Length-Weight Relationship and Condition Factor of *Rhinomugil corsula* (Hamilton, 1822) (Actinopterygii, Mugiliformes, Mugilidae) in Four Major Estuaries of Gujarat, India

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ABSTRACT

Rhinomugil corsula (Hamilton, 1822) (Mugiliformes: Mugilidae) is the only representative of the genus *Rhinomugil* Gill, 1863, and is found in freshwater and brackish habitats. A study was carried out on *R. corsula* in the four major estuaries of Gujarat (Sabarmati, Mahi, Narmada and Tapi) from June 2017 to March 2018. A total of 680 specimens were examined (115-245 mm TL). Male *R. corsula* from all four estuaries showed positive allometric growth (b>3), while females had negative allometric growth (b<3). Length-weight relationships (LWR) of the four populations indicate that Mahi estuary has the best growing conditions for *R. corsula*, followed by Narmada and Tapi. Condition factor (K) estimates for females were 1.245±0.216 (Mahi), 1.269±0.243 (Narmada), and 1.231±0.138 (Tapi), while males had K values of 1.014±0.081 (Sabarmati), 1.226±0.274 (Mahi), 0.845±0.180 (Narmada) and 1.045±0.134 (Tapi). Assuming fitness of the population is high when K is close to 1, the males were more fit than the females in all four estuaries. Fitness of the male population was highest in Sabarmati estuary followed by Tapi, Narmada and Mahi. Females of Tapi estuary were more fit than in Mahi and Narmada. The present study provides information regarding biological aspects of the species which can be used in fisheries management and potential application by the aquaculture sector.

Keywords: Condition factor, Estuary, Length-weight relationship, Mullet, *Rhinomugil corsula*

INTRODUCTION

The estuarine zone is a unique habitat forming a transition between marine and freshwater ecosystems (Sarkar *et al*., 2012). In India, 14 major, 44 mid-sized, and numerous minor estuaries are present along with coastal lagoons and backwaters, draining approximately 2,000 km^2 of land (Venkataraman and Raghunathan, 2015). In estuarine ecosystems, species diversity may be lower than in adjacent aquatic environments, but the populations that are present have much higher abundance (Chang and Iizuka, 2012). In tropical countries, estuaries are important economically and as a major source of fish for local people.

Among teleost fishes, only a small portion (<10 %) are adapted to migrate between fresh and marine water environments; these are the euryhaline fishes (Nordlie, 2015). In India, out of 3,231 known fish species (Gopi and Mishra, 2015), approximately 113 inhabit estuaries (Sarkar *et al*., 2012). The

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Received 23 February 2021 / Accepted 18 June 2021

members of family Mugilidae Jarocki, 1822 are euryhaline, and are widely used as food by locals due to their high nutritive value. *Rhinomugil corsula* (Hamilton, 1822) (Mugiliformes: Mugilidae) is the only representative of the genus *Rhinomugil* Gill, 1863. It is commonly known as "corsula" mullet in India and is widely distributed throughout the Indian sub-continent including Bangladesh, India, Nepal and Myanmar (Froese and Pauly, 2021). It attains a maximum total length of 450 mm (Menon, 1999) and is categorized as "least concern" by the IUCN Red List and as "vulnerable" in India (Dahanukar *et al*., 2010). It can tolerate wide environmental fluctuations and is found in freshwater, brackish and marine habitats at depths of 10-15 m (Sultana *et al*., 2013). *R. corsula* is a surface dweller and feeds on organic matter, detritus, small fish and insects, thus playing a vital ecological role. It is cultured in many developing countries in brackish conditions due to its wide tolerance of temperature and salinity, and due to its availability in shallow coastal waters and estuarine areas. It is widely used as a food due to its highly proteinaceous flesh (Sultana *et al*., 2013). It is caught throughout the year, thus it is a valuable source of food during the offseason of other commercial fisheries (Sultana *et al*., 2013).

The length-weight relationship (LWR) and condition factor (CF) of a fish population are important biometric relationships for fisheries management and research (Anderson and Gutreuter, 1983; Ecoutin and Albaret, 2003). The LWR is an important growth index used in estimating the average weight at a given length (Abowei and Hart, 2009). The established relationship between length and weight is an essential component for the calculation of production and biomass of a fish population (Sani *et al*., 2010). It also allows morphological comparisons among species or among populations of the same species from different habitats or regions (Moutopoulos and Stergiou, 2002). LWR and CF are frequently used to follow seasonal variations in fish growth and to estimate condition indices (Anderson and Gutreuter, 1983; Safran, 1992; Richter *et al*., 2000). Growth indices can be affected by several factors such as stress, sex, season, availability of food, and water quality parameters (Khallaf *et al*., 2003). The present study evaluates the LWR and CF of *R. corsula*, which are fundamental for evaluating the ecological status of the species in the estuarine system. Information gained from this study can be applied to sustainable management of *R. corsula* fisheries in all four major estuaries of Gujarat.

MATERIALS AND METHODS

Study area and sample collection

The present investigation was performed in four major estuaries of Gujarat (Sabarmati, Mahi, Narmada and Tapi), on the west coast of India, from June 2017 to March 2018. Specimens were identified as *Rhinomugil corsula* (Hamilton, 1822) (Figure 1) using standard identification keys (Day, 1888; Thompson, 1997; Bhatt and Mankodi, 2020). A total of 680 *R. corsula* individuals were collected from several landing sites within each of the four estuaries (Figure 2). Female specimens were not found from the Sabarmati estuary. The mouth of the estuary opens at the uppermost region of the Gulf of Cambay. A combination of mud flats at the river mouth and low flows during summer can prevent the mixing of freshwater during breeding time (April to June) (Sultana *et al*., 2013). Also, Sabarmati estuary is currently polluted by the release of industrial effluents (Deshkar *et al*., 2012; Haldar *et al*., 2014). These factors may cause females to avoid this habitat for breeding. Few individuals may migrate towards this region in search of food.

Length-weight relationship

Length-weight relationships were expressed by the equation $W = aL^b$, where W and L represent weight and length, respectively. For length-weight relationships (LWR), total length (TL) was measured to the nearest 0.1 mm and total body weight (BW) to the nearest 0.01 g. Total length was measured from the anterior-most tip of the snout to the tip of the upper lobe of the caudal fin. The parameters a and b in the formula were calculated using the logarithmic form of the LWR equation: Log(BW) = Log(a) + b Log(TL) (Froese *et al*., 2011). In this relationship, "a" indicates the rate of change with regards to length and "b" represents the weight at unit length. If b = 3, this indicates isometric growth, which means body length and weight increase in the same proportion; b<3 indicates negative allometric growth and b>3 indicates positive allometric growth (Morey *et al*., 2003). Further, 95 % confidence limits for a, b and the coefficient of determination were estimated. Student's t-test was performed for the null hypothesis of isometric growth (H_0: b = 3) using the equation $t_b = (b–3)/s_b$, where S_b is the standard error of the slope (p = 0.05) (Morey *et al*., 2003). LWR was estimated among estuaries, both as separate male and female populations and as a pooled sample to check whether the growth of the individual population is isometric or not.

Condition factor

Fulton's condition factor (K) was estimated to evaluate the condition of each individual sampled in each month using the equation $K = 100 \times (BW/TL^3)$, where BW = total body weight in g and TL = total length in mm (Fulton, 1904). An overall robustness or well-being for fish species is assumed when K values are equal or close to 1 (Jisr *et al*., 2018). Condition factor was compared among estuaries, both as separate male and female populations and as a pooled sample.

Figure 1. *Rhinomugil corsula* (Hamilton, 1822): (a) specimen examined in the laboratory; (b) head, dorsal view; (c) head, lateral view.

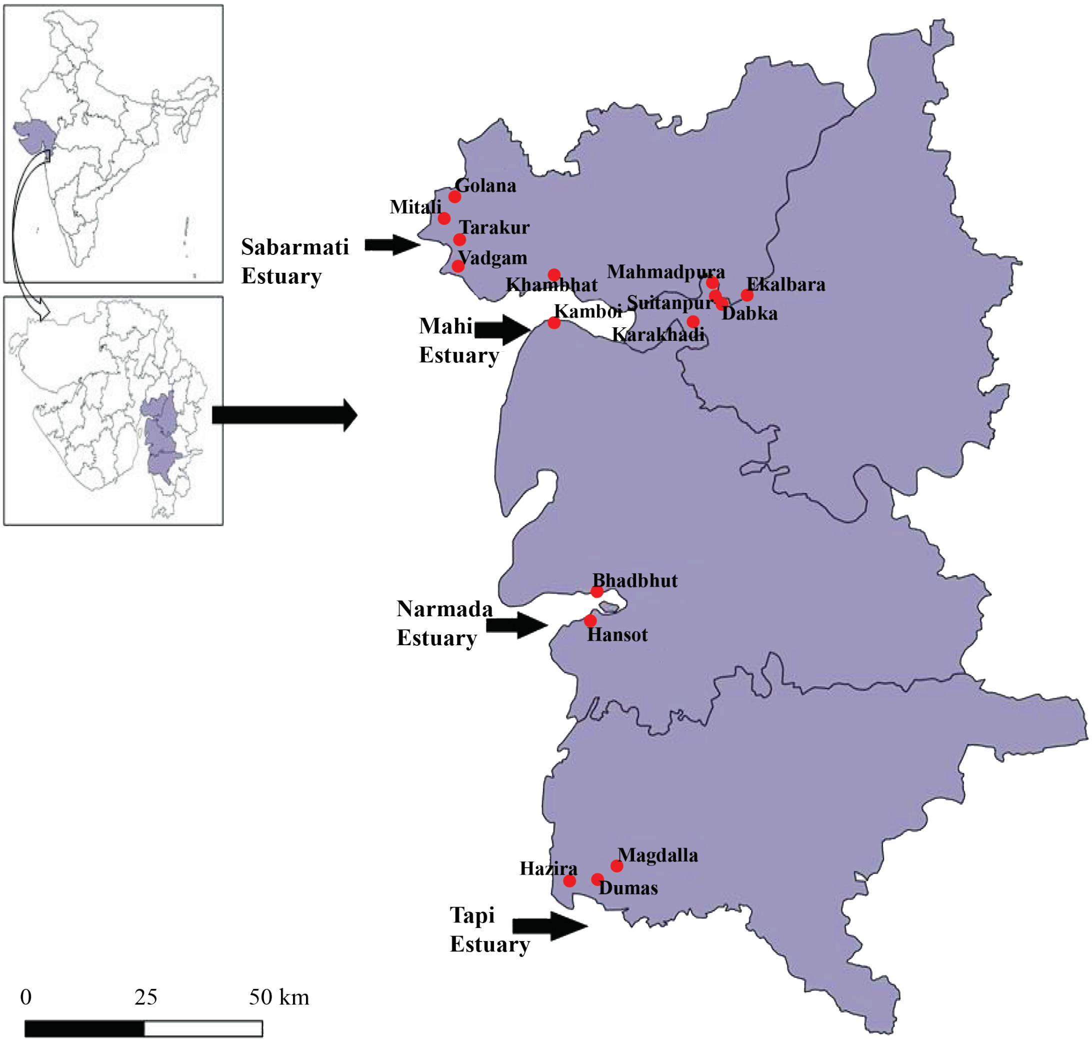

Figure 2. Sampling sites for *Rhinomugil corsula* in four major estuaries of Gujarat, India. **Sabarmati Estuary:** Golana (22°27'33.50"N, 72°25'6.29"E), Mitali (22°25'1.99"N, 72°23'45.51"E), Tarakpur (22°22'34.19"N, 72°25'41.05"E), Vadgam (22°19'22.13"N, 72°25'33.68"E), Khambhat (22°18'26.92"N, 72°37'11.89"E); **Mahi Estuary:** Ekalbara (22°15'57.25"N, 73°0'37.51"E), Dabka (22°14'58.81"N, 72°57'31.65"E), Mahmadpura (22°17'27.03"N, 72°56'24.44"E), Sultanpur (22°15'56.31"N, 72°56'50.43"E), Karakhadi (22°12'45.37"N, 72°54'2.44"E), Kamboi (22°12'49.38"N, 72°37'14.04"E); **Narmada Estuary:** Bhadbhut (21°41'03"N, 72°50'39"E), Hansot (21°34'55"N, 72°48'42"E); **Tapi Estuary:** Magdalla (21°8'41.27"N, 72°44'52.70"E), Dumas (21°7'7.06"N, 72°42'30.47"E), Hazira (21° 6'59.93"N, 72°39'5.80"E).

RESULTS AND DISCUSSION

Length-weight relationship

Length-weight relationship statistics for *Rhinomugil corsula* (Table 1) show that linear regressions of log-transformed data were highly significant ($p<0.001$) except for the pooled (male and female) population of Mahi estuary and the male and pooled populations of Narmada (Figure 3d, 3e, 3g). The "b" value of the male population of Narmada ($t_b = 0.217$, df = 99, p = 0.585) and pooled population of Mahi ($t_b = 1.088$, df = 199, p = 0.277) were not significantly different from the cubic value associated with isometry ($H_0 = 3$) (Figure 3d, 3e). However, the "b" value for males of Sabarmati ($t_b = 1.137$, df = 79, p = 0.002), Mahi ($t_b = 2.996$, df = 99, p = 0.003) and Tapi ($t_b = 2.845$, df = 99, p = 0.005) were significantly different from the expected cubic value, representing positive allometric ($H_0 \neq 3$) growth, which means body weight of individuals increased faster than body length (Figure 3a, 3b, 3i). In contrast, the females of Mahi ($t_b = -2.574$, df = 99, p = 0.005), Narmada ($t_b = -2.876$, df = 99, p = 0.002) and Tapi ($t_b = -2.897$, df = 99, p = 0.002) showed highly significant negative allometric growth (Figure 3c, 3f, 3h). The pooled populations of Narmada ($t_b = 1.819$, df = 199, p = 0.964) and Tapi ($t_b = 4.756$, df = 199, p = 0.000003) also showed a highly significant difference from the expected cubic value, and indicated positive allometric growth (H0 $\neq$ 3) (Figure 3g, 3j). Female individuals were longer in body size compared to males. The LWRs of *R. corsula* sample groups in the four estuaries were modelled by the following equations: Sabarmati: $W = 0.004L^{3.16}$ (M); Mahi: $W = 0.002L^{3.49}$ (M), $W = 0.014L^{2.71}$ (F) and $W = 0.005L^{3.11}$ (P); Narmada: $W = 0.005L^{3.05}$ (M), $W = 0.016L^{2.65}$ (F) and $W = 0.003L^{3.29}$ (P); and Tapi: $W = 0.003L^{3.26}$ (M), $W = 0.014L^{2.71}$ (F) and $W = 0.003L^{3.37}$ (P). The logarithmic forms of these equations are shown in the graphs (Figure 3a to 3j). The values of "b" can differ due to many factors including sex, age, season, and feeding (Ricker, 1975; Bagenal and Tesch, 1978). The intercept (a) values were within the normal range of 0.001-0.05 proposed by Froese (2006), though there was significant variation among female populations. A study of *R. corsula* performed in the Padma River of northwest Bangladesh reported negative allometric growth of males (b = 2.896), females (b = 2.615), and the population as a whole (b = 2.761) (Hossain *et al*., 2013). Similarly, Mortuza and Rahman (2006) studied LWR in *R. corsula* and found the parameter 'b' to be 2.941, 3.008 and 2.984 for males, females and sexes combined, respectively.

Condition factor

Fulton's condition factor (K) was estimated and variation in condition was compared among estuaries and months, as well as between sexes. According to Froese (2006), the value of K provides information on the well-being of fish in a given habitat. Heincke (1908) suggested that better nutritional conditions should yield a higher K. The condition factor of male *Rhinomugil corsula* ranged from 0.906 (Dec–lowest) to 1.131 (Feb–highest) in Sabarmati estuary, from 0.841 (Dec) to 1.739 (Jul) in Mahi, from 0.636 (Sep) to 1.186 (Jun) in Narmada, and from 0.777 (Feb) to 1.294 (Jun) in Tapi. For females, K ranged from 1.003 (Mar) to 1.737 (Jan) in Mahi, from 1.003 (Feb) to 1.827 (Jun) in Narmada, and from 1.021 (Nov) to 1.393 (Jul) in Tapi. The average values of K for females were 1.245±0.216 (Mahi), 1.269±0.243 (Narmada), and 1.231±0.138 (Tapi). Means were somewhat lower for males: 1.014±0.081 (Sabarmati), 1.226±0.274 (Mahi), 0.845±0.180 (Narmada) and 1.045±0.134 (Tapi). The fitness or well-being of fish is high when the value of K equals to or is close to 1 (De Vries *et al*., 2020). Thus, the male populations in Mahi, Narmada, and Tapi were more fit than the females. The fitness of males in Sabarmati estuary was highest, followed by Tapi, Narmada and Mahi. Females in Tapi estuary were more fit than those in Mahi and Narmada. Monthly values of K for male and female *R. corsula* from the four estuaries are shown in Figure 4. The previously mentioned study by Hossain *et al*. (2013) in Bangladesh reported K

Table 1. Statistical analysis of length-weight relationship of *Rhinomugil corsula* in estuaries of Sabarmati, Mahi, Narmada and Tapi rivers of Gujarat, India.

Estuary	Sex	N	TL (mm)		TW (g)		Regression Parameters					Growth (t-test)	p
			Min	Max	Min	Max	a	95 % CI – a	b	95 % CI – b	r^2		
Sabarmati	♂	80	115	217	12.38	108.3	0.004	0.003-0.009	3.16	2.88-3.44	115	b>3	HS
	♀	-	-	-	-	-	-	-	-	-	-	-	-
	Pooled	-	-	-	-	-	-	-	-	-	-	-	-
Mahi	♂	100	125	241	16.56	120.01	0.002	0.001-0.005	3.49	3.17-3.83	125	b>3	HS
	♀	100	147	239	31.49	144.56	0.014	0.009-0.024	2.71	2.48-2.93	147	b<3	HS
	Pooled	200	125	241	16.56	144.56	0.005	0.004-0.009	3.10	2.91-3.30	125	b>3	NS
Narmada	♂	100	122	222	15.26	109.7	0.005	0.002-0.016	3.05	2.58-3.52	122	b>3	NS
	♀	100	147	239	31.49	143.59	0.016	0.009-0.029	2.65	2.40-2.89	147	b<3	HS
	Pooled	200	122	239	15.26	143.59	0.003	0.002-0.007	3.29	2.98-3.61	122	b>3	NS
Tapi	♂	100	115	245	15.17	112.4	0.003	0.003-0.006	3.26	3.08-3.44	115	b>3	HS
	♀	100	150	241	35.39	144.19	0.014	0.009-0.023	2.71	2.51-2.91	150	b<3	HS
	Pooled	200	115	245	15.17	144.19	0.003	0.003-0.005	3.37	3.18-3.44	115	b>3	HS

Note: N = number of individuals; TL = total length; TW = total weight; CI = confidence interval; S = significant ($p \leq 0.05$); NS = non-significant ($p > 0.05$); HS = highly significant ($p \leq 0.01$).

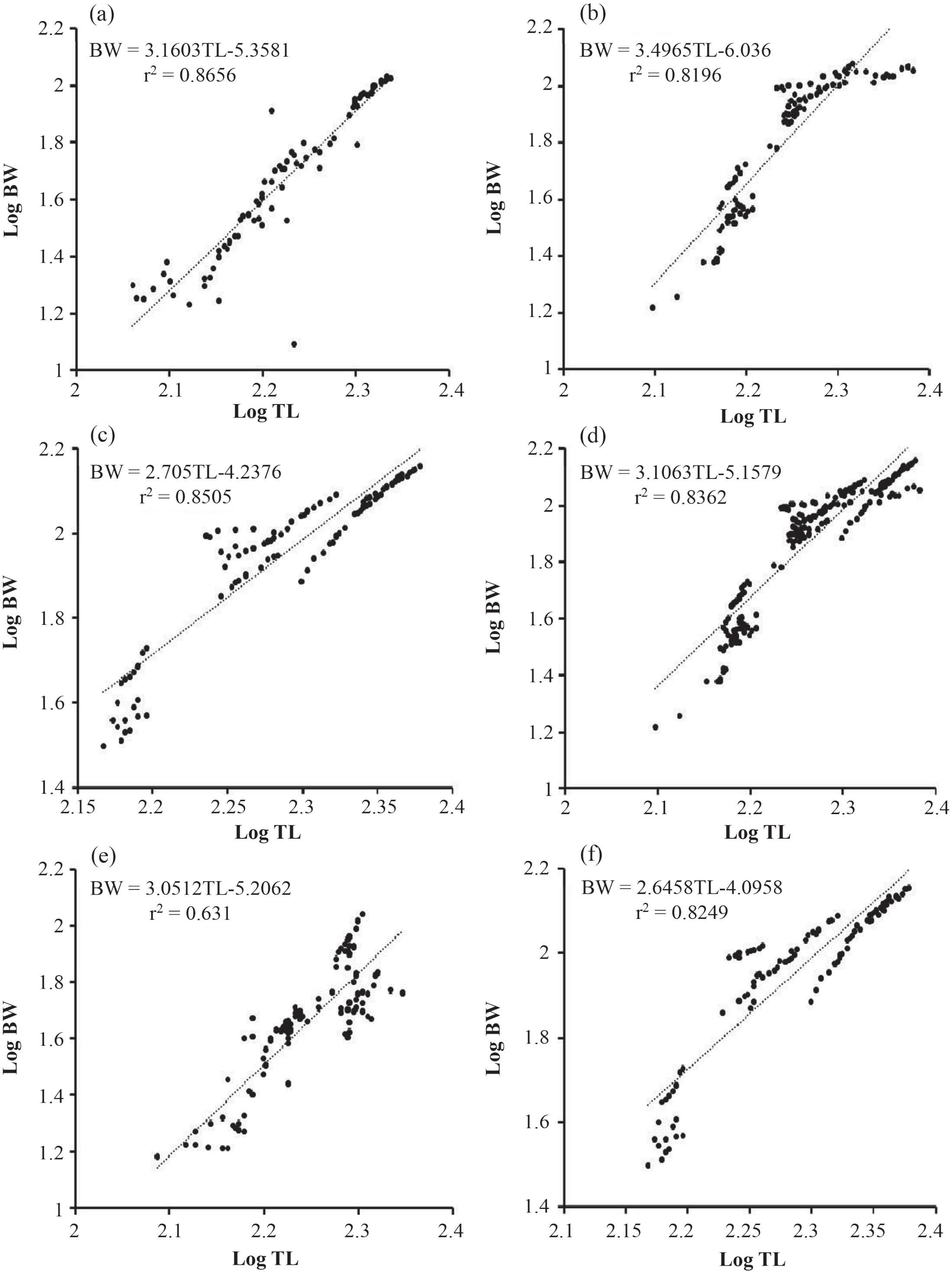

Figure 3. Logarithm form of length-weight relationship of *Rhinomugil corsula*: (a) Males–Sabarmati estuary, (b) Males–Mahi estuary, (c) Females–Mahi estuary, (d) Pooled–Mahi estuary, (e) Males–Narmada estuary, (f) Females–Narmada estuary.

values for this species ranging from 0.63 to 1.79 (mean = 1.14±0.28) and from 1.09 to 1.20 (1.03± 0.27) for males and females, respectively. The present study suggests that the estuaries sampled have better growing conditions (i.e., higher K values, which represents comparatively higher body weight at given length and implies ample amount of food available) for females compared to those of Padma River. For males, only Mahi estuary has better growing conditions than Padma River.

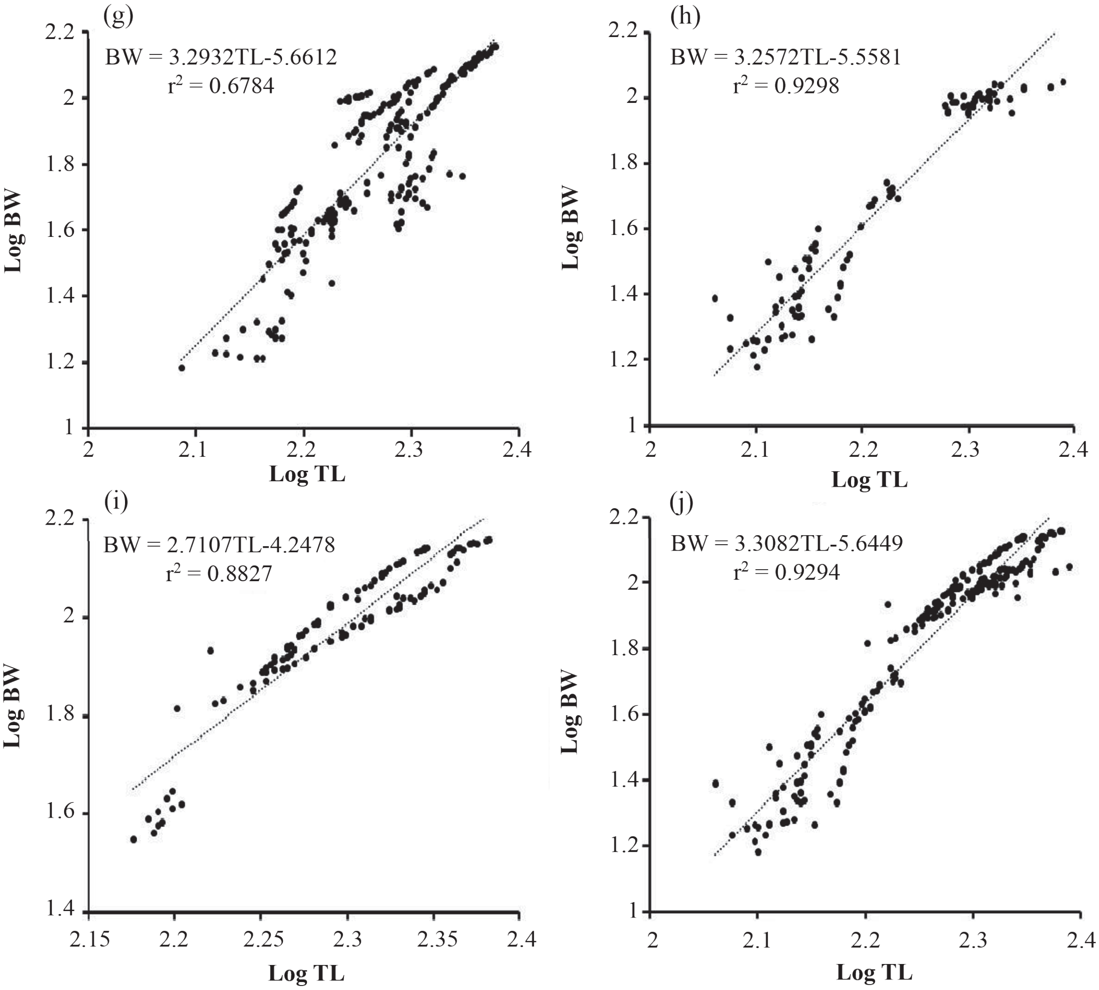

Figure 3 (cont.). Logarithm form of LWR of *Rhinomugil corsula*: (g) Pooled–Narmada estuary, (h) Males–Tapi estuary, (i) Female–Tapi estuary, (j) Pooled–Tapi estuary.

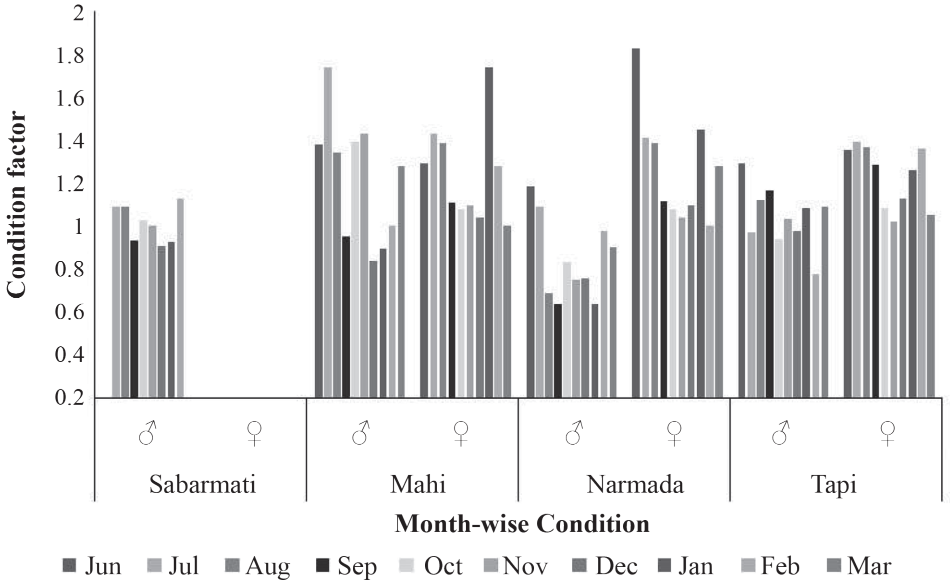

Figure 4. Fulton's condition factor (K) of *Rhinomugil corsula* in four major estuaries (Sabarmati, Mahi, Narmada and Tapi) of Gujarat, India.

CONCLUSION

The present study indicates that the slope (b) of the length-weight relationships of *Rhinomugil corsula* from all four major estuaries of Gujarat are within the expected range of 2.5-3.5 (Froese, 2006). The data indicate negative allometric growth in females and positive allometric growth in males, which suggests that females use more energy for biological functions such as gonad maturation and migration. The LWRs for combined sexes show that Mahi estuary has the best growing conditions, followed by Narmada and Tapi. Considering only males, highest K values were obtained from Mahi estuary while for females, highest K values were obtained from Narmada estuary. Thus, ideal nutritional conditions may vary between sexes. In the case of robustness of body (i.e., K near 1), Sabarmati and Tapi estuaries were indicated as the most suitable habitats for male and female populations, respectively. The variation in LWR and CF reflect the differences in food availability and other environmental conditions among sites, factors which should be pursued in future research. This study provides useful information for fisheries managers to take appropriate precautionary measures. It also encourages further study of the potential for brackish-water culture of *R. corsula* in this region, as all of the estuaries show relatively good growing conditions for this species.

ACKNOWLEDGEMENTS

The authors would like to thank the Head of the Department of Zoology, The Maharaja Sayajirao University of Baroda, Vadodara for permission to conduct research in departmental laboratory. Authors also thank Mr. Parth Prajapati, Dr. Khushali Pandya, Ms. Jalpa Jadeja, Mr. Marut Adroja, Ms. Niketa Maheta, Ms. Sheikh Gazala and Mr. Ajay Baldaniya for their continuous encouragement and help, and Miss Mahima Doshi for her valuable help. The local fishermen are thankfully acknowledged for their valuable support during the specimen collection.

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