

LENGTH–WEIGHT RELATIONS OF JUVENILE AND ADULT FISHES (ACTINOPTERYGII) FROM SHALLOW WATERS IN THE LOWER GUANABARA BAY ESTUARY, BRAZIL

Marcus R. da COSTA^{1,3*}, Rafael de A. TUBINO^{1,2}, and Cassiano MONTEIRO-NETO^{1,3}

¹*Laboratório de Biologia do Nécton e Ecologia Pesqueira (ECOPESCA), Universidade Federal Fluminense, Niterói, Brazil*

²*Departamento de Biologia Animal, Universidade Federal Rural do Rio de Janeiro, Seropédica, Brazil*

³*Programa de Pós-Graduação em Biologia Marinha e Ambientes Costeiros, Departamento de Biologia Marinha, Instituto de Biologia, Niterói, Brazil*

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Abstract. Length–weight relations (LWR) are presented herewith for 15 fish species from shallow waters of three sandy beaches in the lower Guanabara Bay estuary, south-eastern Brazil. The following species were examined: *Albula vulpes* (Linnaeus, 1758); *Harengula clupeiola* (Cuvier, 1829); *Brevoortia aurea* (Spix et Agassiz, 1829); *Anchoa lyolepis* (Evermann et Marsh, 1900); *Umbrina coroides* Cuvier, 1830; *Menticirrhus littoralis* (Holbrook, 1847); *Menticirrhus americanus* (Linnaeus, 1758); *Trachinotus carolinus* (Linnaeus, 1766); *Trachinotus falcatus* (Linnaeus, 1758); *Diplodus argenteus* (Valenciennes, 1830); *Polydactylus virginicus* (Linnaeus, 1758); *Mugil curema* Valenciennes, 1836; *Haemulon aurolineatum* Cuvier, 1830; *Haemulon steindachneri* (Jordan et Gilbert, 1882); *Sphoeroides testudineus* (Linnaeus, 1758). Specimens were sampled monthly over a four-year period between January 2012 and December 2015. This study presents the first length–weight relation of *Diplodus argenteus* for Brazil. The LWRs for all taxa included juveniles and sub-adults within size ranges commonly found in shallow waters of tropical sandy beaches. Only the adults ($TL > L_{50}$) of *Harengula clupeiola* and *Sphoeroides testudineus* were recorded in the area. The length–weight parameter b for all species ranged from 2.66 to 3.32, with regression coefficients (r^2) between 0.97 and 0.99.

Keywords: ichthyofauna, sandy beach, south-eastern Brazil, growth

INTRODUCTION

The length–weight relation (LWR) in fish biology is useful for predicting weight from length values, indicating a fish condition, and conducting a fish stock assessment (Lin and Tzeng 2010, Romdhani et al. 2013). The relation may also provide information for between region comparisons of species life histories and population dynamics (da Costa et al. 2014).

Since the last century, many ichthyologists have discussed the causes and meanings of growth in fish (e.g., Huxley 1924, 1993, Le Cren 1951, Beyer 1987). Growth rates may vary, among other factors, according to environmental conditions, food availability, and habitat type. Nevertheless, a common pattern on fish growth is the development through a series of phases or stanzas (Barlow 1961), with marked changes in the body shape, mostly in the early life cycle (Fonteles-Filho 2011). Thus, the growth analysis of juvenile versus adult fish should

be conducted under separate LWRs to account for growth stanzas, ontogenetic changes, and developmental phases (Bervian et al. 2006, Froese 2006). The objective of this work was to produce LWR estimates for fishes, mostly juveniles, commonly found in shallow waters of sandy beaches of Guanabara Bay, one of the most important estuaries of south-eastern Brazil. This article is a part of a larger effort to advance research questions on the temporal and spatial patterns of fish recruitment and juvenile habitat use in tropical regions.

MATERIAL AND METHODS

Fishes were sampled in shallow waters of three sandy beaches of the lower Guanabara Bay estuary (outer zone under the marine influence) (22°24'–22°57'S, 42°33'–43°19'W), on a monthly basis between January 2012 and December 2015, under special collecting permit (SISBIO #15787-1). Fishes were caught with a beach

* Correspondence: Dr Marcus Rodrigues da Costa, Universidade Federal Fluminense, Instituto de Biologia, Outeiro de São João Batista s/n, CEP: 24020-971, Centro, Niterói, Rio de Janeiro, Brazil, phone: (+55) 21 2629 2298, e-mail: (MRC) marcusrc@id.uff.br, (RAT) rattubino@gmail.com, (CMN) cmneto@id.uff.br.

seine (16 m long, 2.5 m high, and 7.5 mm mesh) at sites, totalling 144 samples. The sampling unit considered was the total number of fish caught in three replicate tows at each location. All collected specimens were placed in plastic bags, labelled, stored on ice, and transported to the laboratory where they were screened and identified to the lowest taxonomic level. All fishes were measured for total length (± 1 mm) and weighed with an electronic scale (± 0.01 g).

The equation used to calculate LWRs was

$$W = a \times L^b,$$

where, W is the total weight of fishes [g], a is the coefficient related to body shape, L is the total length [cm], and b is an exponent related to changes in body shape. The model was adjusted using Statistica 7.0 software, and parameters a and b were estimated by the log-linear regression

$$\log(W) = \log a + b \log(L)$$

Extreme outlier values were excluded from the analyses. Additionally, 95% confidence limits (CL) of both a and b were estimated. The model fit was measured by the Pearson r -squared (r^2) coefficient. The values of total length and b were compared with the values reported in the FishBase and the literature. Also, the size of first sexual maturity was compiled from the literature to determine species life stages (juvenile/subadult or adult). Monthly length-frequency data were grouped and analysed using the Bhattacharya's method subroutine in the FISAT II package (FAO-ICLARM Stock Assessment Tools) (Sparre and Venema 1998) for cohort identification and estimation of the mean length for each modal group. Voucher specimens were deposited in the ichthyologic collection of ECOPECSA Laboratory at the Fluminense Federal University.

RESULTS

A total of 14 457 individuals representing 15 species and ten families were collected. The following species were examined: *Albula vulpes* (Linnaeus, 1758); *Harengula clupeiola* (Cuvier, 1829); *Brevoortia aurea* (Spix et Agassiz, 1829); *Anchoa lyolepis* (Evermann et Marsh, 1900); *Umbrina coroides* Cuvier, 1830; *Menticirrhus littoralis* (Holbrook, 1847); *Menticirrhus americanus* (Linnaeus, 1758); *Trachinotus carolinus* (Linnaeus, 1766); *Trachinotus falcatus* (Linnaeus, 1758); *Diplodus argenteus* (Valenciennes, 1830); *Polydactylus virginicus* (Linnaeus, 1758); *Mugil curema* Valenciennes, 1836; *Haemulon aurolineatum* Cuvier, 1830; *Haemulon steindachneri* (Jordan et Gilbert, 1882); *Sphoeroides testudineus* (Linnaeus, 1758). For each species, an adequate number of samples including mainly juveniles/sub-adults and some adult stages were examined. The sampling program (four cycles) within the study area using the same fishing gear and a standardized effort allowed grouping the datasets to generate relative growth estimates of species. The best-represented family was the

Sciaenidae with three species, while the most abundant were: *Harengula clupeiola*, *Diplodus argenteus*, *Umbrina coroides*, and *Trachinotus carolinus*. The LWR parameters and related statistics are presented in Table 1. Mean total lengths varied from 1.0 cm (*Umbrina coroides* and *Menticirrhus littoralis*) to 21.5 cm (*Albula vulpes*). The a coefficient ranged from 0.0031 to 0.0315, and the Pearson r -squared coefficient from 0.97 to 0.99. The b values between 2.66 and 3.32 were within the expected range and consistent with the literature (Froese 2006). Length-weight relations for *Diplodus argenteus* were unavailable in FishBase (Froese and Pauly 2016), and the parameters here obtained are the first records in the scientific literature.

DISCUSSION

The great peculiarity of this study is a large number of small individuals of seven species, within minimum size ranges recorded in the literature. Individuals at TLs greater than the L_{50} reported in the literature were obtained for *Harengula clupeiola* and *Sphoeroides testudineus* and considered as adults. These findings suggest that populations from these two species included all strata (young-of-the-year, juvenile, and adult) in the studied sites, with individuals exploring the surf-zone/shallow-water resources until completing sexual maturity. These findings further support the idea proposed by Froese (2006) in which separate LWRs should be used to account for growth stanzas, ontogenetic changes, and developmental phases.

Shallow marine habitats and the surf zone of sandy beaches have long been considered as nurseries for several fish species, many of commercial interest (Monteiro-Neto and Musick 2003, Pereira et al. 2015). The high food availability (Amaral et al. 2016) and protection from larger fish predators (Félix et al. 2007) during the growing phase represent important assets for young fish. Thus, shallow marine habitats play the connectivity role between the young and the adult population (Beck et al. 2001) of species that are commonly found in other habitats as adults. For instance, *Haemulon aurolineatum* was collected at TLs between 2.74 and 4.46 cm in the presently reported study (Table 1). Adults of the species undergo changes in colour pattern and body form at 5.4 cm TL (Darcy 1983), and are often found near reefs (Monteiro-Neto et al. 2008). The absence of adults in our sampling suggests the part-time residency of the species in shallow waters during the juvenile phase.

Differences observed in a and b values of LWRs of fishes (same species or not) in the same habitat may be attributed to a combination of one or more factors:

- Number of specimens examined
- Fish habitat
- Health
- Sex
- Gonadal maturity
- Differences in the observed length ranges of the specimens and
- The preservation techniques used (Hossain et al. 2014)

Table 1
Descriptive statistics and length–weight parameters for 15 fish species caught in shallow waters of the lower Guanabara Bay estuary during January 2012–December 2015

| Family | Species | S | n | TL range [cm] | W range [g] | a | CL95% of a | b | CL95% of b | r ² | No. of Cohorts | Cohort means TL [cm] | L ₅₀ [cm] | |
|----------------|--------------------------------|---|------|---------------|-------------|--------|---------------|-------|-------------|----------------|----------------|-----------------------|------------------------|----|
| | | | | | | | | | | | | | ♀ | ♂ |
| Albulidae | <i>Albula vulpes</i> | J | 137 | 2.2–21.5 | 0.12–82.65 | 0.0050 | 0.0044–0.0056 | 3.181 | 3.125–3.238 | 0.99 | 4 | 5.56–8.83–12.50–15.79 | 48.8 ^B | 1 |
| Clupeidae | <i>Harengula clupeiola</i> | J | 3977 | 1.7–9.6 | 0.05–9.15 | 0.0054 | 0.0054–0.0054 | 3.295 | 3.293–3.297 | 0.99 | 2 | 3.52–6.22 | 8.5–7.4 | 2 |
| Clupeidae | <i>Brevoortia aurea</i> | J | 182 | 5.0–9.1 | 1.29–7.94 | 0.0105 | 0.0087–0.0128 | 2.992 | 2.888–3.097 | 0.97 | 1 | 6.03 | 27.7–26.5 | 3 |
| Engraulidae | <i>Anchoa lyolepis</i> | A | 912 | 2.4–9.4 | 0.14–4.71 | 0.0031 | 0.0029–0.0033 | 3.324 | 3.292–3.356 | 0.98 | 2 | 4.55–7.56 | 6.5 ^C | 4 |
| Sciaenidae | <i>Umbrina coroides</i> | A | 2872 | 1.0–17.5 | 0.04–51.85 | 0.0110 | 0.0107–0.0113 | 2.987 | 2.973–3.001 | 0.99 | 3 | 4.78–9.52–12.37 | 11.3–11.2 ^C | 5 |
| Sciaenidae | <i>Menticirrhus littoralis</i> | J | 523 | 1.0–16.3 | 0.04–53.72 | 0.0087 | 0.0082–0.0092 | 2.993 | 2.957–3.029 | 0.99 | 4 | 3.13–8.19–12.56–15.1 | 23 ^F | 6 |
| Sciaenidae | <i>Menticirrhus americanus</i> | J | 118 | 2.0–12.4 | 0.12–17.02 | 0.0111 | 0.0094–0.0131 | 2.827 | 2.703–2.951 | 0.97 | 3 | 5.00–7.00–9.00 | 16.7–15.4 | 7 |
| Carangidae | <i>Trachinotus carolinus</i> | J | 1578 | 1.2–12.5 | 0.03–31.66 | 0.0171 | 0.0166–0.0177 | 2.845 | 2.821–2.869 | 0.98 | 4 | 2.59–6.35–9.03–11.00 | ≥ 20.0 ^B | 8 |
| Carangidae | <i>Trachinotus falcatus</i> | J | 135 | 1.5–19.8 | 0.10–87.90 | 0.0315 | 0.0280–0.0354 | 2.663 | 2.587–2.738 | 0.98 | 2 | 3.68–8.43 | 54.7–48.6 | 9 |
| Sparidae | <i>Diplodus argenteus</i> | J | 3187 | 1.2–9.0 | 0.02–11.34 | 0.0107 | 0.0103–0.0110 | 3.188 | 3.162–3.214 | 0.97 | 2 | 3.91–7.09 | 20.3 ^F | 10 |
| Polimeidae | <i>Polydactylus virginicus</i> | J | 397 | 3.4–14.0 | 0.33–19.60 | 0.0071 | 0.0066–0.0076 | 3.092 | 3.051–3.133 | 0.99 | 3 | 4.64–6.00–9.58 | 19.0 ^C | 11 |
| Mugilidae | <i>Mugil curema</i> | J | 185 | 2.8–13.6 | 0.20–24.98 | 0.0096 | 0.0086–0.0107 | 3.089 | 3.016–3.162 | 0.98 | 2 | 4.31–7.16 | 24.8 ^B | 12 |
| Haemulidae | <i>Haemulon aurolineatum</i> | J | 106 | 1.5–12.3 | 0.04–26.13 | 0.0092 | 0.0074–0.0115 | 3.240 | 3.090–3.390 | 0.97 | 2 | 2.74–4.46 | 15.0–15.3 | 13 |
| Haemulidae | <i>Haemulon steindachneri</i> | J | 77 | 4.4–10.0 | 0.44–6.64 | 0.0061 | 0.0053–0.0070 | 3.118 | 3.040–3.195 | 0.99 | 1 | 6.07 | 7.5 ^B | 14 |
| Tetraodontidae | <i>Sphoeroides testudineus</i> | A | 71 | 1.5–14.7 | 0.09–66.83 | 0.0313 | 0.0277–0.0355 | 2.828 | 2.752–2.903 | 0.99 | 4 | 3.65–6.29–8.00–13.00 | 10.8 ^F | 15 |

S = developmental stage, n = number of individuals, TL = total length, a = intercept, b = slope, CL = confidence limits, r² = coefficient of determination, L₅₀ = length at first maturity, A = adults (♂) = juveniles; B = both sexes; C = L₅₀ of congeneric species, F = female; Sources: 1 = Tiburino 2011, 2 = Peña-Alvarado et al. 2009, 3 = Lajud et al. 2016, 4 = Esper (1982) (referring to *Anchoa januaria*), 5 = Zanetti-Prado and Vazzoler 1976 (referring to *U. canosai*), 6 = Braun and Fontoura 2004, 7 = Freitas et al. 2011, 8 = Lemos et al. 2011, 9 = Crabtree et al. 2002, 10 = David et al. 2005, 11 = Froese and Pauly 2016 (referring to *P. octonemus*), 12 = Fernandez and Dias 2013, 13 = Lessa et al. 2004, 14 = Cavalcante 2014, 15 = Rocha et al. 2002.

Froese (2006) and Gubiani et al. (2009) pointed out that variations in the exponent b may be also attributed to different length ranges of the specimens and the area-seasonal effect. The presence of at least one mode, defined from a modal decomposition routine, is a good indication of habitat use by the species. The occurrence of multiple modes supports the premise of multiphase growth, common to most bony fishes (Bervian et al. 2006). Peyton et al. (2016) reinforced the idea that WLR estimates of juvenile fishes occurring in shallow waters are needed to compare temporal and spatial recruitment patterns. Petrakis and Stergiou (1995) observed that LWR parameters vary over a seasonal cycle within a year, depending on the average condition of the specimens. Fish habitat, sexual maturity, and size structure were addressed in the presently reported study, providing additional information towards the understanding of shallow habitats as nursery areas for several fish species in the tropical Atlantic, within the outer limits of an important estuarine environment, Guanabara Bay. Thus, the results of this study provide valuable information that will be helpful in future fisheries management and fish conservation.

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