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Age and Growth of Hardhead Catfish and Gafftopsail Catfish in Coastal Louisiana, USA

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Abstract

The Hardhead Catfish *Ariopsis felis* and Gafftopsail Catfish *Bagre marinus* are marine catfishes that have low recreational and commercial landings in U.S. waters, although they are among the most abundant species in coastal waters of the Gulf of Mexico. Few biological studies exist on marine catfishes, with most studies focusing on their unique reproductive biology. This study evaluated weight–length relationships for Gafftopsail Catfish ($n = 264$) and Hardhead Catfish ($n = 823$) sampled from across coastal Louisiana, USA, during 2016–2018; subsamples (93 and 266, respectively) were aged using lapilli for age and growth analyses. Hardhead Catfish showed a small but significant difference in weight as a function of length between males and females, with females being slightly heavier than males at any given length. No sexual dimorphism in weight and length was observed in Gafftopsail Catfish. Ages ranged from 0 to 10 years for Gafftopsail Catfish and from 0 to 24 years for Hardhead Catfish. Both sexes of Gafftopsail Catfish attained larger maximum average sizes (asymptotic length L_∞) and exhibited larger growth coefficients (k) than both sexes of Hardhead Catfish. Length at age of Hardhead Catfish in Louisiana was greater than that of Florida fish. The estimated k for Gafftopsail Catfish in Louisiana was almost three times greater than that observed in Florida, with fish reaching their L_∞ rapidly compared to those in Florida. Given the increasing evidence for an equilibrium life history strategy (i.e., K strategy), the spatial differences in size at age, and the potential for increased exploitation, continued investigations into both species' biology and life history should be undertaken.

The Hardhead Catfish *Ariopsis felis* and Gafftopsail Catfish *Bagre marinus* typically comprise the true marine catfishes in coastal waters of the U.S. Atlantic Ocean and Gulf of Mexico. Some freshwater catfishes may overlap in (estuarine) distribution and have shown some salinity tolerance—for example, the Flathead Catfish *Pylodictis* *olivaris* (Bringolf et al. 2005) and Blue Catfish *Ictalurus furcatus* (Fabrizio et al. 2017)—however, Hardhead Catfish and Gafftopsail Catfish are also found in oceanic habitats, such as the coastal shelf, and are considered permanent residents of marine environments. Hardhead Catfish and Gafftopsail Catfish have overlapping distributions

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in the southeastern U.S. Atlantic and U.S. Gulf of Mexico. Although both species occur in parts of the Caribbean, only Gafftopsail Catfish are distributed in South America, where they are found in coastal areas as far south as Rio de Janeiro, Brazil (Pinheiro et al. 2006). Within U.S. waters, marine catfishes are considered common to abundant. Fishery-independent sampling of marine catfishes (primarily Hardhead Catfish) in the Atlantic Ocean yielded high annual CPUE until the mid-1990s, at which point they nearly disappeared from catches, and they have yet to strongly return (Ballenger 2018). No such decline has been reported in the U.S. Gulf of Mexico, where marine catfishes remain common and can be found in such high local abundances that some fisheries reportedly avoid areas due to unwanted marine catfish bycatch (Armstrong et al. 1996). Although some catfishes are harvested as bycatch (Eustis 2011), commercial fishing of marine catfishes in the U.S. federal waters off the Gulf of Mexico is currently thought to be non-existent or at very low levels, with only 15 metric tons of commercial "sea catfishes" taken in 2016 (Figure 1; National Marine Fisheries Service [NMFS], Fisheries Statistics Division, Silver Spring, Maryland, personal communication). Recreational harvest of marine catfishes is also thought to be low (Figure 1; NMFS, Fisheries Statistics Division, personal communication), although Gafftopsail Catfish are known to have a desirable taste and are targeted by some recreational fishers.

Considering the ubiquity of marine catfishes, relatively little is known about their life history. A few unique aspects of their reproductive attributes have attracted some attention: marine catfishes produce some of the largest eggs (14–19-mm diameter) of all teleosts (Merriman 1940), and they are known for very low fecundity (typically < 100 eggs; Ward 1957; Jones et al. 1978) and intense male egg rearing, which can include eggs and juveniles living in the mouth of the male for up to 3 months (Jones et al. 1978). It is possible that these egg production and rearing strategies could influence other life history traits; for example, given the size of the fish (both male and female) required for large eggs and mouth-brooding, maturity could occur later in life and patterns of growth could reflect late maturity. However, determining age at maturity and lifetime growth relies on obtaining age estimates, which are rare in the literature for these marine catfishes.

In addition to the limited age information available, the reliability of some of the earlier age estimates of marine catfishes has recently come into question. Specifically, Benson (1982) reported a life expectancy of 2 years and a maximum age of 5 years for Hardhead Catfish (reported as "Sea Catfish" by Benson 1982) in Mississippi waters. Doermann et al. (1977) also concluded a relatively short life span of 3–8 years for Hardhead Catfish, although neither Benson (1982) nor Doermann et al. (1977) reported on any age or growth modeling. Gunter and Hall (1963) reported age-0 Hardhead Catfish reaching 133 mm
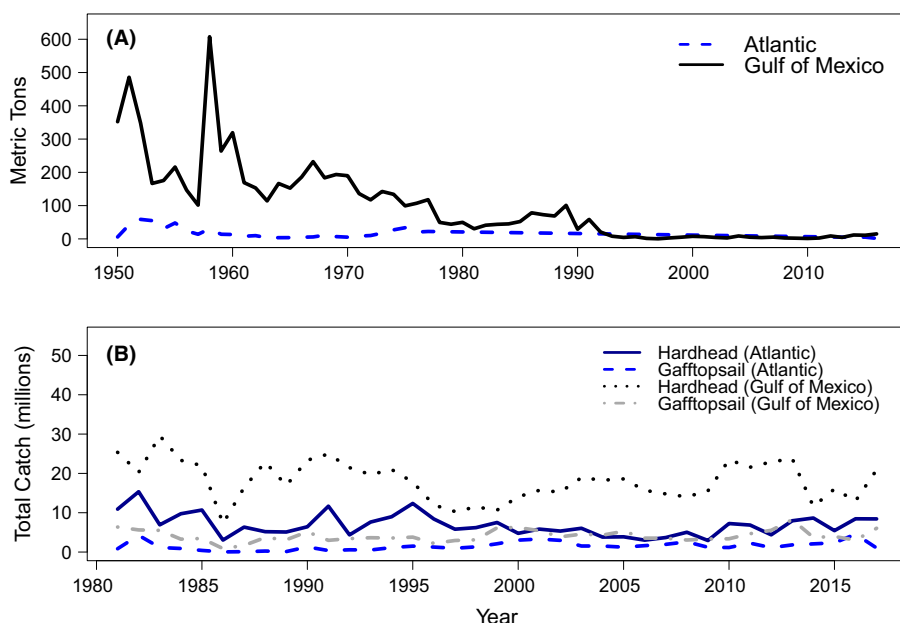

FIGURE 1. (A) Commercial landings and (B) recreational landings of marine catfishes in the U.S. Atlantic Ocean and Gulf of Mexico. Commercial landings are combined into sea catfishes (although Gafftopsail Catfish were specified in the landings data in small quantities during 2015 and 2016). Recreational catch data were available for each species; Hardhead Catfish were more commonly landed than Gafftopsail Catfish. (Data are from the National Marine Fisheries Service, Fisheries Statistics Division, personal communication).

TL and age-1 individuals reaching 193 mm TL in Florida. However, a Florida stock assessment of marine catfishes (Armstrong et al. 1996), including Hardhead Catfish ($n = 563$) and Gafftopsail Catfish ($n = 332$) from Tampa Bay, estimated much older maximum ages: 23 years for Hardhead Catfish and 24 years for Gafftopsail Catfish. Growth models were also fitted, and maximum asymptotic lengths (L_∞) were estimated at 325 mm (males and unsexed) and 342 mm (females and unsexed) for Hardhead Catfish and at 501 mm (males and unsexed) and 557 mm (females and unsexed) for Gafftopsail Catfish (Armstrong et al. 1996).

Although marine catfishes do not currently contribute to a major U.S. fishery, improved age and growth information remains important because of these species' high abundance, wide distribution, and potential for further exploitation. They also likely play a substantial role in coastal ecosystems (Walters et al. 2008), perhaps in trophic dynamics. Major fishing effort is not currently directed at marine catfishes, but Gafftopsail Catfish do experience some harvest, which is evidenced by limited recreational effort and a small commercial fishery (in recent years reporting only Gafftopsail Catfish; NMFS, Fisheries Statistics Division, personal communication). Outside the USA, such as in Tabasco, Mexico, Gafftopsail Catfish have been reported as constituting (1) the highest volume (61%) of total catch and (2) over the longer term (two decades), the most abundant species in landings (Mendoza-Carranza 2003). There is no expectation that marine catfishes will soon dominate U.S. landings; however, interest in the species may continue to increase as other species reach their maximum sustainable harvest and it is continually recognized that marine catfishes are generally easy to catch. Therefore, the objective of this study was to better understand the age and growth of common marine catfishes in the northern Gulf of Mexico.

METHODS

Sample collection.— All sampling was conducted in coastal waters of south Louisiana by the Louisiana Department of Wildlife and Fisheries within Coastal Study Areas I (North Pontchartrain Basin) and V (Timbalier/Terrebonne and Barataria Basin; Figure 2). Individuals were taken opportunistically from fishery-independent sampling that used seines, gill nets, and trammel nets. Bag seines (15.24×1.83 m, with a 1.83- $\times 1.83$-m bag) were fished monthly. Experimental gill nets (228.6×2.44 m; consisting of five 45.72-m panels of 2.54-, 3.18-, 3.81-, 4.45-, and 5.08-cm bar mesh) were sampled under a varying schedule throughout the year: 10–30 sampling events took place between April and September, whereas half as much sampling effort took place during October–

March. A three-walled trammel net (228.6×1.83 m) was fished once monthly from October through March. Marine catfishes were sampled opportunistically from the sampling programs during July 2016–June 2018, with attempts to sample up to 20–30 randomly sized fish per month from each of the two coastal study areas. Individual fish were frozen at the time of capture and were later thawed to record biological information, including TL (mm), total weight (W; g), and sex. Lapillar otoliths were extracted and stored dry for later sectioning to estimate ages.

Otolith sample preparation.— Thin sections containing the core were taken from the left lapillar otolith of each individual or from the right otolith if the left was unavailable or damaged. Otolith sections were made with a Hillquist Model 800 thin-sectioning machine following the protocol outlined by Cowan et al. (1995). Liquid coverslip (DePex Mounting Medium) was added to sections to improve contrast in cross-sectional features (i.e., putative annuli). Otolith reads were performed using a dissecting microscope under 7–40× magnification with transmitted light. Opaque annulus counts were made along the sulcus from the core to the proximal edge (Figure 3). Annulus counts were performed by two independent readers, with each reader being naïve to the other reader's annulus estimate as well as to any biological information, such as fish TL. During aging, an edge analysis was undertaken based on Harris et al. (2007) in order to evaluate the hypothesis that marine catfishes produce only one opaque zone (a putative annulus) per year. Edge codes were assigned based on distance from the last annulus to the edge of the otolith as follows: 1 = opaque zone forming on the edge; 2 = narrow translucent zone, with a width less than 30% of the previous increment; 3 = translucent zone width about 30–60% of the previous increment; and 4 = translucent zone width over 60% of the previous increment. Ages estimated by the two readers were also directly compared using an age-bias plot (Campana et al. 1995; Ogle 2015). An index of between-reader average percent error (APE) was calculated based on the methods of Beamish and Fournier (1981). When age disagreements occurred, the sectioned otolith was viewed by both parties simultaneously and a consensus final age was decided.

Weight–length relationships.— Prior to modeling any individual lengths and weights, we randomly assigned sex (male or female) to any unsexed fish smaller than 200 mm TL. Maturity has been reported to occur at sizes larger than 200 mm (Armstrong et al. 1996), and many of the small individuals we sampled had small and unidentifiable gonadal tissue (and therefore were left unsexed). Exploratory evaluation of weight as a function of length for fish smaller than 200 mm showed a high correlation, regardless of sex; therefore, these small fish were assigned sexes only to increase the available data over which the models were fitted and not to influence the parameter estimates. Sex
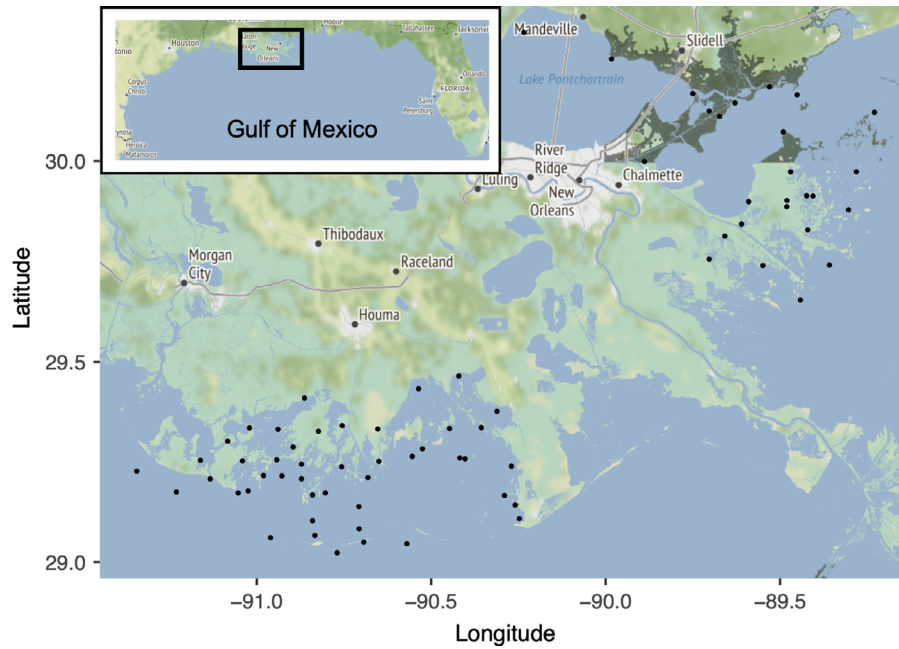
FIGURE 2. Map of sampling locations (black dots) in coastal Louisiana. The inset in the top left corner shows the map location within the Gulf of Mexico.
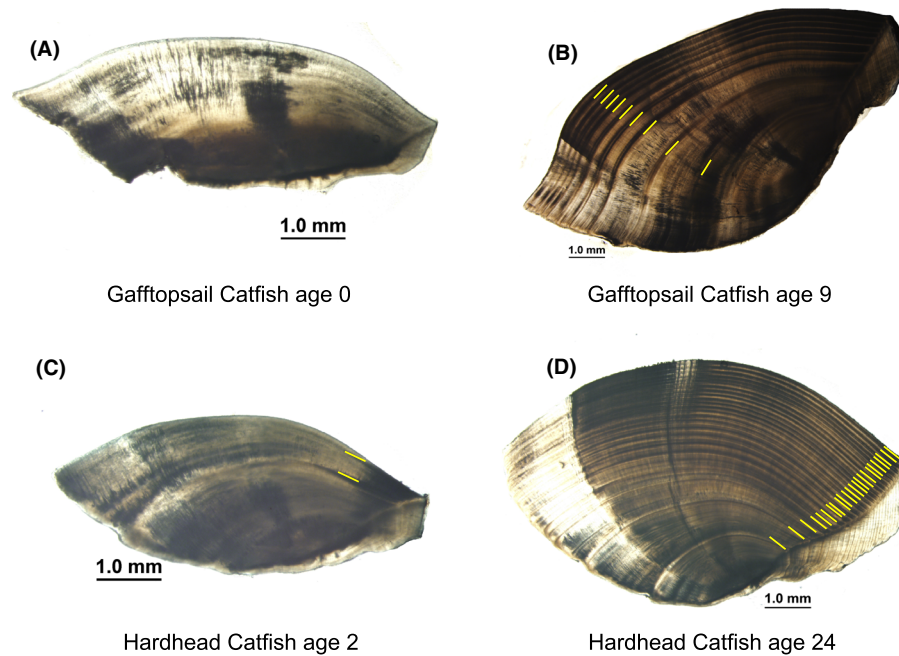

FIGURE 3. Sectioned lapilli from Gafftopsail Catfish estimated to be **(A)** age 0 and **(B)** age 9 and from Hardhead Catfish estimated to be **(C)** age 2 and **(D)** age 24. Opaque annuli are indicated by yellow lines.

was assigned randomly to 132 unsexed Gafftopsail Catfish and 22 unsexed Hardhead Catfish.

Weight–length relationships were fitted to data from each species by using the linearized version of the standard power function ($W = a\mathrm{TL}^b$) as

$$\log_{10}(W_i) = \log_{10}(a) + b\log_{10}(\mathrm{TL}_i) + \varepsilon_i, \qquad (1)$$

where TL_i is total length (mm), W_i is total weight (g), and ε_i is the residual error. Parameters a and b are the coefficient and exponent, respectively, of the power function. A

covariate for sex was incorporated into equation (1) to test for any difference in sex-specific weight–length relationships, essentially turning the equation into an ANCOVA. Statistical significance for all tests was determined based on $P \leq 0.05$.

Age and growth analysis.— To evaluate species- and sex-specific growth, observed length-at-age data from all catfishes that were aged and also directly sexed were fitted to the von Bertalanffy growth model (VBGM) because of its common use in estimating fish growth and the comparability of the parameter estimates it produces. We opted to use a hierarchical version of the VBGM (Midway et al. 2015) that allowed for putative groups (species × sex combinations) to have their own parameter estimates in addition to an overall estimate. This model parameterization, combined with Bayesian estimation, produces posterior estimates of parameter values; the credible intervals of these estimates can be compared for overlap and statistical differences. Non-overlapping 95% credible intervals were established a priori as a metric of statistical difference.

Observed length-at-age data were fitted to a hierarchical VBGM,

$$\text{TL}_{ij} = L_{\infty j}\left(1 - e\left(-k_j\left(t_{ij} - t_{0j}\right)\right)\right) + \varepsilon_{ij}, \qquad (2)$$

where TL_{ij} is the total length (mm) for fish i within the species × sex combination j; $L_{\infty j}$ is the asymptotic length (mm); k_j is the Brody growth coefficient; and t_{0j} is the hypothetical age at a length of zero. All three parameters are estimated five times: $j = 4$ times for each of the species × sex combinations and then once for a grand mean parameter estimate. The residual error (ε_{ij}) was assumed to be independently and identically distributed as N (0, σ^2). Parameters were log transformed during fitting (Kimura 2008) to help with model convergence. Additional model fitting details are provided by Midway et al. (2015). Models were fitted with diffuse prior probability distributions and with three Markov chains starting with different values. In total, 150,000 iterations were run; however, 90,000 were discarded as burn-in and 40,000 were discarded from thinning, resulting in a total of 20,000 values for analysis. Final posterior distributions were assessed for convergence with the Brooks–Gelman–Rubin statistic where $\widehat{R}$ values < 1.1 indicate convergence) along with visual assessment of posterior distributions. Models were fitted using the *rjags* package (Plummer 2016) run from within R (R Core Development Team 2018).

RESULTS

Catfishes were sampled from September 2016 to May 2018, and samples were obtained during all months of the year. Only one fish was sampled in March and two fish were sampled in January, but all other months were represented by over 30 fish. Overall, 1,087 fish were sampled, including 264 Gafftopsail Catfish (25 female, 91 male, and 148 immature) and 823 Hardhead Catfish (500 female, 276 male, and 47 immature). Gafftopsail Catfish TL ranged from 104 to 557 mm, and Hardhead Catfish TL ranged from 35 to 492 mm. Weight ranged from 9 to 1,850 g for Gafftopsail Catfish and from 6 to 970 g for Hardhead Catfish (Figure 4).

Weight–Length Relationship

We fitted a total of four weight–length relationships— one for Gafftopsail Catfish (sexes combined), one for Hardhead Catfish (sexes combined), and one each for the separate Hardhead Catfish sexes based on the significant covariate of sex in the combined-sexes model (Figure 4). The sex covariate was found to be nonsignificant ($P = 0.801$) for the Gafftopsail Catfish model with combined sexes; therefore, a single relationship could be used to describe the relationship between Gafftopsail Catfish weight and length. The sex covariate was found to be
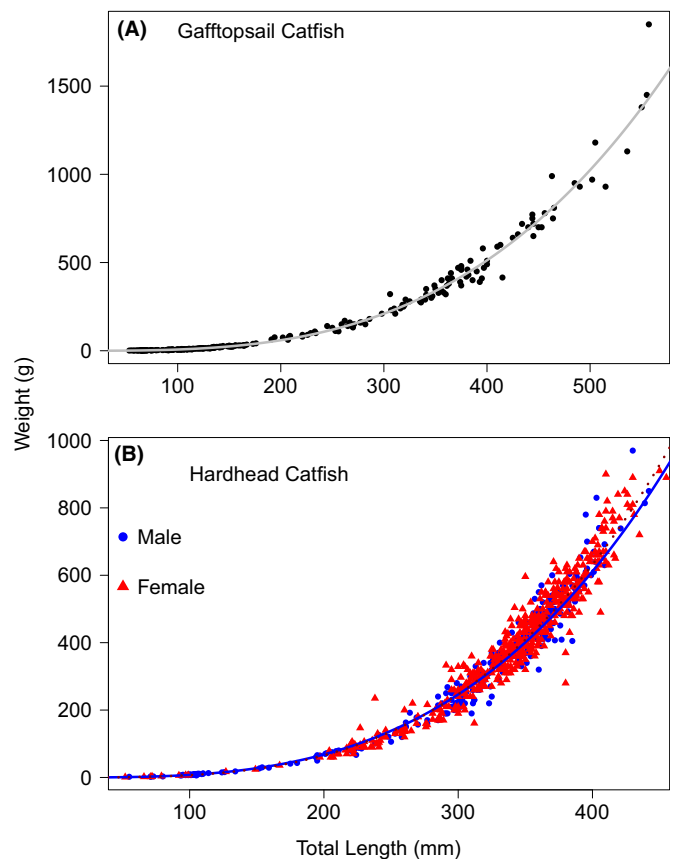

FIGURE 4. Weight–length regressions for **(A)** Gafftopsail Catfish (with sexes combined) and **(B)** Hardhead Catfish (separate data for each sex). Associated parameter estimates are given in Table 1.

significant ($P = 0.0002$) when comparing male and female Hardhead Catfish, and this led us to run separate models for the sexes. Estimates of $\log_{10}(a)$ ranged between −12.35 (Gafftopsail Catfish combined) and −13.10 (Hardhead Catfish females; Table 1). All estimates of b were close to 3, ranging from 3.10 (Gafftopsail Catfish combined) to 3.26 (Hardhead Catfish females).

Age Estimation

A total sample of 359 fish was used to estimate ages. Gafftopsail Catfish ($n = 93$) included 19 females and 74 males that ranged in age from 0 to 10 years, with age-2 individuals ($n = 40$) being the most common age. Hardhead Catfish ($n = 266$) ranged in age from 0 to 24 years and included 118 females and 148 males. Hardhead Catfish were much older than most Gafftopsail Catfish; the oldest Hardhead Catfish was estimated to be age 24, with many fish exceeding age 10.

The APE for all samples was 6.2%, and APE was slightly higher for Gafftopsail Catfish (7.0%) than for Hardhead Catfish (5.7%). Using estimated ages from both readers, an age-bias plot showed no significant bias between readers when comparing ages (Figure 5). Although some fish were sampled during each month of the year, some months had low numbers of samples and, when split by species, some months were absent. Despite some differences in growth between the two species, the environments (e.g., seasonal temperatures that drive growth) they experience are likely similar; this, along with the need for greater sample sizes, justified combining the species to evaluate otolith edge types by month (Figure 6). The edge analysis showed only one peak in the greatest proportion of edge type 1 (opaque annulus on the edge) in the spring (April–June), providing strong indirect evidence for the formation of one opaque zone per year (Figure 6).

Growth Modeling

We modeled sex-specific growth within both species and found little evidence for sexually dimorphic growth (Table 2; Figure 7); within each species, L_∞ estimates

TABLE 1. Weight–length regression coefficients (SE in parentheses) for Hardhead Catfish and Gafftopsail Catfish from coastal Louisiana waters.

Species and sex	Parameter	
	Log(a)	b
Hardhead Catfish		
Female	−13.10 (0.13)	3.26 (0.02)
Male	−12.52 (0.09)	3.16 (0.02)
Combined	−13.10 (0.03)	3.26 (0.02)
Gafftopsail Catfish		
Combined	−12.35 (0.03)	3.10 (0.03)

between sexes were similar, with overlapping 95% credible intervals. The mean maximum size of Gafftopsail Catfish was very similar between sexes, although the low overall sample size resulted in relatively large estimates of uncertainty. The mean maximum size of Hardhead Catfish was estimated with relatively high confidence, and although the 95% credible intervals overlapped between the sexes there was not as much overlap as seen in Gafftopsail Catfish. Gafftopsail Catfish had significantly higher estimates of k than Hardhead Catfish. Given that there were no differences in growth between sexes of each species, we also estimated growth parameters on a species-specific basis with sexes pooled (Table 2).

DISCUSSION

Hardhead Catfish from Louisiana coastal waters in our study were much older than indicated in previous studies from the northern Gulf of Mexico and were more comparable to the same species sampled from the west coast of Florida (Armstrong et al. 1996). For example, Benson (1982) suggested that the maximum age of marine catfishes (which included both Gafftopsail Catfish and Hardhead Catfish) was 5 years; Doermann et al. (1977) similarly estimated life spans to be between 3 and 8 years. Although our ages were not validated directly, we are confident from our aging estimates (relatively low APE) that Hardhead Catfish are relatively long-lived fish. We estimated Hardhead Catfish ages of up to 24 years, which agreed with the maximum ages of Hardhead Catfish in Florida (Armstrong et al. 1996).

Although Gafftopsail Catfish are much larger than Hardhead Catfish, our maximum observed age for Gafftopsail Catfish was only 10 years, which was much younger than the maximum age for Hardhead Catfish. However, our sample size was low, and few larger and therefore older fish were represented in the sample. Armstrong et al. (1996) estimated Gafftopsail Catfish ages to 23 years; based on the fact that our maximum age for Hardhead Catfish was three times the previous estimates from the northern Gulf of Mexico, it is likely that Gafftopsail Catfish in Louisiana are also much older than previously indicated by the Benson (1982) study. There are several possible explanations for this age estimation difference: at least one reason attributable to observer error and one attributable to process error. First, the aging structure differs in some studies; for example, Doermann et al. (1977) used pectoral spines to estimate a maximum age of 8, whereas Armstrong et al. (1996) and the present study used otoliths. If pectoral spines underestimate ages (i.e., observer error; e.g., Barada et al. 2011), this could contribute to the differences we found. Another possible reason for estimated age differences is that different ages of fish use different habitats. In this case, the
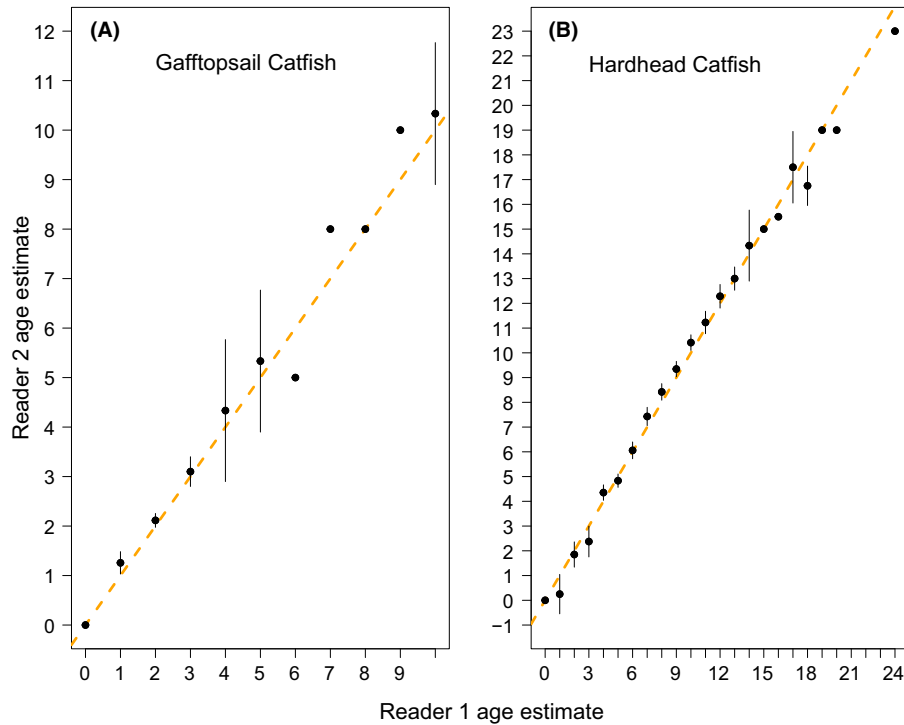
FIGURE 5. Age-bias plots for **(A)** Gafftopsail Catfish and **(B)** Hardhead Catfish. In both panels, estimated ages by reader 1 (the most experienced reader) are on the *x*-axis and estimates by reader 2 are on the *y*-axis. Black circles represent the mean estimated age, and the associated vertical line represents the 95% confidence interval. The orange dashed line represents the 1:1 agreement line.
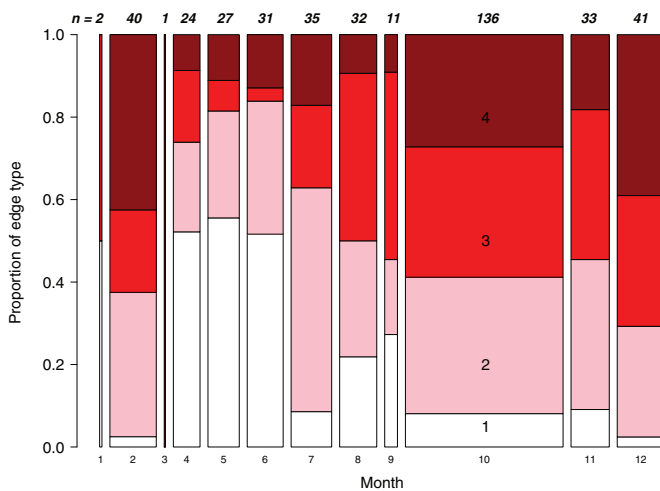

FIGURE 6. Proportion of otolith edge types by month for both Gafftopsail Catfish and Hardhead Catfish (i.e., species combined) from coastal Louisiana. Edge types are indicated by color, with October (month 10) serving as the legend. Edge codes were assigned based on distance from the last annulus to the edge of the otolith: 1 = opaque zone forming on the edge; 2 = narrow translucent zone, with a width less than 30% of the previous increment; 3 = translucent zone width about 30–60% of the previous increment; and 4 = translucent zone width more than 60% of the previous increment. The widths of the monthly bars are proportional to the sample sizes, which are reported above the bar for each month.

estimated ages may be very precise, but the ages may only reflect the unique demographic or age-group that is present at a given sampling location. Both Gafftopsail Catfish and Hardhead Catfish are known to live outside of estuaries on the continental shelf, and those habitats may hold different life stages of fish. Finally, different (fishing) mortality rates could be at play and could contribute to different age structures between the two populations.

We did not find a difference between male and female weight–length relationships for Gafftopsail Catfish, which suggests that a common model could be used for all individuals captured. However, we did detect an effect of sex for Hardhead Catfish, with females being slightly heavier than males at a given length. This matches what Armstrong et al. (1996) found (but for both species). One possible explanation for this difference could be the very large investment in gonadosomatic growth that females exhibit for multiple months of the year. While sampling the fish used in this study, it was common for the ovaries to represent approximately 10–20% of the body weight of a female during certain months of the year. For the weight–length regressions to be directly comparable between males and females throughout spawning and nonspawning seasons, it would be necessary to use body

TABLE 2. Estimates (sex specific and combined) of von Bertalanffy parameters for Hardhead Catfish and Gafftopsail Catfish from coastal Louisiana waters (L_∞ = asymptotic length [mm]; k = Brody growth coefficient; t_0 = hypothetical age at a length of zero). Parameter estimates represent posterior means (95% credible intervals in parentheses). There were no statistically significant differences between sexes for either species; therefore, combining sexes may be appropriate for modeling growth.

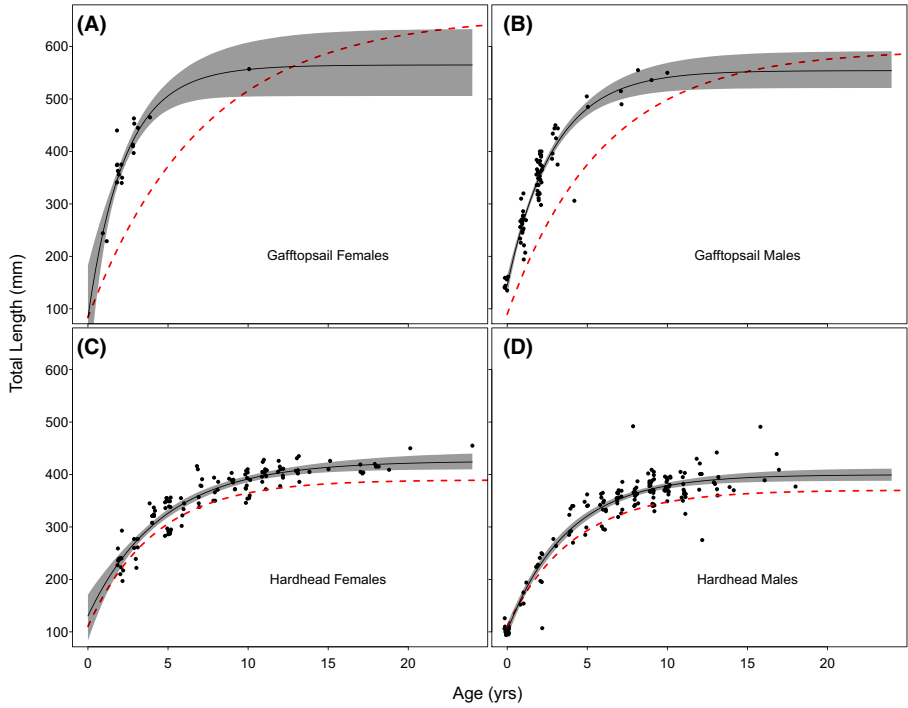| Species and sex	N	Parameter		
		L_∞	k	t_0
Hardhead Catfish				
Female	118	426 (410, 445)	0.22 (0.17, 0.28)	−1.73 (−2.89, −0.83)
Male	148	400 (388, 413)	0.27 (0.23, 0.31)	−1.12 (−1.39, −0.87)
Combined	266	410 (400, 421)	0.25 (0.21, 0.30)	−1.24 (−1.85, −0.72)
Gafftopsail Catfish				
Female	19	565 (509, 631)	0.43 (0.28, 0.63)	−0.45 (−1.26, 0.11)
Male	74	553 (521, 591)	0.35 (0.29, 0.42)	−0.87 (−1.11, −0.67)
Combined	93	540 (509, 573)	0.39 (0.33, 0.46)	−0.76 (−0.99, −0.53)

FIGURE 7. Sex-specific von Bertalanffy model fits for (A) Gafftopsail Catfish females, (B) Gafftopsail Catfish males, (C) Hardhead Catfish females, and (D) Hardhead Catfish males sampled in coastal Louisiana. The solid black line in each panel represents the fitted von Bertalanffy growth model; the 95% credible region for the model is represented with the gray polygon around the model fit line. The red dashed line represents the von Bertalanffy growth model fit based on species- and sex-specific estimates presented by Armstrong et al. (1996), with FLs converted to TLs using conversions from J. Courtney, T. Klinkmann, J. Torano, and M. Courtney, BTG Research and U.S. Air Force Academy, unpublished manuscript; https://arxiv.org/abs/1210.3062.

weights corrected for variable gonad weight (i.e., gonadec-tomized weights).

Gafftopsail Catfish and Hardhead Catfish are often lumped together as marine (or sea) catfishes, which is not a robust reason to assume a similar biology. In fact, we found different growth characteristics between the species. Although 95% credible intervals for L_∞ overlapped for

comparisons of sexes within each species, no credible intervals overlapped between the two species. This finding provides strong evidence that Gafftopsail Catfish attain larger sizes than Hardhead Catfish regardless of sex. Somewhat surprisingly, Gafftopsail Catfish also exhibited much greater estimates of k, suggesting that they grow relatively quickly in their first few years of life and reach

their L_∞ rapidly compared to Hardhead Catfish. In fact, we sampled several individual Gafftopsail Catfish that were larger than 400 mm TL by age 3, regardless of sex.

The strongest comparison we can make between our catfish growth estimates and previous studies' results is with the findings of Armstrong et al. (1996). Given the VBGM fits based on species- and sex-specific estimates presented by Armstrong et al. (1996), we used FL-to-TL conversions presented by Courtney et al. (unpublished manuscript) to directly compare growth between the studies. In both studies, Hardhead Catfish had the greatest sample sizes, yet we found that Hardhead Catfish in Florida waters were generally smaller at age than those in Louisiana waters (Figure 7). Although we were unable to recreate an uncertainty estimate for the Florida catfish growth estimates, the growth curve for Florida Hardhead Catfish occurred almost entirely outside of the 95% credible interval for Louisiana fish, suggesting a significant difference in size at age and growth between areas of the Gulf of Mexico. Our sample sizes for Gafftopsail Catfish were smaller than those from Florida, but again we found apparently substantial differences in size at age and growth. Gafftopsail Catfish in Louisiana were larger at earlier ages than Gafftopsail Catfish in Florida. We were again unable to recreate an uncertainty estimate from the Florida growth estimates, and our data lacked old and large fish; however, both studies had good representation of younger (<5 years) Gafftopsail Catfish and we had very high aging agreement for ages 1–5, suggesting that our age estimates were reliable and that spatial differences likely exist.

We were able to sample a wide range of sizes for both catfish species as well as to evaluate samples from each month of the year. We are confident in our estimates of age and growth, but we recognize that more work is needed to understand marine catfish biology and life history. For example, marine catfishes reportedly have some of the largest eggs of all fishes (Merriman 1940) and have very low fecundities (Jones et al. 1978); however, large gaps remain in our understanding of their reproductive biology and timing of maturity. Given their potential for a relatively long life span ($\geq$24 years), it is possible that marine catfishes do not mature until older ages (e.g., Armstrong et al. 1996 estimated maturity at around age 5) and overall exhibit more of an equilibrium life history strategy (Winemiller and Rose 1992). With additional maturity work on Louisiana catfishes, we may also find that life history strategies vary by region. If an equilibrium life history strategy is further supported by maturity or other life history information, it creates a greater imperative for proactive as opposed to reactive management. Extreme declines (to near disappearance) of both species in the Atlantic Ocean off the southeastern USA during the 1990s (Ballenger 2018) have not been attributed to any cause. Nevertheless, this recent collapse and the growing evidence of an opportunistic life history strategy highlight the need to understand and manage Gafftopsail Catfish and Hardhead Catfish before any increases in fishing pressure or other changes to their population dynamics occur in U.S. waters.

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