Thalassas: An International Journal of Marine Sciences (2020) 36:309–314
https://doi.org/10.1007/s41208-020-00223-x

# Length-Weight Relationships of Fifty Fish Species from Indian Waters

Subal Kumar Roul[1] · A. R. Akhil[2] · T. B. Retheesh[2] · K. M. Rajesh[3] · U. Ganga[2] · E. M. Abdussamad[2] · Prathibha Rohit[3]

Received: 19 February 2020 / Revised: 15 May 2020 / Published online: 27 May 2020


**Abstract**

Length-weight relationships (LWRs) were estimated for 50 fish species belonging to 14 families from Indian waters. During the fishery surveys, specimens were collected from various fishing gears such as ring seines, gill nets, trawls and long lines between 2015 and 2017. The number of specimens measured varied by species. All the values of the parameter *b* were found within the expected range of 2.5–3.5. The *b* values in the relationships, $W = aL^b$ varied between 2.562 (*Stolephorus insularis*) and 3.461 (*Auxis thazard*) with mean value of 3.032 (SE = ± 0.029). The LWRs of all the 50 fish species estimated in this study were highly significant ($p < 0.001$, $r^2 \geq 0.850$). The study provides the first estimate of LWRs for *Scomber indicus*, *Sphyraena arabiansis* and *Upeneus margarethae*, and complements the existing LWRs in the international literature and FishBase database. In addition, this study reports the new maximum size for *Nematalosa nasus* (28.5 cm TL, 281 g TW), *Scomberoides commersonnianus* (122 cm TL, 11400.5 g TW), *Scomberoides tol* (56 cm TL, 1000 g TW), *Alepes djedaba* (33.5 cm TL, 343.8 g TW) and *Upeneus margarethae* (19 cm TL, 87 g TW). This study provides basic biological information in the form of a length-weight key for 50 commercially important fish species from Indian waters as a valuable tool to assist fishery managers.

**Keywords** Length-weight relationships · Indian waters · Isometric growth · Allometric growth

## Introduction

Biometric relationships have been frequently used in fisheries research and management in order to transform the field-collected data to suitable indexes (Anderson and Gutreuter 1983). Length-weight relationships (LWRs) is one of the most commonly used tools for any analysis of fishery data (Türker et al. 2018). The LWRs is predominantly useful to estimate the average weight for a given length group, and convert length measurement into weight where technical difficulty exists in weighing, particularly the large-sized fishes in the field or on-board vessels (Froese 2006; Froese et al. 2011). Besides the estimation of weight from length data, it has got several other applications in fishery science, such as conversion of a growth equation in length into a growth equation in weight (Pauly 1993), estimation of yield and biomass of a fish population (Anderson and Gutreuter 1983), biometry and morphological comparisons between species or populations of the same species from different geographical areas or habitats (Herath et al. 2014; Roul et al. 2017a, b, 2018, 2019), provides information on seasonal variations in fish growth and estimation of condition indexes (Anderson and Gutreuter 1983; Safran 1992; Richter et al. 2000), assessing the ecological processes and life history parameters, and comparisons of life histories between regions (Pauly 1993).

India is one of the 12 mega-biodiversity countries and 25 hotspots of the world (Myers et al. 2000). It has a long coastline supporting highly diverse marine ecosystems. However, basic information such as LWRs of several fish species remains scarce and poorly studied, with many literature and FishBase (Froese and Pauly 2020) estimates being tentative, and/or decades old and thus unlikely representative for today. Therefore, the present study aimed to investigate the length-weight relationships (LWRs) of 50 major commercial fish species from Indian waters.

✉ Subal Kumar Roul
subalroul@gmail.com

[1] Puri Field Centre of ICAR-Central Marine Fisheries Research Institute, 752 002 Puri, Odisha, India

[2] ICAR-Central Marine Fisheries Research Institute, 682 018 Cochin, Kerala, India

[3] Mangalore Research Centre of ICAR-Central Marine Fisheries Research Institute, 575 001 Mangaluru, Karnataka, India

## Materials and Methods

Fishes were captured by using various gears: ring seines (mesh size 8–24 mm), trawls (30–40 mm cod-end mesh size), long lines (hook number VI-XII) and, small-mesh (26–90 mm) and large-mesh (120–170 mm) gillnets. Fishes were identified at species level (Fischer and Whitehead 1974; Fischer and Bianchi 1984; Doiuchi and Nakabo 2005; Uiblein and Heemstra 2010; Abdussamad et al. 2015; Abdussamad et al. 2016) and scientific name checked according to Froese and Pauly (2020). Specimens of all the species were measured on weekly basis between October 2015 to September 2017, from Cochin Fishing Harbour ($09^{0}$56′327″N, 76015′764″E), Munambam Fishing Harbour ($10^{0}$10′965″N, 76010′258″E), Kalamukku ($09^{0}$59′ 924″N, 76014′564″E), Chellanam ($09^{0}$47′950″N, $76^{0}$16′551″ E), Kerala except for *Sphyraena obtusata* which was collected from Tuticorin Fishing Harbour ($8.7945^{0}$ N, $78.1584^{0}$ E), Tamil Nadu. Fork length (FL) was taken as standard measurement for tunas, lower jaw fork length (LJFL) for billfishes, pre-anal length (PAL) for ribbon fishes and total length (TL) for all other fishes. The length of each fish was measured to the nearest 0.1 cm and individual total body weight was recorded to the nearest 0.1 g. The length-weight relationships (LWRs) for each species was calculated using the expression, $W = aL^b$ (Huxley 1932; Le Cren 1951), where $W$ is the total body weight (g), $L$ is the length measurement (cm), $a$ is the intercept (initial growth coefficient or condition factor) and $b$ is the slope (growth coefficient i.e., fish relative growth rate). This equation can also be expressed in its logarithmic form: $lnW = lna + blnL$ (Le Cren 1951; Ricker 1975). The parameters $a$ and $b$ of LWRs were estimated by linear regression analysis (least-squares method) on log-transformed data. Extreme outliers were removed from the regression analysis by performing a log-log plot of the length-weight pairs (Froese, 2006). The 95% confidence limits (*CL*) of parameters $a$ and $b$, and co-efficient of determination ($r^2$) were estimated. The growth of a fish can be assessed as isometric when $b = 3$, i.e., relative growth of both variables is identical (Mayrat 1970; Ricker 1975; Quinn II and Deriso 1999); negative allometric growth when $b <$ 3 and is defined as hypo-allometry, increases more in length than predicted by its weight; positive allometric growth when $b > 3$ and is defined as hyper-allometry, increases more in weight than predicted by its length (Shingleton et al. 2009; Shingleton 2010). The $b$ value of each species was tested by *t*-test (Sokal and Rohlf 1987) with 95% confidence limit in order to confirm if it was significantly different from the isometric value ($H_0$: $b = 3$).

## Results

Length-weight relationships (LWRs) were analyzed for 50 fish species belonging to 14 families (Table 1). Descriptive statistic such as sample size (N), length range (cm), mean length (cm), weight range (g), mean weight (g), parameters of LWRs with 95% *CL* of $a$ and $b$, coefficient of determination ($r^2$) and type of growth for each species are presented in Table 1. All the LWRs were highly significant ($p < 0.001$; $r^2 \geq 0.850$). In the present study, the $r^2$ values ranged from 0.850 for *Stolephorus insularis* to 0.999 for *Gymnosarda unicolor*, *Scomberoides commersonnianus* and *Xiphias gladius*. All the estimated values of the parameter $b$ in the LWRs were found within the expected ranges of 2.5–3.5. The $b$ values ranged from 2.562 for *Stolephorus insularis* to 3.461 for *Auxis thazard* with a mean value of 3.032 ($SE = \pm 0.029$). The median and mode values of $b$ were estimated at 3.012 and 3.1, respectively (see Fig. 1). The type of growth for each species was determined by Student's *t*-test. This analysis revealed that sixteen species showed isometric growth ($b = 3$) whereas for other species, $b$ value was significantly different from 3 (*t*-test, $p < 0.05$). Twenty species showed positive allometric growth ($b > 3$) and fourteen species showed negative allometric growth ($b < 3$) (Table 1). Out of 50 species analyzed, the study provides the first estimate of LWRs for three species: *Scomber indicus*, *Sphyraena arabiansis* and *Upeneus margarethae*, and new estimates for other fish species from Indian waters (Table 1). Further, this study reports the new maximum size for *Nematalosa nasus* (28.5 cm TL, 281 g TW), *Scomberoides commersonnianus* (122 cm TL, 11400.5 g TW), *Scomberoides tol* (56 cm TL, 1000 g TW), *Alepes djedaba* (33.5 cm TL, 343.8 g TW) and *Upeneus margarethae* (19 cm TL, 87 g TW).

## Discussion

In fishes, the parameter $b$ values of length-weight relationships (LWRs) are usually found within the expected range of 2–4 (Bagenal and Tesch 1978) or 2.5–3.5 (Froese 2006). In the present study, the estimated LWRs of 50 fish species were found well within these expected ranges. In terms of growth type, fourteen species showed negative allometric growth ($b < 3$) indicating that the fish grows faster in length compared to their weight; twenty species showed positive

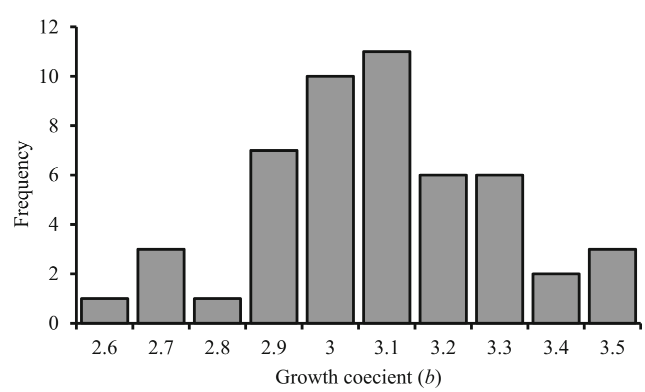


**Fig. 1** Frequency distribution of the allometric growth coefficients ($b$) of 50 marine fish species from Indian waters

**Table 1** Descriptive statistics and estimated parameters of LWRs for 50 marine fish species in Indian waters

| Family | Species | N | Type of length | Length range (cm) | Mean length | Weight range (g) | Mean weight | Parameters of length-weight relationships | | | | | Growth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | a | 95% CL of a | b | 95% CL of b | $r^2$ | |
| Clupeidae | *Anodontostoma chacunda* (Hamilton, 1822) | 146 | TL | 7.2–15.7 | 10.2 | 4.6–49.4 | 14.2 | 0.007 | 0.006–0.008 | 3.255 | 3.194–3.316 | 0.987 | A+ |
| | *Nematalosa nasus* (Bloch, 1795) | 87 | TL | 5.3–**28.5** | 14.6 | 1.9–**281** | 40.5 | 0.012 | 0.010–0.015 | 2.968 | 2.896–3.039 | 0.988 | I |
| | *Escualosa thoracata* (Valenciennes, 1847) | 537 | TL | 5.2–11.6 | 8.5 | 1.0-13.4 | 5.7 | 0.005 | 0.004–0.005 | 3.278 | 3.215–3.340 | 0.952 | A+ |
| | *Hilsa kelee* (Cuvier, 1829) | 133 | TL | 8–20 | 12.6 | 5–84 | 23.3 | 0.012 | 0.010–0.014 | 2.958 | 2.885–3.032 | 0.980 | I |
| Dussumieriidae | *Dussumieria acuta* Valenciennes, 1847 | 119 | TL | 6.5–19.1 | 12.9 | 2.2–52.2 | 19.0 | 0.006 | 0.005–0.007 | 3.113 | 3.067–3.160 | 0.993 | A+ |
| Engraulidae | *Encrasicholina devisi* (Whitley, 1940) | 301 | TL | 5.2–9.3 | 7.1 | 1.1-5.0 | 2.8 | 0.007 | 0.006–0.008 | 3.014 | 2.953–3.076 | 0.969 | I |
| | *Encrasicholina punctifer* Fowler, 1938 | 32 | TL | 6.5–8.8 | 7.8 | 2.0-4.8 | 3.3 | 0.007 | 0.004–0.013 | 3.009 | 2.687–3.332 | 0.924 | I |
| | *Stolephorus commersonnii* Lacepède, 1803 | 337 | TL | 5.3–12.2 | 8.0 | 1.2–13 | 4.2 | 0.007 | 0.007–0.008 | 3.007 | 2.955–3.059 | 0.975 | I |
| | *Stolephorus insularis* Hardenberg, 1933 | 148 | TL | 4.5–7.8 | 7.0 | 0.9–3.7 | 2.9 | 0.019 | 0.014–0.027 | 2.562 | 2.386–2.738 | 0.850 | A- |
| | *Thryssa hamiltonii* Gray, 1835 | 41 | TL | 14.7–23.2 | 18.7 | 27–104 | 52.8 | 0.008 | 0.005–0.013 | 2.978 | 2.814–3.141 | 0.971 | I |
| | *Thryssa mystax* (Bloch & Schneider, 1801) | 178 | TL | 10–20 | 15.5 | 7.4–57.8 | 28.6 | 0.005 | 0.004–0.007 | 3.124 | 3.027–3.221 | 0.958 | A+ |
| | *Thryssa polybranchialis* Wongratana, 1983 | 271 | TL | 7-18.3 | 11.7 | 2.6–55.9 | 15.5 | 0.006 | 0.006–0.007 | 3.120 | 3.082–3.158 | 0.990 | A+ |
| | *Thryssa setirostris* (Broussonet, 1782) | 55 | TL | 7–17 | 13.3 | 2.7–40.4 | 20.8 | 0.009 | 0.007–0.012 | 2.953 | 2.857–3.048 | 0.986 | I |
| Pristigasteridae | *Opisthopterus tardoore* (Cuvier, 1829) | 218 | TL | 3.9–18.5 | 10.8 | 0.5–39.6 | 10.6 | 0.008 | 0.007–0.009 | 2.886 | 2.838–2.934 | 0.985 | A- |
| Scombridae | *Acanthocybium solandri* (Cuvier, 1832) | 141 | TL | 75–148 | 114.8 | 1800–20000 | 9177.4 | 0.001 | 0.001–0.001 | 3.399 | 3.337–3.460 | 0.989 | A+ |
| | *Scomber indicus* Abdussamad, Sukumaran & Ratheesh ,2016 | 287 | TL | 8–38 | 24.4 | 3.9–655 | 160.6 | 0.005 | 0.004–0.005 | 3.219 | 3.170–3.268 | 0.983 | A+ |
| | *Thunnus albacares* (Bonnaterre, 1788) | 350 | FL | 13.5–164 | 54.7 | 47-83000 | 4457.6 | 0.011 | 0.009–0.013 | 3.137 | 3.091–3.182 | 0.981 | A+ |
| | *Thunnus tonggol* (Bleeker, 1851) | 64 | FL | 37.2–84 | 53.8 | 845–7350 | 2478.9 | 0.051 | 0.035–0.074 | 2.693 | 2.598–2.788 | 0.981 | A- |
| | *Sarda orientalis* (Temminck & Schlegel, 1844) | 50 | FL | 36-51.5 | 44.4 | 695–2130 | 1456.3 | 0.007 | 0.002–0.027 | 3.222 | 2.868–3.576 | 0.874 | A+ |
| | *Gymnosarda unicolor* (Rüppell, 1836) | 32 | FL | 45–110 | 80.6 | 1335–17500 | 7801.2 | 0.025 | 0.022–0.028 | 2.860 | 2.833–2.887 | 0.999 | A- |
| | *Katsuwonus pelamis* (Linnaeus, 1758) | 267 | FL | 38–70 | 51.1 | 990–8935 | 2984.1 | 0.004 | 0.003–0.005 | 3.443 | 3.364–3.522 | 0.965 | A+ |
| | *Euthynnus affinis* (Cantor, 1849) | 304 | FL | 23.5–77.5 | 45.4 | 210–6780 | 1758.6 | 0.011 | 0.009–0.014 | 3.107 | 3.053–3.160 | 0.978 | A+ |
| | *Auxis thazard (Lacepède, 1800)* | 56 | FL | 25–42 | 37.7 | 245–1260 | 949.3 | 0.003 | 0.001–0.007 | 3.461 | 3.242–3.680 | 0.949 | A+ |
| | *Auxis rochei* (Risso, 1810) | 65 | FL | 21.7–27.8 | 24.1 | 130–290 | 190.5 | 0.017 | 0.007–0.039 | 2.928 | 2.667–3.188 | 0.889 | A- |
| Carangidae | *Atule mate* (Cuvier, 1833) | 136 | TL | 11-24.5 | 15.8 | 13.2–158 | 46.1 | 0.012 | 0.009–0.015 | 2.972 | 2.882–3.062 | 0.970 | I |
| | *Decapterus macarellus* (Cuvier, 1833) | 61 | TL | 23-37.7 | 28.9 | 140–480 | 242.1 | 0.024 | 0.015–0.038 | 2.733 | 2.592–2.873 | 0.962 | A- |
| | *Decapterus macrosoma* Bleeker, 1851 | 31 | TL | 9–17 | 13.4 | 6.8–46.8 | 20.3 | 0.007 | 0.004–0.013 | 3.028 | 2.796–3.260 | 0.961 | I |
| | *Decapterus russelli* (Rüppell, 1830) | 71 | TL | 9.7–13 | 11.3 | 8.0–21 | 12.8 | 0.006 | 0.004–0.009 | 3.144 | 2.974–3.314 | 0.952 | A+ |
| | *Elagatis bipinnulata* (Quoy & Gaimard, 1825) | 227 | TL | 24–105 | 46.5 | 110–6895 | 944.8 | 0.010 | 0.008–0.011 | 2.913 | 2.876–2.951 | 0.991 | A- |
| | *Scomberoides commersonnianus* Lacepède, 1801 | 116 | TL | 13.2–**122** | 73.3 | 19.5-11400.5 | 3378.7 | 0.013 | 0.012–0.014 | 2.850 | 2.834–2.866 | 0.999 | A- |
| | *Scomberoides lysan* (Forsskål, 1775) | 55 | TL | 8.5–74 | 49.5 | 3.7–2300 | 1000.6 | 0.007 | 0.005–0.009 | 2.988 | 2.909–3.067 | 0.991 | I |

**Table 1** (continued)

| Family | Species | N | Type of length | Length range (cm) | Mean length | Weight range (g) | Mean weight | Parameters of length-weight relationships | | | | | Growth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **a** | **95% CL of a** | **b** | **95% CL of b** | $r^2$ | |
| | *Scomberoides tol* (Cuvier, 1832) | 461 | TL | 8.3–56 | 31.7 | 3.6–**1000** | 219.8 | 0.006 | 0.005–0.006 | 3.005 | 2.982–3.027 | 0.993 | I |
| | *Selar crumenophthalmus* (Bloch, 1793) | 113 | TL | 12.7–28.4 | 22.4 | 21-286.9 | 148 | 0.009 | 0.007–0.011 | 3.094 | 3.028–3.159 | 0.987 | A+ |
| | *Selaroides leptolepis* (Cuvier, 1833) | 84 | TL | 10–15 | 12.7 | 10.2–36.1 | 24.2 | 0.018 | 0.011–0.030 | 2.826 | 2.621–3.030 | 0.902 | A- |
| | *Alepes djedaba* (Forsskål, 1775) | 256 | TL | 12-33.5 | 20.4 | 20.5-**343.8** | 108 | 0.004 | 0.004–0.005 | 3.267 | 3.202–3.332 | 0.975 | A+ |
| Elopidae | *Elops machanata* (Forsskål, 1775) | 61 | TL | 20.4–67 | 40.6 | 38.5-1584.3 | 521.7 | 0.004 | 0.003–0.004 | 3.087 | 3.043–3.131 | 0.997 | A+ |
| Megalopidae | *Megalops cyprinoides* (Broussonet, 1782) | 192 | TL | 7–68 | 46.4 | 3-2613 | 1125 | 0.009 | 0.008–0.010 | 2.982 | 2.963–3.001 | 0.998 | I |
| Istiophoridae | *Istiophorus platypterus* (Shaw, 1792) | 395 | LJFL | 28.5–270 | 175.1 | 82-60000 | 23673.5 | 0.003 | 0.003–0.004 | 3.031 | 3.006–3.055 | 0.993 | I |
| | *Istiompax indica* (Cuvier, 1832) | 108 | LJFL | 27–341 | 203.8 | 341.3-202000 | 75026.6 | 0.057 | 0.042–0.077 | 2.638 | 2.581–2.695 | 0.988 | A- |
| Xiphidae | *Xiphias gladius* Linnaeus, 1758 | 260 | LJFL | 50–229 | 128.7 | 882.7-154914.7 | 32641.9 | 0.002 | 0.001–0.002 | 3.395 | 3.388–3.403 | 0.999 | A+ |
| Lobotidae | *Lobotes surinamensis* (Bloch, 1790) | 86 | TL | 26–74 | 48.7 | 307-7098.4 | 2368.7 | 0.018 | 0.016–0.021 | 2.991 | 2.952–3.030 | 0.996 | I |
| Sphyraenidae | *Sphyraena arabiansis* Abdussamad & Retheesh, 2015 | 144 | TL | 53–152 | 97.5 | 682.8-21000 | 4957 | 0.003 | 0.003–0.004 | 3.070 | 3.046–3.094 | 0.998 | A+ |
| | *Sphyraena barracuda* Jordan & Seale, 1905 | 106 | TL | 68–168 | 103.7 | 1584.4-29127.3 | 7252.1 | 0.002 | 0.002–0.003 | 3.214 | 3.158–3.269 | 0.992 | A+ |
| | *Sphyraena forsteri* Cuvier, 1829 | 206 | TL | 23–66 | 39.4 | 70.3-1146.2 | 338.6 | 0.017 | 0.016–0.018 | 2.652 | 2.633–2.670 | 0.998 | A- |
| | *Sphyraena jello* Cuvier, 1829 | 125 | TL | 18.2–133 | 79.9 | 25.0-8706.7 | 2833.1 | 0.006 | 0.006–0.007 | 2.889 | 2.866–2.912 | 0.998 | A- |
| | *Sphyraena putnamae* Jordan & Seale, 1905 | 537 | TL | 11–88 | 40.2 | 7.9–2380 | 416.2 | 0.008 | 0.007–0.008 | 2.858 | 2.842–2.873 | 0.996 | A- |
| | *Sphyraena obtusata* Cuvier, 1829 | 30 | TL | 18.2–39 | 29.4 | 29.0-291 | 138.8 | 0.005 | 0.004–0.006 | 3.017 | 2.942–3.092 | 0.996 | I |
| | *Sphyraena pinguis* Günther, 1874 | 73 | TL | 16.5–26 | 21.3 | 21–108 | 57.3 | 0.005 | 0.003–0.011 | 3.037 | 2.800-3.274 | 0.902 | I |
| Mullidae | *Upeneus margarethae* Uiblein & Heemstra, 2010 | 34 | TL | 10.5–**19** | 13.3 | 12.6–**87** | 32.5 | 0.004 | 0.003–0.008 | 3.407 | 3.203–3.612 | 0.973 | A+ |
| Trichiuridae | *Trichiurus lepturus* Linnaeus, 1758 | 151 | PAL | 18-46.5 | 28.1 | 94-1100 | 362.9 | 0.025 | 0.018–0.036 | 2.830 | 2.721–2.939 | 0.946 | A- |

*N*, number of specimens studied; *a*, intercept of relationship; *b*, slope of relationship; *CI*, confidence interval; $r^2$ , coefficient of determination; *TL*, total length; *FL*, fork length; *LJFL*, lower jaw fork length; *PAL*, pre-anal length; I: isometric growth; A+: positive allometric growth; A-: negative allometric growth. Bold, new maximum size recorded allometric growth ($b > 3$), the fish grows faster in weight than length; and sixteen species showed isometric growth ($b = 3$), increase in weight with length is isometric (see Table 1).

There were some variations in the estimated $b$ values in the present study for several species in comparison with the previous estimates that exist in the international literature and database of FishBase (Abdurahiman et al. 2004; Karna 2017; Kumar et al. 2018; Froese and Pauly 2020). Generally, differences in $b$ values in the LWRs can be attributed to several factors such as sample size, length range covered, type of habitat, ontogenetic development, season, population, sex, gonad maturity, diet, health, disease and parasite loads of the fish (Tesch 1971; Ricker 1975; Froese 2006). Furthermore, the precision of $b$ values may be affected due to sampling bias i.e. when the sample size is relatively small, size range covered not fully species representative, no independent and standardized sampling protocol followed (Roul et al. 2017c). The use of the LWRs presented here should thus be limited to the length ranges presented in Table 1, as larval stages were not included in this present study. Therefore, a standardized sampling procedure with a research vessel equipped with a bongo net should be employed in order to obtain the different size classes of ichthyoplankton of each species. The study contributes to providing the first estimate of LWRs of three fish species: *Scomber indicus*, *Sphyraena arabiansis* and *Upeneus margarethae* and complementing the several LWRs that exist in the international literature and FishBase database (Froese and Pauly 2020). In addition, this study also reports the new maximum size for *Nematalosa nasus*, *Scomberoides commersonnianus*, *Scomberoides tol*, *Alepes djedaba* and *Upeneus margarethae* (Froese and Pauly 2020). Recent studies reporting LWRs for substantial numbers of fish species with distributions across the Indo-Pacific region (e.g. Wang et al. 2016; Perkins et al. 2019), using robust sample sizes, greatly strengthen the evidence base by which accurate fisheries management is conducted. Our study is a further improvement on this, filling important knowledge gaps by providing basic biological information such as LWRs and a length-weight key for 50 major commercial important marine fish species caught in Indian waters, which will assist regional fisheries management and conservation.

**Acknowledgements** The authors are highly grateful to Dr. A. Gopalakrishnan, Director, ICAR-CMFRI, Cochin for providing all necessary facilities and constant support during the entire study period.

## Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

**Ethical Approval** This article does not contain any experimental studies with animals performed by any of the authors.

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