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Carapace width and weight relationships, condition factor, relative condition factor and gonado-somatic index (GSI) of mud crabs (*Scylla spp.*) from Chilika Lagoon, India.

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Carapace width (CW)-weight relationship, condition factor (K), relative condition factor (Kn) and gonado-somatic index (GSI) for meaty and post-moulted crabs of both sexes of the two mud crab species, *Scylla serrata* (Forskal) and *S. tranquebarica* (Fabricius) co-existing in Chilika lagoon, Orissa, India, were studied during August, 2005 to July, 2007. CW-weight equations and correlation co-efficient (r) obtained for both sexes of meaty and water crabs of the two species were significant ($P< 0.05$-0.01). Regression slopes (b) were higher for males and fattened crabs in both the species. The K and Kn values recorded in each month for different size groups of both sexes of the two species were higher in male and values were relatively higher in *S. tranquebarica* than *S. serrata*. Increase in Kn values beyond 1.0 from 81-91 mm CW in *S. serrata* and 111-120 mm CW in *S. tranquebarica* indicated the size at first maturity. Higher monthly values indicated that breeding period was extended from August-November and March-July in *S. serrata* and *S. tranquebarica* respectively. Species-specific study aimed at establishing difference in biological characters between two species of *Scylla[a']* from same brackishwater habitat. CW-weight relationship may be useful in setting feeding rates for a particular species in aquaculture.

Keywords: Chilika lagoon, *Scylla spp.*, carapace width and body weight

Introduction

In the context of recent revision of taxonomy of genus *Scylla*[1], it sets out to highlight areas where even basic biological information is lacking at species level, especially when relevant to fisheries management and aquaculture[2]. Although review of literatures revealed that several studies on biological aspects of Indian mud crabs were done in southern part of India and elsewhere, those works related to the cryptic identity of *Scylla* species, mostly mentioning the monospecific term *Scylla serrata*. No reports are available in country on the species-specific biological studies of *Scylla* species, except captive broodstock development, induced breeding and larval rearing of *S. serrata* and *S. tranquebarica* in hatchery[3-4]. Information about individual body weight-length/width relationships in population characteristics is in general of great importance for estimating the population size of a stock for the purpose of its exploitation[5]. The condition factor is used to compare the condition or well being of any species and is based on the hypothesis that the higher weight at a given length is in better condition. Higher gonado-somatic index indicates the progression of maturity and breeding period. The condition factor is affected by length as well as several other factors like environment, food supply, degree of parasitism, and above all, the sexual cycle[6]. Carapace width-weight relationship, condition and relative condition factors in mud crabs are simple but important equations in their biological studies, which are at present concerned with building available catch databases transforming catch in weight into catch in numbers, and incorporating these into yield per recruit model analysis, and age structured model analysis[7]. Such studies would also establish difference in biological characteristics among species under one genus.

Among the edible brackishwater/ marine crabs of India, mud crabs (*Scylla spp.*) command[a[2]] a unique

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status by virtue of their delicacy in local as well as export markets[3]. Chilika lagoon in Orissa, the largest brackish water ecosystem of its kind in the South-East Asian region and a Ramsar Site sprawls along the east coast of India is a potential source for the production of mud crabs (*Scylla sp*.) with an average annual landing of more than 100 tonnes. Earlier, the mud crab from Chilika lagoon was known in the monospecific term *S. serrata*. Mohanty *et al.*[8] for the first time reported the occurrence of two species (*S. serrata* and *S. tranquebarica*) from Chilika lagoon being co-existed since old times. The lagoon had suffered rapid degradation during past few decades due to incessant anthropogenic pressure and natural changes; in the process the fishery resources became the worst casualty. In the process of eco-degradation, both environmental values and resource development opportunities were threatened by potential loss of marine influence and lagoon characteristics[9]. However, a classic hydrological intervention for eco-restoration of the lagoon was accomplished with opening of an artificial lagoon mouth in September, 2000[10]. Such intervention indicated positive impact on fisheries enhancement. The average annual landings of mud crabs (*Scylla* species) during the study period was increased by twelve folds as compared to the average annual landing for last decade before opening of the new artificial lagoon mouth.

For proper conservation and management of mud crab, a proper knowledge on its biology is crucial[11]. However, the stock status and detail biological studies of the two species of mud crabs from Chilika lagoon are still lacking except the landing information[12-13]. Increasing exploitation of mud crabs (*Scylla spp.*) in Chilika lagoon due to increasing demand in the live mud crab export market has distinctively indicated decline of naturally available mud crab resources. Present species-specific study of carapace width-body weight relationship, condition factor, relative condition factor and gonado-somatic index of the two species of mud crab (*S. serrata* and *S. tranquebarica*) from Chilika lagoon was undertaken during August, 2005 to July, 2007, with a view to utilizing the information for the growth projection[14], conservation and management[2] of its natural fishery particularly, the regulation for economic fishing and to use the CW-weight data for different sizes of a particular crab species in setting feeding rates in aquaculture[15].

Materials and Methods

Study area

Chilika is the largest lagoon along the east coast of India, situated between latitude 19° 28' and 19° 54' N and longitude 85° 05' and 5° 38' E. The lagoon is a unique assemblage of marine, brackish and freshwater ecosystem with estuarine characters. The water-spread area of the lagoon varies between 1100 and 900 sq.km[a^3] during monsoon and summer. A 32 km long narrow outer channel was connecting the main lagoon to the Bay of Bengal near the village Arakhakuda (old mouth) before the hydrological intervention. An artificial mouth called new mouth was opened at a shorter distance for the better exchange of tidal salt water. The lagoon itself is broadly divided into four natural sectors based on the ecological characters i.e. the southern sector, central sector, northern sector and the outer channel sector (Fig.1). The lagoon receives fresh water inflow in northern sector through several branches of Mahanadi Delta river system and western catchment streams. Influx of tidal salt water from the Bay of Bengal through the lagoon mouth effects exchange with the lagoon water. The vital outer channel is connected to the lagoon proper at a point known as Magarmukh, which is also called the gateway between the lagoon and the inlet channel connecting the sea.

Sampling design

Since the historical data indicated that there was a flourishing mud crab fishery in Chilika lagoon in the past covering all the four ecological sectors[13,16]. The reconnaissance survey for mud crab fishing grounds was conducted after opening of the new mouth which indicated that mud crab population was almost absent in the southern sector. Present study was carried out during August, 2005-July, 2007. Mud crab (*S. serrata* and *S. tranquebarica*) specimens were collected once in a month from the central sector, northern and outer channel sectors (Station No. 1, 2, 3, 4, 5, 6 and 9) as indicated in Fig. 1. Station No. 7 and 8 (southern sector) were fixed for periodical monitoring to know if mud crabs were migrating to southern sector after hydrological intervention. Mud crab specimens were collected at each sampling station during early morning from different crab fishing gears (monofilament twine net traps 'khanda', fine mono filament gill nets, split bamboo crab pots 'Khadia', crab lift nets 'Banda', hook and lines, hand scoop nets and triangular push nets) operated by local fishers. The juvenile crabs including first crab instars

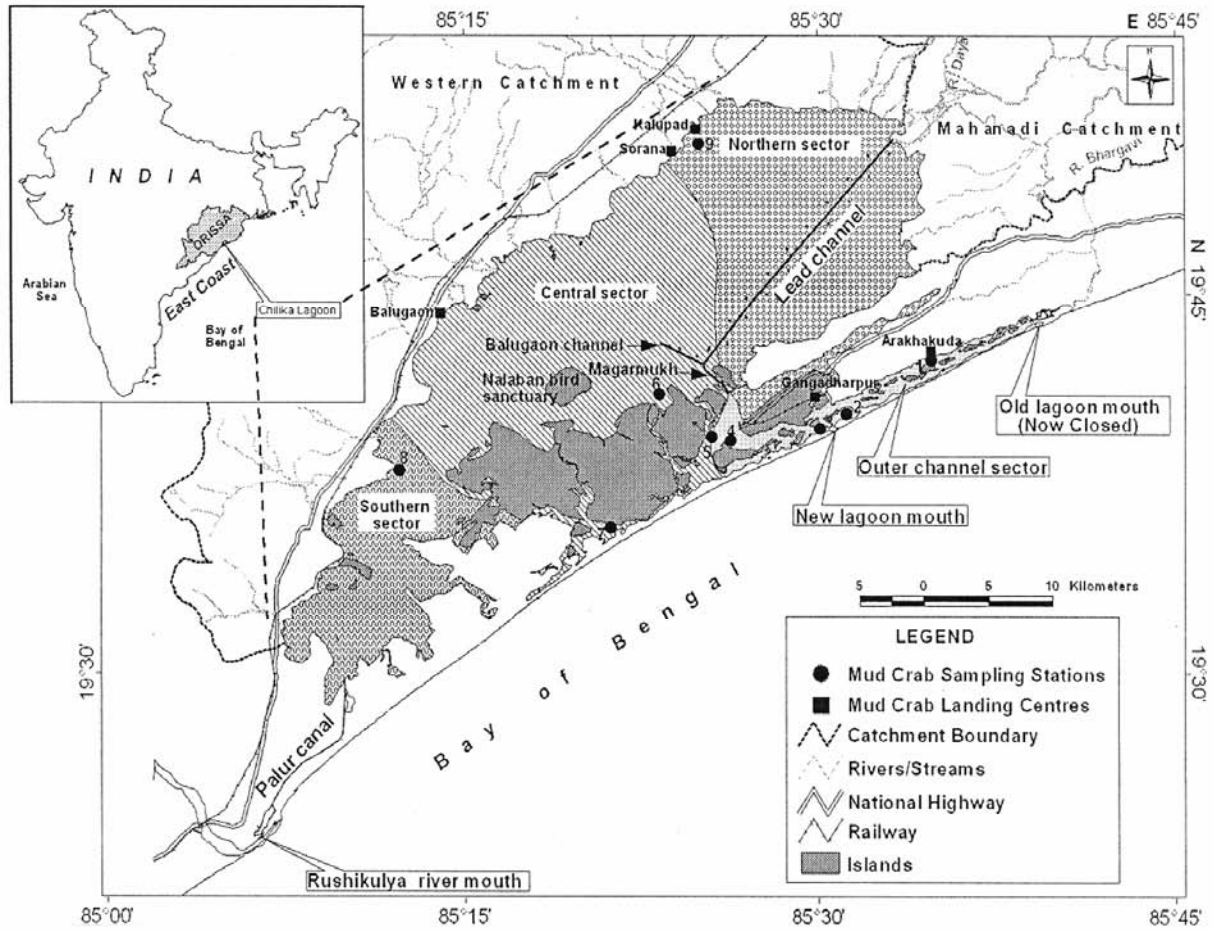

Fig. 1—Mud crab landing and sampling sites in Chilika Lagoon

(baby mud crabs) were mostly caught in net traps (Khandas) and triangular push nets; sub-adults and adults are caught in other fishing gears.

Muds crabs caught by fishermen in the lagoon (outer channel, central and northern sector) are landed daily in live condition at five established landing centres namely, Kaupadaghat, Sorana, Balugaon, Gangadharpur and Arakhakuda (Fig. 1). The width of carapace (CW) between the ninth teeth of left and right antero-lateral boarder was measured in mm by using a cadastral mapping compass and measuring scale with millimetre division and the body weight was recorded in gram at both landing centres and sampling stations using mono pan dial balance of 1 kg (±0.001 g) and 3 kg (±0.1 g). Identification of mud crab species in the field was carried out by following standard literature[1,4]. Water and meaty crabs were identified by pressing the branchial region of the crab with fingers on the ventral side to feel the hardness for meaty crab and sponginess with buzzing sound for water crab[17].

Data analysis

The carapace width-weight relationships for both sexes and for water and hard/meaty crabs of two mud crab species were calculated following Le Cren[6] as follows:

$$W=a\,L^{b}$$

where, 'W' is the derived weight (g), 'L' is the carapace width in mm, a is the intercept of the regression curve (a constant) and b is the regression coefficient (an exponent). Values of the constant 'a' or the proportionality constant[18] and the exponent 'b' or the regression slope[19] are calculated by the formula given by Langer[20].

Fulton's condition factor (K) was calculated by following Bagenal and Tesch[21] as below:

$$K=\frac{100\,W}{L^{b}}$$

where, 'W' weight (g), 'L' is the carapace width (CW) in mm, 'b' is the regression coefficient from the carapace width-weight relationship.

The relative condition factor (Kn) was calculated as

$Kn = W/ a L^b$ (Le Cren[6])

where, 'W' = weight (g), 'L' is the carapace width (CW) in mm, 'a' is the intercept of the regression curve and b is the regression coefficient. In other words, the relative condition factor Kn = w/W, where 'w' is the original weight of the specimen and the 'W' is the derived weight of the specimen. For calculation of condition factor and relative condition factor, only the meaty crabs are taken into consideration, rejecting the water crabs.

The gonado-somatic index (GSI) of the female crabs were calculated following the formula as follows:

$$GSI(\%) = \frac{\text{Drained ovary weight}}{\text{Total live weight}} \times 100$$

Results and Discussion

The b value ranged from 2.751 to 3.220 for *S. serrata* and from 2.782 to 3.113 for *S. tranquebarica* (Table-1). Calculated values indicated a clear sexual dimorphism with males attaining larger size in both the species. For males the b values, above 3 in both the species whereas in females the values were slightly less than 3. Higher b values for males than females in *S. serrata* were observed from Andaman Sea[22], Bangladesh[23], Sunderban mangrove of Bangladesh[11] and coastal region of Bangladesh[24]. Also higher b value in males than females was observed in other brachyuran species[5, 25]. Higher b value in males of both the species in Chilika lagoon was attributed to the allometric enlargement of male chelae with sexual maturation.

The b value was observed to be slightly higher in all meaty (hard) crabs than that of the water crabs in the same sex of the two species. This is the first attempt to calculate the carapace width-weight relationship for water crabs (newly moulted crabs) and meaty (hard) crabs separately from Chilika lagoon. CW-weight relationship in *S. tranquebarica* has been studied for the first time from Chilika lagoon which was hitherto not reported from any part of the world, although the study for *S. serrata* and combined cryptic species of mud crabs has been reported by many workers from different regions. The r value for *S. serrata* ranged from 0.892 to 0.928 and for *S. tranquebarica* from 0.884 to 0.959, which were significant ($P< 0.05$-0.01).

The overall sex ratio for both the species is male dominated and significantly differs from the normal 1:1 ratio ($X^2 = 3.181$ for *S. serrata* and $X^2 = 3.01$ for *S. tranquebarica,* d.f. =23, $P< 0.05$). Size frequency distribution did not indicate any clear modal progression in both the species. Absence of clear modal progression in the present study is attributed to continuous fishing mortality and continuous juvenile recruitment. The opening of new artificial lagoon mouth helped in proper exchange of sea and lagoon water, thus the salinity level in the lagoon increased for which the seagrass bed also increased in the lagoon and provided good nursery ground for the mud crabs.

The mean condition factor (K) and the mean relative condition factor (Kn) for both the sexes in the two species are presented in Table 2. Mean condition factor (K) in *S. serrata* varied from 0.0350±0.0012 to 0.0719±0.0026 in males and from 0.0368±0.0032 to 0.0671±0.0025 in females, where as in *S. tranquebarica,* the condition factor varied between 0.0312±0.0031 and 0.0712±0.0014 in males and between 0.0390±0.0021 and 0.0629±0.0024 in females. The relative condition factor (Kn) in *S. serrata* varied from 0.83±0.12 to 1.21±0.16 in males and from 0.84±0.15 to 1.13±0.24 in females while in *S. tranquebarica* the it varied from 0.76±0.29 to 1.35±0.32 in males and from 0.86±0.14 to 1.16±0.21 in females.

Table 1—Carapace width-weight relationship for *Scylla spp*. from Chilika lagoon

Species and sex	Water/fattened	a	b	n	r
Scylla serrata (♂)	Fattened	0.0000628	3.220	3688	0.892
S. serrata (♂)	Water	0.0000611	3.215	202	0.899
S. serrata (♀)	Fattened	0.0002114	2.924	2068	0.928
S. serrata (♀)	Water	0.0004457	2.751	246	0.914
S. tranquebarica (♂)	Fattened	0.0001012	3.113	764	0.884
S. tranquebarica (♂)	Water	0.0000549	3.006	176	0.915
S. tranquebarica (♀)	Fattened	0.0002565	2.892	680	0.942
S. tranquebarica (♀)	Water	0.0001460	2.782	184	0.959

a = intercept of the regression curve (a constant); and b = regression coefficient; n = numbers of crabs; r = correlation coefficient

Table 2—Variation of condition factor (K) and relative condition factor (Kn) value in both the mud crab species from Chilika lagoon in different size groups (mean ± S.D.)

Size groups	K		Kn	
	♂	♀	♂	♀
		S. serrata		
30-40	0.0350 ± 0.0012	0.0368 ± 0.0032	0.83 ± 0.12	0.84 ± 0.15
41-50	0.0386 ± 0.0036	0.0421 ± 0.0024	0.87 ± 0.13	0.86 ± 0.21
51-60	0.0449 ± 0.0021	0.0414 ± 0.0029	0.92 ± 0.21	0.93 ± 0.24
61-70	0.0474 ± 0.0032	0.0460 ± 0.0036	0.94 ± 0.1	0.93 ± 0.23
71-80	0.0528 ± 0.0024	0.0490 ± 0.0028	1.01 ± 0.21	0.99 ± 0.26
81-90	0.0534 ± 0.0025	0.0498 ± 0.0026	1.01 ± 0.19	1.03 ± 0.28
91-100	0.058 ± 0.0036	0.0512 ± 0.0024	1.01 ± 0.17	1.04 ± 0.27
101-110	0.0648 ± 0.0028	0.0561 ± 0.0021	1.03 ± 0.21	1.08 ± 0.29
111-120	0.067 ± 0.0026	0.0568 ± 0.0024	1.04 ± 0.11	1.12 ± 0.19
121-130	0.0671 ± 0.0024	0.0571 ± 0.0021	1.06 ± 0.12	1.13 ± 0.24
131-140	0.0682 ± 0.0021	0.0671 ± 0.0025	1.09 ± 0.13	1.1 ± 0.18
141-150	0.0712 ± 0.0023	0.0661 ± 0.0024	1.08 ± 0.12	1.11 ± 0.16
151-160	0.0709 ± 0.0021	0.0631 ± 0.0031	1.06 ± 0.16	1.09 ± 0.21
161-170	0.0713 ± 0.0025	0.0642 ± 0.0024	1.07 ± 0.15	1.12 ± 0.29
171-180	0.0715 ± 0.0014	0.0629 ± 0.0021	1.09 ± 0.17	1.11 ± 0.21
181-190	0.0716 ± 0.0031		1.12 ± 0.09	
191-200	0.0718 ± 0.0024		1.19 ± 0.12	
201-210	0.0719 ± 0.0026		1.21 ± 0.16	
		S. tranquebarica		
30-40	0.0312 ± 0.0031	0.0390 ± 0.0021	0.76 ± 0.29	0.86 ± 0.23
41-50	0.0315 ± 0.0024	0.0392 ± 0.0032	0.76 ± 0.19	0.86 ± 0.21
51-60	0.0318 ± 0.0026	0.0395 ± 0.0024	0.79 ± 0.24	0.87 ± 0.29
61-70	0.0329 ± 0.0036	0.0412 ± 0.0036	0.81 ± 0.35	0.86 ± 0.24
71-80	0.0346 ± 0.0021	0.0421 ± 0.0036	0.81 ± 0.29	0.88 ± 0.35
81-90	0.0351 ± 0.0032	0.0433 ± 0.0028	0.85 ± 0.21	0.91 ± 0.29
91-100	0.0411 ± 0.0024	0.0476 ± 0.0026	0.91 ± 0.28	0.95 ± 0.21
101-110	0.0473 ± 0.0036	0.0519 ± 0.0024	0.94 ± 0.38	0.98 ± 0.28
111-120	0.0489 ± 0.0021	0.0554 ± 0.0021	0.95 ± 0.26	1.01 ± 0.24
121-130	0.0539 ± 0.0032	0.0576 ± 0.0024	1.01 ± 0.28	1.07 ± 0.38
131-140	0.0546 ± 0.0024	0.0594 ± 0.0021	1.06 ± 0.27	1.13 ± 0.31
141-150	0.0569 ± 0.0025	0.0618 ± 0.0025	1.08 ± 0.29	1.14 ± 0.12
151-160	0.0611 ± 0.0036	0.0619 ± 0.0024	1.16 ± 0.19	1.12 ± 0.19
161-170	0.0642 ± 0.0028	0.0621 ± 0.0031	1.18 ± 0.24	1.14 ± 0.24
171-180	0.0651 ± 0.0026	0.0629 ± 0.0024	1.21 ± 0.23	1.16 ± 0.21
181-190	0.0668 ± 0.0024	0.0625 ± 0.0021	1.29 ± 0.21	1.15 ± 0.32
191-200	0.0681 ± 0.0021	0.0621 ± 0.0024	1.31 ± 0.29	1.13 ± 0.14
201-210	0.0692 ± 0.0023		1.34 ± 0.17	
211-220	0.0679 ± 0.0021		1.32 ± 0.21	
221-230	0.0701 ± 0.0025		1.35 ± 0.21	
231-240	0.0712 ± 0.0014		1.35 ± 0.32	

Overall condition factor and relative condition factor in males of both the species were slightly higher than that of the females. The condition factor and relative condition factor in both the sexes of *S. tranquebarica* were slightly higher than that of S. *serrata* indicating inter-specific difference. In males of both the species, there was a continuous increase of K and Kn values with increase in size. However in females, the K and Kn values increased continuously up to the 131-140 mm size group and there after slightly decrease and fluctuating trend was observed in *S. serrata*. In *S. tranquebarica,* the K and Kn values increased up to the 171-180 mm[a^4] size groups and thereafter the values were slightly decreased and fluctuated. Sudden increase in the K and Kn values in the 71-80 mm[a^5] size group in *S. serrata* and 111-120[a^6] mm size group in *S. tranquebarica* gives an indication of the size at first maturity of the species. The peak values and inflections in the value K corresponded to that of Kn values in both the species.

Seasonal variation of K and Kn values more or less related to the sexual cycle of the species[6]. The seasonal variation in K and Kn values of both the species and sexes is presented in Figs 2a & 2b, 3a & 3b. Comparatively higher K and Kn values in

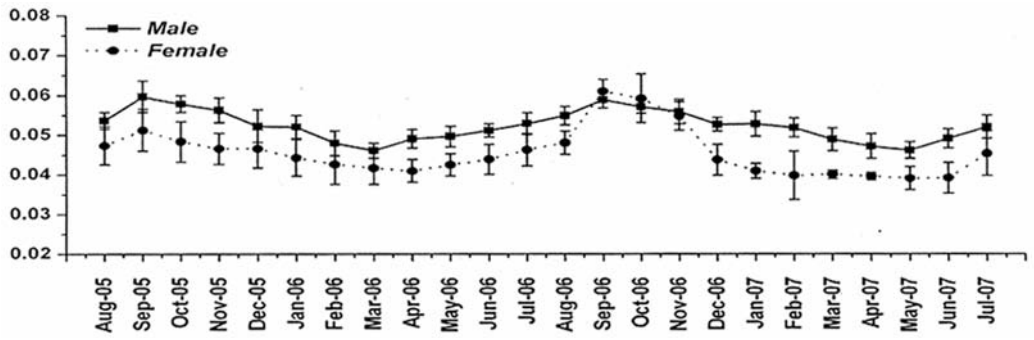

Fig. 2a—Monthly variation in condition factor (K) in *S. serrata*

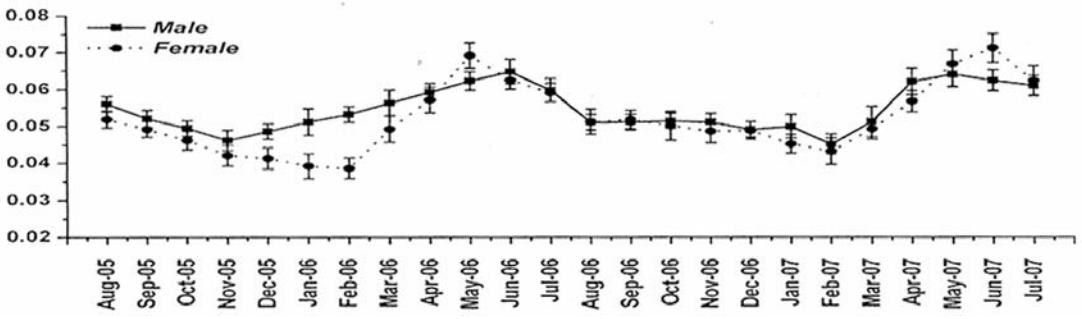

Fig. 2b—Monthly variation in condition factor (K) in *S. tranquebarica*

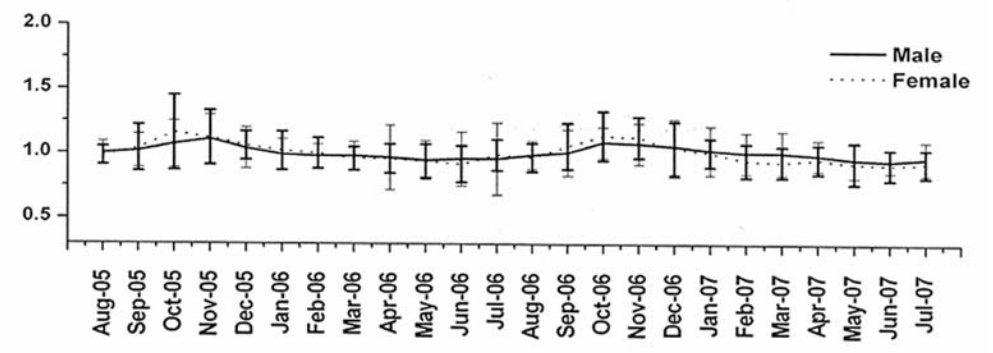

Fig. 3a—Seasonal variation in relative condition factor (Kn) in *S. serrata*

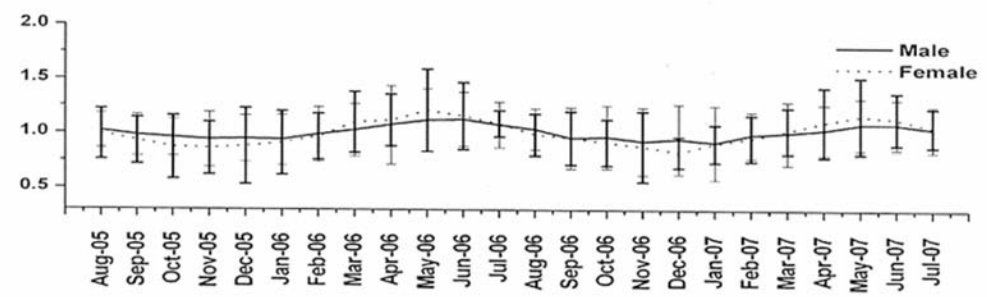

Fig. 3b—Seasonal variation in relative condition factor (Kn) in *S. tranquebarica*

S. serrata were marked from the months of August-November in both the years and the sudden decrease in the K and Kn values in the months of December of both the years infers that the peak breeding season of the species is from August-November, however, *S. serrata* was found to breed through out the year as the juvenile abundance of *S. serrata* was observed round the year. More or less uniform K and Kn values

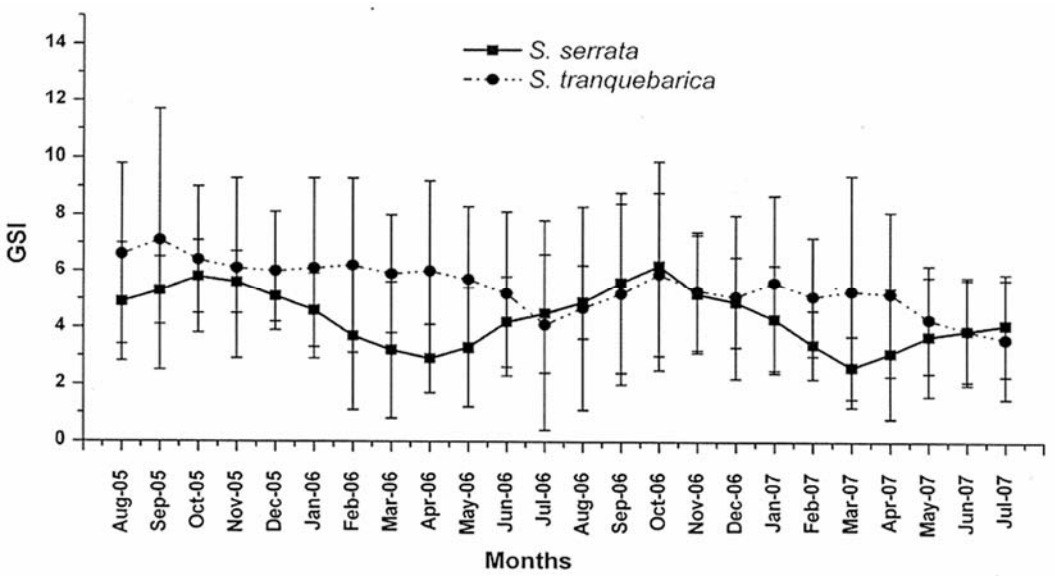

Fig. 4—Temporal changes (Mean±S.D.) in Gonad somatic index (GSI) of both the species of *Scylla* from Chilika Lagoon

round the year except for the month of August-November gives an indication of year round availability of mature crabs. In *S. tranquebarica,* comparatively higher K and Kn values were recorded from the period of March-July in both the years and the lowest K and Kn values in the months of September-November of both the years indicate that the peak breeding season of the species is extended from August-November in Chilika lagoon.

Observed GSI values of *S. serrata* and *S. tranquebarica* was depicted in Fig. 4. Gonadosomatic index (GSI) of *S. serrata* varied from 2.6±1.1 (March-07) to 6.2±3.7 (October-06). GSI in *S. serrata* showed a single oscillation having peak during the months of September to November in both the sampling years. Satapathy[26] reported the GSI of *S. serrata* varied between 1.5 and 6.3, and higher GSI was reported from the months of September-November, which almost match with the present observations. Higher GSI for *S. serrata* during the months of August-November and low female sex ratio during these months indicated the possible migration of *S. serrata* females for spawning in the sea during the months of August-November. GSI for *S. tranquebarica* varied between 3.6 ±2.1 (July-07) to 7.1±4.6 (September, 05). Average GSI during the entire period for *S. tranquebarica* (5.44) is higher than that of the *S. serrata* (4.38) which indicated that females of *S. tranquebarica* are larger than females of *S. serrata*. GSI values in *S. tranquebarica* varied within a very narrow range except for the months of June and July when the GSI values were comparatively lower due to the availability of small sized crabs of the species in the lagoon.

Studies on carapace width (CW)-weight (W) relationship and condition factor and relative condition factors for *S. serrata* and *S. tranquebarica* co-existing in Chilika lagoon established clear difference in the two species. Observed data can be utilized in determining the spawning season, biomass projection in aquaculture and implementation of responsible fishing for sustainable fishing of mud crabs.

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