Indian Journal of Geo Marine Sciences
Vol. 51 (12), December 2022, pp. 941-947
DOI: 10.56042/ijms.v51i12.4263

A review on the length-weight relationships of finfishes from the coastal lagoons of India

S Patra[a], R Swain[a], Shesdev Patro*[,a] & Anil Mohapatra[b]

[a]Department of Marine Sciences, Berhampur University, Berhampur, Ganjam, Odisha – 760 007, India
[b]Estuarine Biology Regional Centre, Zoological Survey of India, Ganjam, Odisha – 761 002, India
*[E-mail: shesdevpatro@yahoo.com]

Received 22 November 2022; Revised 18 December 2022

The study provides a review of the Length Weight Relationship (LWR) evaluations from the tropical coastal lagoons to generate an inventory of finfishes and to understand their growth and ecosystem suitability. Published literature indicates that the total finfish diversity of the major Indian coastal lagoons *i.e*., Chilika, Pulicat and Vembanad is represented by around 500 species belonging to 33 orders. A huge data gap is observed between the existing finfish diversity of these tropical lagoons and the LWR studies undertaken. LWR study is carried out only for 15.4 % (77 out of 500) of the reported finfish species diversity. Chilika is comparatively well explored considering the LWR evaluation of finfishes (64 species) than the Pulicat and Vembanad lagoon (10 species from each lagoon). The review indicates the involvement of a handful of researchers as the reason for less exploration of LWR of finfishes from the Indian coastal lagoons. *Etroplus suratensis* (order: Cichliformes) is the commonly explored species for LWR study in all the three coastal lagoons of India. This review encompassing a total of 120 LWR studies for 77 fish species depicts the range of reported *b* value, n value and R^2 values as 1.0368 – 3.538, 10 – 5,737 and 0.681 – 0.999, respectively.

[**Keywords**: Chilika, Diversity, Fish, LWR, Pulicat, Vembanad]

Introduction

World finfish diversity comprises about 36,213 valid species[1]. There are about 3231 finfish species reported from India[2]. Length-Weight Relationship (LWR) provides information on life processes, health of reproductive glands, stoutness, overall well-being or any deformities, and biomass of a fish community[3-4] and indicates the energy balance in a fish population with respect to place and time[5]. Parameters of LWR are used to derive conditional factors[6] and to plot the growth curve[5]. Apart from the assessment of fishery stock, LWR is useful in the initiatives for environment surveys[7].

Coastal lagoons are important habitats of the coastal region sheltering numerous flora and fauna because of their dynamic nature. They are supplied with freshwater inflow from the catchment areas, as well as receive saline water from the sea by the inlet channel and the intermix of these two makes the lagoons a brackish waterbody. In India Chilika, Pulicat and Vembanad are the three major coastal lagoons[8]. Chilika, Asia's largest brackish water lagoon with salinity ranging between 0.5 – 31.6 psu, and with an area of about 950 sq km in summer and 1165 sq km in monsoon extends from Khordha to Ganjam district of Odisha[9]. The area occupied by the water stretch of Pulicat is about 461 sq km, extending from Andhra Pradesh to Tamil Nadu with salinity range of 0 – 52 ppm[8-10]. Vembanad located in Kerala with area of about 300 sq km and salinity range of about 1.8 – 33 ppt has a great importance in being a Ramsar site[8-11]. All the above three coastal lagoons of India are rich in finfish diversity due to their peculiar hydrology, hence the source of livelihood for millions of people. The present study aims to review the LWR studies conducted on finfishes of these three coastal lagoons of India to find out the research gap and to analyse the LWR associated parameters.

Materials and Methodology

The current review on LWR studies of finfishes was focused on three major coastal lagoons of India *viz*. Chilika, Pulicat, and Vembanad. The information regarding finfish diversity and studies on LWR of finfishes from these three coastal lagoons were collected from the published literature including research articles. The status of species by its order was validated with Eschmeyer's Catalog of Fishes

(http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp). The species richness was compared with the number of species on which the LWR studies are undertaken to find out the data gap. The analysis was done at the order level to ease the presentation. Most of LWRs were expressed in terms of $W = aL^b$; where, the '*a*' value interprets the shape of the body but was excluded from the analysis because of the non-uniformity in reported data. Hence all the LWR status was reviewed using the *b* value to find out the suitability of environmental conditions for the growth of the species in the lagoon ecosystem. Data available on LWR of finfishes from these three lagoons vide research articles between 1964 – 2019 were collected and compiled to prepare a checklist with the 'n' value (sample size), '*a*' value, '*b*' value, and 'R^2' (regression value).

Results

From the literature review, it was found that the total finfish diversity of the Indian coastal lagoons is represented by around 500 species belonging to 33 orders. Order Perciformes with 84 species is found as the most dominant order in these coastal lagoons. LWR study has been carried out only in 15.4 % (in 77 species) of the total finfish diversity of the coastal lagoons of India. The finfish diversity and the number of finfish LWR studies carried out from major coastal lagoons of India are represented in Figure 1.

According to Behera *et al.*[12], the finfish diversity of Chilika is represented by 345 species. A critical examination revealed that Behera *et al.*[12] missed a species *Triacanthus nieuhofii* Bleeker, 1852 reported by Karna *et al.*[13] from Chilika. Hitherto, the final number of finfish species in Chilika is 346 belonging to 31 orders. Perciformes is the dominant order with 54 species that make up 16 % of the entire finfish diversity of Chilika followed by Carangiformes (44 species, 13 %) and Clupeiformes (38 species, 11 %). The remaining 28 orders are represented by less than 10 % of the finfish diversity of Chilika. From the review of published articles, it was found that the LWR studies have been carried out for only 64 species in Chilika belonging to 17 orders that is equivalent to only 18.49 % of the total finfish diversity of Chilika. Among the 17 orders, Perciformes

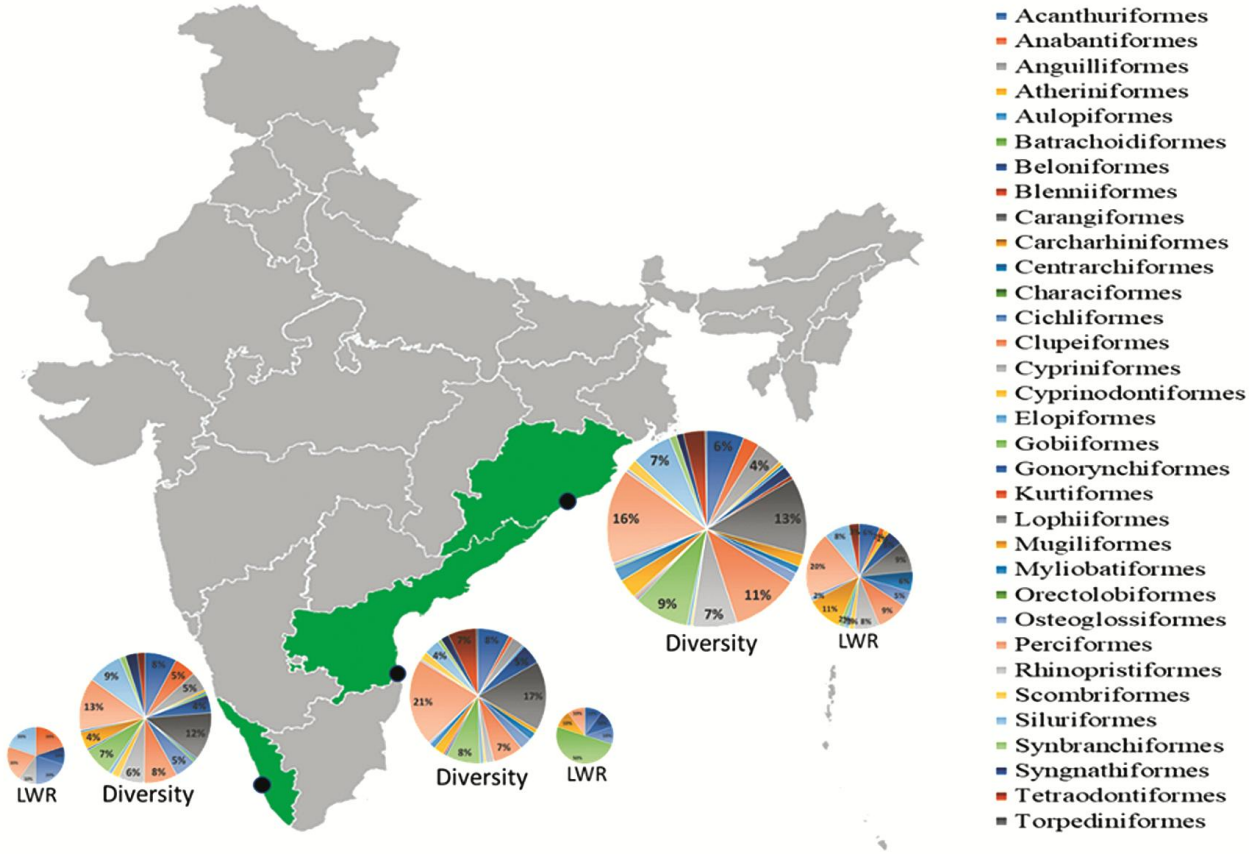

Fig. 1 — Finfish diversity and the fraction of LWR study carried out from coastal lagoons of India

was identified as the most explored order with 13 species which results in 21 % of the entire LWR studies from Chilika followed by Mugiliformes (7 species, 11 %), Carangiformes (6 species, 10 %), Clupeiformes (6 species, 10 %), Cypriniformes (5 species, 8 %) and Siluriformes (5 species, 8 %) (Table S1).

The finfish diversity of the Pulicat lagoon was assessed from the reports of Selvanathan & Kaliyamurthy[14]; Sanjeeva Raj[8]; and Govindan & Ravichandran[15]. It is found that the Pulicat lagoon is reported to inhabit 210 finfish species belonging to 27 orders. Perciformes is the dominant order with 44 species which constitute 21 % of the whole finfish diversity of Pulicat followed by Carangiform (35 species, 17 %), Gobiiformes (17 species, 8 %), Acanthuriformes (16 species, ~8 %) and Clupeiformes (15 species, 7 %). The review concludes that the LWR has been done for only 10 species from the Pulicat belonging to 6 orders which are about 4.76 % of the entire finfish diversity of Pulicat. LWR studies has been done predominantly for 5 species of the order Gobiiformes which makes for 50 % of the total LWR analysis done from Pulicat lagoon and in one species each from the order Acanthuriformes, Beloniformes, Cichliformes, Mugiliformes and Perciformes.

Based on the published literature, the reported finfish diversity of Vembanad is composed of 207 species belonging to 24 orders[16-19]. Perciformes is the dominant order with 27 species which accounts for 13 % of the overall finfish diversity of Vembanad followed by Carangiformes (25 species, 12 %), Siluriformes (18 species, 9 %), Clupeiformes (17 species, 8 %), Acanthuriformes (16 species, ~8 %), and Gobiiformes (15 species, 7 %). The study revealed that the LWR was conducted for only 10 species in Vembanad including 6 orders that is around 4.83 % of whole finfish diversity of Vembanad. LWR has been evaluated for two species each from the order Anabantiformes, Cichliformes, Perciformes, and Siluriformes; while for one species each from the order Beloniformes and Cypriniformes. From the gathered data, it is clear that in terms of the LWR studies, Chilika is the well explored coastal lagoon in India.

Published literature on LWR of finfishes from the major coastal lagoons of India has revealed that LWR has been evaluated for only 77 species of finfishes belonging to 17 orders and 37 families (Table S1). According to the data, the '*b*' value ranges between 1.0368 – 3.538 for the finfishes of the coastal lagoons of India. Out of all 120 LWR studies carried out on finfishes of the coastal lagoons of India, 54 studies show negative allometry *i.e.* $b < 3$ (b = 1.0368 – 2.997), five species show isometric growth *i.e.* $b = 3$ (here we have considered b = 3 – 3.009) and the remaining 61 studies show positive allometry *i.e.* $b > 3$ (b = 3.01 – 3.538) (Fig. 2). The mean value of '*b*' for all LWR studies of 77 fish species is 2.967 for all the three coastal lagoons of India. The mean value of '*b*' from each coastal lagoon *i.e.* Chilika, Pulicat and Vembanad are calculated as 2.99, 2.81 and 2.90, respectively. *Etroplus suratensis* (order: Cichliformes) is the only species explored by the LWR study in all the three coastal lagoons. *Etroplus suratensis* shows nearly isometric and positive allometric growth in Chilika (b ranges 2.9 – 3.101) in four studies carried out during the year 2008 to 2016[refs. 20-23]. However, its growth in Pulicat (b = 1.03) and Vembanad (b = 2.67) is reported as negative allometric[24-25]. *Anabas testudineus*, *Mystus gulio* and *Daysciaena albida* were studied commonly for Chilika and Vembanad where the *b* value of *Anabas testudineus*, *Mystus gulio* and *Daysciaena albida* ranged between 2.93 – 3.16 in Chilika[21-23] and 2.4089 – 3.07 in Vembanad[26-28]. Similarly, *Mugil cephalus* and *Siganus javus* were studied commonly for Chilika and Pulicat where the *b* value for *Mugil cephalus* and *Siganus javus* ranged between 2.60 – 3.11 in Chilika[21,23,29-31] and 2.76 – 3.06 in Pulicat[32-33]. LWR studies of nineteen species in Chilika is undertaken more than once which enabled to observe the temporal variation in *b* values and also suggests the environmental suitability of the species over a time scale. For 18 species the *b* value ranged between 2.56 – 3.44. In the case of *Osteomugil speigleri* the *b* value ranged between 2.45 – 2.88[refs. 21,34-35]. While

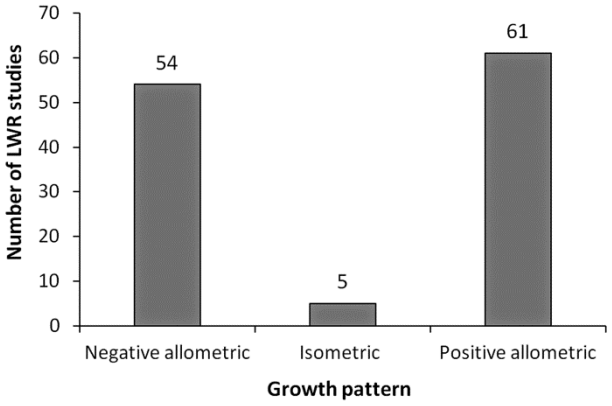

Fig. 2 — Growth pattern of 77 finfish species from 120 length-weight relationships studies from coastal lagoons of India

different time scale studies of LWR in Chilika suggest a decrement in the '*b*' value over time for *Tenualosa ilisha* (3.44 to 2.92 for n = 81 and 25, respectively), *Rhabdosargus sarba* (3.021 to 2.9), and *Terapon jarbua* (2.97 to 2.86 for n = 104 and 74, respectively). The review indicates *Favonigobius reichei* is the only species that was studied from Pulicat in the year 2018 – 2019 which has the *b* value > 3.5 *i.e*. *b* = 3.538 for n = 44[(ref. 32)]. *Gerres filamentosus* showed '*b*' value 2.2558 for 164 unsexed specimens from Vembanad[26].

The n value ranged between 10 – 5,737 for Chilika, 18 – 415 for Pulicat and 40 – 1241 for Vembanad. For all the 77 species R^2 ranged between 0.681 – 0.999. The values of regression were high for *Epinephelus coioides* (R^2 = 0.999) and *Anabas testudineus* (R^2 = 0.998) from Chilika for a small sample size (n = 10 and 11, respectively)[23]. But LWR study for *Thryssa kammalensoides* from Chilika reported the lowest regression value (R^2 = 0.681) for a reasonable sample size (n = 862)[36]. The species *Arcygobius baliurus* (R^2 = 0.88) and *Oxyurichthys microlepis* (R^2 = 0.834) from Pulicat are reported with good regression with a good sample size of 69 and 370, respectively[32]. Likewise, from Chilika *Gibelion catla* (n = 43), *Planiliza planiceps* (n = 102), and *Plotosus canius* (n = 27) instead of studying an adequate sample size reported R^2 were 0.769, 0.89 and 0.868, respectively[21,31]. While the rest of the species share a significant value of R^2 in proportion to the 'n' value.

Discussion

The results of the present review revealed that the coastal lagoons of India are diverse with approximately 500 finfish species that are represented by 346 species from Chilika, 207 from Vembanad and 210 from Pulicat. According to Sanjeeva Raj[8], lagoons with brackish water found in the tropical region are more productive in comparison to freshwater lagoons or saltwater lagoons, or the lagoons of the temperate region. Hence, the heterogeneity of finfish is obvious in the Indian tropical coastal lagoons.

Among the three coastal lagoons of India, LWR studies of maximum species are carried out at Chilika (64 species) followed by Vembanad (10 species) and Pulicat (10 species) which are about 18.49 %, 4.83 %, and 4.76 %, respectively of their total finfish diversity. Considering the total finfish diversity of each lagoon, it is distinct that there is a huge gap in the data of LWR from these Indian coastal lagoons. The finfish order Perciformes, Clupeiformes, Gobiiformes, Carangiformes, Cypriniformes, Siluriformes and Acanthuriformes are represented by a large number of species in all three coastal lagoons of India and despite their easy catch, these orders have been explored nominally for their LWR studies. This research gap in the LWR studies may be due to the lack of research interest as observed from this review that only a few researchers are actively involved in the LWR studies of the finfish inhabiting the coastal lagoons of India. For example, from Chilika, the LWR of 61 species (95.31 % of total LWR report from Chilika) was reported by Subodh Kumar Karna as the first author. Similarly, Moulitharan Nallathambi reported LWR of 6 species out of 10 species studied for LWR from Pulicat and Kuttanelloor Roshni reported LWR of 6 species out of 10 species studied for LWR from Vembanad.

Chilika is reviewed as the most explored coastal lagoon in India for the LWR studies because of the continuous contribution by active researchers. Additionally, Chilika has always dragged the attention of researchers because of its unique biodiversity, various designations and the fact of being the largest brackish water lagoon of Asia. Chilika has been ecologically well explored in various ways when compared to Vembanad and Pulicat.

The mean value of *b* = 2.967 indicates the overall suitability of the environment of the coastal lagoons of India for the growth of the finfish. According to Froese[6], the acceptable range of *b* value is 2.5 to 3.5. For majority of the finfish species of coastal lagoons of India, the *b* value fell within the above range which suggests the suitability of lagoon environmental conditions for the finfishes. The population of *Etroplus suratensis* in Chilika as well as Vembanad shares nearly isometric or slightly positive allometric to negative allometric growth as the *b* value ranges from 2.9 to 3.1 for Chilika[20-23] and 2.67 for Vembanad[25] which specifies that Chilika is comparatively more appropriate habitat for the growth of *Etroplus suratensis* than Vembanad. However, the *b* value for *E. suratensis* was reported as 1.0368 from Pulicat which indicates that the environmental conditions of Pulicat is not convenient for their growth[24] and hence needs an updated management plan for protecting the species population in Pulicat. This analysis demands a revised study of LWR for *Etroplus suratensis* and immediate actions to manage its population in Pulicat. *Osteomugil speigleri* is a single species from Chilika in which the value of *b* reported is < 2.5 for the study year 2009, while, a repetitive study on its LWR in the year 2016 – 2017

reported the *b* value of 2.883. This shows the relative adaptability of the species to sustain in the environmental conditions of Chilika. Few species from Chilika such as *Tenualosa ilisha*, *Rhabdosargus sarba* and *Terapon jarbua* showed inclination in the '*b*' value over time. This may be due to the environmental pressure and conflict between different species for food and space[36]. In case of *T. ilisha*, the *b* value has been shifted from 3.4 to 2.96 over time. Though the value is still under expected range, but the decreasing *b* value suggest the reduction in environmental suitability for the species. According to Mohanty & Nayak[37], catch of *T. ilisha* is declining markedly from Chilika because of over exploitation and catch of the undersized individuals. Hence this study claims for development of a proper management plan for the conservation of *T. ilisha* as well as *R. sarba* and *T. jarbua* in Chilika. LWR study carried out from Pulicat for 44 examples of *Favonigobius reichei* having mean total length of 4.95 cm and mean weight of 1.86 g showed '*b*' value greater than 3.5, which might be due to the result of the analysed samples being larger by thickness than the length or being at their maturation phase[6]. LWR of both *Gerres filamentosus* and *Daysciaena albida* carried out in 1980 from Vembanad, showed the value of '*b*' less than 2.5 for the unsexed individuals of *Gerres filamentosus* and female individuals of *Daysciaena albida*. While mean *b* value for male, female and unsexed samples of both the species comes between the appropriate range of growth *i.e.* 2.5 – 3.5; however, a recent LWR study is required to understand the current status of these species in Vembanad.

The values of 'n' and 'R^2' are analyzed to find out the significance of the relationship, but eight species out of the total 77 species for which the LWR had been reported share an inverse proportionality between the R^2 and n value. Analysis indicates that for *Epinephelus coioides* and *Anabas testudineus* small sample size is sufficient for the LWR study as the value of R^2 is greater than 0.9 with n = 10 and n = 11, respectively or else may have a probability of error in the sampling method or analysis[38]. Also, a revised study of LWR should be carried out for the concerned species to eliminate the insignificant relationship that may be resulted due to some error.

Conclusion

A critical review of LWR studies on finfish from the coastal lagoons of India reveals a significant research gap in relation to its diversity. LWR assessment is highly beneficial to understand the population dynamics, conservation criteria and growth of a particular species in different geographical and environmental conditions. However, the deficiency of data regarding the LWR from these tropical lagoons partly refrained from such type of analysis. Based on the present existing data, the study suggests for development of a management plan for conservation of *T. ilisha* in Chilika and *E. suratensis* in Pulicat. This study further suggests for exclusive research on the LWR of finfishes from the coastal lagoons to understand their growth and biology, their environmental suitability and to develop necessary conservation strategies.

Supplementary Data

Supplementary data associated with this article is available in the electronic form at https://nopr.niscpr.res.in/jinfo/ijms/IJMS_51(12)941-947_SupplData.pdf

Acknowledgements

Authors thank the Vice-Chancellor of Berhampur University for providing basic research facility.

Conflict of Interest

Author(s) declared no conflict of interest.

Ethical Statement

All authors agreed to the ethical principles.

Author Contributions

SP (First author) & RS: Literature search, data analysis, data interpretation and manuscript preparation. SP & AM: Data interpretation, manuscript preparation and critical revision of the work.

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