Length-Weight Relationships and Other Morphological Traits of Fishes in the Mangrove of Hainan, China

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Abstract: The length–weight relationships (LWR) and other morphological traits for 6417 specimens in 74 fish species collected seasonally, from July 2020 to April 2021, in the mangrove of Dongzhaihong Bay, Hainan Province, China, are presented. This involved, for all species, a sample size, and minimum and maximum lengths; in addition, for most species, it involved linear relationships between the standard length and body height and width, the height of the caudal peduncle, the pectoral fin length, and the eye diameter. This extensive coverage of mangrove-resident fish species (as opposed to species using the mangrove only as a nursery) is a first for Hainan. The various morphological traits of the mangrove fish are, for several species, the first to be published since these species’ original descriptions.

Keywords: functional diversity; morphological diversity; body shape; FishBase

1. Introduction

Mangroves are one of the most important marine ecosystems, supporting small-scale fisheries throughout the tropical and subtropical world [1]; however, their extent has declined dramatically, mainly due to shrimp farming and other coastal developments [2–5]. The fisheries in mangrove areas are based on two groups of fish: one consisting of species whose ontogeny is fully confined to a mangrove ecosystem; and the other group consisting of fish that use the mangrove only as a nursery, and eventually leave for adjacent ecosystems, such as, e.g., a mudflat or coral reef.

Chiefly because of their small sizes, but also because they are usually exploited by subsistence or small-scale commercial fishers in rural and often remote areas of poorer countries [6], the fishes of mangroves are understudied; i.e., the major features of their life history are not available in the scientific literatures. In the following, we present the first extensive study of morphological traits of mangrove fishes from the Hainan Province; the Province has the highest mangrove cover in all of China (Figure 1). Among these traits, we emphasize the length–weight relationship (LWR) because, in addition to being an important trait, LWR is also used for various practical purposes; these include turning growth curves in length into growth curves in weight, as required for fish population assessments [7].
Figure 1. Map of Dongzhaigang Bay, Hainan Province, China, showing the distribution of mangrove trees around the bay (green color); and the location of Dongzhaigang Bay in the northeast of Hainan (1st insert), in the south of China (2nd insert).

2. Material and Methods

This study is based on data collected during field surveys by Xiamen University in the Dongzhaigang National Reserve, Hainan Province, China from July 2020 to April 2021. Fish were collected seasonally using 10 m nets with 1 cm meshes. All the collected fish specimens were immediately put on ice and transported to a laboratory where they were weighted to the nearest 0.1 g and length measurements (standard, fork, and total length; body height and width; height of the caudal peduncle; pectoral fin length and eye diameter) were taken to the nearest millimeter.

The parameters of the length–weight relationships (LWR) of the form $W = a \cdot L^b$ were estimated by two methods. One consisted of plotting the standard length (L) vs. weight (W) in form of linear regressions of log (W) vs. log (L). These regressions have intercepts ($\alpha$) which, after elimination of a few obvious outliers, provide estimates of $a = 10^{\alpha}$; in addition, they have slopes that provide estimates of $b$; while their coefficients of determination ($r^2$) indicate the fraction of the variance in L and W explained by the LWR [8,9].

The other method was used for species for which either few L–W data pairs were available, or for which specimens were measured that covered only a narrow range of sizes. This method consists of assuming $b$ to be equal to 3, as is frequently the case [9]; calculating values for each available L–W data pair and averaging them; or using it as is in cases where only one L–W data pair was available [7].

With both methods, the LWR were computed only for species whose maximum observed length was above 50% of the maximum length provided by FishBase [10] for the species in question. The purpose of this was to ensure that: (i) LWR were computed only...
for fishes that mostly occur in the mangrove, rather than use them only as nursery grounds; and (ii) the LWR presented here do not refer only to juveniles, but also include at least young adults. Fish species that did not meet the 50% criterion were considered to use the mangrove only as a nursery for their young; and their length–weight relationships were not computed, although their other traits were.

Finally, linear regressions were run for all species for which there were sufficient numbers of measurements, covering a sufficient range of lengths: between their standard length, and their body height and width; the height of the caudal peduncle; and the pectoral fin length and eye diameter.

3. Results

We collected 74 fish species belonging to 12 orders and 68 families during the sampling period; however, the above criteria allowed the estimation of the LWR for only 36 species, 22 using linear regression (Table 1) and 14 by assuming $b = 3$ (Table 2). Figure 2A–D providing graphical examples for four species (see Supplementary Materials graphical representation of the other LWR).

Table 1. Fish species sampled in the mangrove of the Dongzhaihong National Reserve, Hainan Province, China, and for which enough specimens (incl. relatively large ones) were measured for length–weight relationships (LWR) of the form $W = aL^b$ to be calculated (for $L =$ standard length). All the lengths are in centimeters; $n =$ number of individuals.

| Scientific Name          | $n$ | Minimum   | Maximum     | FishBase Max. a | Standard Length/Total Length | LWR | $r^2$ |
|--------------------------|-----|-----------|-------------|-----------------|-----------------------------|-----|-------|
| Acentrogobius caninus    | 178 | 2.6/3.3   | 10.5/12.6   | -/18.3          | 0.0185                      | 3.007 | 0.962 |
| Acentrogobius chlorostigmatoides | 100 | 5.0/6.4   | 10.1/12.4   | -/11.0          | 0.0362                      | 2.771 | 0.885 |
| Acentrogobius viridipunctatus | 1017 | 3.4/4.6   | 11.2/13.9   | -/16.5          | 0.0316                      | 2.783 | 0.870 |
| Ambassis gymnocephalus   | 920 | 1.7/2.3   | 7.1/8.8     | -/16.0          | 0.0173                      | 3.083 | 0.855 |
| Boleophthalmus pectinirostris | 111 | 5.8/7.3   | 12.2/14.8   | -/20.0          | 0.0260                      | 2.665 | 0.817 |
| Bostrychus sinensis      | 138 | 6.9/8.5   | 18.0/20.8   | -/22.0          | 0.0109                      | 3.204 | 0.950 |
| Batis butis              | 9   | 7.1/11.2  | 10.2/12.4   | -/15.0          | 0.0142                      | 3.123 | 0.967 |
| Batis kolomatodon        | 18  | 3.8/4.8   | 6.9/8.6     | -/10.7          | 0.0173                      | 3.199 | 0.958 |
| Escualosa thoracata      | 166 | 4.6/5.9   | 8.0/10.2    | 10.0/-          | 0.00737                     | 3.361 | 0.946 |
| Gerres japonica          | 21  | 4.1/5.4   | 12.2/15.4   | 20.0/-          | 0.0166                      | 3.222 | 0.996 |
| Gerres lucidus           | 235 | 2.8/3.5   | 11.9/15.1   | -/15.0          | 0.0214                      | 3.129 | 0.993 |
| Glossogobius olivaceus   | 37  | 6.2/7.4   | 11.2/13.6   | 17.0/-          | 0.00964                     | 3.266 | 0.971 |
| Konosirus punctatus      | 10  | 4.8/5.7   | 14.1/18.0   | -/32.0          | 0.0197                      | 2.870 | 0.988 |
| Leigognathus brevirostris| 315 | 2.1/3.0   | 8.3/10.1    | -              | 0.0170                      | 3.071 | 0.940 |
| Liza carinata            | 52  | 4.6/5.9   | 16.0/18.8   | -/18.0          | 0.0297                      | 2.700 | 0.965 |
| Liza subviridis          | 491 | 3.3/4.1   | 21.1/25.7   | 40.0/-          | 0.0316                      | 2.762 | 0.964 |
| Oxynichthys opthalmomemus| 403 | 3.9/5.4   | 11.3/16.4   | -/18.0          | 0.00955                     | 3.190 | 0.926 |
| Siganus guttatus         | 72  | 4.0/6.1   | 21.5/26.2   | -/42.0          | 0.0309                      | 3.002 | 0.996 |
| Takifugu niphobles       | 29  | 3.4/4.4   | 11.5/13.8   | -/15.9          | 0.0799                      | 2.611 | 0.909 |
| Tridentiger              | 16  | 4.6/5.8   | 8.3/10.2    | -/11.0          | 0.0198                      | 3.139 | 0.994 |
| Vespicula trachinoides   | 21  | 2.7/36.8  | 5.9/7.3     | 5.8/-           | 0.0232                      | 3.321 | 0.966 |
| Zenarchopterus buffonis   | 33  | 5.6/7.0   | 13.1/15.3   | -/23.0          | 0.00601                     | 3.094 | 0.941 |

a The maximum lengths from FishBase (www.fishbase.org (accessed on 2 May 2022)) are provided to document: (1) that no species is included that did not at least reach 50% of the maximum length in FishBase; this ensures that species that use the mangrove only as nurseries are not included; and (2) that the LWRs are based on a wide range of sizes.
Table 2. Fish species sampled in the mangrove of the Dongzhaigang National Reserve, Hainan Province, China, and for which a sufficient number of specimens, covering a wide range of lengths were not available; the length–weight relationships (LWR) were thus assumed to have the form $W = a \cdot L^3$ (with $L$ = standard length). All the lengths are in centimeters; $n$ = number of individuals.

| Scientific Name                        | $n$ | Minimum      | Maximum      | FishBase Max. a | a        |
|----------------------------------------|-----|--------------|--------------|-----------------|---------|
| **Standard Length/Total Length (SL/TL)**                                    |
| *Amoya chusanensis*                   | 18  | 5.7/7.0      | 7.3/9.1      | -/7.2           | 0.0145  |
| *Hypoatherina valenciennei*           | 1   | 6.1/7.6      | -            | -/12.0          | 0.0140  |
| *Leiognathus ruconius*                | 1   | 4.6/5.8      | -            | -/8.0           | 0.0271  |
| *Mugilobius abei*                     | 1   | 2.8/3.4      | -            | 4.1/-           | 0.0214  |
| *Muraenichthys macropterus*           | 2   | 22.7/23.0    | 27.5/27.8    | -/25.0          | 0.00113 |
| *Pteropthalmus modestus*              | 9   | 5.7/6.9      | 6.7/8.5      | -/10.0          | 0.0149  |
| *Pisodonophis boro*                   | 2   | 52.0/52.0    | 57.0/57.0    | -/100.0         | 0.000817|
| *Plotosus lineatus*                   | 1   | 17.6/19.5    | -            | -/32.0          | 0.00834 |
| *Pterygoplichthys multisirradiatus*   | 1   | 30.3/37.7    | -            | -/50.0          | 0.0142  |
| *Sardinella zunasi*                   | 2   | 7.6/10.2     | 8.4/10.6     | -/18.0          | 0.0164  |
| *Scartelaos histophorus*              | 6   | 10.3/12.9    | 12.9/14.9    | 14.0/-          | 0.00526 |
| *Strongylura strongylura*             | 1   | 20.1/22.2    | -            | 40.0/-          | 0.00289 |
| *Taenioides cirratus*                 | 2   | 22.6/24.4    | 23.2/25.2    | -/30.0          | 0.00163 |
| *Trypauchen vagina*                   | 1   | 12.7/14.6    | -            | -/22.0          | 0.00499 |

a The maximum lengths from FishBase (www.fishbase.org (accessed on 2 May 2022)) are provided to document: (1) that no species is included that did not have at least one L–W data pair above 50% of the maximum length in FishBase; this ensures that species that use the mangrove only as nurseries are not included; and (2) that the estimate of ‘a’ is based on adult fish, and not juveniles.

Figure 2. Example of different types of length–weight relationships (LRW) derived for mangrove fishes from Dongzhaigang Bay, China from July 2020 to April 2021. (A): a common LWR, covering a wide range of size with numerous L–W data pairs, and whose parameters (a, b) were estimated by a linear regression of log(W) vs. log(L); see also Table 1. (B): an LWR with b set at an assumed value of 3 because the L–W data pairs cover only a narrow range of sizes. (C): the same, with only 2 L–W data pairs. (D): the same with only 1 L–W data pair. See Table 2 for more cases similar to (B–D), and the text for comments on the assumption that b = 3.
The linear relationships between the standard length and various morphological traits of fish species with enough data are illustrated, for example, by the greenback mullet (*Liza subviridis*) in Figure 3; and they are documented in tabular and/or graphic form for the other 64 species we investigated. The Supplementary Materials include species which grow well beyond double the maximum length that was sampled, and which therefore can be assumed to use the mangrove only as a nursery. For these species, the traits reported here should be assumed to apply only to their juveniles.

Figure 3. Linear regressions between the morphological traits and standard length (SL) in the greenback mullet (*Liza subviridis*) sampled in Dongzhaiqang Bay, Hainan Province, China from July 2020 to April 2021. (A): body height vs. SL; (B): caudal peduncle width vs. SL; (C): pectoral fin length vs. SL; (D): eye diameter vs. SL; (E): body width vs. SL.

4. Discussion

This study estimated the LWR in numerous species of mangrove fish for which important information was lacking in the literature, and thus in FishBase [10] as well. Hence, the
data in Tables 1 and 2 will fill numerous gaps; even though FishBase compensates for the gaps by generating the LWR via a Bayesian routine, from taxonomically related species of similar shape [11]. The point here is that the LWR of Table 2, even if based on only a few L–W data pairs, or even on one, will improve the predicted LWR.

The computed LWR (Table 1) had a mean exponent $b = 3.03$, which corroborated the hypothesis that 3 should be the default assumption in LWR studies [9]; and which implies that, with $b \approx 3$, the fish in question maintain their overall shape as they grow from juveniles to adults, i.e., their growth is isometric.

One species that did not fit well in our study was the goldfish *Carassius auratus*, of which one specimen of 19.3 cm SL was caught in the mangrove. *C. auratus* can briefly tolerate brackish water [12]; however, it can reproduce only in freshwater. Thus, we assume that this specimen escaped from a nearby freshwater pond or was discharged from an aquarium.

Current biodiversity assessments tend to focus on taxonomic diversity, such as species richness or abundance; these do not account for the different biological characteristics or traits of species; i.e., for their functional diversity [13]. Yet, species with different morphological traits perform different roles in ecosystems [14]. Thus, considering functional diversity can contribute to better understand how ecosystems function and provide services [15].

Therefore, the data on the morphological diversity of the fishes of the mangroves of Hainan presented therein, jointly with related data on fish biodiversity in FishBase [10], will help in future work aiming to characterize these ecosystems.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/fishes7050238/s1, figures of per species; Table S1: Relationship between the standard length (cm) and body height (cm) of fish in the mangrove of Hainan, China (n = sample size); Table S2: Relationship between standard length (cm) and caudal peduncle width (cm) of fish in the mangrove of Hainan, China; n= sample size.; Table S3: Relationship between standard length (cm) and pectoral fin length (cm) of fish in the mangrove of Hainan, China; n= sample size.; Table S4: Linear relationship between standard length (cm) and Eye diameter (cm) of fish in the mangrove of Hainan, China; n= sample size.; Table S5: Linear relationship between standard length (cm) and Body width (cm) of fish in the mangrove of Hainan, China; n= sample size.

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**Data Availability Statement:** Data are available upon reasonable request.

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**Conflicts of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
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