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Research Article

Length-Weight Relationships of Native and Non-Native Fishes in the Lower Red River Catchment, USA

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Length-weight relationships are useful for stock assessments and modeling alternative conservation and management strategies for both native and non-native fishes. We developed length-weight relationships for 18 native and non-native riverine fishes in the lower Red River catchment. Fishes were sampled in the summer and autumn seasons between May 2021 and March 2024 via electrofishing and gill nets. Measurements for each specimen consisted of total length (mm) and weight (g). We provide L-W relationships for 14 native fishes consisting of 5 families (Lepisosteidae, Catostomidae, Ictaluridae, Sciaenidae, and Polyodontidae) and 4 non-native species belonging to the family Cyprinidae. We collected 6,845 individuals ranging from 67 alligator gar to 1,848 smallmouth buffalo. All the L-W relationships were significant ($p < 0.05$), and the majority (72% of species) of relationships between length and weight had r^2 values > 0.70. Our findings provide insight into the L-W relationships of riverine fishes and can be useful for modeling alternatives targeted at native fishes of recreational value and the removal efforts of non-native fishes.

1. Introduction

Length-weight (L-W) relationships are important for fisheries management including their use in stock assessments, production modeling, and biomass estimations [1]. L-W relationships are useful for a variety of conservation and management applications ranging from calculating indices related to fish condition to assessing growth patterns in relation to environmental factors [2]. L-W relationships are insightful for fish-population dynamics across spatial and temporal scales. In this study, we modeled L-W relationships for 18 native and non-native riverine fishes of the lower Red River catchment, USA, to describe the biometric relationships among varying large-bodied fishes of the Red River catchment located in the Great Plains ecoregion. The Red River basin is characterized by extended periods of floods and droughts [3]. These highly dynamic shifts in flow regime are relatively unique to the lower Red River catchment and variation of natural conditions that native assemblages in the region have evolved to cope with but may become more difficult with the introduction and presence of non-native species such as carp. Although much is known about the effects of both Bighead and Silver Carp where they have been introduced and become established over time (i.e., competition of planktivorous resources with native riverine fishes), little information is available in the Red River, where carp are not yet well established [4, 5]. By investigating the L-W relationships among both native and non-native riverine fishes, insight into the population demographics of the lower Red River catchment assemblage can be further assessed to produce effective management strategies that target the removal or control of non-native species and the management of native species.

2. Materials and Methods

We sampled 6,845 fishes comprising 14 native and four non-native species in reaches (1.5–2 rkm) of the lower Red River

catchment in Arkansas (above the AR-LA state line), Oklahoma, and Texas. We sampled using a combination of electrofishing and gillnet from May 2021 until March 2024. We set three experimental sinking gillnets (54.8 m long in the mainstem Red River and 30.5 m long in the tributaries with 8.9, 10.16, and 10.8 cm bar-length mesh panels) and allowed them to soak for approximately 6 h. After net placement, we electrofished using standard settings (American Fisheries Society) with an 80 amp high-conductivity electrofishing unit (Midwest Lakes Electrofishing Systems, Polo, Missouri). Beginning at the upstream end of the site, we electrofished downstream in a cloverleaf pattern throughout each reach. Total length (mm, ± 1 mm) and weight (g, ± 10 g) were recorded for fishes sampled from both gears.

Total length and weight were log (base 10)-transformed, and linear regression was used to determine length-weight (L-W) relationships using the following equation:

$$\log_{10} W = \log_{10} a + b(\log_{10}\mathrm{TL}), \quad (1)$$

where W is the weight (g), TL is the total length (mm), a is the intercept, and b is the slope of the regression. All regressions were developed using Program R (version 4.2.2). We also examined the L-W relationships between female and male Bighead Carp as that was the only species where we were confident in sex determination (i.e., related to an ongoing tagging and age and growth study).

3. Results

We sampled native and non-native riverine fishes from the Red River. Our sample size varied based on relative abundance, ranging from 67 alligator gar to 1,848 smallmouth buffalo (Table 1). Total length and weight varied but were limited to the size of fishes that were recruited to our sampling gears. We report the 95% confidence interval for a and b. Our estimated values of b reflect an acceptable range between 2.5 and 3.5, indicating adequate sample sizes and distribution of species' proportional growth [2]. However, paddlefish (2.89), shortnose gar (3.88), and grass carp (2.80) a and b values did not fall within this acceptable range. All the L-W relationships were significant ($p < 0.05$), and most of the relationships (72% of species) between length and weight had coefficients of determinations >0.70 (Table 1). The species with the strongest L-W relationships ($r^2 > 0.90$) were blue catfish, channel catfish, and flathead catfish, whereas the species with the weakest L-W relationships ($r^2 < 0.60$) were paddlefish, shortnose gar, and bighead carp.

We examined the L-W relationships between female and male bighead carp ($r^2 = 0.58$) and silver carp ($r^2 = 0.79$) to investigate the variability in our estimates of L-W relationships. We found that although young female bighead carp were initially smaller than their male counterparts, as they grew older, they became much bigger than male bighead carp (Figure 1). However, female silver carp recruited to our sample gears were always bigger than their male counterparts (Figure 2).

4. Discussion

Our results indicate that the L-W relationships of native and non-native fishes varied considerably. This variation might be attributed to smaller sample sizes or error in measurements for species with narrow length ranges or associated sex classes [6]. Variation in b may relate to biological, environmental, and sampling effects (e.g., maturity, seasonality, and size ranges of species captured [7–9]). Most of our L-W relationship equations were similar to those previously documented by Hall and Jenkins [10], Bur [11], Brown and Murphy [12], Bister et al. [13], Neely et al. [14], Stewart et al. [15], Wanner and Klumb [16], Snow et al. [17]; however, the species L-W relationships included in Bister et al. [13] are only those with an $r^2 > 0.90$. The L-W relationships we report for black buffalo and shortnose gar, however, were different than previous reports. Our findings showed that L-W relationships between taxonomically related species in the family Lepisosteidae consisting of alligator gar, longnose gar, shortnose gar, and spotted gar had varied a values despite moderate differences in sampling sizes and b values which may be related to variation in both body shape and condition [2, 18]. Though this trend was not noted in other taxonomically related species (e.g., Ictaluridae and Cyprinidae), this variation might be worth exploring in understudied fishes such as shortnose gar.

Though our findings among bighead and silver carp L-W relationships were similar to those within their native and introduced range [19, 20], we did observe variability in our L-W relationships for both species. Therefore, we further investigated the differences between female and male carp species. Generally, we found that both female bighead and silver carp in the lower Red River catchment were larger compared to male carp. The differences in L-W relationships between female and male carp species may be due to our sampling season occurring during the spawning period [21, 22] and/or to catchment-specific conditions [23]. DeGrandchamp et al. [24] examined female and male carp species in the Illinois River catchment and found that female bighead carp were larger than males, whereas no sex class differences were observed in female and male Silver Carp. However, Papoulias et al. [25] found that silver carp females from the Missouri River were larger than males, whereas no sex differences were observed in bighead carp. Given that both these studies occurred in different rivers and regions, there is evidence to suggest that L-W relationships among both bighead and silver Carp may be site-specific and allotted to local environmental conditions.

Our findings not only provide greater insight into the L-W relationships of both native and non-native fishes of the Great Plains ecoregion which are scarce but also broaden our understanding of basic relationships among native and no-native fishes that are likely to be abundant and wide-ranging throughout riverine environments [26].

Table 1: Length-weight relationships for 18 fish species (14 native and 4 non-native) sampled from the lower Red River catchment of Arkansas, Texas, and Oklahoma.

Species	*N*	TL range (mm) (mean ± SE)	Weight range (g) (mean ± SE)	L-W regression	*b*	Intercept 95% CI		Slope 95% CI		r^2
Alligator gar (*Atractosteus spatula*)	67	801.0–2012.0 (1347.5 ± 25.1)	2250.0–50000.0 (14596 ± 969.8)	$\log_{10}$ weight = −6.25 + 3.31 ($\log_{10}$ length)	3.31	−7.13	−5.37	3.03	3.60	0.89
Bigmouth buffalo (*Ictiobus cyprinellus*)	974	343.0–1021.0 (610.3 ± 2.5)	425.0–22000.0 (4085.9 ± 66.0)	$\log_{10}$ weight = −5.65 + 3.31 ($\log_{10}$ length)	3.31	−5.94	−5.36	3.21	3.42	0.80
Black buffalo (*I. niger*)	682	289.0–990.0 (661.8 ± 3.7)	125.0–22000.0 (4974.1 ± 110.5)	$\log_{10}$ weight = −6.36 + 3.55 ($\log_{10}$ length)	3.55	−6.72	−6.00	3.42	3.67	0.82
Blue catfish (*Ictalurus furcatus*)	199	128.0–1118.0 (654.1 ± 11.7)	30.0–21000.0 (3647.9 ± 237.6)	$\log_{10}$ weight = −6.17 + 3.41 ($\log_{10}$ length)	3.41	−6.58	−5.76	3.27	3.56	0.92
Blue sucker (*Cycleptus elongatus*)	431	247.0–731.0 (530.0 ± 3.7)	75.0–4700.0 (1236.7 ± 33.6)	$\log_{10}$ weight = −6.58 + 3.53 ($\log_{10}$ length)	3.53	−6.96	−6.21	3.39	3.67	0.86
Channel catfish (*I. punctatus*)	57	195.0–1052.0 (567.1 ± 20.3)	100.0–18600.0 (2541.2 ± 387.3)	$\log_{10}$ weight = −6.38 + 3.50 ($\log_{10}$ length)	3.50	−7.16	−5.60	3.21	3.78	0.92
Flathead catfish (*Pylodictis olivaris*)	113	154.0–1146.0 (418.9 ± 23.7)	40.0–25250.0 (2314.8 ± 439.8)	$\log_{10}$ weight = −5.36 + 3.14 ($\log_{10}$ length)	3.14	−5.65	−5.06	3.03	3.26	0.96
Freshwater drum (*Aplodinotus grunniens*)	198	182.0–749.0 (407.0 ± 7.7)	50.0–5600.0 (1017.3 ± 72.6)	$\log_{10}$ weight = −5.30 + 3.12 ($\log_{10}$ length)	3.12	−5.77	−4.77	2.93	3.31	0.84
Longnose gar (*Lepisosteus osseus*)	594	433.0–1512.0 (886.9 ± 8.4)	50.0–11900.0 (2149.6 ± 85.1)	$\log_{10}$ weight = −7.37 + 3.59 ($\log_{10}$ length)	3.59	−7.70	−7.03	3.47	3.70	0.87
Paddlefish (*Polyodon spathula*)	205	950.0–1690.0 (1296.7 ± 9.8)	3500.0–39000.0 (9178.1 ± 275.5)	$\log_{10}$ weight = −2.89 + 2.19 ($\log_{10}$ length)	2.19	−3.98	−1.79	1.84	2.54	0.42
River carpsucker (*Carpiodes carpio*)	621	151.0–689.0 (333.5 ± 2.8)	25.0–3700.0 (459.0 ± 15.2)	$\log_{10}$ weight = −4.10 + 2.65 ($\log_{10}$ length)	2.65	−4.45	−3.76	2.51	2.79	0.70
Shortnose gar (*L. platostomus*)	167	481.0–810.0 (622.3 ± 5.8)	250.0–2000.0 (792.1 ± 26.1)	$\log_{10}$ weight = −3.88 + 2.42 ($\log_{10}$ length)	2.42	−4.91	−2.86	2.05	2.78	0.50
Smallmouth buffalo (*Ictiobus bubalus*)	1848	182.0–920.0 (528.5 ± 1.9)	50.0–15700.0 (2507.4 ± 32.5)	$\log_{10}$ weight = −5.37 + 3.20 ($\log_{10}$ length)	3.20	−5.59	−5.15	3.12	3.28	0.76
Spotted gar (*L. oculatus*)	115	353.0–853.0 (549.9 ± 9.2)	95.0–2250.0 (613.4 ± 35.2)	$\log_{10}$ weight = −5.76 + 3.10 ($\log_{10}$ length)	3.10	−6.51	−5.01	2.82	3.37	0.81
*Bighead carp (*Hypophthal. nobilis*)	119	868.0–1382.0 (1110.8 ± 9.8)	8250.0 37500.0 (17177.5 ± 567.8)	$\log_{10}$ weight = −4.23 + 2.77 ($\log_{10}$ length)	2.77	−5.52	−2.93	2.35	3.20	0.58
*Common carp (*Cyprinus carpio*)	30	494.0–986.0 (699.0 ± 21.9)	750.0 13600.0 (5094.0 ± 567.6)	$\log_{10}$ weight = −6.61 + 3.61 ($\log_{10}$ length)	3.61	−8.25	−4.98	3.03	4.18	0.85
*Grass carp (*Ctenopharyn. idella*)	110	614.0–1560.0 (945.3 ± 11.2)	5000.0 21750.0 (9941.6 ± 355.0)	$\log_{10}$ weight = −2.80 + 2.28 ($\log_{10}$ length)	2.28	−3.78	−1.82	1.95	2.60	0.63
*Silver carp (*Hypophthal. molitrix*)	315	532.0–1100.0 (877.8 ± 4.5)	1750.0 16900.0 (8497.0 ± 145.0)	$\log_{10}$ weight = −5.21 + 3.10 ($\log_{10}$ length)	3.10	−5.72	−4.69	2.92	3.27	0.79

*Fishes that are non-native to the Red River catchment. Sampling was completed from May 2021 to March 2024 using electrofishing and gill nets. Sample size (*N*) varied by species. The range of the species total length (TL) and weight are provided. The regression equation (L-W regression), *b* values, and 95% confidence intervals (CI) for the intercept and slopes and the coefficient of determination (r^2) are indicated.

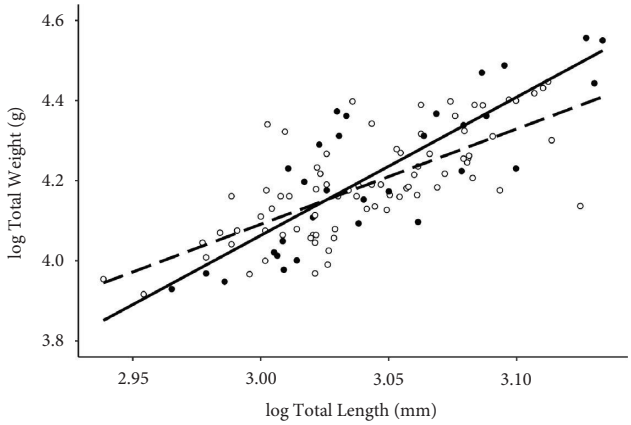

FIGURE 1: Relationship between total length (mm) and body weight (g) (log-transformed) for both sexes of bighead carp in the lower Red River catchment of Arkansas, Texas, and Oklahoma. The black dots and the solid line represent female bighead carp, whereas white dots and the dashed line represent male bighead carp.

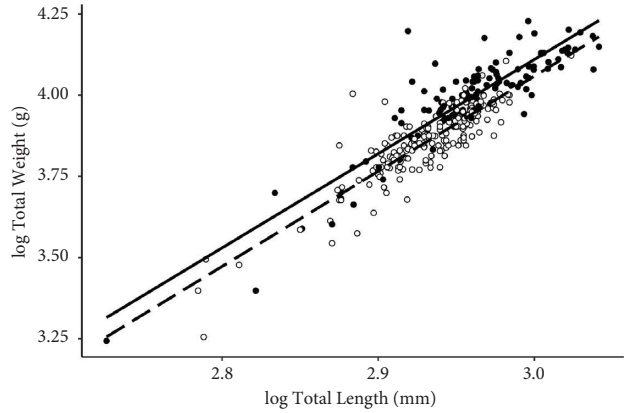

FIGURE 2: Relationship between total length (mm) and body weight (g) (log-transformed) for both sexes of silver carp in the lower Red River catchment of Arkansas, Texas, and Oklahoma. The black dots and the solid line represent female silver carp, whereas white dots and the dashed line represent male silver carp.

Data Availability

Data used in this study to support our findings are available upon request from Jim Burroughs (jim.burroughs@odwc.ok.gov).

Disclosure

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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