



Short Communication

Length–Weight Relationships of Eleven Deep-Sea Fishes (Order: Stomiiformes) from the South China Sea

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ABSTRACT

Length–weight relationships (LWRs) were estimated for 11 mesopelagic fish species representing Stomiiformes in the South China Sea: *Astronesthes cyaneus*, *Astronesthes indicus*, *Astronesthes splendidus*, *Borostomias pacificus*, *Chauliodus sloani*, *Diplophos taenia*, *Heterophotus ophistoma*, *Idiacanthus fasciola*, *Malacosteus niger*, *Photoneustes albipennis*, and *Sigmops elongatus*. Specimens were collected via a midwater trawl in 13 cruises and 25 hauls from 2014 to 2022 (except 2020). Total wet weight (TWW) and standard length (SL) of each individual were measured to the nearest 0.01 g and 0.1 cm, respectively. Collections of one species were considered as a whole for estimates of LWRs. Correlation coefficients (r^2) ranged from 0.947 to 0.997, and CL b values ranged from 2.642 to 3.311. This study provides first LWRs for 7 species and new maximum SLs for 3 species. These findings will contribute to improve the knowledge of Stomiiformes fishes and have implications for the assessment of mesopelagic fish biomass.

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Authors' Contribution

HT analysed the data and wrote the paper. YJ and JQ were responsible for specimens' collection and identification. JZ saved and accumulated historical data. ZC designed the paper, SX, JZ and WY performed the docking work of experimentation.

Key words

Length–weight relationships, Stomiiformes, Stomiidae, Gonostomatidae, South China Sea

Stomiiformes is one of the major orders of mesopelagic fish, with diverse morphologies, acting as key trophic mediators in the mesopelagic ocean and play an important role in the biological and carbon pump in carbon sequestration (Catul *et al.*, 2011; Cavan *et al.*, 2019; Sarmiento-Lezcano *et al.*, 2022; Sutton, 2003). Obtaining basic biological information about them is of paramount importance for their management and conservation. The length–weight relationships (LWRs) are widely used to predict the biomass of a fish stock, identify differences in growth of the same species in different regions, and provide parameters for ecological modeling (Froese, 2006; Froese *et al.*, 2011; Hosseini-Shekarabi *et al.*, 2015).

Nevertheless, there are few relevant reports, and only limited information on LWRs for Stomiiformes is available (Eduardo *et al.*, 2020; Lopez-Perez *et al.*, 2020). Studies of the basic biological characteristics of mesopelagic fish have been reported in the South China Sea, but they lack LWRs for most Stomiiformes (Jiang *et al.*, 2017). The present study reports LWRs for 11 stomiiform fishes inhabiting the South China Sea.

Materials and methods

The specimens were collected from the South China Sea, including the Xisha, Nansha, Dongsha, and northern slope waters (9°30'–20°30.01'N, 110°22'–116°09'E). Sampling was performed from May to November each year from 2014 to 2022 (except for 2020). The sampling phase covered 25 hauls over 13 cruises. The duration of each cruise was approximately 15 days. A mid-water trawl was used in the study with cod-end mesh size of 10 mm and 40 mm mesh in the forward section. Each haul began at around 12:00 a.m. and lasted for 1 h at a speed of 1.5–2.5 m/s at depths of 400–600 m. Fishes were immersed in seawater and stored immediately and independently at –40 °C. After each voyage, all specimens were identified in the onshore

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laboratory, and biological characteristics were collected for each individual, including total wet weight (TWW, to the nearest 0.01 g) and standard length (SL, to the nearest 0.1 cm). For each species, data accumulated from multiple cruises were analyzed as a whole in this study.

LWRs were determined by the formula $W = aL^b$ (Le-Cren, 1951; Froese, 2006), where W is TWW (g), L is SL (cm), a is the intercept of the regression curve, and b is the regression slope. Both a and b were estimated via the transformed logarithmic expression $\log(W) = \log(a) + b\log(L)$ (Froese, 2006). The coefficient of determination r^2 was used to measure the fit of the model to the data. Confidence intervals (95%) of CL a and CL b were calculated in Origin version 9.9.0.225.

Results

A total of 1095 stomiiform specimens were measured for LWRs (Table I). Summarized data including sample size (n), parameters a and b , ranges of TWW and SL,

and coefficient of determination (r^2) are presented in Table I. LWRs are presented for 11 species, representing Gonostomatidae (2 species) and Stomiidae (9 species). Parameter a ranged from 0.00180 for *Diplophos taenia* to 0.01833 for *Borostomias pacificus*, and b ranged from 2.64 for *B. pacificus* to 3.31 for *Astronesthes indicus*. All LWRs were highly significant ($p < 0.01$), with r^2 ranging from 0.947 for *Photonectes albipennis* to 0.997 for *Astronesthes cyaneus*.

Sample sizes varied by species, ranging from 16 to 451 specimens, with rare species accumulated from multiple voyages. This study provides the first information on LWRs for 7 species, *Astronesthes splendidus*, *A. cyaneus*, *A. indicus*, *B. pacificus*, *Heterophotus ophistoma*, *Idiacanthus fasciola*, and *P. albipennis*, according to FishBase (Fishbase, 2023). New records of maximum length are provided for 3 species: *A. cyaneus*, *A. splendidus*, and *B. pacificus*. Estimates for CL b ranged from 2.64

Table I. Descriptive statistics and estimated LWRs parameters for eleven deep-sea fishes from order Stomiiformes in the South China Sea.

Taxa	n	TWW range (g)	SL range (cm)	a (95% CL of a)	b (95% CL of b)	r^2
Gonostomatidae						
<i>Diplophos taenia</i> Gunther, 1873	104	0.15–8.21	2.2–16.6	0.00180 (0.00142–0.00218)	3.03 (2.95–3.11)	0.962
<i>Sigmops elongatus</i> Gunther, 1878	91	3.02–28.00	10–20.7	0.00227 (0.00177–0.00277)	3.11 (3.04–3.19)	0.969
Stomiidae						
<i>Astronesthes cyaneus</i> Brauer, 1902	17	0.60–54.00	4.6–18.7	0.00455 (0.00334–0.00576)	3.21 (3.11–3.30)	0.997
<i>Astronesthes indicus</i> Brauer, 1902	18	0.30–23.72	4.0–15.5	0.00340 (0.00070–0.00610)	3.31 (3.02–3.60)	0.964
<i>Astronesthes splendidus</i> Brauer, 1902	74	0.10–28.83	2.1–15.2	0.00360 (0.00289–0.00431)	3.30 (3.22–3.37)	0.972
<i>Borostomias pacificus</i> Imai, 1941	16	0.38–79.12	4.9–23.9	0.01833 (0.01300–0.03133)	2.64 (2.55–2.73)	0.993
<i>Chauliodus sloani</i> Bloch and Schneider, 1801	451	0.05–54.40	1.4–27.2	0.00211 (0.00186–0.00236)	3.06 (3.02–3.10)	0.960
<i>Heterophotus ophistoma</i> Regan and Trewavas, 1929	25	25.40–310.20	13.0–34.3	0.00659 (0.00299–0.01019)	3.03 (2.88–3.19)	0.962
<i>Idiacanthus fasciola</i> Peters, 1877	193	0.03–3.21	2.0–27.9	0.00019 (0.00016–0.00022)	2.92 (2.87–2.98)	0.961
<i>Malacosteus niger</i> Ayres, 1848	90	0.32–86.00	4.8–24.2	0.00295 (0.00252–0.00338)	3.23 (3.18–3.28)	0.973
<i>Photonectes albipennis</i> Doderlein, 1882	16	2.71–84.00	1.1–26.1	0.00330 (0.00059–0.00601)	3.11 (2.86–3.37)	0.947

n , sample size; TWW, total wet weight; SL, standard length; a , initial growth index; b , slope of the regression; CL, confidence limits; r^2 , coefficient of determination. Bold, new LWR in Species or new maximum length in SL.

for *B. pacificus* to 3.31 for *A. indicus*. The sample sizes of *Sigmops elongatus*, *Chauliodus sloani*, and *Malacosteus niger* were greater than those of previous studies and together with *D. taenia* provided biological information on the Stomiiformes.

Discussion

In the present study, specimens were preserved individually via a cryogenic seawater immersion method. Although we safeguarded the integrity of the specimens during measurement, especially from tooth loss, which is common for Stomiiformes, LWRs presented here may be slightly different from those found for living specimens because of the damage incurred during the haul, such as loss of scales and fins. Estimates for CL b ranged from 2.64 to 3.31 in the present study, within the expected range of 2.5 to 3.5 (an interval covering CL b values for most species proposed by Froese (2006), indicating that the specimens we used have the validity to reflect WLRs for these species. In addition, smaller individuals may have been missed, which might affect the b values for species due to selectivity of the mesh and the unknown nature of the early life history of Stomiiformes (Froese, 2006). In future studies, the sampling area and frequency should be increased to investigate the effects of gender and regional differences on LWRs. Some previous investigations comparing eviscerated and non-eviscerated fish have revealed some differences, especially in predatory fish, which should also be noted in future studies (Froese, 2006; Knutsen *et al.*, 2023). In conclusion, the basic information provided here will help fill gaps in biological knowledge of the Stomiiformes and contribute to the understanding of deep-sea fishes in the South China Sea.

DECLARATIONS

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IRB approval

The animal study was reviewed and approved by the South China Sea Fisheries Research Institute Animal Welfare Committee (Ethical approval number: SCSFRI

Document number 40/2016). Approval date: 18 March 2016.

Ethical statement

The author declares that the sampling of the species under investigation was conducted in accordance with the international conventions on the use of animals in scientific research.

Generative AI and AI-assisted technology statement

During the preparation of this article, the author did not utilize generative AI and AI-assisted technology.

Statement of conflict of interest

The authors have declared no conflict of interest.

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