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ORIGINAL ARTICLE

Estimation of key population parameters of *Penaeus indicus* H. Milne Edwards, 1837 (Crustacea: Penaeidae) in the Andharmanik River, southern Bangladesh: implications for sustainable management

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ABSTRACT

This study was conducted to estimate the key population parameters to understand both the current status and the yield of *Penaeus indicus* H. Milne Edwards, 1837 in the Andharmanik River, southern Bangladesh, using monthly samples collected from July 2019 to June 2020. We found that the size at first sexual maturity of *P. indicus* is 15.5 mm CL. The spawning season was August – December with a peak in September. Recruitment occurred at ~8.4 mm CL for an extended period of the year with two pulses: one in November (minor recruitment pulse) and another in February (major recruitment pulse). The von Bertalanffy growth equation gave the following results: $CL_\infty = 31.9$ mm and $K = 1.14$ year^{-1}. The overall growth performance index was 3.37 and the longevity was 2.6 years. The estimated total, natural, and fishing mortalities were 3.53, 2.15, and 1.38 year^{-1}, respectively. Therefore, the exploitation rate was 0.39 and the maximum sustainable yield was 0.42, indicating that the stock is almost optimally exploited. Hence our work should help improve decisions to (i) conserve the stock, (ii) maximize economic returns from the stock, and (iii) continue ensuring that the stock is exploited in an ecologically sustainable way.

KEYWORDS

Growth, mortality, recruitment, reproduction, yield

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Introduction

Shrimps are regarded as the most consumed fishery products in most developed countries, so their demand is increasing in global markets. Both the demand and high foreign exchange earnings have driven the exploitation of most shrimp stocks to an unhealthy level. In many areas of the world, shrimp exploitation is a major problem (FAO, 2000), associated with growth overfishing that causes reduction and depletion of spawners (Garcia, 1985; Courtney and Die, 1995; FAO, 2000; Abdallah, 2004; Chando, 2005; Saputra, 2008). As a result, the recruitment process and stock recovery are greatly hampered. Therefore, it is very important to formulate sustainable management policies for fisheries resources by determining both the current status and the maximum sustainable yield (MSY). The study of key population parameters (e.g., reproduction, recruitment, growth, and mortality) helps to estimate the yield and formulate fisheries management strategies. Growth and mortality are the main determinants of MSY. The various aspects of reproduction (*e.g.*, the size at first sexual maturity and timing of spawning) and recruitment are important for addressing management measures.

Penaeus indicus H. Milne Edwards, 1837 is one of the major commercial penaeid shrimps distributed in the Indo-West Pacific from eastern and south-eastern Africa, through India, Malaysia, and Indonesia to southern China and northern Australia at depths of 2 to 90 m (FAO, 1980). However, the species is most abundant in shallow waters under 30 m in depth (FAO, 1985). This shrimp is euryhaline and inhabits brackish, estuarine, and marine environments (Kutty *et al.*, 1971; Branford, 1981; Khan *et al.*, 2001; Macia, 2004).

The shrimp fishery plays an important role in the economy of Bangladesh. A total of 60 shrimp species are available in both freshwater and marine environments in Bangladesh (DOF, 2019), of which 10 species are commercially exploited and 4 are commercially exported to other countries (Ahmed, 1990). *Penaeus indicus* is one of the major commercially exploited and exported species of this country. Several works concerning the biology and fishery of this species have been undertaken in almost all of its major distribution areas except Bangladesh, *e.g.*: the east coast of India (Devi, 1986; 1987; Rao *et al.*, 1993); southern (Nissanka, 1997) and western coasts (Jayakody and Costa, 1988; Jayawickrema and Jayakody, 1992; Jayawardane *et al.*, 2002a; 2002b) of Sri Lanka; Manila Bay, Philippines (Agasen and Del Mundo, 1988); Sonmiani Bay, Balochistan (Amanat and Qureshi, 2011); Red Sea (Branford, 1981); Lake Saint Lucia, South Africa (Champion, 1988); Arabian Sea (Mehanna *et al.*, 2012); Ghubat Hasish Bay, Gulf of Masirah, Oman (Mohan and Siddeek, 2008); Segara Anakan Lagoon (Saputra, 2008); and northern coastal waters (Saputra *et al.*, 2019) of Central Java, Indonesia.

Therefore, our study was conducted to estimate key population parameters, including reproduction, recruitment, growth, and mortality to understand both the current status and the yield of *P. indicus* in the Andharmanik River, southern Bangladesh. Hence, our work should improve decisions to (i) conserve the stock, (ii) maximize economic returns from the stock, and (iii) ensure that the stock is exploited in an ecologically sustainable way. Our findings are compared with available reports on this species from different habitats to enrich existing knowledge.

Material and Methods

Study site and sampling

The present study was conducted in the Andharmanik River (21°59′N 90°10′E) (Fig. 1), which is one of the larger coastal tributaries of the Ganges - Padma River system (Rob, 2012), that originates from the Tiakhali River (Barguna district) and falls into the Bay of Bengal in Patuakhali district, Bangladesh. Monthly samples of *P. indicus* were collected with the help of small-scale artisanal fishers using set bag netting (Akerman, 1986) from July 2019 to June 2020. The collected specimens were immediately preserved on ice and then fixed with 10 % formalin upon arrival at the laboratory.

Shrimp measurement

The specimens were sexed as male or female based on the presence of the petasma or thelycum, respectively. For each individual, carapace length (CL) was measured from the posterior margin of the orbit to the mid-dorsal posterior edge of the carapace using a digital slide caliper (Mitutoyo, CD-6"CSX) to the nearest 0.01 mm. Body weight (BW) was recorded using a digital balance (AND, FSH, Korea) with 0.01 g accuracy. To study the reproductive aspects (length at first sexual maturity, spawning season), only female specimens were used, whereas other parameters were estimated using length-frequency based analysis of FiSAT II software (Gayanilo *et al.*, 1996) using combined sexes.

Sexual maturity and spawning season

Whole ovaries were removed from each female and weighed to 0.001 g accuracy. Gonadosomatic index (GSI) was calculated as follows:

$$\text{GSI (\%)} = 100 \times \text{OW/BW},$$
where OW is ovarian weight (g).

To determine the size at first sexual maturity, CL and GSI values of all females were shown in a paired scatter plot and the CL of the smallest female having advanced development ovary was considered as the minimum CL of maturity for the population. The spawning season was estimated based on the monthly variation of GSI. Monthly air temperature and photoperiod data were obtained for the study period online (from https://www.worldweatheronline.com/kalapara-weather-averages/bd.aspx) to correlate with the spawning season of *P. indicus* using Spearman rank-correlation tests.

Recruitment pattern

A histogram using CL data pooled from all monthly samples of 1 mm intervals was constructed. A series of component normal distributions was fitted to the frequency distribution using the Bhattacharya (1967) method, a normal-distribution separator routine of the FiSAT II program (Gayanilo *et al.*, 1996).

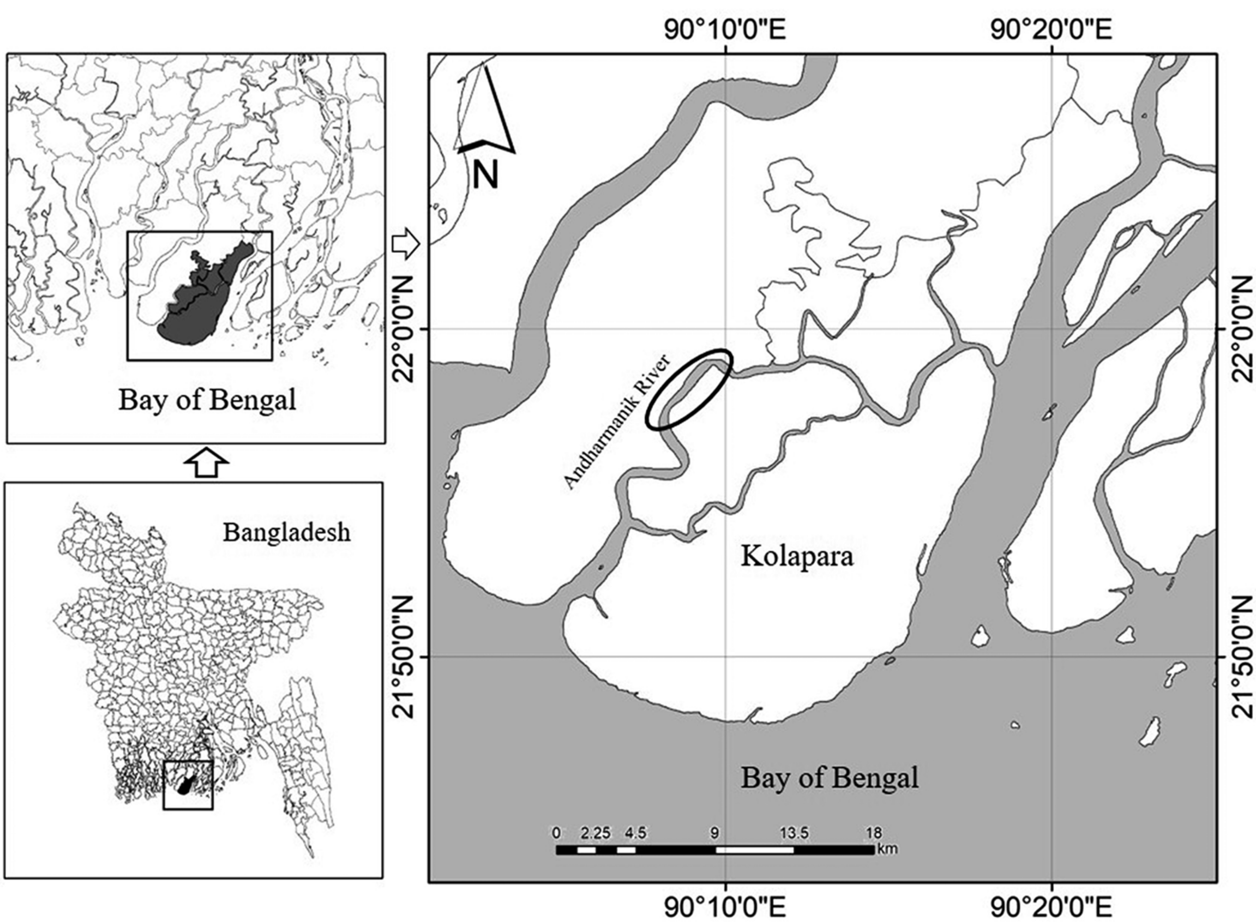

Figure 1. Map showing the study site, Andharmanik River, southern Bangladesh.

Each component normal distribution was assumed to represent an age group in the population. The mean CL of the smallest size group was considered as the length at recruitment of *P. indicus* in the Andharmanik River, *i.e.*, individuals with mean + SD CL or smaller sizes were considered as recruits in the stock (King, 1995). Yearly recruitment pattern was determined by observing the monthly percentage of recruitment during the studied period.

Growth analysis

Monthly length-frequency distributions (LFD) for combined sexes were constructed using 1 mm intervals for CL. We used the electronic frequency analysis (ELEFAN I) method (Gayanilo *et al.*, 1996) to analyze our length-frequency data. Growth parameters were estimated using the following von Bertalanffy (1938) equation:

$$L_t = L_\infty\, [1\text{-}\exp\{\text{-}K(t\text{-}t_0)\}],$$

where L_t is the CL (mm) at age t (month), L_∞ is the asymptotic CL (mm), K is the growth coefficient (year^{-1}), and t_0 is the hypothetical age when CL would be zero.

First, we used the Powell-Wetherall plot (Powell, 1979; Wetherall, 1986) — as modified by Pauly (1986) — using pooled length-frequency data as initial estimates of L_∞ and Z/K. In this method, input parameter graphical identification of the smallest length of fully recruited shrimp (L′, or cut-off length) by the gear has a function of the form:

$$\overline{L} - L' = a + bL',$$

where $\overline{L}$ is the mean length of all shrimps ≥ L′ mm. L_∞ and Z/K were computed from the above equation as $L_\infty = a/b$, and Z/K = - (1+b)/b.

This initial estimate of L_∞ was used as seed value in the ELEFAN I procedure to fit the von Bertalanffy growth function (VBGF) to the length-frequency data. The best growth curve passing through the maximum number of peaks was identified based on the index of goodness-of-fit (R_n) as ESP/ASP, where ESP is the expected sums of peaks and ASP is the available sums of peaks in the length-frequencies.

Growth performance and longevity

From the estimated values of L_∞ and K of VBGF, we calculated the index of overall growth performance (Ø’) (Pauly and Munro, 1984) as:

$$Ø' = \log_{10} K + 2\log_{10} L_\infty$$

The longevity t_{max} of *P. indicus* was estimated from the following relationship (Taylor, 1958; Pauly, 1980):

$$t_{max} \approx 3/K$$

Estimation of mortality and exploitation rate

The instantaneous rate of total mortality (Z) was estimated using the length converted catch curve method (Pauly, 1983) as:

$$\ln(N_t/\Delta_t) = a + bt,$$

where N is the number of individuals of relative age (t) and Δ_t is time needed for the shrimp to pass through a length class.

The slope b of the curve, with its sign changed, gives an estimate of Z (King, 1995). The instantaneous rate of natural mortality (M) was estimated using the empirical formula of Pauly (1980) as:

$$\log_{10} M = -0.006 - 0.279 \log_{10} L_\infty + 0.654 \log_{10} K + 0.463 \log_{10} T,$$

where T is the average annual water temperature (°C) in which the stocks live.

Fishing mortality (F) was estimated by subtracting natural mortality from the total mortality. Exploitation rate (E) was calculated as the proportion of the fishing mortality relative to total mortality (Gulland, 1969):

$$E = F / Z = F / (F + M)$$

Maximum sustainable yield

We predicted the relative yield-per-recruit (Y′/R) using the Beverton and Holt (1966) length-based methods, as modified by Pauly and Soriano (1986):

$$Y'/R = EU^{M/K}(1\text{-}(3U)/(1+m)+(3U^2)/(1.2m)\text{-}(U^3)/(1.3m)\},$$

where $U = 1- (L_c/L_\infty)$ is the fraction of growth to be completed by the shrimp after entry into the exploitation phase, $m = (1-E)/(M/K) = (K/Z)$, $E = F/Z$ is the exploitation rate, F is the instantaneous rate of fishing mortality, and L_c is the length at first capture.

The relative biomass-per-recruit (B′/R) was estimated as:

$$B'/R = (Y'/R)/F$$

Then E_{max} (exploitation rate producing maximum yield), $E_{0.1}$ (exploitation rate at which the marginal increase of Y'/R is 10 % of its virgin stock), and $E_{0.5}$ (the exploitation rate under which the stock is reduced to half of its virgin biomass) were computed through the first derivative of the Beverton and Holt (1966) function.

Results

Sexual maturity

The relationship between CL and GSI of female *P. indicus* is shown in Fig. 2. The lowest and highest GSIs recorded during this study were 0.72 and 5.93, respectively. The GSI (> 3.0 %) rose sharply at ~15.5 mm CL for females. Hence, the size at first sexual maturity was considered to be 15.5 mm CL, and individuals with a GSI ≥ 3.0 % could be roughly defined as mature females at the study site.

Spawning season

Figure 3 reveals the monthly changes of mean GSI with minimum and maximum values of female *P. indicus*. Mature (GSI ≥ 3.0 %) or near mature gonads were observed in all months except in July, March and May indicating a prolonged spawning season. However, the occurrence of mature gonads (GSI ≥ 3.0 %) was high during the months of August to December, with a peak in September. Therefore, the main spawning season of *P. indicus* was estimated to be from August to December. The spawning season of *P. indicus* was not correlated with temperature ($r_s = -0.478$, $p = 0.051$) unlike photoperiod ($r_s = -0.566$, $p < 0.05$).

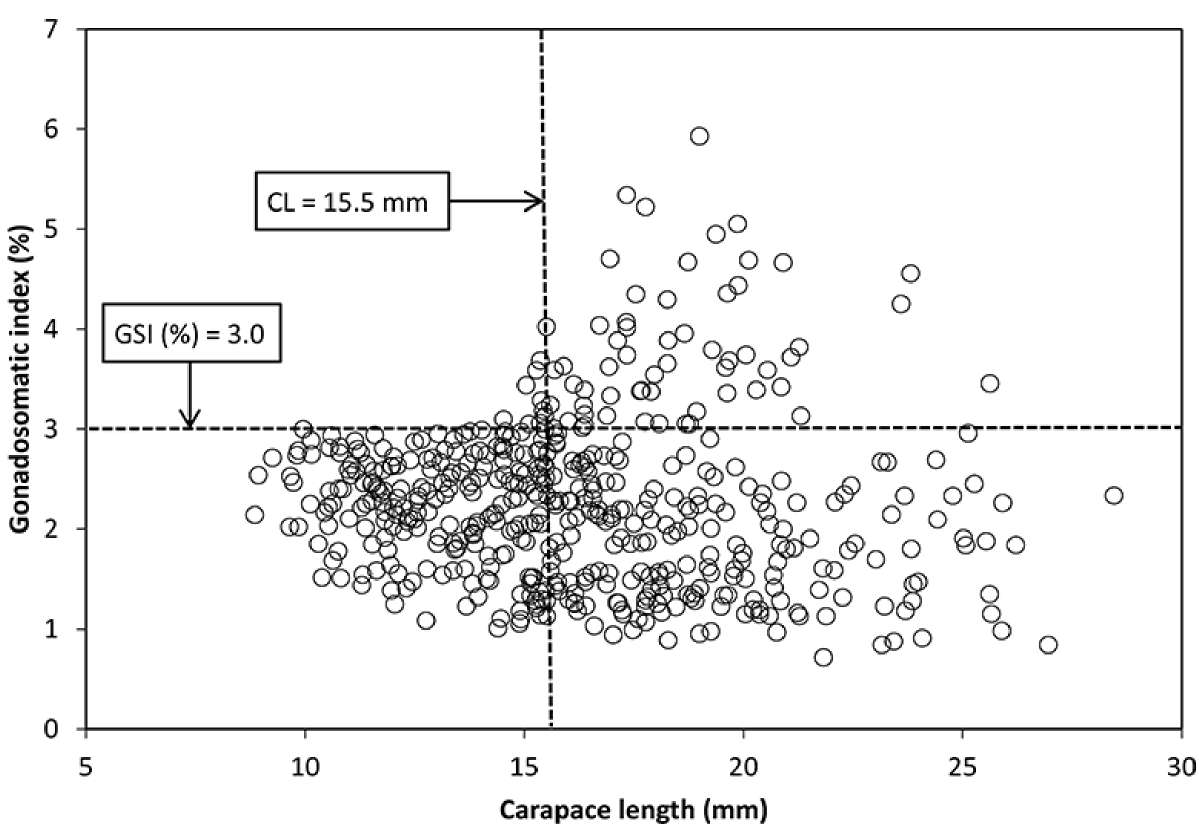

Figure 2. Relationship between gonadosomatic index and carapace length (mm) of female *Penaeus indicus* in the Andharmanik River.

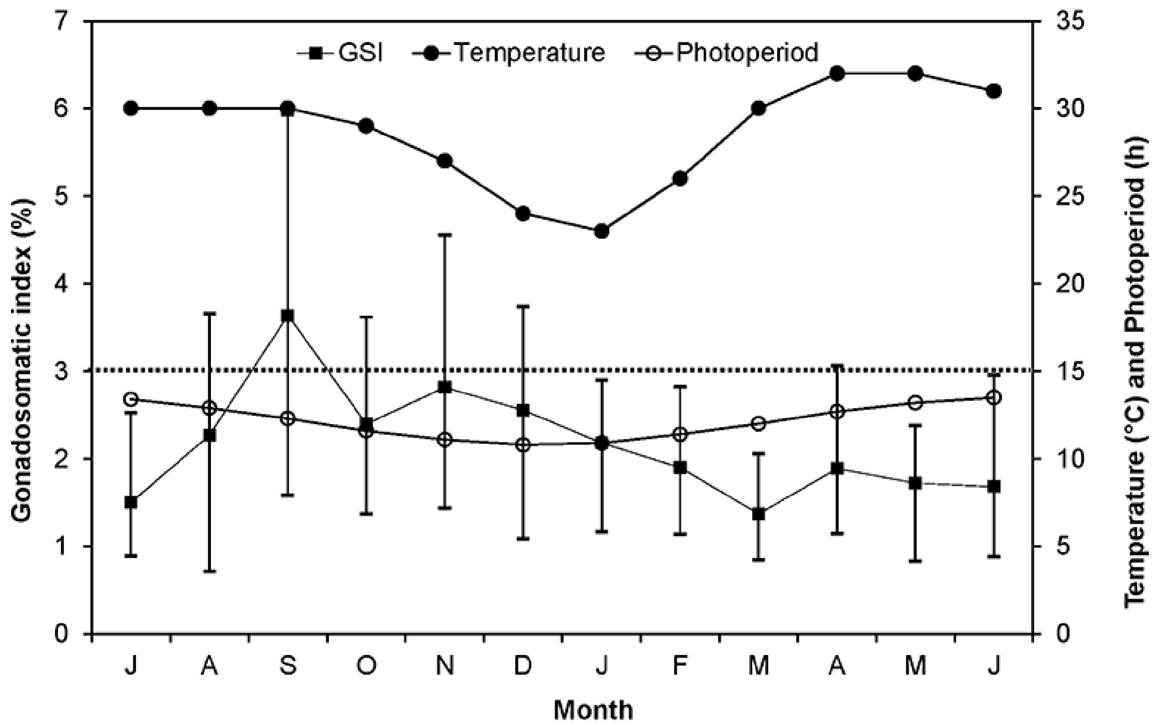

Figure 3. Monthly changes of mean gonadosomatic index (GSI) with minimum and maximum values of female *Penaeus indicus* in the Andharmanik River compared to average monthly variations of air temperature and photoperiod.

Recruitment pattern

The Bhattacharya (1967) method separated the length frequency data into three component normal distributions, each of which indicates a size group with their mean CL calculated (Fig. 4A). The mean length of the smallest size group, *i.e.*, 8.4 mm CL, was considered as the length at recruitment of *P. indicus* in the Andharmanik River where fishing occurred. The yearly recruitment indicated an extended pattern from October to May with two pulses, namely a minor recruitment pulse in November and a major recruitment pulse in February (Fig. 4B).

Growth analysis

The analysis of the length-frequency data by the Powell-Wetherall procedure gave an initial CL_∞ value of 32.0 mm and Z/K of 3.71 (Fig. 5). Using $CL_\infty = 32.0$ mm as a seed value, the ELEFAN I analysis yielded to an optimized von Bertalanffy growth curve with the following parameters: $CL_\infty = 31.9$ mm and K = 1.14 year^{-1}. We assumed that the value of the third parameter of the von Bertalanffy growth function t_0 is zero (Pauly and David, 1981). The computed growth curve using these parameters is shown over the restructured length-frequency distribution in Figure 6. The overall growth performance index (Ø') for *P. indicus* in the Andharmanik River was 3.06, and the longevity of this shrimp was 2.6 years.

Mortality and exploitation rate

From the length-converted catch curve (Fig. 7), we obtained Z = 3.53 year^{-1}. The average temperature in the Andharmanik River is 28 °C. The calculated value of M = 2.15 year^{-1} so the value of F = 1.38 year^{-1}. From the estimate of the fishing and total mortalities, the exploitation rate was calculated as E = 0.39 of *P. indicus* in the Andharmanik River.

Maximum sustainable yield

The plot of relative yield-per-recruit (Y′/R) and relative biomass-per-recruit (B′/R) against exploitation rate (E) using the knife-edge procedure of *P. indicus* in the Andharmanik River showed the maximum sustainable yield (E_{max}) = 0.42 (Fig. 8). The estimated value of $E_{0.1}$ and $E_{0.5}$ were 0.36 and 0.28, respectively.

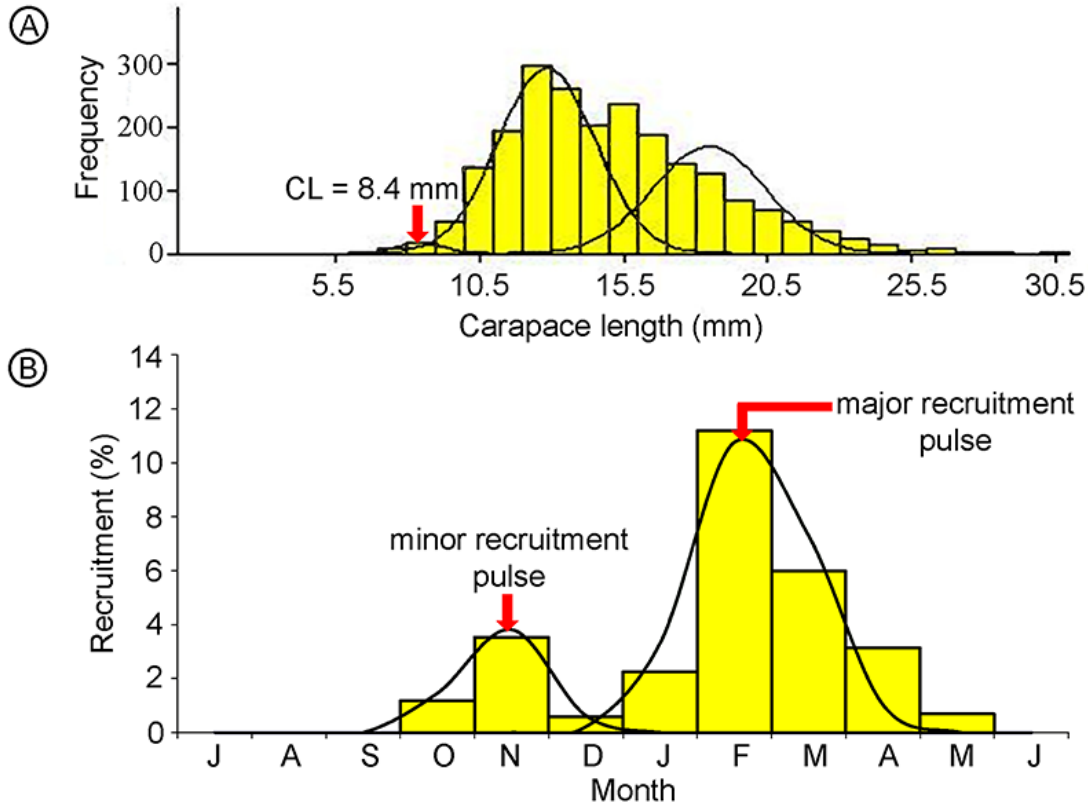

Figure 4. Length-frequency and recruitment patterns of *Penaeus indicus* in the Andharmanik River.

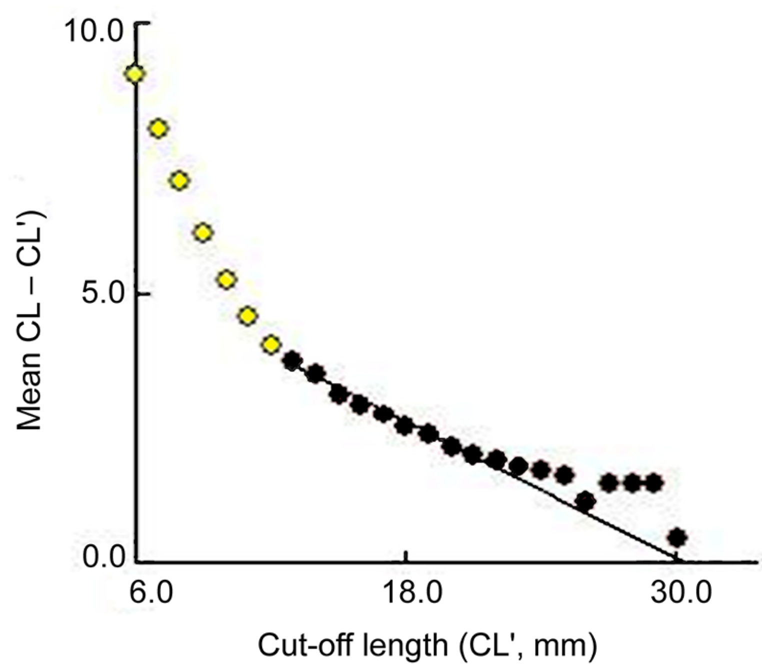

Figure 5. A Powell-Wetherall plot for *Penaeus indicus*. Solid black points are used in the regression (y = 6.43 - 0.21x, r = -0.982) which provides asymptotic CL_{∞} = 32.0 mm and Z/K = 3.71.

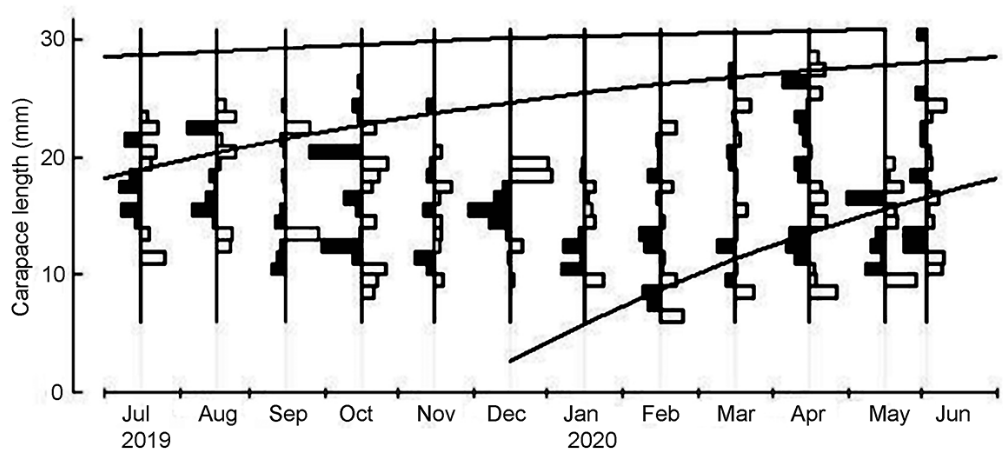

Figure 6. von Bertalanffy growth curve (CL_∞ = 31.9 mm, K= 1.14 $year^{-1}$ and Rn = 0.208) of *Penaeus indicus*, as superimposed over the restructured length-frequency histograms.

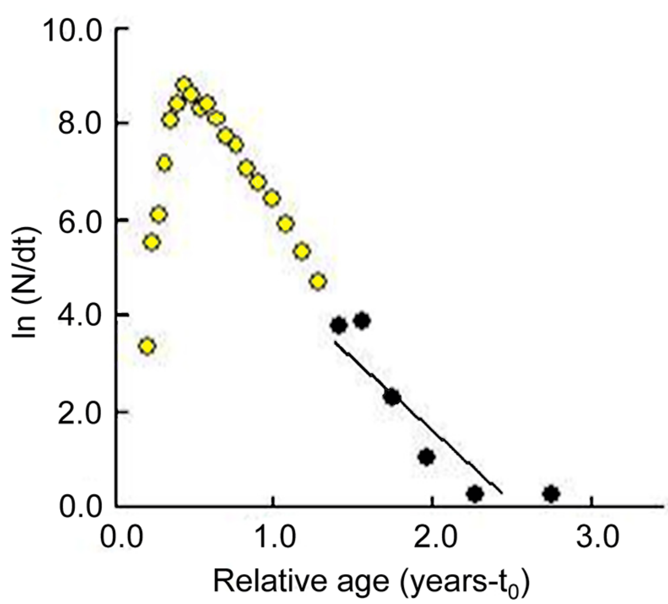

Figure 7. Length-converted catch curves for *Penaeus indicus* in the Andharmanik River. Data included in the regression are shown as black solid points.

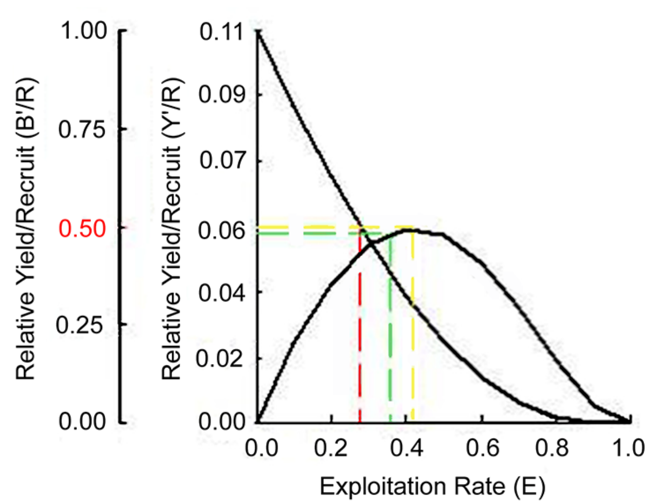

Figure 8. Relative yield-per-recruit (Y′) and relative biomass-per-recruit (R′) of *Penaeus indicus* in the Andharmanik River.

Discussion

To successfully manage an exploited fishery, it is imperative to study the population parameters, namely reproduction (*e.g.*, sexual maturity, spawning season), recruitment, growth, and mortality of the target species, which could be used either in estimating yield or providing a basis for fisheries management strategies. Determination of size at first sexual maturity is indispensable for fisheries management, as it has widely been used as an indicator for minimum permissible capture size of exploited stocks (Lucifora *et al.*, 1999; Vitale *et al.*, 2006). This information helps set mesh size of the gear to restrict catching of immature shrimps thus leaving the smallest mature shrimp to spawn at least once in their life-cycle (Chen *et al.*, 2014). The size at first sexual maturity of *P. indicus* in our study was 15.5 mm CL based on the relationship between CL and GSI. However, Champion (1988), Amanat and Qureshi (2011), and Henry *et al.* (2019) estimated the size at sexual maturity of this species based on the relationship between CL and percentage mature females using logistic regression (L_{m50}; the size at which 50 % shrimps are mature) as 18.0, 13.3, and 20.0 mm CL in the St Lucia Lake, South Africa; Sonmiani Bay, Pakistan; and Kilifi Creek, north-coast Kenya, respectively. The size at sexual maturity of the same species may vary in different habitats due to the divergent climatic and trophic parameters (Sinovcic and Zorica, 2006).

Penaeus indicus showed a prolonged spawning season with a single peak during the period August – December. Numerous studies, mostly from Indian waters, of the spawning season of *P. indicus* indicate lengthy spawning with 1 – 2 peaks. Like our study, a single spawning peak was reported by Subrahmanyam (1963) during March/May – September in Madras coast, India; Crosnier (1965) during March/April in Madagascar waters; Rao (1968) during October-April in Cochin waters, India; and Manisseri and Manimaran (1981) during July–October in Tinnevelly coast, Tamil Nadu, India. In contrast, two spawning peaks were reported by George (1962) during November – December and February – April in the backwaters of Cochin, India; George *et al.* (1963), during December – January and May – June in the coastal waters off Cochin, India; Devi (1986), during different times across years in the coastal waters off Kakinada, India; Jayawardane *et al.* (2002b), during March/April and July/August in the west coast of Sri Lanka; and Amanat and Qureshi (2011), during August – October and February – March in the Sonmiani Bay, Pakistan. The most vital environmental factors directly or indirectly influencing estuarine/marine invertebrate reproduction are temperature and photoperiod (Ohtomi, 1997; Lawrence and Soame, 2004). The seasonality of temperature and/or photoperiod is also important in ensuring that larvae emerge during the periods of abundant food supply (Lawrence, 1996), thus influencing the biological cycles of phytoplankton production. In our study, we found no significant, distinct pattern of temperature to explain the seasonality of spawning, though relatively high temperature (ranging from 23 to 32 °C) throughout the year of our study site may cause an extended spawning season of this species as reported by several studies (Kikuchi, 1966; Allen, 1966; Wear, 1974; Bauer, 1992; Oh *et al.*, 2002; Ahamed and Ohtomi, 2011). Nevertheless, a prolonged spawning season might also be a life-history adaptation for short life-span species (Bauer, 1989). In our study, the peak/main spawning season in August – December of this species was significantly associated with photoperiod lasting roughly from the summer solstice (longest daytime) to the winter solstice (shortest daytime), which is concordant with Ohtomi (1997) for *Plesionika semilaevis* Spence Bate, 1888 from Kagoshima Bay, Japan.

This study indicated that *P. indicus* underwent an extended recruitment pattern from October to May with two pulses: a minor recruitment pulse in November and a major recruitment pulse in February. Several studies reported a prolonged recruitment pattern of *P. indicus* with bimodal peaks; *i.e.*, Nissanka (1997) reported recruitment peaks in May and October from Rekawa Lagoon, Sri Lanka; Jayawardane *et al.* (2002b), in March and September from the Western Coastal Waters of Sri Lanka; and Saputra *et al.* (2019), between April – June and September – November from the coastal waters of Western central Java, Indonesia. Recruitment of the present study was synchronized with the main spawning season (August – December), with a time-lag of 2 – 3 months. The duration of this time-lag depends upon the time of spawning, as well as environmental and hydrologic conditions (George, 1962; Garcia and Le Reste, 1981; King, 1995).

The von Bertalanffy growth model fitted the data of *P. indicus* provided the best results of growth parameters based on the high score functions (R_n = 0.208) as: CL_∞ = 31.9 mm and K = 1.14 year^{-1}. Available information on growth parameters along with growth performance index (Ø') and longevity of *P indicus* from different studies are summarized in Tab. 1. Our estimated asymptotic length value was comparable with the value reported by Saputra (2008) in Segara Anakan Lagoon Cilacap central Java, Indonesia, and Saputra *et al.* (2019) in northern coastal waters of western central Java, Indonesia. However, our CL_∞ value exceeds the value reported by Nissanka (1997) in Rekawa lagoon, Sri Lanka but was lower compared with other studies. These differences in asymptotic length may be attributed to differences in environmental factors across habitats. The K-value in our study was in the midrange of several studies (Tab. 1) and fell within the range (0.39 – 1.6) reported by Pauly *et al.* (1984) for penaeid shrimps. In our study, the overall growth performance index Ø' for *P. indicus* is 3.06, which is very close to the value provided by Devi (1986) and Rao *et al.* (1993). Compared to the other studies our computed value was higher except for the value (3.87) provided by Mehanna *et al.* (2012) for coalesced sexes. The longevity of this shrimp was 2.6 years, which was higher than other studies (Tab. 1) and within the range reported by Garcia and Le Reste (1981) for penaeid shrimps as being 1.0 to 3.0 years.

Generally, shrimps are not long-lived crustaceans and their short lifespans imply high mortality rates (Caddy, 1996). Our calculated Z, M, and F values for *P. indicus* were 3.53, 2.15, and 1.38 year^{-1}, respectively. From the estimate of the fishing and total mortalities, the exploitation rate was E = 0.39 for *P. indicus* in the Andharmanik River. Compared to other studies on this species, our Z value was similar to the value 3.50 year^{-1} reported both by Saputra *et al.* (2019) from the northern coastal waters of western central Java Sea, and Agasen and Del Mundo (1988) from off Tinnevelly Coast, Tamil Nadu. However, our-Z value was lower than for Kakinada, India (Z = 9.42 year^{-1}) (Devi, 1986), the Manila Bay (Z = 4.66 year^{-1}) (Agasen and Del Mundo, 1988), the waters of Sofala Bank, Mozambique (Z = 4.95) (Silva and De Sousa 1992), the Rekawa Lagoon, Sri Lanka (Z = 4.93 year^{-1}) (Nissanka, 1997), the waters of Segara Anakan Cilacap (Z = 3.95 year^{-1}) (Saputra, 2008), and the Arabian Sea (Z = 6.81 year^{-1}) (Mehanna *et al.*, 2012). The high rate of total mortality is the result of the high rate of fishing mortality, indicating a high exploitation rate. Our computed exploitation rate (E = 0.39) is slightly below our predicted maximum sustainable value of E_{max} = 0.42. Thus, the fishing pressure on the stock is not excessive, and the situation does not demand management intervention. However, because this is an open-access fishery, caution should be taken about over-capitalization that could cause over-exploitation.

Table 1. Literature summary of the growth parameters (CL_∞ and K), along with growth performance index (Ø') and longevity (years) for *Penaeus indicus* in different habitats. (M = male, F = female).

<table>
<tr><th colspan="2">CL_∞ (mm)</th><th colspan="2">K (year^{-1})</th><th colspan="2">Ø'</th><th colspan="2">Longevity</th><th rowspan="2">Locality</th><th rowspan="2">Author/s</th></tr>
<tr><th>M</th><th>F</th><th>M</th><th>F</th><th>M</th><th>F</th><th>M</th><th>F</th></tr>
<tr><td>193.9*</td><td>197.7*</td><td>0.16</td><td>0.11</td><td colspan="2">–</td><td>1.5</td><td>2.0</td><td>Kerala, India</td><td>Kurup and Rao, 1974</td></tr>
<tr><td>227.2*</td><td>218.9*</td><td>1.80</td><td>2.00</td><td colspan="2">2.98</td><td>1.6</td><td>1.4</td><td>Kakinada, India</td><td>Devi, 1986</td></tr>
<tr><td colspan="2">41.0</td><td colspan="2">1.00</td><td colspan="2">2.63</td><td colspan="2">1.0</td><td>Manila Bay, Philippines</td><td>Agasen and Del Mundo, 1988</td></tr>
<tr><td colspan="2">44.3</td><td colspan="2">1.00</td><td colspan="2">2.70</td><td colspan="2">1.0</td><td>Punnaikayal, India</td><td>Agasen and Del Mundo, 1988</td></tr>
<tr><td colspan="2">42.1</td><td colspan="2">1.10</td><td colspan="2">2.70</td><td colspan="2">1.0</td><td>Munapad, India</td><td>Agasen and Del Mundo, 1988</td></tr>
<tr><td colspan="2">56.5</td><td colspan="2">1.80</td><td colspan="2">2.78</td><td colspan="2">2.0</td><td>Negombo & Chilaw, Sri Lanka</td><td>Jayakody and Costa, 1988</td></tr>
<tr><td colspan="2">219.6*</td><td colspan="2">1.58</td><td colspan="2">2.88</td><td colspan="2">–</td><td>West coast Sri Lanka</td><td>Jayawickrema and Jayakody, 1992</td></tr>
<tr><td>200.0*</td><td>230.0*</td><td>2.00</td><td>2.00</td><td colspan="2">3.02</td><td colspan="2">1.0</td><td>East coast of India</td><td>Rao et al., 1993</td></tr>
<tr><td>192.0*</td><td>199.0*</td><td>1.51</td><td>1.87</td><td>2.74</td><td>2.82</td><td colspan="2">–</td><td>West coast, Sri Lanka</td><td>Jayawardane et al., 2002A</td></tr>
<tr><td colspan="2">20.3</td><td colspan="2">1.00</td><td colspan="2">2.62</td><td colspan="2">–</td><td>Rekawa lagoon, Sri Lanka</td><td>Nissanka, 1997</td></tr>
<tr><td colspan="2">35.7</td><td colspan="2">1.26</td><td colspan="2">–</td><td colspan="2">–</td><td>Central Java, Indonesia</td><td>Saputra, 2008</td></tr>
<tr><td>57.1</td><td>68.6</td><td>2.11</td><td>1.69</td><td>3.84</td><td>3.90</td><td>1.0</td><td>1.5</td><td>Arabian Sea</td><td>Mehanna et al., 2012</td></tr>
<tr><td>37.0</td><td>38.5</td><td>0.97</td><td>0.85</td><td colspan="2">–</td><td colspan="2">–</td><td>Central Java, Indonesia</td><td>Saputra et al., 2019</td></tr>
<tr><td colspan="2">31.9</td><td colspan="2">1.14</td><td colspan="2">3.06</td><td colspan="2">2.6</td><td>Andharmanik River, Bangladesh</td><td>Present study</td></tr>
</table>

* Total length

Conclusions

This is the first comprehensive study of *P. indicus* from Bangladeshi waters. The species has a prolonged spawning season, with a single peak but recruitment occurs in two pulses. The life-span is ~2.6 years. The species is being exploited almost optimally, but no management intervention is needed now. However, if this fishery gets over-exploited in the future, then our findings could play an important role in formulating necessary management intervention.

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