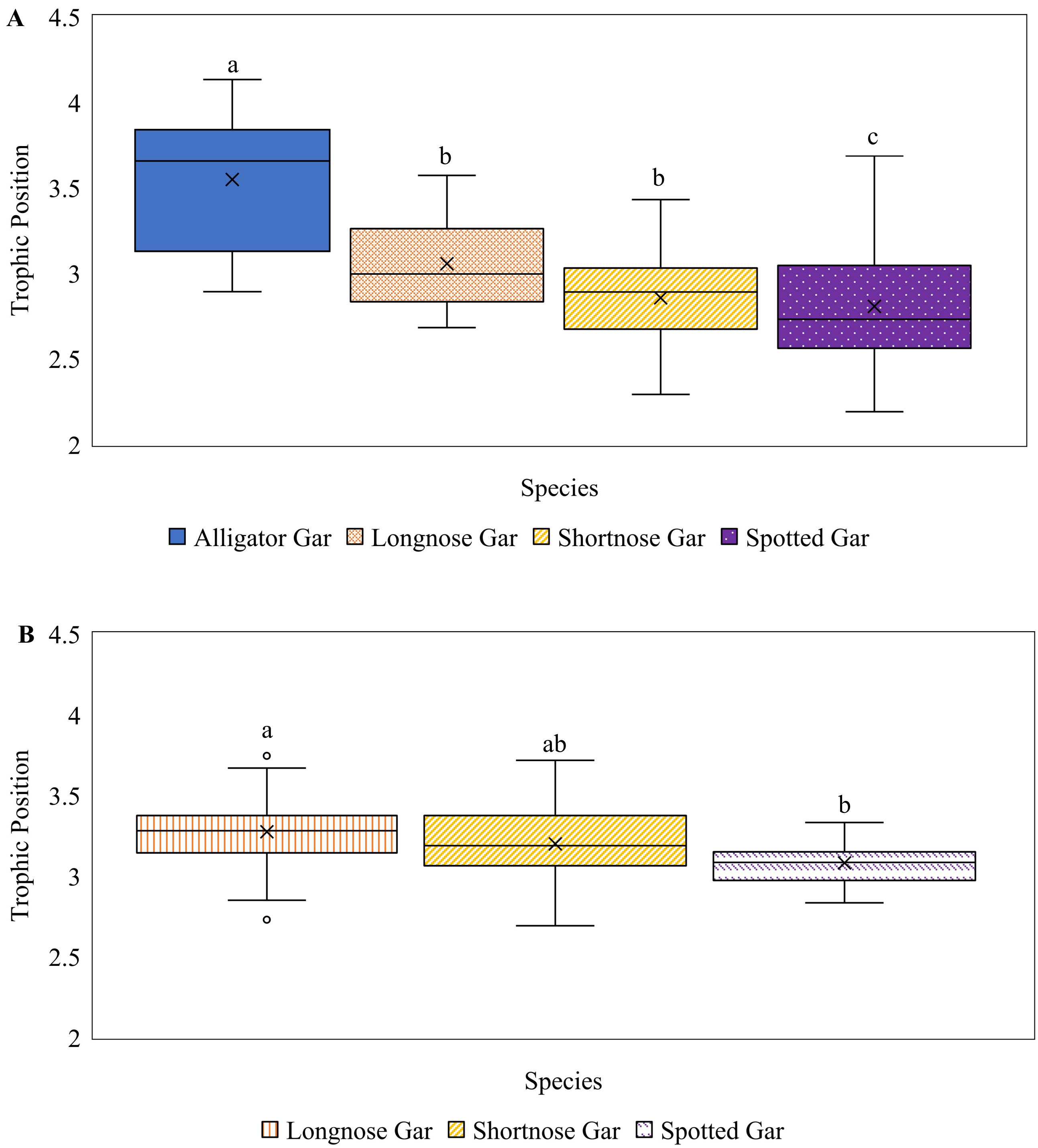

Figure 20. Box and whisker plots of Alligator Gar (n = 6), Longnose Gar (n = 16), Shortnose Gar (n = 71), and Spotted Gar (n = 51) trophic position from Floodplain (A) and Longnose Gar (n = 52), Shortnose Gar (n = 62), and Spotted Gar (n = 12) trophic position from Riverine (B) sites at Loch Leven, MS. Different letters indicate significant differences between groups ANOVA and Tukey's post hoc test and "X" indicates the mean.

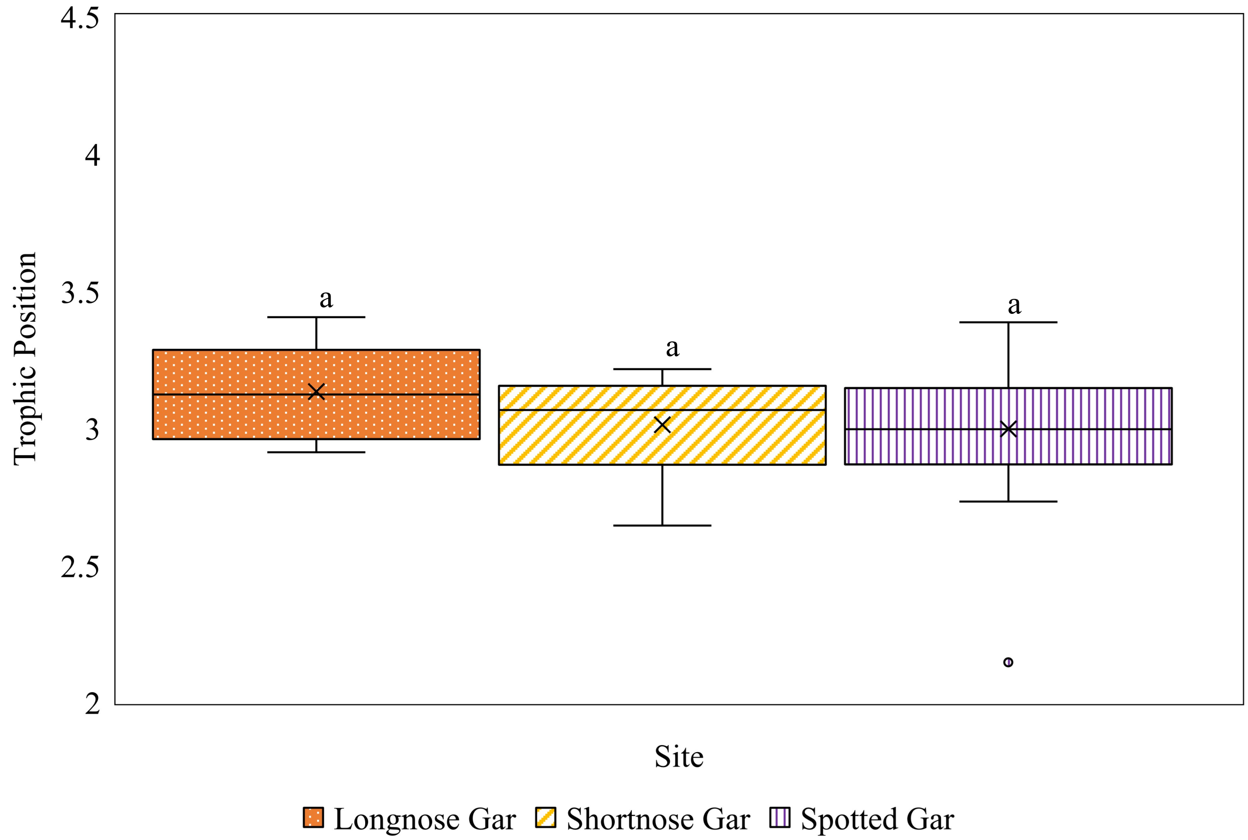

Figure 21. Box and whisker plots of gar trophic position from Richard K. Yancey WMA, LA (RKY) for Longnose Gar (n = 8), Shortnose Gar (n = 20), and Spotted Gar (n = 44). Different letters indicate significant differences between groups based on ANOVA and Tukey's post hoc test, and "X" indicates mean trophic position.

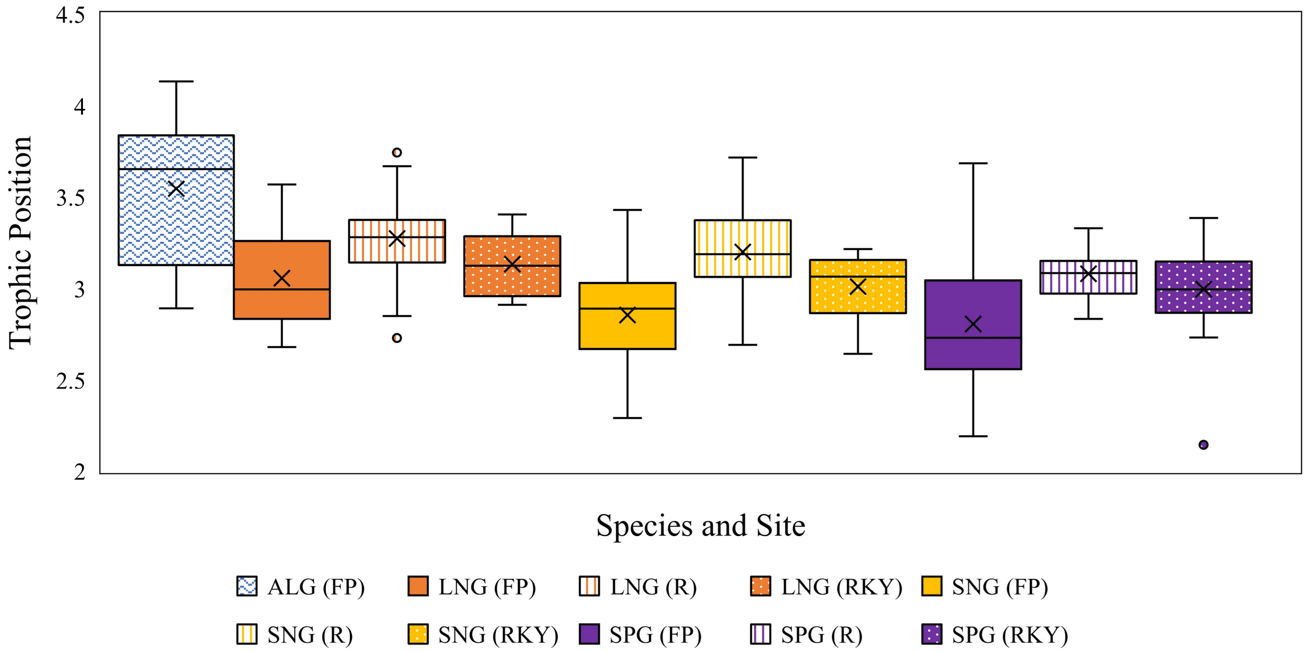

Figure 22. Box and whisker plots of Alligator Gar (ALG), Longnose Gar (LNG), Shortnose Gar (SNG), and Spotted Gar (SPG) trophic position from "Floodplain" (FP) and "Riverine" (R) sites at Loch Leven, MS, and Richard K. Yancey WMA, LA (RKY). The "X" indicates the mean. Number of gars per site and species were ALG (FP) n = 6, LNG (FP) n = 16, LNG (R) n = 52, LNG (RKY) n = 8, SNG (FP) n = 71, SNG (R) n = 62, SNG (RKY) n = 20, SPG (FP) n = 51, SPG (R) n = 12, and SPG (RKY) n = 44.

Table 11. Mean trophic position ± SE of gars at Floodplain and Riverine sites from Loch Leven, MS, and Richard K. Yancey WMA, LA.

Species	Site	n	Mean Trophic Position
Alligator Gar	Floodplain	6	3.55 ± 0.16
Longnose Gar	Floodplain	16	3.06 ± 0.06
	Riverine	52	3.27 ± 0.03
	Richard K. Yancey	8	3.13 ± 0.06
Shortnose Gar	Floodplain	71	2.86 ± 0.03
	Riverine	62	3.20 ± 0.03
	Richard K. Yancey	20	3.01 ± 0.04
Spotted Gar	Floodplain	51	2.81 ± 0.05
	Riverine	12	3.08 ± 0.04
	Richard K. Yancey	44	3.00 ± 0.03

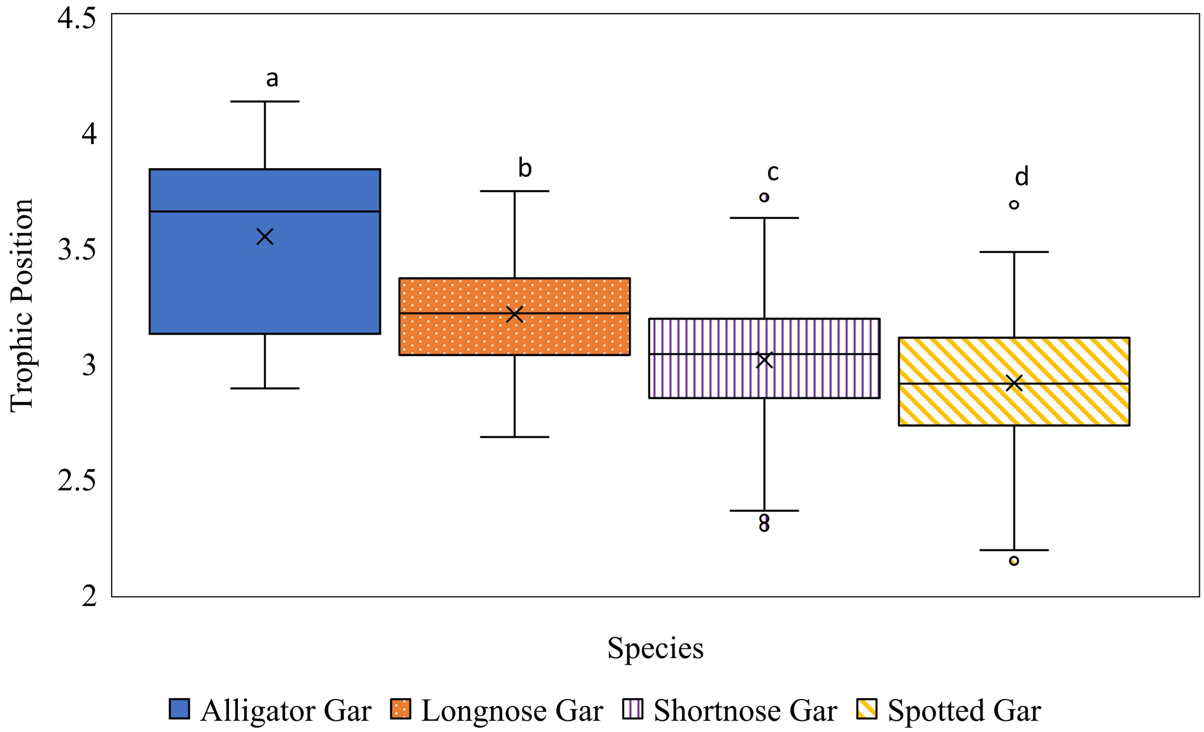

Figure 23. Box and whisker plots of mean trophic position (indicated by "X") of Alligator Gar (ALG) (3.55 ± SE 0.16, n = 6), Longnose Gar (LNG) (3.21 ± 0.03, n = 76), Shortnose Gar (SNG) (3.02 ± 0.02, n = 153), and Spotted Gar (SPG) (2.92 ± 0.03, n = 107) in the Mississippi River Floodplain. Different letters indicate significant differences based on ANOVA and Tukey's post hoc test.

Riverine Spotted Gars (3.08 ± 0.04, n = 12), but not those in the Floodplain (2.81 ± 0.05, n = 51). An individual Shortnose Gar found at LL occupied an extremely low trophic position below 2.2. Trophic position was also compared across different species within a site. Trophic position of young-of-year (YOY) gars at LL were not significantly different between species (Figure 24).

Mississippi River Floodplain Gars Compared to Other Populations

To investigate differences in growth and trophic ecology across systems, MRFP Spotted Gars were compared to Spotted Gar populations from a Near-coastal marsh (NCM) near Chauvin, LA, Little Bayou Sorrel in the Atchafalaya River Basin (ARB), and Bayou Chevreuil in the Upper Barataria Estuary (UBE) (Figure 25). Mississippi River Floodplain female Spotted Gars had a significantly larger mean total length compared to all other sites and sexes except NCM female Spotted Gars. Spotted Gars from UBE had a significantly smaller mean total length compared to all other sites except ARB males. Each population of Spotted Gars exhibited sexually dimorphic growth with females significantly larger (mean total length) compared to males except for UBE gars where males and females were similar. Male Spotted Gars from NCM had a significantly lower mean age compared to MRFP and NCM female Spotted Gars. Standard von Bertalanffy growth models were created for females (Figure 26) and males (Figure 27), model parameters K and L_∞ were also compared (Figure 28). Asymptotic length (L_∞) was significantly higher in MRFP. female Spotted Gars (755.69 mm [715.87 to 814.38], n = 34) compared to all other sites and sexes. Spotted Gars from MRFP (620.31 mm [594.75 to 658.36], n = 32), NCM female Spotted Gars (662.40 mm [641.01 to 680.68], n = 22), and ARB females (648.21 mm [622.18 to 684.46], n = 27) were not significantly different from each other but were significantly different compared to all other groups. NCM male Spotted Gars (555.60 mm [525.33 to 584.09], n = 16), ARB male Spotted Gars (555.60 mm [525.33 to 584.09], n = 26),

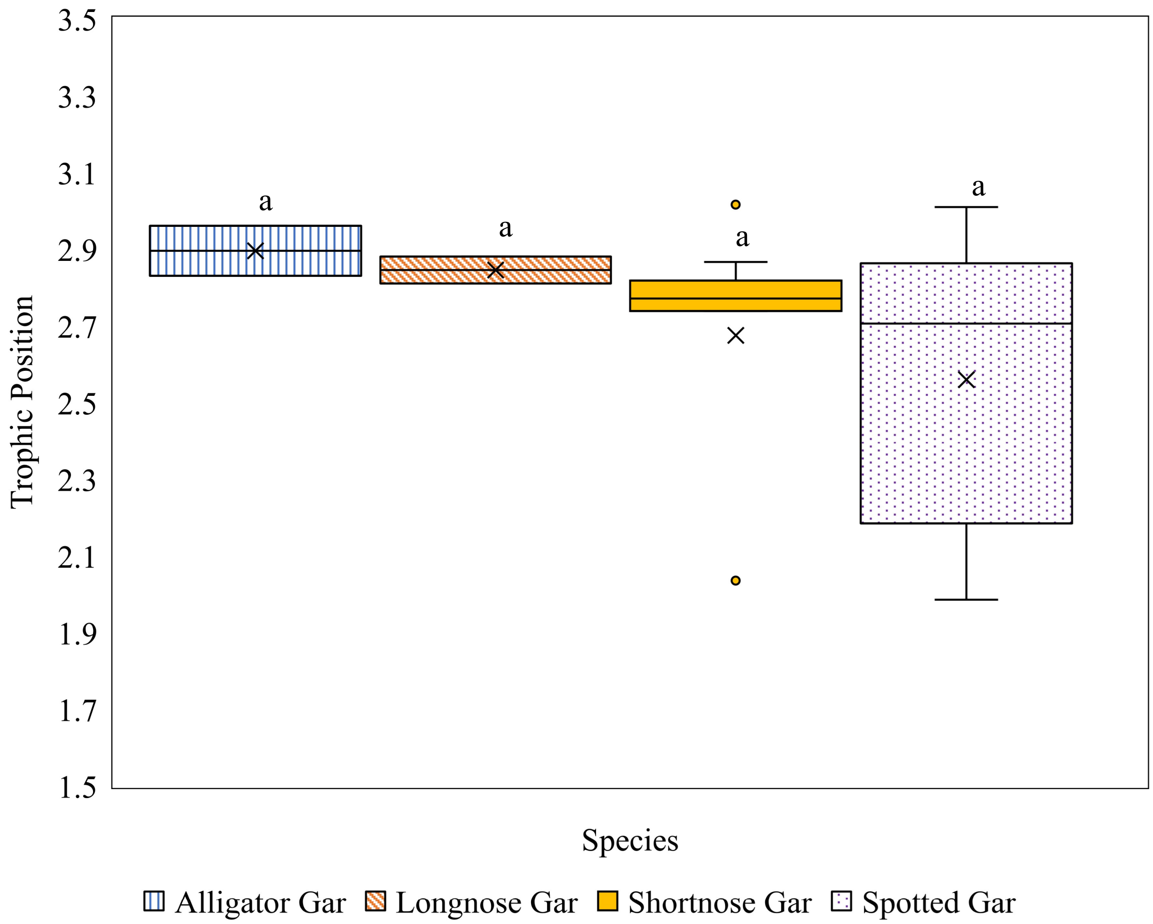

Figure 24. Box and whisker plots of trophic position of young-of-year (YOY) gars at Loch Leven, MS. Mean trophic position (indicated by "X") by species was Alligator Gar 2.90 (± SE 0.05, n = 2), Longnose Gar 2.85 (± 0.02, n = 2), Shortnose Gar 2.68 (± 0.09, n = 11) and Spotted Gar 2.56 (± 0.07, n = 22). Significant differences denoted with different letters based on ANOVA and Tukey's post hoc test.

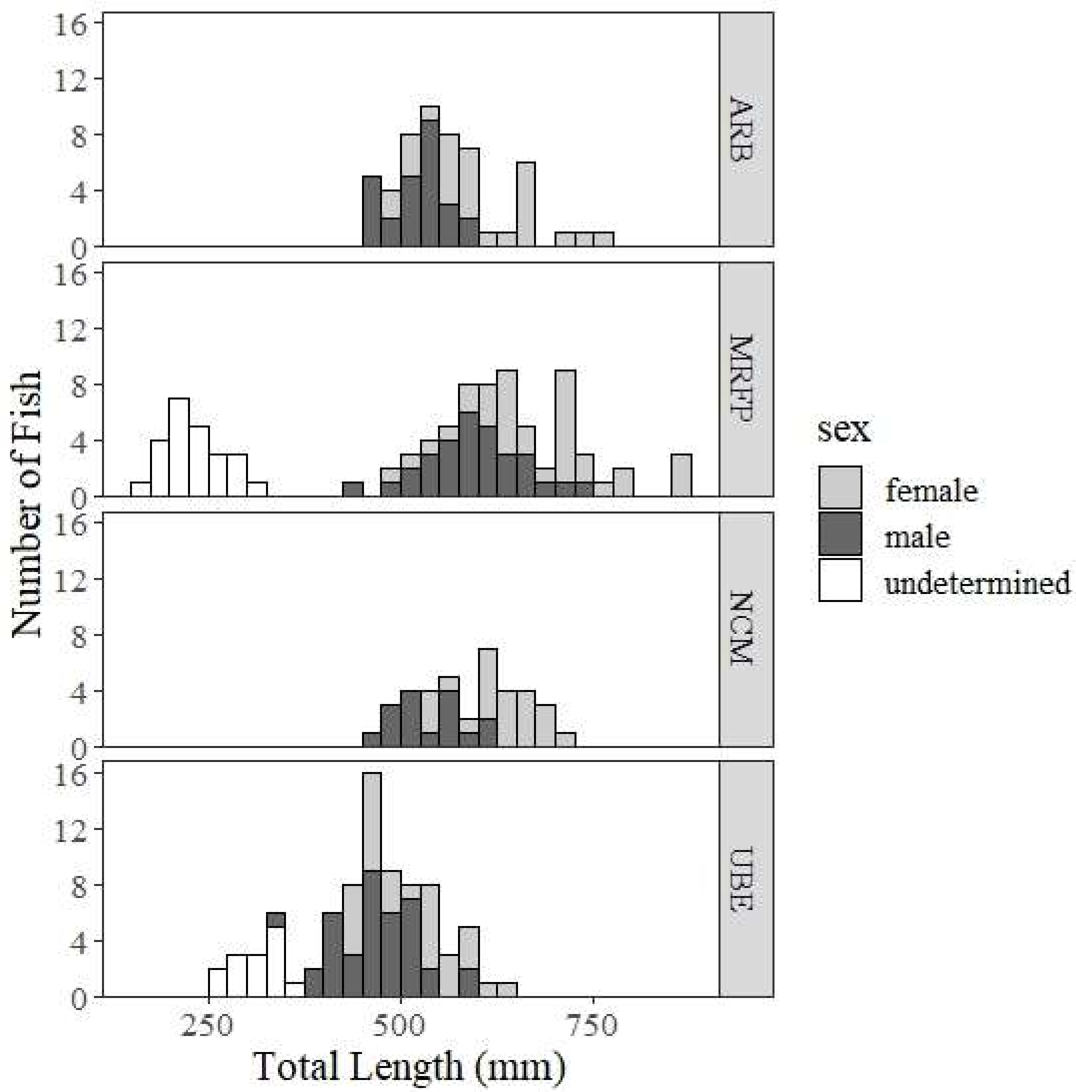

Figure 25. Size distributions (total length) of Spotted Gars collected from Bayou Chevreuil, Upper Barataria Estuary (UBE), Little Bayou Sorrel, Atchafalaya River Basin (ARB), Loch Leven & Richard K. Yancey Wildlife Management Area, Mississippi River Floodplain (MRFP) and a Near-coastal Marsh, Chauvin, LA (NCM).

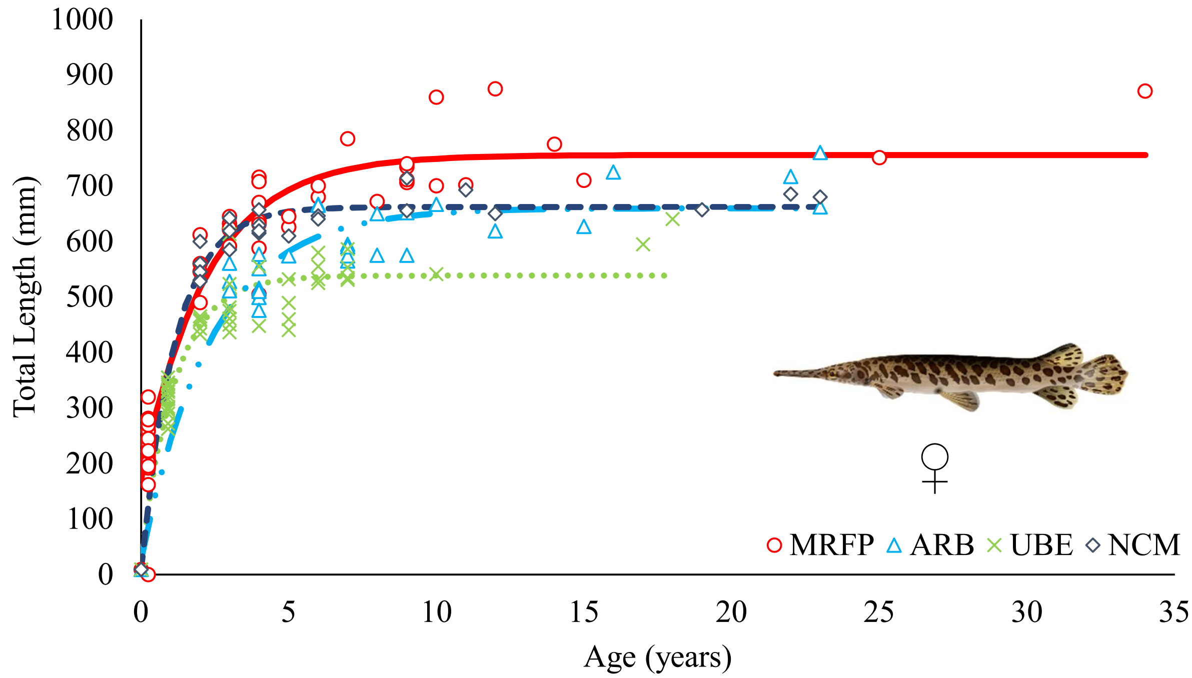

Figure 26. Von Bertalanffy growth curves fit for female Spotted Gars from Upper Barataria Estuary (UBE), Atchafalaya River Basin (ARB), Mississippi River Floodplain (MRFP) and Near-coastal March (NCM). Number of adult female gars per site was UBE (n = 30), ARB (n = 27), MRFP (n = 34), and NCM (n = 22).

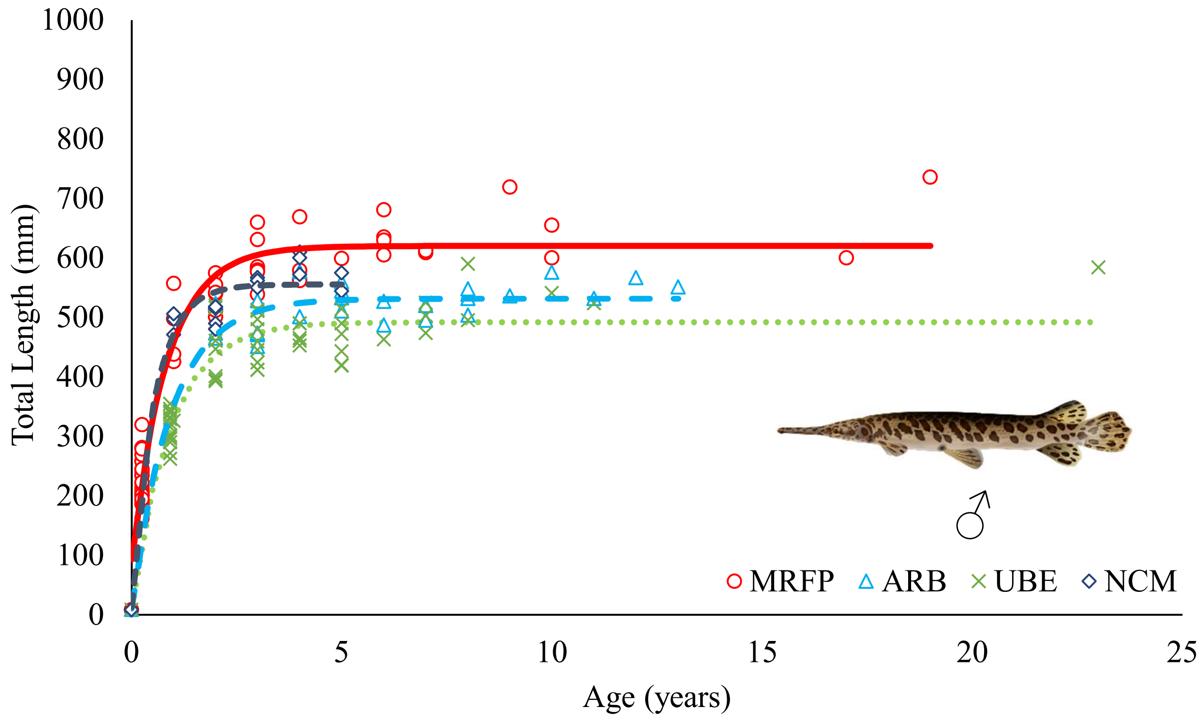

Figure 27. Von Bertalanffy growth curves fit for male Spotted Gars from Upper Barataria Estuary (UBE), Atchafalaya River Basin (ARB), Mississippi River Floodplain (MRFP) and Near-coastal March (NCM). Number of adult male gars per site was UBE (n = 38), ARB (n = 26), MRFP (n = 32), and NCM (n = 16).

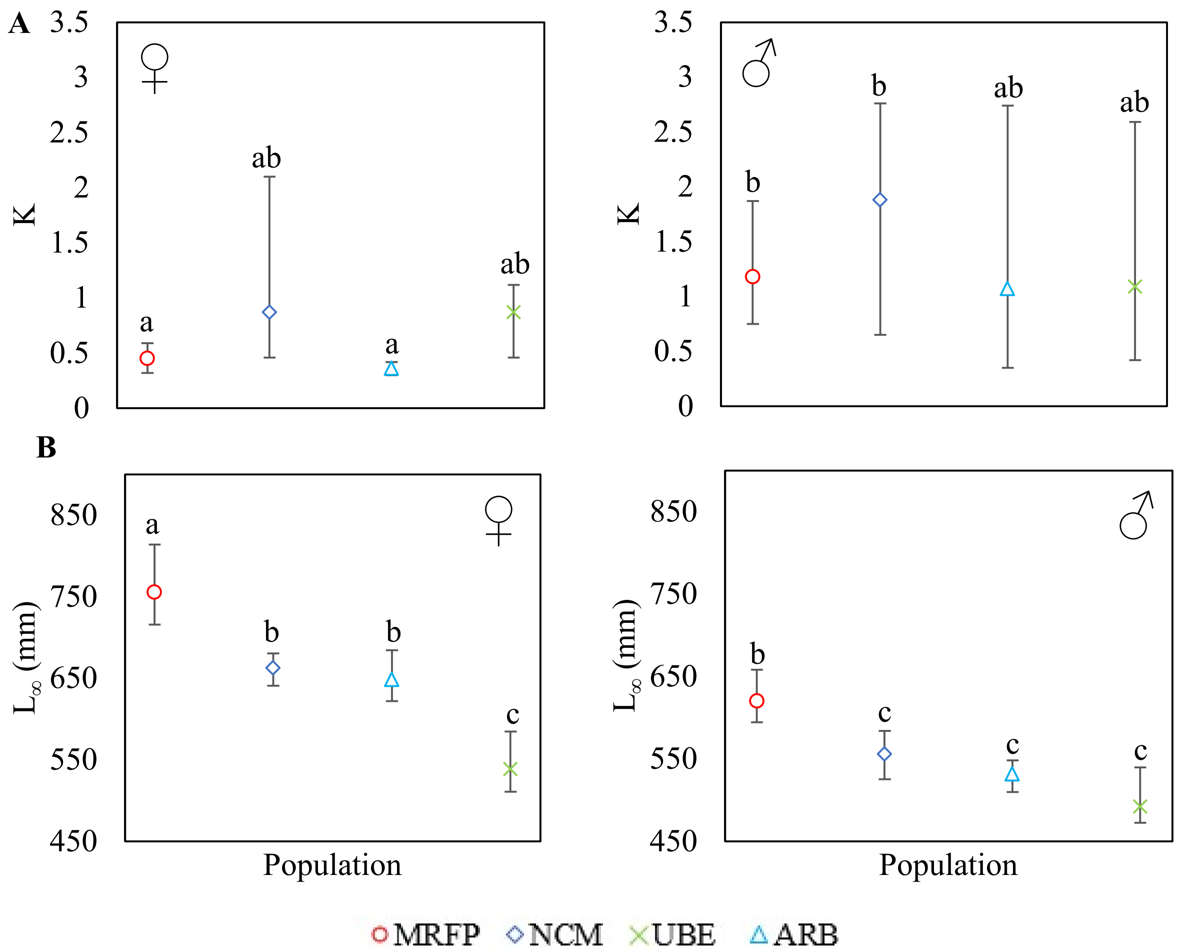

Figure 28. Parameter estimates for asymptotic length L_∞ and growth coefficient K (with 95% Confidence Intervals) from standard von Bertalanffy growth curves fitted for Spotted Gars from the Upper Barataria Estuary (UBE), Atchafalaya River Basin (ARB), Mississippi River Floodplain (MRFP) and a Near-coastal March (NCM). Females (A) and males (B) denoted by symbols. Different letters indicate significant differences between populations based on 95% confidence intervals. Number of adult female gars per site was UBE (n = 30), ARB (n = 27), MRFP (n = 34), and NCM (n = 22). Number of adult male gars per site was UBE (n = 38), ARB (n = 26), MRFP (n = 32), and NCM (n = 16).

and UBE male (492.17 mm [472.51 to 539.75], n = 38) and female (531.67 mm [509.84 to 548.33], n = 26) Spotted Gars all had similar L_∞ values and were different from all other groups (Table 12). For all groups except for UBE, female gars had significantly higher L_∞ values than males at the same site.

Mean Length at Age of Spotted Gars

Mean length at age of male and female Spotted Gars from ages 2-10 years were compared among MRFP, NCM, ARB, and UBE (Figure 29A and B). Female MRFP Spotted Gars (Table 13) had a significantly greater mean length at age compared to female UBE Spotted Gars at ages 2, 3, 4, 5, and 6, and significantly greater mean length at age compared to female ARB Spotted Gars at ages 4, 6, and 9. Female NCM Spotted Gars exhibited a longer mean length at age compared to female UBE Spotted Gars at ages 2, 3, and 6, and longer mean length at age compared to female ARB Spotted Gars at age 4. Mississippi River Floodplain male Spotted Gars (Table 14) were larger at ages compared to UBE males at ages 2, 3, 4, and 7, and significantly larger at age compared to male ARB Spotted Gars at ages 3 and 7. Male NCM Spotted Gars were larger at age compared to male UBE Spotted Gars at ages 3, 4, and 5. Atchafalaya River Basin female Spotted Gars had a significantly greater mean length at age compared to UBE female Spotted Gars at age 6, and male ARB Spotted Gars were larger compared to male UBE Spotted Gars at age 5 (Table 15) Analysis of covariance (ANCOVA) was used to compare the growth rates of Spotted Gars from hatch to three years of age between among sites are compared in Table 16. Female MRFP Spotted Gars (slope = 0.66) and males (0.67) showed significantly higher growth rates (based on linear regression of $\log_{10}$ age (years) and log length (mm)) compared to populations from ARB (♀ 0.60 ♂ = 0.60), UBE (♀ = 0.59, ♂ = 0.59), and NCM (♀ = 0.66, ♂ = 0.63) sites. Female NCM female Spotted Gars also had significantly higher growth

Table 12. Life History and standard von Bertalanffy parameters for Spotted Gars from the Upper Barataria Estuary (UBE), Atchafalaya River Basin (ARB), Mississippi River Floodplain (MRFP), and Near-coastal March (NCM). Von Bertalanffy growth curves estimated parameters for asymptotic length (L_∞), growth coefficient (K) and age at 0 length parameter (t_0) with 95% Confidence Intervals (in parentheses). Mean total length (TL) and mean age were compared using ANOVA and Tukey's post hoc test. Letters indicate significant differences between groups. Young-of-year gars, in parentheses, not included in mean total length and age.

Site	Sex	n	Mean TL (range)	Mean Age (range)	L_∞ (mm)	K	t_0
MRFP	♀	34 (24)	677.00 (490-871)^{A}	7.50 (2.00-34.00)^{AB}	755.69 (715.87-814.38)^{A}	0.45 (0.32-0.59)^{A}	-0.58 (-0.85--0.40)^{A}
	♂	32 (24)	586.59 (426-736)^{BC}	4.94 (1.00-19.00)^{B}	620.31 (594.75-658.36)^{B}	1.18 (0.75-1.87)^{B}	-0.13 (-0.34--0.01)^{B}
NCM	♀	22	625.41 (528-714)^{AB}	7.14 (2.00-23.00)^{AB}	662.40 (641.01-680.68)^{B}	0.87 (0.46-2.10)^{AB}	-0.02 (-2.90-0.52)^{AB}
	♂	16	535.94 (471-600)^{CE}	2.75 (1.00-5.00)^{BC}	555.60 (525.33-584.09)^{C}	1.88 (0.65-2.76)^{B}	-0.01 (-3.71--0.00)^{AB}
ARB	♀	27	599.56 (476-760)^{B}	8.63 (3.00-23.00)^{B}	648.21 (622.18-684.46)^{B}	0.36 (0.30-0.42)^{A}	-1.28 (-1.54--1.06)^{C}
	♂	26	520.23 (451-576)^{CD}	6.11 (2.00-13.00)^{B}	531.67 (509.84-548.33)^{C}	1.07 (0.35-2.74)^{AB}	-0.02 (-7.57-1.17)^{C}
UBE	♀	30 (14)	508.43 (433-640)^{DE}	5.27 (2.00-18.00)^{B}	538.62 (511.09-584.69)^{C}	0.87 (0.46-1.12)^{AB}	-0.06 (-1.15-0.08)^{AB}
	♂	38 (14)	471.11 (326-590)^{D}	4.76 (1.00-23.00)^{B}	492.17 (472.51-539.75)^{C}	1.09 (0.42-2.59)^{AB}	-0.02 (-1.43-0.47)^{A}

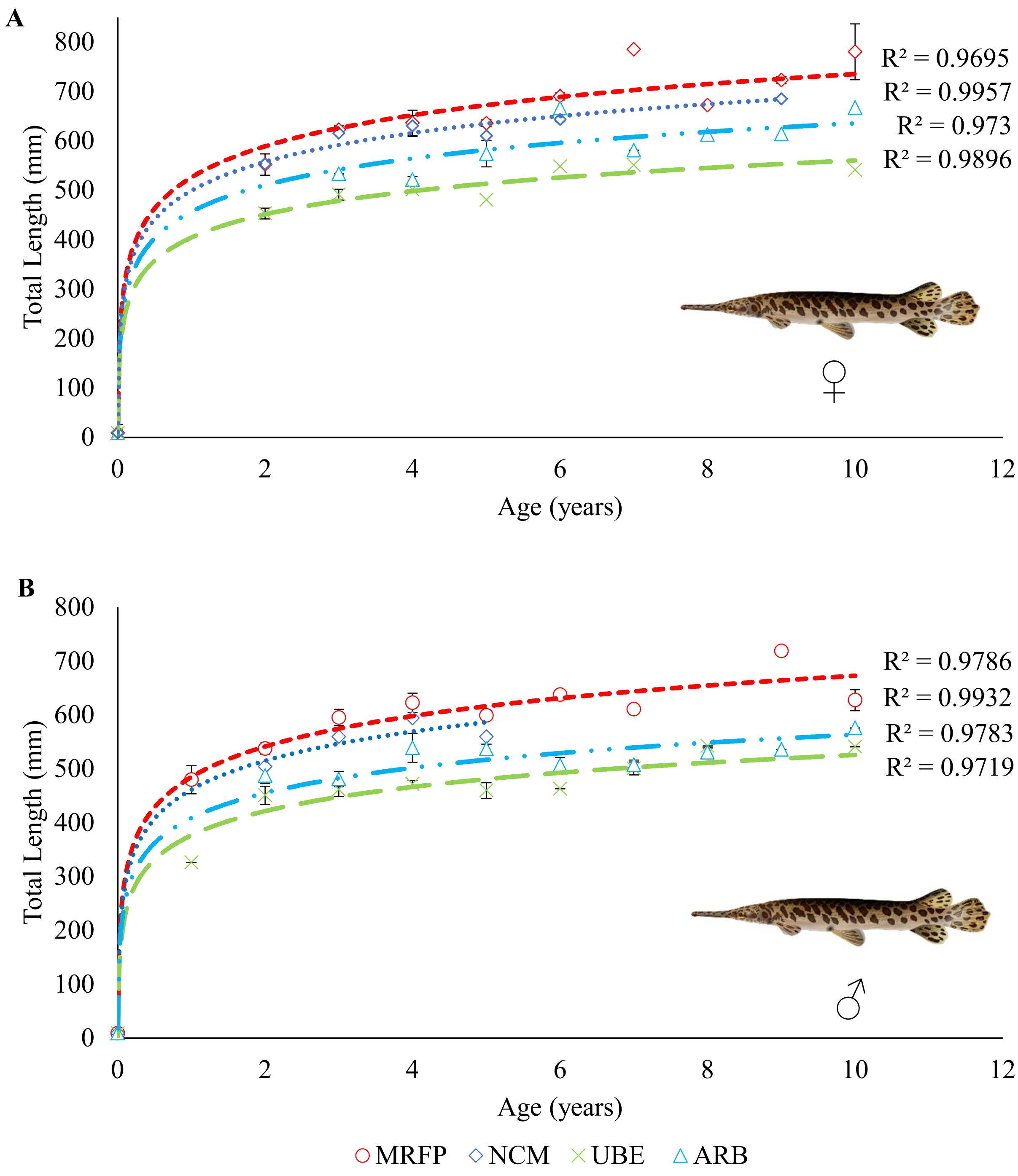

Figure 29. Mean length at age of female (A) and male (B) Spotted Gars up to 10 years old for Mississippi River Floodplain (MRFP), Near-coastal Marsh (NCM), Atchafalaya River Basin (ARB), and Upper Barataria Estuary (UBE). Mississippi River Floodplain male and female Spotted Gars were significantly larger at multiple ages compared to other populations.

Table 13. Mean total length (TL) at age ± SD for female Spotted Gars ages 1-10 from Mississippi River Floodplain (MRFP), Near-coastal Marsh (NCM), Atchafalaya River Basin (ARB), and the Upper Barataria Estuary (UBE) populations.

Age	MRFP		NCM		ARB		UBE	
	n	Mean TL (mm)	n	Mean TL (mm)	n	Mean TL (mm)	n	Mean TL (mm)
1	0	-	0	-	0	-	0	-
2	4	552.00 ± 43.43	5	552.6 ± 26.36	0	-	6	453.00 ± 11.24
3	5	622.60 ± 17.85	3	615.33 ± 23.41	3	533.33 ± 20.76	7	491.29 ± 55.89
4	7	636.29 ± 73.29	4	630.00 ± 18.94	6	521.50 ± 26.58	2	501.50 ± 75.66
5	2	635.50 ± 9.50	1	610.00 ± 0.00	1	574.00	4	480.25 ± 21.55
6	2	690.00 ± 10.00	2	643.00 ± 3.00	2	666.00 ± 1.00	4	548.00 ± 21.55
7	1	785.00	0	-	4	581.00 ± 12.06	4	551.00 ± 21.90
8	1	672.00	0	-	2	612.5.00 ± 37.50	0	-
9	4	722.75 ± 14.52	2	684.50 ± 29.50	2	613.5.00 ± 38.50	0	-
10	2	780.00 ± 80.00	0	-	1	667.00	1	541.00

Table 14. Mean total length (TL) at age ± SD for male Spotted Gars ages 1-10 from Mississippi River Floodplain (MRFP), Near-coastal Marsh (NCM), Atchafalaya River Basin (ARB), and the Upper Barataria Estuary (UBE) populations.

Age	**MRFP**		**NCM**		**ARB**		**UBE**	
	n	**Mean TL (mm)**	**n**	**Mean TL (mm)**	**n**	**Mean TL (mm)**	**n**	**Mean TL (mm)**
1	4	479.75 ± 52.28	3	491.33 ± 14.84	0	-	1	326.00
2	6	537.50 ± 24.90	5	504.20 ± 16.03	3	487.33 ± 25.49	8	450.75 ± 48.00
3	6	595.33 ± 7.13	3	559.67 ± 7.13	4	481.00 ± 28.54	7	474.00 ± 34.51
4	4	593.50 ± 50.90	3	594.00 ± 19.70	2	539.00 ± 53.74	5	471.80 ± 17.17
5	1	599.00 ± 0.00	2	559.50 ± 15.50	4	537.00 ± 17.82	6	459.67 ± 35.42
6	4	637.75 ± 27.44	0	-	2	507.00 ± 20.00	1	463.00
7	2	610.50 ± 1.50	0	-	2	507.50 ± 12.50	3	500.67 ± 20.89
8	0	-	0	-	4	530.75 ± 16.45	2	542.50 ± 47.50
9	1	719.00	0	-	1	536.00	0	-
10	2	627.50 ± 27.50	0	-	1	576.00	0	-

Table 15. Pairwise comparison of Spotted Gar mean length at age for populations from the Mississippi River Floodplain (MRFP), a Near-coastal Marsh (NCM), the Atchafalaya River Basin (ARB), and the Upper Barataria Estuary (UBE). Significant differences in age classes are listed for each comparison. Female Spotted Gars are listed on top and male Spotted Gars listed on bottom. Age classes with only one value per year were not compared. Pairwise ANOVA was used for groups when comparing only two age classes and a Tukey's HSD test was used when comparing three or more groups. A minimum of two values per age class were used for comparisons.

Population	MRFP	NCM	ARB	UBE
Mississippi River Floodplain		None	4, 6, 9	2, 3, 4, 5, 6
Near-coastal Marsh	None		4	2, 3, 6
Atchafalaya River Basin	3, 7	None		6
Upper Barataria Estuary	2, 3, 4, 7	3, 4, 5,	5	

Table 16. Pairwise comparisons of growth rates of Spotted Gars at the Mississippi River Floodplain (MRFP), Near-coastal Marsh (NCM), Atchafalaya River Basin (ARB), and Upper Barataria Estuary (UBE) up to 3 years of age. Males are listed above diagonal and females are listed below diagonal. Significant differences in slope were based on linear regression of $\log_{10}$ age (years) and log length (mm) and indicated with asterisks. The first value in each row is from the column heading and the second value is from the row heading.

Population	MRFP	NCM	ARB	UBE
Mississippi River Floodplain		0.63/0.67*	0.60/0.67*	0.59/0.67*
Near-coastal Marsh	0.66/0.63*		0.60/0.63	0.59/0.63*
Atchafalaya River Basin	0.66/0.60*	0.66/0.60*		0.59/0.60
Upper Barataria Estuary	0.66/0.59*	0.66/0.60*	0.60/0.60	

rates compared to females from UBE and ARB populations. Male Spotted Gars from NCM had significantly higher growth rates compared to male UBE Spotted Gars. Growth rates of male and female Spotted Gars from UBE and ARB were not significantly different.

Trophic position of Spotted Gars from “Floodplain and RKY” and “Riverine” sites were compared with trophic position of YOY gars from MRFP, adult spotted gars from ARB, and adult Spotted Gars from UBE (Figure 30). Riverine Spotted Gars (Mean = 4.77 ± SE 0.06, n = 6) occupied a significantly higher trophic position than “Floodplain and RKY” Spotted Gars (4.34 ± 0.03, n = 66). Young-of-year Spotted Gars from MRFP (3.54 ± 0.12, n = 22), Spotted Gars from ARB (3.54 ± 0.05, n = 30), and UBE (3.62 ± 0.02, n = 49) were not significantly different from each other but were significantly lower than both “Riverine” and “Floodplain and RKY” sites.

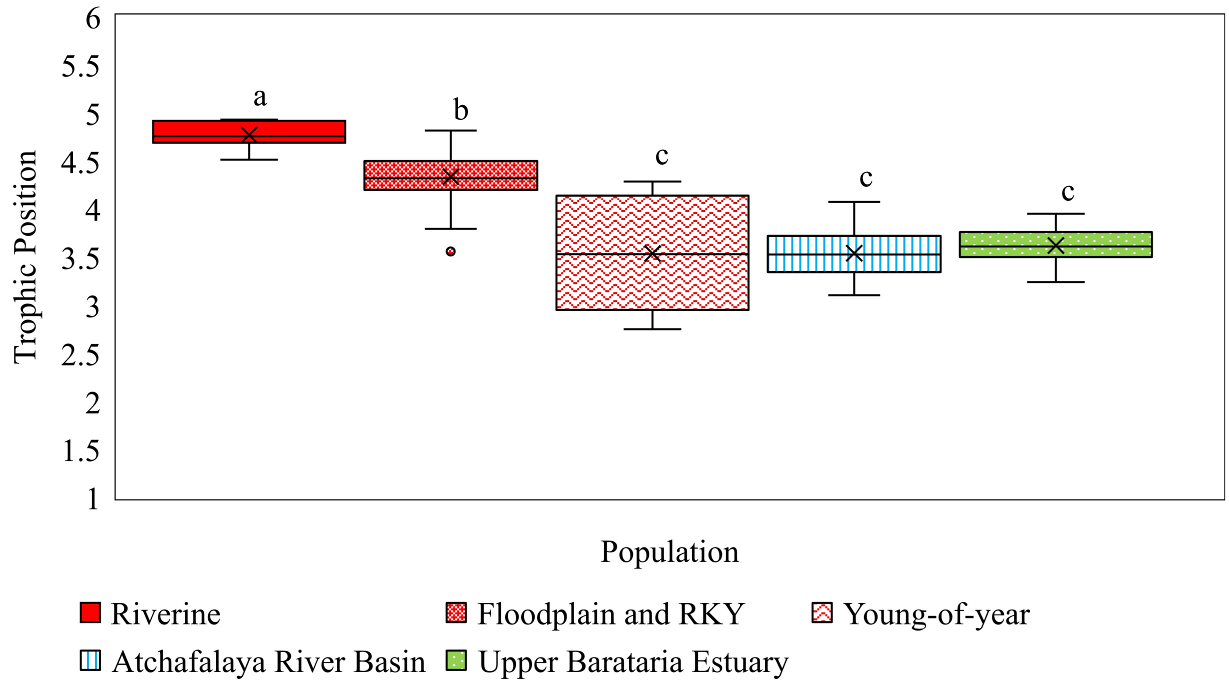

Figure 30. Box and whisker plots of trophic position of Spotted Gars collected from "Riverine" sites at Loch Leven, MS (Mean = 4.77 ± SE 0.06, n = 6), from Richard K. Yancey WMA, LA (RKY) and "Floodplain" sites at Loch Leven (4.34 ± 0.03, n = 66), Young-of-year (YOY) Spotted Gars from Loch Leven (3.54 ± 0.12, n = 22), and adults from Atchafalaya River Basin (ARB) (3.54 ± 0.05, n = 30) and Upper Barataria Estuary (UBE) (3.62 ± 0.02, n = 49). Different letters indicate significant differences between groups and the mean is indicated by the "X".

Discussion

The purpose of this study was to explore life history characteristics of four gar species in two Mississippi River Floodplain restoration sites, and to compare Spotted Gar populations in Mississippi River Floodplains to other Spotted Gar populations. Gars at LL and RKY were similar in length and age, supporting my initial hypothesis, however the presence of large Alligator Gar at LL and not RKY may suggest that different habitats exist between the two floodplains. Trophic ecology differed between Floodplain and Riverine sites, which also suggests differences in habitat use by gars. Trophic position comparisons between sites with a consistent flood pulse and those without did not support my hypothesis. The MRFP trophic position of gars was significantly higher than the mean trophic position of Spotted Gars at ARB. This suggests that a consistent flood pulse is not the only factor affecting trophic position. Populations from both sites were higher than the mean trophic position value for UBE, which does support that a consistent flood pulse may allow organisms to feed at a higher trophic level compared to an irregular flood pulse. For population comparisons, I hypothesized that Spotted Gars in floodplain sites would experience similar growth and asymptotic length, however the MRFP Spotted Gars grew significantly faster and to a larger size which further suggests that not all flood pulses have the same effect on fish communities.

Abundance and Length of Gars

The presence of all four gar species in both floodplains (LL and RKY), including Alligator Gar, which are considered uncommon (Baker et al. 1991) is a sign of suitable gar habitat at both restoration sites. Over the two-year study period, YOY, juvenile, and adults of all four gar species were found at LL, indicating that all life stages use floodplain habitat. Differences in Longnose Gar length between LL and RKY was likely the result of the number collected and sex ratios. At RKY, only 10 Longnose Gars were collected, and the majority were males, possibly leading to shorter mean total length due to sexual dimorphic growth (McGrath and Hilton 2012).

Age and Sex of Gars

Maximum age estimates of “rough fish”, or fish deemed to be of low economic value such as Bigmouth Buffalo *Ictiobus cyprinellus* have previously been underestimated, suggesting that other “rough fish” such as gars may also have underestimated longevity (Lackmann et al. 2019). This study supported rough fish longevity concepts proposed by Lackmann et al. (2019) by identifying relatively old individuals of several gar species. The oldest Shortnose Gar (49 years), collected at LL, is also the oldest individual of the species on record. Maximum age of Alligator Gar at LL (56 years) was similar to the oldest Alligator Gar (53 years) identified in a study evaluating trophy populations in the Trinity River, Texas (Buckmeier et al. 2016). The oldest Longnose Gar (23 years), from LL was similar to the oldest individuals found in coastal populations in South Carolina (25 years) (Smylie et al. 2016). Maximum age of Spotted Gar (34 years) in the Mississippi River Floodplain was also similar to maximum ages found in recent studies. Buckmeier et al. (2018) aged Spotted Gar in Texas up to 27 years old, while King et al. (2018) found Spotted Gar in Illinois at a maximum age of 24 years old. Snow and Porta (2019) reported Spotted Gars up to 43 years old. Prior to 2006, the maximum known age of Spotted Gars was 18 years old (Redmond 1964; COSEWIC 2005), suggesting that modern aging techniques may be more accurate than previous methods. Prior studies likely underestimated the maximum age of gars due to older aging techniques, or the use of non-otolith aging structures (e.g. branchiostegal rays,pectoral fin rays), which may underestimate age (Buckmeier et al. 2012). Mississippi River Floodplain gar populations (LL and RKY combined) displayed sexual dimorphism within species, with females of all species significantly larger (mean total length) than males, which is consistent with other studies (Love 2002, McGrath and Hilton 2012, McDonald et al. 2013). Among gar populations in RKY, only Spotted Gar exhibited sexual dimorphism, which may be due to lower sample size of other species (Shortnose Gar, n = 15, Longnose Gar, n = 8, Alligator Gar, n = 1). Differences in male-dominated sex ratio in Shortnose Gars at LL may have been the result male dominated spawning groups that moved onto the floodplain. During spawning, these groups normally consist of one large female and multiple males (Love 2004). If these groups were caught in the gill nets during sampling, it may appear that the population consisted of more males and less females.

Gar Growth of Different Species

The L_∞ parameter (asymptotic length) was similar for males and females from both sites, suggesting that Spotted Gars at RKY and LL reach approximately similar lengths at maturity. The K parameter (growth coefficient) was significantly higher at LL compared to RKY, which suggests that Spotted Gars at LL reach their asymptotic length faster than those at RKY which could indicate variances in resource use between sites. Despite differences in access to LL and RKY, at the time of collection, gars were able to move freely in and out of floodplain habitats and may have even switched between LL and RKY sites. Out of 46 tagged Alligator Gar in the lower Trinity River in Texas, several used over 100km of the river, although 83% had home ranges that were less than 60km (Buckmeier et al. 2013), suggesting that some individuals move between different areas in the river. A sample of tagged Spotted Gar (n = 37) in the Atchafalaya River Basin had a median movement rate of 130.1 m/d in with a 265.1 ha home range in the spring and a 34.6 m/d movement rate in fall/winter with a home range of 10.5 ha (Snedden et al.

1999). Seasonal movement of gars from river to floodplain and back could account for some of the similarities between gar populations at LL and RKY sites.

The L_∞ VB growth parameter for female MRFP Longnose Gars was most similar to female Longnose Gar populations in Alabama (L_∞ = 1132 mm), collected below a dam (Ferrara 2001) and aged with whole otoliths, and female Longnose Gar populations from a Texas lake (L_∞ = 1132 mm) (Kelley 2012) aged with branchiostegal rays. Kelley (2012) suggested that longer foraging periods, higher mean temperatures, and a similar growing season (such as populations in the same ecoregion) could lead to similarities between populations, such as those seen in L_∞ similarities from female Longnose Gars in Texas, Alabama, and in the MRFP (Louisiana/Mississippi). All three areas also support an abundance of shad (*Dorosoma spp.*) which has been thought to be a primary driver of growth in Longnose Gars (Kelley 2012). Klaassen and Morgan (1974) suggested that Longnose Gar may grow faster and larger in reservoirs compared to rivers based on an increased abundance of Gizzard Shad *Dorosoma cepedianum*, however Longnose Gars in floodplains and below dams may experience the same benefits if there is also an abundance of shad and other prey such as YOY fishes. Young-of-year were abundant at LL and RKY sites, and a YOY gar was even seen in the stomach of a Shortnose Gar at LL.

One study was found with VB parameters to compare with Shortnose Gar VB parameters from MRFP populations. Sutton et al. (2009) found that L_∞ of combined males and females from the Wabash River in Indiana and Illinois was 660 mm. Mississippi River Floodplain male and female Shotnose Gar were both larger than the Wabash River estimated parameter, which did not fall within the CI for males or females from MRFP. Size range (total length) of Wabash River Shortnose Gars was similar to MRFP), although several larger individuals were found in MRFP communities. Wabash River Shortnose Gars were aged using branchiostegal rays with an estimated range of 2-12 years. MRFP Shortnose Gar ages ranged from 0.25-49 years, although most individuals were between 0-15 years of age. The largest and oldest MRFP Shortnose Gars were larger and older than the maximum size and age of individuals from the Wabash River. Differences in age and VB parameters could be a result of aging techniques or population differences, and VB parameters from the Wabash River were influenced by combing male and female individuals. Gars are sexually dimorphic (Love 2002, McGrath and Hilton 2012, McDonald et al. 2013) with females generally reaching a larger size at maturity compared to males. Combing males and females in one growth model does not account for the number of males and females, which makes it difficult to compare to other studies.

Mississippi River Floodplain L_∞ for Spotted Gar females and males were compared to combined male and female Spotted Gar VB parameters from Lake Thunderbird, a reservoir Lake in Oklahoma. Combined (males and females) Lake Thunderbird Spotted Gar $L_\infty = 609$ mm (Frenette and Snow 2016) fell within the 95% CI from MRFP male Spotted Gars but was significantly smaller than L_∞ for MRFP females. Mean total length for Lake Thunderbird Spotted Gars (female, 651.7 ± 124.2 mm, male 582.7 ± 48.9 mm) were similar to MRFP mean TL for Spotted Gar males and females (females 677.00 ± 91.23 mm TL, males 586.59 ± 68.96 mm). Combining males and females likely lowered L_∞ for Spotted Gars collected in Lake Thunderbird, where sexual dimorphic growth was observed and more males (n = 66) were caught compared to females (n = 24), making accurate comparisons difficult. Frenette and Snow (2016) aged gars using whole otoliths, with ages ranging from 1-14 years. MRFP Spotted Gars had a wider age range (1 – 34 years) than those aged from Lake Thunderbird. David (2012) also estimated VB parameters from core and peripheral populations of Spotted Gars with males and females combined. Mississippi River Floodplain L_∞ for female Spotted Gars was similar to L_∞ for Michigan (777.00 mm [712.00 to 842.00]), Lake Erie (872.00 mm [744.00 to 1004.00]), and Louisiana (781.00 mm [615.00 to 947.00]) (collected from Bayou Chevreuil in the Upper Barataria Estuary) populations. Ages of gars from David (2012) may also be underestimated due to older aging techniques relative to Buckmeier et al. 2012, which would impact VB parameters. Other factors could also account for differences, such as combining males and females.

Although few Alligator Gar were collected in MRFP sites, the presence of at least two individual Alligator Gar over 15 years old, including one over 50 years of age suggests that the conditions in the LL floodplain can support trophy-sized Alligator Gar (Buckmeier et al 2016). Estimated L_∞ from MRFP and NCM female Alligator Gars resulted in a large CI, which likely resulted from low sample size (n = 10) and large age range in creation of the VB growth curve. The L_∞ parameter from MRFP and NCM female Alligator Gar was similar to Double von Bertalanffy estimated L_∞ (1760.00 mm ± SE 77.10 mm) from female Alligator Gars in multiple Texas systems (Daugherty et al. 2019). The Double von Bertalanffy curve fits two models, one for fish below a critical age, and one for those above a critical age, and creates one growth curve from both models, which would likely estimate a larger L_∞ compared to a typical VB growth model.

Trophic Ecology of Gars

Trophic position of gars on the River and Floodplain at LL were similar to those observed by Ellis (2021), with gars feeding at a significantly lower trophic position on the Mississippi River floodplain compared to those feeding closer to the Mississippi River. A decrease in trophic position may be indicative of an increase in feeding options due to floodplain access, as fish consume a wider variety of prey as a result of hydrological seasonality (Correa and Winemiller 2014). Largemouth Bass *Micropterus salmoides* and Smallmouth Bass *Micropterus dolomieu* also displayed similar patterns of nitrogen depletion in floodplain habitats of the Upper Mississippi River (Roach et al. 2009). In Amazon River floodplains, piscivores and omnivores tend to occupy a lower trophic position during the wet season by increasing plant and/or invertebrate consumption (Wantzen et al. 2002; McMeans et al. 2019) although species do not always follow a specific pattern based on body size or functional group. Floodplain fishes have also been observed having greater niche breadth (Azevedo et al. 2021) and diverse diets on floodplains (Fisher et al. 2001). Bonvillain and Fontenot (2020) found that predatory fish fed on more Red Swamp Crayfish *Procambarus clarkii* and Southern White River Crayfish *P. zonangulus* in the Atchafalaya River Basin during floodplain inundation periods and shifted their diet to other invertebrates, fish, and herpetological resources during low water. Although YOY and shad appeared to be abundant at both MRFP sites, it's possible an increase in crayfish and other invertebrates may have influenced nitrogen depletion and a lower trophic position in the floodplain. Longnose, Shortnose, and Spotted Gars at RKY had mean trophic positions that were above the Floodplain trophic position and below the Riverine trophic position for each of their respective species, however it was not always a significant difference. Because Mississippi River water flows directly through RKY, it is possible that gars on the floodplain are able to come and go more easily, leading to a mix of riverine and floodplain nitrogen signatures, and diverse trophic position levels.

Similar studies have found varying trophic levels for gar species, dependent upon choice of baseline organism and fractionation constant. Winemiller et al. (2007) estimated a trophic position of 3.0 for Spotted Gars ($n = 1$) in a coastal marsh in Northeast Texas using a baseline nitrogen reference of 5.6, which was a combination of plant, sediment, algae, benthos, and plankton samples and a fractionation constant of 3.3. Roach et al. (2009) estimated a Longnose Gar trophic position of 4.25 (n = 11), and Shortnose Gar trophic position of 4.02 (n = 1), using Zebra Mussels *Dreissena polymorpha* as baselines and 3.4 as the fractionation constant. Akin and Winemiller (2006) used the trophic position equation by Adams et al. (1983), and prey composition as the baseline and found Alligator Gar had a summer trophic position of 3.28 (n = 20), and a winter trophic position of 3.07 (n = 10). Variability in baseline use, fractionation constant, and equations to calculate trophic position makes comparisons difficult, however in each study, gars were typically near the top of the food web. Size of fishes has been positively correlated with trophic position (Romanuk et al. 2011) which follows the size structure of gar species in relation to trophic position.

It is well-established that gars feed on fish and macroinvertebrates, with smaller gar species feeding on smaller prey, Longnose Gar feeding mostly on fish, and Alligator gar often scavenging (Darnell 1961; Goodyear 1967; Seidensticker 1987; Robertson et al. 2008). In this study, gars with a larger maximum length fed at a higher trophic position, except for similarly-sized Spotted and Shortnose Gars. Spotted Gars have been known to grow longer than Shortnose Gars (Echelle and Grande 2014), however in the MRFP sample, the longest Shortnose Gar collected had a longer total length compared to the longest Spotted Gar. Similarities in Shortnose and Spotted Gar sizes may have led to similarities in feeding strategies and similar trophic positions, with Shortnose gar possibly feeding on more fish, elevating their trophic position. In Shortnose Gars from an Iowa lake, fish composed 60% of their diet and crayfish composed 40% (Potter 1923). A larger sample size throughout the year would benefit trophic position comparisons, and more research should be done comparing other species in floodplain habitats such as Largemouth Bass, White Bass *Morone chrysops*, and Bluegill *Lepomis macrochirus*.

Trophic position of YOY gars was not different between species, however there were significant differences in trophic position of Spotted and Shortnose Gar from different sites within LL, likely influenced by microhabitat structure. One group of Spotted (n = 8) and Shortnose Gar YOY (n = 2) from a particular site within Loch Leven, that had significantly lower trophic positions than those form other sites. Juvenile Alligator gar have been shown to resource partition in disconnected floodplain habitats (Solomon et al. 2013) which could lead to differences in trophic position within microhabitats if difference prey is present at each site. Juvenile Lake Sturgeon *Acipenser fulvescens* have also been known to partition resources (Smith and King 2005), as well as Largemouth and Striped Bass *Morone saxatilis* in Southern US reservoir habitats (Matthews et al. 1992). As habitats become unsuitable or resources become depleted, YOY gars may move within LL, resort to cannibalism, be predated, or dry up and die if water levels drop too low. Microhabitat use by YOY fishes should be investigated further within floodplains habitats to inform understanding of floodplain resource use and benefits to YOY fishes.

<u>Von Bertalanffy Growth Curves of Spotted Gars from Different Populations</u>

The addition of "length at hatch" Spotted Gar into the von Bertalanffy growth models likely created more accurate models, but also likely reduced the value of L_∞ and increased the value of K (Derek Ogle, personal communication). However, because these additions were applied to all populations, it should still allow for accurate comparisons between sites. Growth modeling from the VB suggests that Mississippi River Floodplain Spotted Gars may attain a larger asymptotic length compared to several other Louisiana systems. Mississippi River Floodplain females and males had significantly larger L_∞ and K compared to males and females from other sites. Growing to a larger size benefits fish by allowing them to feed on larger prey and avoiding predation (Birkeland and Dayton 2005). Larger female gars also tend to have higher fecundity and produce more high-quality eggs and larvae, which may increase survival rates in offspring (Daugherty et al. 2019). Echelle and Grande (2014) found that fecundity increased exponentially with longer body length in gars. Access to the floodplains and the Mississippi River also allows gars to exploit river and floodplain resources, while fish in more static environments such as the Upper Barataria Estuary may be limited in habitat and resource choices. Spotted Gars also appeared to grow rapidly in their first year of life which is consistent with prior studies (Matthews et al. 2012, David et al. 2015). Frenette and Snow (2016) found that Spotted Gar reached half of their maximum total length at one year of age and approached their maximum total length by four years of age. Male Spotted Gars from all four study sites appear to reach asymptotic length by four years old, although females may take longer to reach asymptotic length based on the VB, likely due to a larger asymptotic length.

Length at Age and Growth Rate of Spotted Gars from Different Populations

Comparison of gar growth rates up to three years old showed significantly higher growth rates of Spotted Gars in Mississippi River Floodplain compared to other Louisiana populations, which may indicate a higher abundance of resources in these habitats. Floodplains provide access to additional food, spawning, habitat, and nursery refuge for juvenile fish, all of which could contribute to increased growth rates (Junk et al. 1989; Bayley 1995; Ropke et al. 2015). Jeffres et al. (2008) found that juvenile Chinook Salmon grew faster in ephemeral floodplain habitats compared to those in intertidal river sites below floodplains, possibly as a result of warmer temperatures and higher productivity. De Graaf (2003) found that Rainbow Gourami *Colisa fasciatus* and Spotted Snakehead *Channa punctata* experienced higher growth during flood years in Bangladesh. Plentiful spawning habitat on floodplains could also lead to more young-of-year

(YOY) gars, which could feed on each other and other YOY fish, many of which were also documented at RKY and LL. Gars are also cannibalistic, meaning more YOY gars could serve as additional food, and YOY gars were found in the stomachs of other gars during dissections of fish from the Mississippi River Floodplains. Many of the observed habitats on the floodplain contain complex woody debris which may be difficult for predators to to navigate which could decrease predation of YOY and adult gars. Significant differences in mean length at age of multiple age classes for male and female Spotted gars also support the idea that these fish are benefiting from MRFP resources. The ARB also receives a large flood pulse and is more expansive than the heavily modified Lower Mississippi River floodplain. As flood waters recede, gars in the MRFP have the Mississippi River or other deep-water refuge such as the "Blue Lake" at LL to return to, while many gars in ARB may end up being unable to move out of swamps and bayous with more limited resources (as opposed to main channel or reservoir habitat) to use until the next flood pulse (Chris Bonvillain, personal communication). Gars in UBE likely benefit from some irregular flooding, but not seasonal flooding, limiting access to additional resources. Gars from the NCM site also experienced greater age at length than UBE and ARB fish for multiple age classes, and had a higher growth rate up to 3 years old compared to UBE gars. This particular site is now considered freshwater, but still contains fish characteristic of saltwater or brackish water communities such as Ladyfish *Elops saurus* and Sheepshead Minnow *Cyprinodon variegatus variegatus*. Salt marshes may provide valuable food and refuge to coastal species (Boesch and Turner 1984) and it's likely that NCM provides similar value to gars and other predatory species as it is near-coastal.

Trophic Position of Spotted Gars from Different Populations

Higher trophic position of MRFP Spotted Gars suggests that Spotted Gars may be feeding on more fish in and around Mississippi River Floodplains compared to other sites. As gars moved from the Mississippi River floodplain, they appeared to become nitrogen depleted, but the overall trophic position of MRFP combined gars was still higher than those found in ARB and UBE. Gars are known to partition by habitat, with different species being more or less abundant in certain habitat types (Goodyear 1967; Robertson et al. 2008). Differences in diet preferences may be a result of opportunistic feeding (Robertson et al. 2008). Spotted Gars from Mississippi bayous fed mostly on crabs (*Uca pugnax* and *Callinectes sapidus*) (Goodyear 1967), and Spotted Gars in Texas rivers (Bonham 1941) and Louisiana floodplain lakes fed mostly on crayfish (Snedden et al. 1999). Differences in trophic position could also be a result of more complex food webs in larger environments. Arctic Char *Salvelinus alpinus* occupied higher trophic niches in large lakes compared to small or medium-sized lakes due to more competition in larger lakes (Eloranta et al. 2015). The Lower Mississippi River has a larger main channel than the ARB and UBE, which likely allows for higher species diversity, and more niche complexity (Eloranta et al. 2015), which may elevate gars to a higher trophic position due to competition for resources and their ability to feed on organisms that are occupying lower trophic positions that are not present in ARB and UBE systems.

Biases and Limitations

Sampling during the flood season made it difficult to place nets in the same location, and to use only one gear type. During low water sampling, steep banks and shallow water made it difficult to place gill nets, therefore cast nests with smaller bar mesh were used. The use of cast nets with smaller mesh could create a sampling bias by allowing for the capture of small fish that would normally swim through gill nets. Although cast nets were used at both sites, they were used opportunistically, and not all casts had an equal opportunity to catch fish based on how much the net opened per cast. The variability in casts and sampling technique made it difficult to compare a CPUE (catch per unit effort) between sites.

High water levels in 2020 and 2021 made sampling during early spring dangerous when Alligator Gar move onto floodplains to spawn (Kimmel et al. 2014). A reduced number of sampling trips during this season likely reduced the chances of catching large Alligator Gar during spawning. Large females may have been using the floodplain during this time, but were not captured by the sampling team.

For population comparisons, the addition of more juvenile gar (< 2 years of age) from sites other than LL would be valuable in creating more accurate growth curves and in analyzing YOY growth rates at floodplain and non-floodplain sites. The addition of "length at hatch" Spotted Gar into the von Bertalanffy growth models likely created more accurate models, but also likely reduced the value of L_∞ and increased the value of K (Derek Ogle, personal communication). If young-of-years gars were caught at NCM, ARB, and UBE sites, it would allow for more accurate comparisons between sites.

The use of different species of snails for Trophic Position comparisons may have also caused a bias if they accumulate nitrogen at different rates. Although efforts were made to collect the same baseline organism at each site, it was not always possible. Using the same species of baseline would likely make comparisons more accurate, however some isotopic studies do not include the use of a baseline organism at all (Azevedo et al. 2021).

Future Recommendations

Based on this study, floodplains are valuable areas that may increase Spotted Gar growth, size, and trophic position based on faster growth rates up to 3 years of age, von Bertalanffy growth parameters, and trophic position. Floodplain restoration is important to maintain these benefits to gars and possibly other organisms. More research should be done at LL and RKY, along with other floodplain sites to further explore river-floodplain interactions. Tracking studies on gar or other fish species could also further knowledge about species movement in and out of floodplains.

Future high-water sampling and continued monitoring should also be done to better assess the presence and absence of large Alligator Gar and other species using the floodplains for spawning. Despite a lack of high-water sampling, large Alligator Gar were found in the "Blue Lake" reservoir at LL that remains inundated year-round, which suggests suitable habitat exists in LL. The maximum depth of "Blue Lake" is deeper than the three scar lakes at RKY, which may allow Alligator Gar to overwinter in "Blue Lake" but not in the RKY scar lakes. Nearby St. Catherine Creek National Wildlife Refuge contains deep water refuge in an area called the "Blue Hole" which supports healthy overwintering populations of large Alligator Gar (Kimmel et al. 2014). Future restoration projects should consider incorporating the creation of deep-water refuge on floodplains to encourage Alligator Gar overwintering and spawning. Alligator, Longnose, and Shortnose Gar populations from non-flood pulse sites should also be compared to those from floodplain habitats to learn more about floodplain resource benefits.

This study created a baseline of life history characteristics for four gar species that can be compared to other systems. Although abundant in some areas of the United States, gar species have been extirpated or are imperiled in several parts of their range: Alligator Gar is listed as

Extirpated in Ohio and Indiana and Imperiled or Critically Imperiled in seven states: Spotted Gar is listed as Extirpated in New Mexico and Critically Imperiled in three states: Shortnose Gar is listed as Extirpated in Pennsylvania and Alabama, and Critically Imperiled in Montana, Ohio, and South Carolina (Nature Serve 2019). Scarnecchia (1992) called for a reappraisal of gars and Bowfin *Amia calva* in fisheries management, and attitudes appear to be changing regarding gars and other species that were historically perceived to be of little value (Rypel et al. 2021). This study's age and growth models suggest that Mississippi River floodplains support faster growth and larger size in gars. This may also be the case for other species. Monitoring changes of fish communities over time should continue at both restoration sites. These valuable freshwater ecosystems should be conserved, and other similar sites should be restored.

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Appendix A
Fish Species Lists from Study Sites

Table A.1. A total of 26 different fish species representing 10 families were collected at Loch Leven, MS during sampling between June 2020 and December 2021.

Common Name	Family	Species Name
Silverside	Atherinopsidae	*Menidia spp.*
Black Buffalo	Catostomidae	*Ictiobus niger*
Smallmouth Buffalo	Catostomidae	*Ictiobus bubalus*
Black Crappie	Centrarchidae	*Pomoxis nigromaculatus*
Bluegill	Centrarchidae	*Lepomis macrochirus*
Green Sunfish	Centrarchidae	*Lepomis cyanellus*
Largemouth Bass	Centrarchidae	*Micropterus salmoides*
Longear Sunfish	Centrarchidae	*Lepomis megalotis*
Redear Sunfish	Centrarchidae	*Lepomis microlophus*
White Crappie	Centrarchidae	*Pomoxis annularis*
Gizzard Shad	Clupeidae	*Dorosoma cepedianum*
Skipjack Herring	Clupeidae	*Alosa chrysochloris*
Blacktail Shiner	Cyprinidae	*Cyprinella venusta*
Common Carp	Cyprinidae	*Cyprinus carpio*
Golden Shiner	Cyprinidae	*Notemigonus crysoleucas*
Blue Catfish	Ictaluridae	*Ictalurus furcatus*
Channel Catfish	Ictaluridae	*Ictalurus punctatus*
Flathead Catfish	Ictaluridae	*Pylodictis olivaris*
Alligator Gar	Lepisosteidae	*Atractosteus spatula*
Longnose Gar	Lepisosteidae	*Lepisosteus osseus*
Shortnose Gar	Lepisosteidae	*Lepisosteus platostomus*
Spotted Gar	Lepisosteidae	*Lepisosteus oculatus*
White Bass	Moronidae	*Morone chrysops*
Yellow Bass	Moronidae	*Morone mississippiensis*
Striped Mullet	Mugilidae	*Mugil cephalus*
Freshwater Drum	Sciaenidae	*Aplodinotus grunniens*

Table A.2. A total of 25 different fish species representing 9 families were collected at Richard K. Yancey Wildlife Management Area, LA during sampling between October 2020 and October 2021.

Common Name	**Family**	**Species Name**
Smallmouth Buffalo	Catostomidae	*Ictiobus bubalus*
Bigmouth Buffalo	Catostomidae	*Ictiobus cyprinellus*
Quillback	Catostomidae	*Carpiodes cyprinus*
White Crappie	Centrarchidae	*Pomoxis annularis*
Bluegill	Centrarchidae	*Lepomis macrochirus*
Largemouth Bass	Centrarchidae	*Micropterus salmoides*
Longear Sunfish	Centrarchidae	*Lepomis megalotis*
Black Crappie	Centrarchidae	*Pomoxis nigromaculatus*
Orangespotted Sunfish	Centrarchidae	*Lepomis humilis*
Gizzard Shad	Clupeidae	*Dorosoma cepedianum*
Threadfin Shad	Clupeidae	*Dorosoma petenense*
Skipjack Herring	Clupeidae	*Alosa chrysochloris*
Blacktail Shiner	Cyprinidae	*Cyprinella venusta*
Common Carp	Cyprinidae	*Cyprinus carpio*
Black Carp	Cyprinidae	*Mylopharyngodon piceus*
Silver Carp	Cyprinidae	*Hypophthalmichthys molitrix*
Channel Catfish	Ictaluridae	*Ictalurus punctatus*
Alligator Gar	Lepisosteidae	*Atractosteus spatula*
Longnose Gar	Lepisosteidae	*Lepisosteus osseus*
Shortnose Gar	Lepisosteidae	*Lepisosteus platostomus*
Spotted Gar	Lepisosteidae	*Lepisosteus oculatus*
American Paddlefish	Polyodontidae	*Polyodon spathula*
Freshwater Drum	Sciaenidae	*Aplodinotus grunniens*
White Bass	Moronidae	*Morone chrysops*
Striped Bass	Moronidae	*Morone saxatilis*

Biographical Sketch

Derek Christopher Sallmann was born in Waukesha, Wisconsin, in 1995. After graduating from Waukesha West High School in 2013 he attended Wisconsin Lutheran College in Milwaukee, Wisconsin, and graduated in 2017. At Wisconsin Lutheran he worked closely with Dr. Robert Anderson on multiple projects including a dam removal study on the Bark River in Delafield, Wisconsin, and coral reef and fish community research in Grenada (West Indies). After graduation he worked as Outreach and Engagement Coordinator with the Friends of the Mukwonago River. He also worked at Aquaganix Depot, performing water quality and maintenance of aquaponic systems. In the summer of 2019, Derek worked with the Wisconsin Department of Natural Resources on the Environmental Protection Agency's National Rivers and Streams Assessment, sampling fish communities throughout the state of Wisconsin and collecting water, periphyton, and invertebrate samples. In spring of 2020 Derek was accepted into the Marine and Environmental Biology graduate program at Nicholls State University. While at Nicholls Derek also interned with the Barataria-Terrebonne National Estuary Program, worked as an independent contractor with SEG Environmental LLC. doing breeding bird surveys on barrier islands. Derek also co-hosts the YouTube shows "Badgerland Birding" and "Badgerland Fishes" with his brother Ryan.

Curriculum Vitae

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EDUCATION:

August 2020 – present
Nicholls State University, Thibodaux, LA
M.S. Marine and Environmental Biology GPA 4.0

August 2013 – May 2017
Wisconsin Lutheran College, Milwaukee, WI
B.S. Biology (Ecology track) GPA: 3.67 (cum laude)

September 2009 – May 2013
Waukesha West High School, Waukesha, WI

WORK EXPERIENCE:

May 2021-June 2021 (8 hours/week)
Breeding Bird Survey Independent Contractor, Louisiana

- Cataloged target breeding bird species on Louisiana's barrier islands
- Collected data during surveys
- Worked as a team to complete fieldwork

June 2019-December 2019 (40+ hours/week)
Water Resources Management Specialist with the Wisconsin Department of Natural Resources, Madison, Wisconsin

- Worked with a team as part of the EPA's National Rivers and Streams Assessment
- Operated a mini boom shocker and backpack electroshocker for fish collection
- Collected and organized data in the field and in the lab
- Identified and counted Wisconsin fish species throughout the state
- Completed CPR/AED/boating and electrofishing safety certification

January 2018-present (12 hours/week)
Aquaganix Depot, Dousman, Wisconsin

- Monitored and controlled pH levels in grow tanks
- Cared for various plant species and harvested fruits/microgreens
- Mixed and applied nutrients and antifungal sprays

December 2017-2020 (10 hours/week)

Outreach and Engagement Coordinator with "Friends of the Mukwonago River", Mukwonago, Wisconsin

- Led hikes and paddle events for community members, noting unique species of plants and animals
- Attended meetings and conferences as a representative of the organization
- Organized and planned community events

April 2018 – July 2018 (6 hours/week)

Menomonee River Fish Passage Study, Milwaukee, Wisconsin

- Led a team of students (from Wisconsin Lutheran College) in electroshocking a stretch of the river
- Identified all species and collected data

September – December 2017 (4 hours/week)

Riley Creek Stream Health Assessment, Marengo, Illinois

- Used a backpack stream shocker to electroshock, collect, and identify fish
- Used Microsoft Excel to organize the data
- Used a dichotomous key to identify macroinvertebrates

August 2017 (4 hours/week)

Friends of Beaver Lake Water Chemistry Report, Waukesha, Wisconsin

- Analyzed water chemistry data and assisted in taking dissolved oxygen and temperature readings
- Assisted in organizing the data and the writing of the final report

Summer of 2015, 2016-August 2017 (2 hours/week)

Independent Contractor working with WE Energies, Oak Creek, WI

- Collected and identified fish taken in from Lake Michigan
- Collected data in the field and entered data using Microsoft Excel

Summer of 2015 (4 hours/week)

Menomonee River Dissolved Oxygen and Temperature Study, Milwaukee, WI

- Worked with a team on the Menomonee River to gather dissolved oxygen and temperature data
- Acquired skills using dissolved oxygen and temperature reading tools such as Xylem's "YSI" and entering data
- Gained skills in team work and overcoming adversity in making sure our job was complete even in inclement weather

VOLUNTEERING OPPORTUNITIES:

- **Nicholls State University Graduate Student**
  - Had the opportunity to volunteer with other students and help with fieldwork
  - Assisted with box turtle/diamondback terrapin surveys
  - Barataria-Terrebonne National Estuary Program barrier island bird survey volunteer
  - Assisted with Atchafalaya River Basin crayfish collection and crayfish stream surveys using backpack electroshocker, seine net, and dip nets

- **2021 and 2022 Bayou Lafourche Cleanup**
  - Picked up trash on the site of the road
  - Collected data on abundance and type of garbage collected

- **Presenter at the 2021 National American Fisheries Society Meeting**
  - Delivered oral presentation titled "Toothy Filter Feeder? Evidence of Alligator Gar Feeding on Zooplankton"

- **Presenter at the 2021 and 2022 Louisiana Academy of Sciences**
  - 2022 "Best Graduate Oral Presentation" for Botany/Zoology for presentation titled "Toothy Filter Feeder? Evidence of Alligator Gar Feeding on Zooplankton"
  - 2021 "Best Graduate Poster Presentation" in Agriculture/Forestry/Wildlife/ Environmental Science for poster titled "A comparison of floodplain restoration sites on the Mississippi River with a focus on gars (Lepisosteidae)"

- **Presenter at the 2017 Wisconsin American Fisheries Society Conference**
  - As part of my capstone project, wrote a paper on northern sunfish length trends in the Lower Mukwonago River including recommendations to maintain the population
  - Developed a comprehensive plan to help manage the species
  - Presented on "Population Trends of Northern Sunfish in the Lower Mukwonago River in Mukwonago, WI from 2003-2015"

- **2015-2017 Grenada Coral Reef Scuba Diving Research Team**
  - Worked with a team of students and teachers from Wisconsin Lutheran College (11 days per year) in Grenada as part of an ongoing scuba diving study on the health of the coral reefs
  - Studied and identified fish, and plants and animals living in the benthic zone of the reef
  - Collected additional data using "Coral Point Count with Excel Extensions" (CPCe) in the lab
  - Created a presentation based on a portion of the data including recommendations for future actions to be taken in Grenada

- **Presenter at the "Milwaukee-area Undergraduate Biological Research Conference"**
    - Presented a paper on the "Effects of Dam Removal on Macroinvertebrate and Fish Communities in the Middle Bark River, Wisconsin"
    - Collected fish and macroinvertebrate data in a stream and compared the type and number of organisms before and after a dam was removed
- **Wisconsin Lutheran College Research Volunteer**
    - Lead or assisted teams in electroshocking and identifying fish on the Menomonee, Upper Mukwonago, and Bark Rivers.
    - Worked as part of a scuba diving team to identify and remove invasive plant species from Lulu Lake by hand

- **Mukwonago River Fish Study with John Lyons**
    - Worked with a team of researchers including Wisconsin Department of Natural Resources fisheries biologist John Lyons and students from various colleges to sample, identify, and count fish in the Lower Mukwonago River including the northern sunfish

- **Beaver Lake Fyke Net Sampling Volunteer (Spring 2017)**
    - Worked with a team to collect scales and fin clips from different species of fish collected in the fyke net survey