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Ingression, abundance and settlement dynamics of Penaeid shrimp postlarvae in backwaters and adjacent tidal ponds in Cochin, India

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Abstract

Dynamics of penaeid postlarval ingression and settlement in the backwaters of Cochin were studied. Postlarval recruits were constituted by *Metapenaeus dobsoni* (70.8-78.4%), *Penaeus indicus* (17.5-24.6%), M. *monoceros* (3.8-4.6%) and *P. monodon* (0.3-0.4%). Their composition varied with location and season. Postlarval abundance and ingression were influenced by diel, tidal, lunar and seasonal factors. Ingression is mainly nocturnal in all species with nearly 84% of the activity during night hours. Abundance and ingression peaked up during high tides at night with major peaks coinciding with spring tides of full and new moon. It also followed a generalized seasonal pattern with two well-defined peaks for all species. It was pre-monsoon followed by post-monsoon for *P. indicus* and *M. monoceros* and post-monsoon followed by pre-monsoon for *M. dobsoni*. Sizes of the recruits were relatively small during pre-monsoon and post-monsoon and large during monsoon.

Key words: Penaeid shrimp, Ingression, Abundance, Backwater

Introduction

Penaeids during postlarval phase enter inland bays, estuaries and tidal ponds and utilise it as their nurseries. Earlier workers provided considerable information on the seasonal pattern of penaeid postlarval abundance in Cochin backwaters and adjacent areas (George 1962, Menon 1980, Suseelan and Kathirvel 1982, Easo and Mathew 1989, Mathew and Selvaraj 1993). However, only little is documented on the dynamics of migrating postlarvae from this region. Such information is useful for resource managers for formulating management and conservation measures. The present study was aimed to quantify postlarval ingression and to understand and evaluate various factors governing postlarval dynamics during their ingression into nursery grounds.

Materials and methods

Study was conducted in four tidal ponds and their feeder canals in Cochin backwaters. Sites selected were Edavanakkad, Kannamali, Panangad and Tripunithura located towards north, south and east of Cochin bar mouth. These sites were exposed to varying levels of marine and freshwater influence and hence have different ecological conditions. These enabled to study the influence of varying ecological conditions on postlarval ingression and settlement.

Migrating postlarvae were sampled by 'set-nets' made of 1 mm synthetic netting with 50 x 50 cm framed mouth and 1.2 m long body, as described by Staples and Vance (1985; 1986) and Haywood and Staples (1993). Set-net was operated against incoming flood tide in the intake channel to collect incoming postlarve and against ebb tide to collect those leaving the tidal ponds. Entire water column to a depth of 1.7-2.0 m was sampled by lowering and lifting the net vertically from surface to bottom. Calibrated flow meter (Arkon-make) measured the volume of water filtered by the net during sampling. Sampling frequency and sample sizes were decided statistically to accommodate diel, tidal and lunar influences (Alagaraja 1984). Abundance was estimated as number of postlarvae caught per unit volume of water filtered and ingression rate as number per unit time of sampling (Yokel *et al.* 1969).

Postlarval settlement was studied by sampling tidal pond population by vertically lifting circular lift nets (umbrella net), of 1.2 m diameter fitted with 2 mm netting, from tidal pond bottom (Cheng and Chen 1990) at randomly selected sites. A total of 27,609 postlarvae were collected for studying ingression and 16,044 postlarvae for studying settlement.

Data were subjected to hypothesis tests for means for paired observations, multiple regression analysis, analysis of variance and F-test (Snedecor and Cochran 1967). Arc sin values were used, wherever necessary, to stabilise extreme variances in the percentage values.

Results

Species composition

Postlarval recruits were constituted by *Metapenaeus dobsoni*, *Penaeus indicus*, *M. monoceros* and *P. monodon* (Table 1). *M. dobsoni* was most dominant, 70.8 to 78.4% of annual recruits at all areas. Their composition varied between 26.7% of the total recruits during May and 91% during October. Annual composition of *P. indicus* varied between 17.5 and 24.6% at different sites during the period. They form 6.2% of the total recruits in October and 60.3% in May. *M. monoceros* showed an almost uniform representation (3.8 to 4.6%) at all areas. They form 17.8% of the total recruits in April and were totally absent during August-September.

Table 1. Species composition (%) and average annual abundance (no/1000 m^3) of immigrating postlarval population at different tidal pond sites

Tidal pond & Location	*P. indicus* (%)	*P. monodon* (%)	*M. dobsoni* (%)	*M. monoceros* (%)	Abundance (no/1000 m^3)
Edavanakkad (F1)	23.0	0.3	72.8	4.0	387
Panangad (F2)	23.0	0.4	72.6	4.0	378
Tripunithura (F3)	17.5	0.3	78.4	3.8	350
Kannamali (F4)	24.6	0.3	70.8	4.3	418

Diel periodicity

Ingression was large during night hours ($p<0.01$), (Table 2). About 84.4% of the total ingression occurred during night hours. Relatively strong nocturnal activity was displayed by *M. monoceros* with 90% of the ingression during night hours. It was 84.6 and 82.8% respectively for *P. indicus* and *M. dobsoni.*

Table 2. Effects of diel, tidal and lunar cycles on postlarval ingression rate (no /10 min)

Particulars	*P. indicus*	*P. monodon*	*M. dobsoni*	*M. monoceros*	Total
a. Diel cycle					
Day (nos.)	10	2	30	2	44
(%)	(15.6)	(12.5)	(17.5)	(10.0)	(16.1)
Night (nos.)	54	14	141	18	229
(%)	(84.4)	(87.5)	(82.5)	(90.0)	(83.9)
(*t*-value)	*-4.2118*	-	*-4.5766*	*-5.663*	-
(*df*)	*5*	-	*5*	*5*	-
(*p*)	*0.0042*	-	*0.00298*	*0.0012*	-
b. Tidal phase					
Spring tide (nos.)	76	8	220	12	317
(%)	(86.4)	(88.9)	(84.3)	(92.3)	(85.2)
Neap tide (nos.)	12	1	41	1	55
(%)	(13.6)	(11.1)	(15.7)	(7.7)	(14.8)
(*t*-value)	*-9.4789*	-	*-3.5441*	*-2.4665*	-
(*df*)	*5*	-	*5*	*5*	-
(*p*)	*0.00011*	-	*0.00825*	*0.0284*	-
c. Lunar phase					
New moon (nos.)	47	6	122	7	182
(%)	(53.4)	(66.7)	(46.7)	(53.8)	(49.1)
Full moon (nos.)	41	3	139	6	189
(%)	(46.6)	(33.3)	(53.3)	(46.2)	(50.9)
(t-value)	*-3.177*	-	*-9.6746*	*-5.2243*	-
(df)	*5*	-	*5*	*5*	-
(p)	*0.0123*	-	*0.0001*	*0.0017*	-

Tidal periodicity

Postlarval abundance in tidal waters and ingression varied with tide phase. It was large for all species during spring tide (Table 2). Species differed in their response to tidal periodicity, but not at significant levels ($p>0.05$). In *P. indicus,* 86.6% of total ingression occurred during spring tide. Ingression rate varied between 76 PL/5 min during spring tide and 12 PL/5 min. during neap tide and abundance between 44 and 31 PL/500 m^3 of tidal water. In *M. dobsoni,* 84% of the ingression occurs during spring tide. Ingression rate varied between 220 and 41 PL/5 min and abundance between 139 and 121 PL/500 m^3 of tidal water during spring and neap tide respectively. *M. monoceros* also exhibited similar tidal periodicity with 92.3% of the ingression during spring tide. Ingression rate was 12 and 1 PL/5 min and abundance, 9 and 6 PL/500 m^3 of tidal water respectively.

Lunar periodicity

Abundance and ingression varied with the phase of moon (Table 2). Peak activity invariably coincides with new and full moon periods In *P. indicus* and *M. monoceros* large peaks associated with new moon phase, respectively accounting 53.4 and 53.8% of total ingression. Unlike these species, large peaks always coincided with full moon in *M. dobsoni*, accounting 53.3% of total ingression.

Spatial variation

Abundance and ingression varied with location of the site. It was large at areas near bar mouth and decreased gradually towards upper regions. Average abundance of *P. indicus* was 103 postlarvae/1000 m^3 of tidal water near bar mouth and 68 postlarvae 1000/m^3 at the farthest site studied. During May, the peak period of recruitment, their abundance was 251 and 163 postlarvae/1000 m^3 postlarvae respectively at these sites.

Similar abundance was observed for *M. dobsoni* and *M. monoceros.* Average abundance of the former was 296 postlarvae/1000 m^3 near bar mouth and 266 postlarvae 1000 m^{-3} at the farthest site. During November/December, peak period of their recruitment, abundance was 562 and 489 postlarvae/1000 m^3 respectively at these sites. In the case of *M. monoceros* average abundance was 16 and 10 postlarvae/1000 m^3 respectively near bar mouth and farthest site. Peak abundances at these sites were 37 and 26 postlarvae/1000 m^3 respectively.

Seasonal periodicity

Abundance and ingression varied widely over the season. Major influx of *P. indicus* occurred during pre-monsoon months and it accounts 44.4% of their annual ingression. Their peak abundance was recorded in May and minimum in August. Major influx of *M. dobsoni* was during post-monsoon months and it accounts 56.2% of the annual ingression. Peak abundance of the species was in November and minimum in August. In the case of M. *monoceros* peak was during pre-monsoon, followed by post-monsoon months. These respectively accounted, 49.0 and 41.8% of the annual ingression. Their peak abundance was in April and was almost absent during August and September. During peak monsoon ingression of all species were low and was restricted to areas close to bar mouth.

Postlarval settlement

Lift-net samples showed that postlarvae once entered tidal ponds or shallow calm areas, they settle down immediately before flow of tide reverses. Numbers of postlarvae moving out with ebb waters were negligible compared to their abundance in floodwaters. Their abundance varied between almost nil and 37 per 1000 m^3 of ebb water during different seasons.

Size at ingression

Size of the postlarval immigrants varied over the season (Table 3). Size of *P.indicus* immigrants varied between 10.9 and 18.4 mm. In the case of *M. dobsoni* it varied between

9.9 and 14.6 mm and *M. monoceros* 9.8 and 15.8 mm. Size of *P. indicus* and *M. monoceros* recruits were small during pre-monsoon and *M. dobsoni* during post-monsoon. It was comparatively large for all species during monsoon.

Table 3. Seasonal variation in the size (range and mean in mm) of postlarval recruits at ingression

Season	*P. indicus*	*P. monodon*	*M. dobsoni*	*M. monoceros*
Pre-monsoon	8.5-20.0 (11.3)	9.0-20.0 (11.7)	9.0-18.0 (10.8)	8.0-16.0 (10.6)
Monsoon	9.0-22 (14.9)	13.0-17.0 (14.6)	8.0-22.0 (12.8)	9.0-19.0 (13.9)
Post-monsoon	9.0-22.0 (12.4)	8.0-18.0 (13.6)	8.0-19.0 (10.0)	9.0-20.0 (11.1)

Environmental Influence

Environmental conditions of the study sites are given in Table 4. Influence of environmental parameters such as salinity, temperature, oxygen level, water pH, productivity and turbidity on postlarval ingression was tested statistically (Table 5). It showed that different environmental factors together descried 70.7% of the variation in ingression in *P. indicus,* 47.4% in *M. dobsoni* and 68.3% in *M. monoceros;* but not at statistically significant level ($p>0.05$). However, among the various factors, salinity had the largest influence on ingression in all species. *M. dobsoni* was more abundant during the periods of medium salinity (4-14 ppt) and *P. indicus* and *M. monoceros* during medium (4-15 ppt) and high 15-26 ppt) salinity. Abundance of all species declined during low salinity.

Table 4. Seasonal variation in the hydrographical conditions of the Cochin backwater (mean values in brackets)

Parameters/Season	Pre-monsoon	Monsoon	Post- monsoon	Mean & SD
Water temperature (°C)	28.8-29.7 (29.2)	26.9-28.4 (27.4)	28.2-29.9 (28.7)	28.4 (±0.78)
Salinity (ppt)	20.6-25.8 (23.41)	1.04-1.93 (1.34)	3.8-13.9 (7.16)	11.2 (±9.48)
Dissolved oxygen (ppm)	4.21-5.01 (4.64)	4.82-5.73 (5.26)	4.28-5.70 (4.93)	4.89 (±0.46)
Water pH	7.98-8.6 (8.34)	7.23-8.40 (7.46)	7.23-8.20 (7.48)	8.03 (±0.42)
Nitrate-N (μg at/l)	1.41-2.06 (1.59)	1.87-2.99 (2.32)	1.92-2.99 (2.41)	2.21 (±0.57)
Phosphate-P (μg at/l)	2.69-2.96 (2.74)	2.95-3.61 (3.24)	2.84-4.06 (3.53)	3.15 (±0.76)
Plankton (ml/m^3)	2.46-3.64 (2.98)	0.94-1.46 (1.27)	1.72-2.26 (1.98)	2.00 (±0.69)

Table 5. Results of multiple regression analysis and analysis of variance table for testing environmental influence on postlarval ingression

a. *P. indicus*			
Std. Error of Est.	60.0374	Adjusted R Squared	0.0365
R Squared	0.7068	Multiple R	0.8405
		Probability:	0.1637
b. *M. dobsoni*			
Std. Error of Est.	148.8553	Adjusted R Squared	0.1312
R Squared	0.4743	Multiple R	0.6887
		Probability:	0.4821
c. *M. monoceros*			
Std. Error of Est.	8.7262	Adjusted R Squared	0.3045
R Squared	0.6838	Multiple R	0.8269
		Probability:	0.2673

Discussion

Variation in abundance, ingression and recruitment of penaeid postlarvae in backwaters related to diel, tidal, lunar and seasonal rhythms and site location was observed. Recruitment of estuarine dependent animals into such habitats was governed by the ability of the young ones to negotiate inlets and ambient ecological conditions (Staples and Vance 1987). In nature, migrations are controlled by variations in salinity, currents, nycthermal and tidal rhythms (Laubier 1989). Ingression of penaeid postlarvae occurred in cyclic manner, with two peaks, coinciding with every new and full moon. Since tide and lunar phases become synchronous, it is difficult to separate their effects from each other. However, numerical superiority of *P. indicus* and *M. monoceros* during new moon phase than full moon and that of *M. dobsoni* during full moon phase, despite similar influence of tidal signals indicated interaction between lunar and tidal cues. Large peaks in postlarval abundance during new moon phase were observed by several workers (Staples and Vance, 1985; Barber and Lee, 1975; Natarajan *et al,*, 1986 and Goswami and Goswami 1992). However, Subrahmanyam, and Ganapati (1971) reported large peaks in abundance during full moon.

So it is to be assumed that abundance was influenced mainly by tidal signals, but modified by lunar signals. The variations observed between moon phases appear to be triggered by prevailing light intensity at the time of flood tides, as it modifies the vertical migration of postlarvae. So increased abundance and dispersal could be expected during new moon phase for species which prefer darkness and for others during full moon phase.

Penaeids being continuous breeders, their postlarvae and juveniles can be expected in the estuaries throughout the year. Under normal condition seasonal variation in reproduction is the major cause for seasonal fluctuation in postlarval ingression and abundance. During southwest monsoon abundance of postlarvae in backwaters declined. Present findings and earlier report of D'Incao (1991) suggested that, decrease in seawater ingression into the estuaries due to increased freshwater discharge during monsoon and the associated low salinity condition will act as a physical barrier limiting postlarval immigration. Spatial variations observed in ingression and abundance can also be attributed to the prevailing salinity of the areas.

Variations were observed in the size of recruits over the season with relatively small size for post and pre-monsoon recruits than monsoon recruits. This suggested rapid migration of postlarvae from spawning grounds into nurseries during those periods. As discussed above, obstructions caused by freshwater discharge delay their entry into estuaries and hence have large size at recruitment during monsoon.

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