



Length-weight relationships and relative condition factor of fish species dwelling in the inland saline river Luni, India, with a note on the associated risks and encounters obstructing the fish diversity and ecosystem services

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ABSTRACT

Luni is an ephemeral and inland saline river flowing through the Thar Desert of India. The present study focusses on the length-weight relationships (LWRs) and condition factor analysis of six native and one invasive alien fish species (*Oreochromis mossambicus*) collected from the river Luni during the exploratory surveys conducted from October 2018 to September 2020. LWRs of native fish species showed negative allometric growth for *Aphanius dispar*, *Cirrhinus mrigala* and *Salmostoma bacaila* and positive allometric growth for *Labeo rohita*, *Mystus gulio* and *Systomus sarana*. Despite abundant distribution of *O. mossambicus* in the middle and downstream segments of the river Luni, this study revealed good wellbeing and suitability of this river to native and non-native fish species. This forms the first study that reports the LWRs and Kn value of these fish species from the river Luni, which could be useful for estimating stock characteristics and future evaluation of fish population in this dynamic and fragile ecosystem. Further, results of the present study were also compared with the available literature from nearby and associated ecosystems. The baseline information generated will be helpful in understanding the present status of the fish population and also to carryout ecological studies for their conservation and management in the future.

Keywords: Invasive Alien Species, Length-weight relationship, *Oreochromis mossambicus*, Thar Desert

Introduction

Fish being the staple item in the diet of many people, play imperative role in the nutritional security of a nation (Talwar and Jhingran, 1991). Worldwide, inland fish stocks are declining drastically due to over-exploitation, habitat destruction, pollution, climate change and establishment of invasive alien species (Dudgeon, 2012). The Length-weight relationship (LWRs) models also termed as biometric relationship models help in the management of fish stocks by estimating fish biomass, health and stock condition (Le Cren, 1951; Bagenal and Tesch, 1978; Froese, 2006; Kapiris and Klaoudatos, 2011). LWRs of fish varies with condition of fish in an aquatic ecosystem and they predict the average weight of the fish of a given length group (Sarkar *et al.*, 2009; Mir *et al.*, 2012), generally used as a character for differentiating fish species up to their taxonomic unit level (Thomas *et al.*, 2003) in addition to studies on gonadal development and maturity status (Beyer, 1987).

For conservation and management of fish, information on condition factor is essential as it describes about

its wellbeing (Sarkar *et al.*, 2009; Muchlisin *et al.*, 2010). Being the quantitative parameter, it determines the population success due to its impact on growth, reproduction and survival (Richter, 2007). Therefore, it is pertinent to mention that study of LWR and condition factor is important in fishery assessment and management because these biometric units assist in understanding the general well-being and growth pattern of fish population.

Among the freshwater fishery resources of India, Luni River is an environmentally unique and ecologically fragile river flowing through the Thar Desert region of Indian sub-continent. This river system is unique with diverse habitats due to variation in the salinity regime along its course starting from Aravalli range hills, passing through salt depressed surface in its middle stretch and finally entering to Rann of Kutchh inland saline areas. The vivid and diverse habitat of this river system supports 27 fish species and faces multiple anthropogenic and natural threats in the light of climate change, which has threatened the native fish diversity and the river bed ecology (Pathak *et al.*, 2020). These fish species are ecologically important for the harsh, resource limited desert food chain and

provide economic benefits to the indigenous communities of this region (Banyal *et al.*, 2020). Understanding the growth and wellbeing of the fish species of river Luni is essential for stock assessment and fisheries management (Hamid *et al.*, 2015). Present study forms the first reporting on the LWRs and relative condition factor of six native and one invasive alien fish species from the river Luni. It is expected that the results of the study will be helpful in understanding the health status of the fish stocks and may act as a baseline information to carryout ecological studies for their conservation and management in the future.

Materials and methods

Study area and sampling of specimens

Luni is an ephemeral and inland saline river (462 km length) flowing through the Thar Desert of Rajasthan that finally enters into the Rann of Kutch. It is the largest west flowing river of ecological and socio-economic significance in Indian arid zone and receives its water from south-east of Aravalli mountain ranges. It is often termed as a ‘salt river’ as salinity of this river ranges from 0 to 70 ppt. The spatial variation in the salinity of the river water suggests that the Luni River basin offers diverse habitat and provides a unique habitat to its biodiversity harbouring admixture of fish

species that belongs to Western Himalaya, Aravalli range, Indian Peninsular region and countries in the Middle-East (Yazdani, 1996).

To investigate the fish diversity, exploratory surveys were conducted during monsoon and early post-monsoon season from October 2018 to September 2020 along the river Luni and fish specimens were caught through experimental fishing using different fishing gears such as gillnets, bush nets and cast nets from the selected sampling sites. Specimens of the 6 native fish species (*Aphanius dispar*, *Cirrhinus mrigala*, *Salmostoma bacaila*, *Labeo rohita*, *Mystus gulio* and *Systemus sarana*) and the non-native species *Oreochromis mossambicus* were collected from different sampling sites of the upper, middle and downstream segments of the river, having wide variations in salinity (Fig. 1). The sample size, range of length and weight details of the specimens are given in Table 1. The map of the study area was created using SRTM DEM datasets (<https://earthexplorer.usgs.gov/>) in ArcMap 10.8.1 platform.

Length-weight relationship and condition factor analysis

The length and weight measurements were taken from a total of 400 specimens of 7 fish species. The length (L) of

Table 1. Length-weight relationships and condition factor of seven fish species of river Luni, India

Species	Range of salinity (ppt)	N	Length range TL (cm)	Weight range (g)	Regression equation			Relative condition factor (Kn) (Mean±SD)
					a	b	R ²	
<i>Aphanius dispar</i> (Ruppell, 1829)	5.00-9.15	42	3.8-6.3	7-39	0.238	2.75*	0.76	1.008±0.13
<i>Cirrhinus mrigala</i> (Hamilton, 1822)	1.41-5.00	117	10.8-45	12-867	0.010	2.99	0.98	1.004±0.09
<i>Labeo rohita</i> (Hamilton, 1822)	1.41-3.09	21	9.8-28.2	10-272	0.007	3.13*	0.99	1.002±0.06
<i>Mystus gulio</i> (Hamilton, 1822)	2.42-7.40	35	7.4-17.5	4-65	0.007	3.13*	0.94	1.009±0.14
<i>Salmostoma bacaila</i> (Hamilton, 1822)	2.42-9.15	26	7.5-15.3	3-27	0.011	2.82*	0.91	1.007±0.12
<i>Systemus sarana</i> (Hamilton, 1822)	0.25-7.41	33	7.4-22	2-162	0.006	3.26*	0.95	1.017±0.16
<i>Oreochromis mossambicus</i> (Peters, 1852)	5.00-70.00	126	6.1-26	4-241	0.167	3.08	0.947	0.975±0.26

N-Number of samples; TL - Total length; R² = Coefficient of determination, a = Intercept, b = Regression coefficient

*Significant from value b=3 at p=0.05

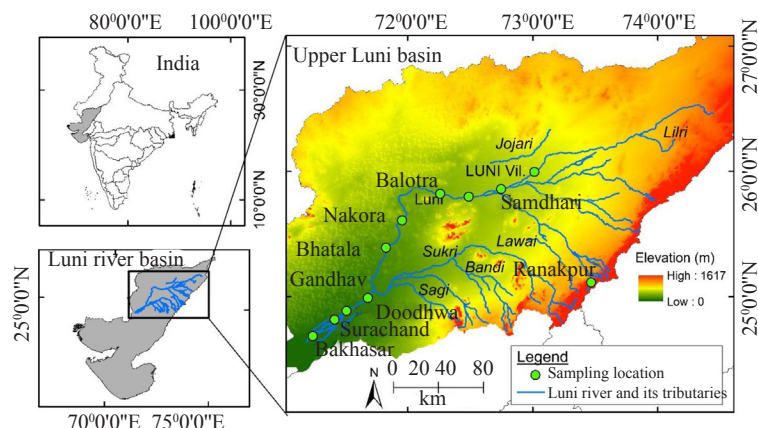


Fig. 1. Map showing the study area and sampling locations along the river Luni, India

each fish specimen was taken from snout tip to the extended tip of the caudal fin (nearest 0.1 cm) and weight (W) (nearest 0.1 g) by digital weighing machine. LWR was calculated using the equation; $W=aL^b$, where 'W' denotes total weight (g), 'L' denotes total length (cm), 'a' is the coefficient related to body form, and 'b' is the exponent and shape parameter of the fish species. When $b=3$, it indicates isometric growth; $b<3$ indicates negative allometric growth and when $b>3$, growth is positive allometric. The parameters 'a', 'b' and coefficient of determination (r^2) were estimated at 95% confidence level. All the data of length and weight were log transformed for ensuing least square linear regression (Zar, 1984) with the weight as dependent variable and the parameters 'a' and 'b' were estimated by the linear regression on the transformed equation; $\text{Log } W = \text{Log } a + b \text{ Log } L$.

For condition factor analysis, the relative condition factor (Kn) is defined as W_o/W_c , where W_o and W_c are the observed and calculated weight, respectively (Le Cren, 1951). $Kn \geq 1$ refers to good growth condition and well-being of the fish compared to an average individual with the same length. The biotic and abiotic environmental conditions prevailing in an ecosystem influence the condition factor of fish species and hence it can be used to assess the status of the aquatic ecosystem (Anene, 2005).

Statistical analysis

The data documentation and all statistical analyses presented in the study were performed using Microsoft Excel 2013 software under Windows operating system. The coefficient of determination (R^2) determined during regression is a measure of linear regression's prediction quality and a value close to 1 indicates a better model.

Results and discussion

The value of coefficient of determination (R^2) in respect of LWR in all the species was found to be >0.90 , except for *A. dispar* (0.75). Moreover, the value of exponent 'b' shows negative allometric growth ($b<3$) for *A. dispar* and *S. bacaila*, isometric growth ($b=3$) for *C. mrigala* and positive allometric growth ($b>3$) for *L. rohita*, *M. gulio* and *S. sarana*. All these values are significantly different from 'b'=3 (Isometric growth) at $p=0.05$, except for *C. mrigala* ($b=2.99$) (Table 1). LWR parameters of these native fish species reported in this study were also compared with data available in published literature (Table 2) from similar as well as adjacent freshwater ecosystems of India and other countries. A systematic comparison showed relatively higher 'b' values for *C. mrigala*, *S. bacaila* and *L. rohita* from the adjacent arid freshwater river Banas in Rajasthan (Lal *et al.*, 2016). Concomitantly, Ujjania *et al.* (2012) and Balai *et al.* (2017) also reported higher 'b' value for

C. mrigala from the river Mahi (3.36) and the Jaisamand Lake (3.02). The 'b' value of *S. sarana* reported in the present study is higher than the value reported from the river Banas. Literature evidences that parameters of LWR in fish is affected by various factors including sex, food, stomach fullness, fitness of fish species, fishing season, gear used and sample size (Tesch, 1971; Bagenal and Tesch, 1978; Froese, 2006; Kapiris and Klaoudatos, 2011) and influences of these factors were not considered in the present study. The present study is based on the limited number of fish specimens collected through experimental fishing from the seasonal river Luni during the monsoon and early post-monsoon season. While comparing the 'b' value of *A. dispar* (2.75) to the values reported in literature (Table 2), it was found lower (Alavi-Yeganeh *et al.*, 2011; Bibak *et al.*, 2012; Froese *et al.*, 2014; Keivany and Zamani-Faradonbe, 2017). *A. dispar* is a native fish species of the Middle East coastal zones (Yazdani, 1996) and abundantly distributed in the saline deep pools along the river Luni (Pathak *et al.*, 2020) and plays important role in the harsh desert ecosystem food chain (Banyal *et al.*, 2020). The mean relative condition factor (Kn) of 6 native fish species calculated in the present study is marginally >1 , which implies the good wellbeing of the fish species and the habitat suitability of the river Luni for these fishes (Table 1). Except *A. dispar*, which is a known saline species, other species are primarily known freshwater species. The results indicate the adaptive capacity of these species to the saline conditions. This is also evident from the fact that, though the calculated 'b' values marginally differ from the values reported for their conspecifics from freshwater ecosystems, the 'b' values were observed to be confirming to the cube law (Froese, 2006).

In case of *O. mossambicus*, the value of b is almost equal to 3 (non-significant from value $b=3$ at $p=0.05$), indicates isometric growth. The coefficient of determination (R^2) provides good fitness of the regression equation ($R^2=0.947$) and indicates a linear relationship between the length and weight of the specimens. LWR parameters of this fish species was also compared with data from published literature and the 'b' value reported for *O. mossambicus* in the present study was found slightly higher than the value reported from Bhima River ($b=2.88$) (Shendge, 2005) and almost equal to Manchar Lake, Sindh, Pakistan ($b=3.04$) (Achakzai *et al.*, 2013). A few other researchers have also reported isometric growth and established populations of *O. niloticus* in tropical reservoir ($b=2.96$) and sub-tropical river system ($b=2.93$) in India (Alam *et al.*, 2019; Jhonson *et al.*, 2020). The relative condition factor (Kn) of *O. mossambicus* specimens ranged from 0.58 to 1.57 with a mean value of 0.97 in its natural habitat. Around 35% of the *O. mossambicus* individuals have $Kn \geq 1$ and this

Table 2. Comparison between parameters of LWR of fish species of river Luni with waterbodies of adjacent river basin of India/other countries

Name of the fish species	N	Regression equation			Name of the aquatic system	References
		a	b	R ²		
<i>Aphanius dispar</i> (Ruppell, 1829)	95	0.010	3.33	0.95	Aghajari River, Borazjan Spring, Iran	Alavi-Yeganeh <i>et al.</i> (2011)
	10	0.010	3.24	0.97	Zohreh River, Iran	Keivany and Zamani-Faradonbe (2017)
	182	0.001	3.20	0.97	Dalaki River, Iran	Bibak <i>et al.</i> (2012)
<i>Cirrhinus mrigala</i> (Hamilton, 1822)	20	0.002	3.46	0.98	Som River and Jaisamand Lake, India	Lal <i>et al.</i> (2016)
	119	0.011	3.02	0.95	Jaisamand Lake, India	Balai <i>et al.</i> (2017)
	180	0.004	3.36	0.98	Mahi River (Mahi Bajaj Sagar), India	Ujjania <i>et al.</i> (2012)
<i>Labeo rohita</i> (Hamilton, 1822)	119	0.006	3.16	0.97	Jaisamand Lake, Rajasthan, India	Balai <i>et al.</i> (2017)
	180	0.004	3.32	0.98	Mahi River (Mahi Bajaj Sagar), India	Ujjania <i>et al.</i> (2012)
<i>Mystus gulio</i> (Hamilton, 1822)	244	0.010	3.01	0.97	Chilika Lagoon, India	Karna <i>et al.</i> (2020)
<i>Salmostoma bacaila</i> (Hamilton, 1822)	18	0.003	3.33	0.95	Som River and Jaisamand Lake, India	Lal <i>et al.</i> (2016)
<i>Systomus sarana</i> (Hamilton, 1822)	52	0.013	3.02	0.98	Som River and Jaisamand Lake, India	Lal <i>et al.</i> (2016)
<i>Oreochromis mossambicus</i> (Peters, 1852)	532	<0.001	2.88	0.98	Bhima River, India	Shendge (2005)
	364	1.7802	3.04	0.96	Manchar Lake, Sindh, Pakistan	Achakzai <i>et al.</i> (2013)

N-Number of samples; R² - Coefficient of determination, a - Intercept, b - Regression coefficient

fluctuation in Kn value, which is directly proportional to weight could be attributed to reproductive status, food availability, as well as habitat conditions (Jisr *et al.*, 2018; Morato *et al.*, 2001).

Risks due to the alien fish species O. mossambicus for native fish communities

The river Luni is facing multiple disturbances through anthropogenic activities, leading to the deterioration of habitat quality. Recent study also evidences on impact of distribution of an invasive alien species *O. mossambicus* on the fish community structure of this river (Pathak *et al.*, 2020). The risks due to exotic fish for native fish community is well regarded in the anthropogenically disturbed environment with deteriorated water quality (Gavioli *et al.*, 2018). The risk intensifies when the exotic fish dominates in the water pools of an ephemeral river, which acts as refuge for the native fish communities during the non-monsoon period (Kerezsy *et al.*, 2017). The survey reveals that *O. mossambicus* is abundantly distributed in the middle and downstream stretches of the river Luni having rich fish diversity, with overall relative abundance of 11.54%. Moreover, this study reports feral population of *O. mossambicus* in the water pools at Gandhav (downstream) with relative abundance of about 50% and presence of different life stages clearly indicating the establishment of its breeding populations in the river. It is considered as pest in the natural waters and affects the native fish community by competing for food and habitat (GISD, 2020). Thus, given the degree of wellness of *O. mossambicus* and increasing stress on the Luni River system may ease the distribution of this species further to the upstream hilly areas of the Aravallis which abode native fish communities (Sharma and Nagar, 2017).

Encounters obstructing ichthyofaunal diversity and ecosystem services

Luni is a rainfed river which flows only for 3 months of the year having diverse habitats which are highly dynamic and vulnerable to climate conditions. The occurrence of deep pools in river Luni is highly limited to certain locations as the river cannot cut a deep bed due to the predominance of sandy terrain. In spite of high salinity, Luni serves as a primary source of irrigation and the water is not saline until it reaches Balotra, where the catchment saline depressions alter its salinity. Being ephemeral and intermittent, this river has been studied poorly for its ichthyofaunal diversity and ecosystem services and often suffers from inadequate management measures and protection/conservation policies.

Presently, Luni is facing multiple threats such as mining, release of excess canal water, mixing of industrial effluents, destruction of riparian habitats and establishment of invasive alien fish species. Besides, ichthyofaunal diversity assessment, it is essential to have an understanding on ecosystem services offered by the river and its evaluation to inform evidence-based policy and conservation measures for sustainable management of the riverine ecosystem.

The present study provides the first-hand information about the growth pattern and relative conditions of six native and one invasive alien fish species (*O. mossambicus*) from inland saline river Luni flowing through the Thar desert region of India. The analysis revealed negative allometric growth for *A. dispar*, *C. mrigala* and *S. bacaila* and positive allometric growth for *L. rohita*, *M. gulio* and *S. sarana* which might be attributed to the environmental

condition, sampling season and fishing effort. K_n of native fish species is marginally >1 , which states the overall condition of wellbeing of fishes under study and habitat suitability of river Luni. The isometric growth and wellbeing of *O. mossambicus* reported in the present study could be attributed to the suitability in environmental and niche conditions. The arid river system Luni is highly dynamic in terms of flow and water quality characteristics, which makes its biological communities extremely vulnerable to the anthropogenic threats. Since, the present study also reports invasion and degree of wellness of *O. mossambicus* along the middle and lower stretches of the river Luni, such invasion might be a serious threat for the native fish communities owing to competition arising out for food and habitat. However, this needs to be further probed through detailed investigations on diet breadth, niche overlap of native and non-native fishes of the river.

The information generated in the present study will help in formulating suitable management strategies for restricting the spread of *O. mossambicus* in the river Luni. The present study, suggests for development of appropriate strategies to maintain the unique ecosystem of the river Luni that harbours native adapted fauna. To achieve this, future studies are needed focusing on the landscape approach of this river using drainage modelling, ground surveys and holistic data on the land use/land cover and risk factors to the river. This will enable developing critical data model for transforming into the strategies so that the ecosystem of the river Luni could be protected. In totality, the present study has fulfilled its aim and the data presented might be helpful in establishing guidelines for fish stock assessment and management studies for fishes of the Luni River and adjacent river basins.

Acknowledgements

Authors are thankful to the Director, ICAR-NBFGR, Lucknow for providing the necessary facilities to carry out the work. This study was supported by the Indian Council of Agricultural Research (ICAR), New Delhi through the in-house funding program (ICAR-NBFGR: FISHNBFGRSIL201800400207).

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