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Demographic Characteristics of *Onychocamptus bengalensis* (Copepoda: Harpacticoida) – A Potential Live Feed for Aquaculture

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Abstract: Onychocamptus bengalensis (O. bengalensis) is an estuarine harpacticoid copepod. Its demographic features – such as a high reproductive potential, large brood size, long reproductive period, large female population, short generation time, and high survival rate – make it a potential live feed candidate for aquaculture. For the purpose of this study, the species was cultured in the laboratory. The results indicated that the duration of embryonic development was 3 days, the naupliar development 6-7 days, the copepodid development 3-4 days, the generation time 15 days, and the interclutch period 4 days. The females produced 8-10 clutches of eggs, each clutch with 8-53 eggs. From first nauplius to adult, O. bengalensis provides a broad spectrum of prey sizes (62 µm-760 µm in length). The culture in different salinities indicated that at 16ppt, it produced 32±2 eggs. The survival rate (91%) and lifespan (69±23 days) were highest at 24ppt. The culture of this species with different food media showed that the diatom medium resulted in larger brood size, a higher percentage of ovigerous females, shorter interclutch period, shorter generation time and a higher survival rate.

Key words: *Onychocamptus bengalensis*, harpacticoid, live feed, aquaculture.

Abstrak

Onychocamptus bengalensis ialah harpactikoid kopepod muara dan ciri demografinya seperti potensi tinggi dalam reproduksi, saiz mengeram yang besar, masa reproduksi yang panjang, populasi betina yang besar, masa kelahiran yang singkat dan kadar yang hidup tinggi menjadikannya sebagai potensi sumber makanan hidup bagi akuakultur. Spesies ini dikulturkan di dalam makmal dan keputusan menunjukkan bahawa jangka masa bagi perkembangan embrio adalah 3 hari, perkembangan *naupliar* adalah 6-7 hari, perkembangan kopepodid adalah 3-4 hari, jangka hayatnya 15 hari dan jangka masa ‘saling menggenggam’ adalah 4 hari. Betinanya menghasilkan 8-10 kelompok telur. Setiap kelompok mempunyai 8-53 biji telur. O. bengalensis daripada tahap *nauplius* hingga dewasa mempunyai pelbagai saiz iaitu sepanjang 62 µm -760 µm. Kultur dalam kemasinan air yang berbeza menunjukkan bahawa pada 16 ppt sebanyak 32±2 telur dihasilkan. Catatan paling tinggi yang hidup adalah pada kadar (91%) dengan jangka hayat (69±23 days) pada 24 ppt. Kultur dalam pelbagai media makanan yang berbeza menunjukkan bahawa medium diatom menghasilkan saiz yang lebih besar, kadar *ovigerous* betina yang lebih tinggi, masa ‘saling menggenggam’ yang lebih pendek, masa kelahiran lebih cepat dan kadar hidup yang lebih tinggi.

Kata kunci: Onychocamptus bengalensis, harpactikoid, makanan hidup, akuakultur

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Introduction

The availability of live food organisms with suitable size, density and high nutritional value is vital for the growth and survival of the early larval stages of most fish and crustaceans. Live food is superior to compounded feed, because it is readily ingested (Kinne 1977), more easily digested (Jirasek et al. 1977), does not affect the water quality (Watanabe et al. 1978) and have essential growth factors. Fish larvae generally grow better on living food than on non-living diets (Uhlig 1981).

Though the rotifer *Brachionus plicatilis* and the *Artemia* have been commonly used as prey during the early but critical periods in the life history of fish and crustaceans, they do not always promote optimal growth. Problems associated with them include nutritional deficiencies and inappropriate prey size (Leger et al. 1986). Alternative food sources that overcome these inadequacies and promote adequate growth are needed. Live food has to satisfy some basic aquaculture demands such as mass production of living food, controlled reproducible nutritional quality and simple low cost management (Kinne 1977).

The copepods tend to be rich in essential fatty acids, most notably 22:6ω-3 and 20:5ωn-3, that are deficient in some strains of *Artemia* (Norsker and Stottrup 1994). The copepod species for mass culture should possess the following demographic characteristics viz., higher reproductive potential, larger brood size, longer reproductive period, larger population of females, shorter generation time, shorter turnover time, faster growth rate and higher survival rate. Other important properties include a diet flexible enough to allow growth on a variety of food sources and tolerance of a wide range of physical environmental factors such as temperature and salinity (Sun and Fleeger 1995). Growth rate, body size, rearing temperature and fecundity of the species as well as the facilities to be used are important considerations for selecting the suitable copepod species for culture (Abu-Rezq et al. 1997).

For the aquaculture industry, mass rearing of copepods in intensive systems had little appeal in the light of the ready availability of *Artemia* cysts. However, economic appraisal of hatchery performance, using the two different feeding strategies (copepods vs. rotifers and *Artemia*) would be beneficial to this issue (Stottrup and Norsker 1997).

For the development of an intensive copepod cultivation system, harpacticoid copepods are preferred because calanoid copepods do not comply with maricultural demands, due to the relative low and instable biomass densities obtained so far. For this reason, increasing attention has been focused on various species of highly reproductive harpacticoid copepods (Uhlig 1984). Small neritic or estuarine harpacticoids are easier to rear than the larger, open sea species (James et al. 1986). Mariculturists have been increasingly interested in harpacticoid copepods. Some species have been thoroughly studied and also successfully mass cultivated, producing relatively high yields of living food (Hirata et al. 1979) and used for early developmental stages of marine fish (Rhodes 2003, Matias-Peralta et al. 2011). The life cycle characteristics of many harpacticoid copepods have been described in relation to temperature and salinity (Matias-Peralta et al. 2005, Zaleha and Jamaludin 2010) which showed species specific variations.

Saboor (2003) redescribed *Onychocamptus bengalensis* using scanning electron microscopy for the first time. The present work deals with the suitability of *O. bengalensis* as a live feed organism in terms of its demographic features and cultural characteristics.

Material and Methods

Onychocamptus bengalensis was collected from the plankton of Adyar Estuary, Chennai (Lat. 13° 00’48” N, Long. 80°16’35” E) where Adyar River meets the Bay of Bengal. It was maintained in the laboratory using filtered habitat water. Its behaviour was observed under a stereomicroscope. To study the life cycle, each pair of *O. bengalensis* that occurs in precopula stage was isolated from laboratory-reared stock to glass bowls containing 50ml of their habitat water. The habitat algae were offered as food and the experiment was carried out at room temperature (27 ± 3 °C) and 12 L: 12 D hours of photoperiod. The water was changed every three days to remove the waste and replenish the food. As soon as the pair separated, the male was withdrawn so as to observe the formation of next ovisac without remating. The female was observed at regular intervals for ovisac formation and hatching of nauplii. After the emergence of nauplii, the female was isolated. The naupliar and copepodite development was observed till their precopula stage. The pairs in copula were maintained separately and as soon as the male and female separated, the male was removed and the female was observed for the successive cycles till its death. Alternatively some females were maintained with their males to know the number of ovisacs formed in its life span. The demographic characteristics such as the time taken for sexual maturity, the duration of precopula stage, the ovisac formation, the incubation (egg to nauplius) period, the duration of naupliar and copepodite stages, the generatioin time (egg to egg), the interclutch period and the life span as well as number of ovisacs formed per female were noted following the procedure of Saboor (2003).

The method of Hagiwara (1995) was modified and adopted to determine the salinity for the growth of *O. bengalensis*. The harpacticoids were batch reared in salinities of 8, 16, 24 and 32 ppt at room temperature (27 ± 3 °C) with a photoperiod of 12 L and 12 D. They were fed with commercial yeast, *Saccharomyces cerevisiae* (0.1 mg/ml). For each experiment 10 pairs (precopula stage) were selected from the batch cultures in the four salinities. Each pair was transferred to a petridish filled with 10ml of water of the experimental salinities. Laboratory culture was attempted to know the effect of food on reproductive potential and survival rate. Four different food items in different concentrations were used, viz., 1) commercial yeast, *Saccharomyces cerevisiae*; 2) diatom (*Amphora ovalis*.); 3) shrimp meal (dried and powdered, < 200 µm) and 4) microencapsulated diet. The animals were maintained in glass bowls with 50ml filtered water (salinity 16ppt). Ovisac formation, number of eggs per ovisac, interclutch period, survival, generation time and life span were studied in each food regime. The experimental data was analyzed using One-way ANOVA followed by Duncan Multiple Range Test.

Results

The females of *O. bengalensis* measured 760 ± 23 µm and the males 612 ± 16 µm in length. This laophontid harpacticoid copepod occurring in the plankton of Adyar estuary was found to tolerate high and low salinity levels (euryhaline) and also low dissolved oxygen levels. These animals showed slow and smooth swimming movements. They showed vertical migration to the water surface during dark hours and to the bottom during intense light. The adults were negatively phototropic while the nauplii were positively phototropic.

O. bengalensis fed on different types of food materials such as detritus (vegetable/animal matter), yeast, algae and bacteria. It was observed that this animal survived for a long time in the absence of particulate food, which suggested that they might ingest liquid food also.

Life cycle

Soon after the moulting of fourth copepodid stage, mate-guarding process commenced in which the male clasped the female. This precopulatory mate guarding continued for 1-2 days. When the partners in this precopula became sexually mature after the final moult, the copulation took place which resulted in the transfer of spermatophore to the female.

The female produced the ovisac within a day and the male usually died after a day or two. Remating was not required for every clutch formation. The female produced about 10 successive clutches after a single mating. However, ovigerous females clasped by the males in precopula were also noticed. The duration of embryonic development (egg to nauplius) was 3 days.

Brood size

The average brood size increased from 20 numbers at 32ppt to 32 numbers at 16ppt. There were significant differences between the 24ppt and other salinities ($P \leq 0.05$). One way ANOVA showed salinity had effect on brood size.

Number of clutches formed in lifetime:

The mean number of clutches (ovisacs) formed by a female after a single mating was 7.8 at 8ppt to 9.8 at 24ppt. The difference was not significant.

Naupliar hatching success:

All the eggs present in the ovisac developed into nauplii irrespective of the difference in salinity. Therefore salinity (8-32 ppt) had no effect on the hatching process.

Survival:

Survival at 24ppt was highest. Salinity 8ppt was significantly different compared to other salinities ($P \leq 0.05$). One way ANOVA showed salinity had effect on survival rate.

Sex ratio:

The average percentage of females ranged from 61% to 71%. The salinity had no effect on the sex ratio.

Life span:

The mean life span of the females ranged from 35 to 69 days in different salinities. They had longer life spans at 24ppt than 16ppt, 8ppt and 32ppt.

Table 1. Culture of *Onychocamptus bengalensis* in different salinities

S. No	Salinity (ppt)	Female life span in days (Mean ± S.D)	Brood size (Mean ± S.D)	No. of ovisacs in life time (Mean ± S.D)	Survival rate (Mean ± S.D)	Sex ratio (No. of females/Adults)
1	8	41 ± 12	24.1 ± 4.15^a	7.8 ± 2.8	0.65 ± 0.09^a	0.70 ± 0.18
2	16	52 ± 7	32.0 ± 2.21^a	9.3 ± 2.3	0.65 ± 0.11^a	0.71 ± 0.15
3	24	69 ± 23	22.0 ± 3.92^b	9.8 ±1.3	0.91 ±0.05^b	0.61 ± 0.28
4	32	35 ± 10	20.0 ± 1.15^a	8.3 ± 1.8	0.35 ± 0.30^b	0.67 0.31

Values in same column with different superscripts are significantly different ($P \leq 0.05$).
a- significant difference when compared to 24ppt
b- significant difference when compared to 8ppt.

Brood size

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The mean life span of the females ranged from 35 to 69 days in different salinities. They had longer life spans at 24ppt than 16ppt, 8ppt and 32ppt.

Table 2. Culture of *Onychocamptus bengalensis* in different feeding regimes

S. No.	Food regime	Brood size (Mean±S.D)	% of ovigerous females (Mean±S.D)	Female sex ratio (Mean±S.D)	Inter clutch period in hrs (Mean±S.D)	Number of clutches (Mean±S.D)	Generation time in days (Mean±S.D)	Survival rate (Mean±S.D)
1	Yeast (0.1mg/ml)	35 ± 5.37^a	30 ± 6.86	0.6 ± 0.12^a	86 ± 3.65^a	8 ± 2.05^a	14.5 ± 1.65^a	0.90 ± 0.01
2	Diatoms ($2x10^5$cells/ml)	36 ± 10.28^b	50 ± 5.33	0.7 ± 0.11^b	72 ± 8.35^b	10 ± 1.76^b	14.0 ± 1.16^b	0.93 ± 0.02
3	Shrimpmeal (0.05mg/ml)	22 ± 9.18^a	30 ± 10.69	0.5 ± 0.20^b	88 ± 4.78^b	8 ± 2.00^b	14.2 ± 2.35^a	0.88 ± 0.03^b
4	Microencapsulated diet	0	0	0	0	0	0	0

Values in same column with different superscripts are significantly different ($P \leq 0.05$).
a- significant difference when compared to Diatoms
b- significant difference when compared to Yeast.

One-way ANOVA indicates that all the parameters show significant difference ($P \leq 0.05$).

Brood size:

The average number of eggs per ovisac ranged from 0 to 36 in different food regimes. Diatoms and yeast medium showed similar results. There was a considerable reduction of brood size in shrimp meal medium and complete absence of ovisac in micro-encapsulated diet medium. Yeast and diatom media show significant difference ($P \leq 0.05$).

Number of clutches:

In the total life span, the average batches of eggs produced by a female ranged from 8 (in yeast and shrimp meal medium) to 10 (in diatom medium) as the inter clutch period is short in diatom medium. Yeast medium is significantly different from diatom and shrimp meal medium ($P \leq 0.05$).

Interclutch period:

The period between formation of one ovisac to the next ovisac ranges from 72 hours in diatom medium to 86 hours in yeast medium and 88 hours in shrimp meal medium. There was no ovisac formation in micro encapsulated diet. Shrimp meal medium is significantly different from yeast medium ($P \leq 0.05$).

Naupliar hatching success:

The first three food media supported 100% hatching of nauplii whereas there was no ovisac formation in the micro encapsulated diet medium.

Survival ratio:

It is the ratio of the number of surviving adult to the number of nauplii hatched. Survival of the nauplii that reached the sexual maturity stage ranged between 88% and 93%. Shrimp meal medium is significantly different from yeast medium ($P \leq 0.05$).

Sex ratio:

The ratio of mature females to the total adult individuals was highest in diatom medium and reduced in yeast and shrimp meal. Diatom and shrimp meal media are significantly different from yeast medium ($P \leq 0.05$).

Percentage of ovigerous females:

The ratio of ovigerous females to the adult individuals was more in the diatom medium. The microencapsulated diet did not support the formation of ovisac. Yeast and shrimp meal showed lesser percentage than that in diatom medium.

Generation time:

The average time taken for an egg to become an ovigerous female (egg to egg) ranged from 14 to 14.5 days, without much difference in the first three food regimes. Diatom medium is significantly different from yeast and shrimp meal ($P \leq 0.05$).

Life span:

The average life is 52 days without much difference in various food regimes except the micro encapsulated diet (28 days), which did not support growth of the species.

Discussion

Harpacticoids appear to be suitable feed organisms for mariculture in many respects. Of particular importance are their tolerance to a wide range of environmental conditions, and their ability to utilize different food sources. Similarly their high reproductive capacity, their relatively short life cycle, and their ability to produce high population densities in appropriate culture systems are important (Uhlig 1984). Harpacticoids are less prone to infestations (Michajlow 1969). Harpacticoids have a relatively high caloric content per unit weight and superior nutritional value compared to many traditional food sources (Kahan et al. 1982 and Gee 1989).

Evidence suggests that harpacticoid copepods may serve as exceptional live prey for hatchery reared fish and crustaceans (Watanabe et al. 1983). Harpacticoids from first nauplius to adult provide a broad spectrum of prey sizes (80 to > 900 µm in length and up to 3-5 µg dry weight) suitable for ingestion by an equally broad size range of developing fish with small gapes (Gee 1989). *Artemia* may be too large to be suitable prey for many fish larvae or post-larvae with especially small gapes (Kahan 1981). Several harpacticoids are considered to be promising copepods for laboratory cultivation (Ikeda 1973).

Nutritional analysis by Watanabe et al. (1983) showed that the harpacticoid *Tigriopus japonicus* is high in polyunsaturated fatty acids, 20:5n3 and 22:6n3, that are essential to marine fish larvae (Fujii et al. 1976). Fish larvae fed on *T. japonicus* generally show higher viability than those fed on rotifers or *Artemia* (Kitajima 1978). *Nitocra affinis* contains a high level of protein, n-3 and n-6 HUFA, DHA and EPA (Matias-Peralta et al. 2011). Uhlig (1984) found that mass cultivation of the harpacticoid *Tisbe holothuriae*, could satisfy the requirements of mariculture. It can be easily cultured and it eats almost any kind of food. It has proved very useful as culture partner in cultures of benthic ciliates as well as invertebrates to clean the culture dishes from overgrowing microorganisms and various deposits (Uhlig 1981).

The *T. japonicus* is considered as the most promising food organism (Kitajima 1973) and has been widely mass cultured by aquaculturists in Japan to provide an intermediate size class of live food for larval fish (Fukuhara 1978) and it has been part of commercial rearing practices (Fukusho 1980). Zaleha and Jamaludin (2010) cultured *Pararobertsonia* sp. in different salinities and temperatures. In India also, attempts were made to mass culture harpacticoid copepods, to be used as live food. In 1977, Gopalan carried out the experimental mass culture of the harpacticoid, *Nitocra spinipes*. Goswami (1977) cultured *Laophonte setosa* on natural detritus, to offer as food to shrimp larvae.

A species should have certain demographic characters to become a suitable live food organism. *O. bengalensis* satisfies these aquaculture demands. It is a continuous breeder. Anatomical and histological studies on the male reproductive system of *O. bengalensis* indicate that the testis has high gonadal activity throughout the reproductive phase and females in different stages of oogenesis were observed in most of the samples (Saboor 2003). Within a day or two of the precopulatory mate guarding, copulation takes place. But it takes several days in other harpacticoids such as *Tigriopus fulvus* in which the male takes ten days to inseminate a female (Dussart and Defaye 1995).

O. bengalensis takes one day to produce an ovisac, as *Tigriopus californicus* (Powlik et al. 1997), whereas *T. fulvus* takes 2.6 – 3.1 days (Carli et al. 1989). The ovisac of *O. bengalensis* contains 45 ± 8 eggs while that of *Euterpina acutifrons* 43 ± 16 eggs (Saboor 2003). The number of eggs produced in a clutch of these species is more than those of some of the calanoids (Marshall and Orr 1972) and meiobenthic harpacticoids (Moorthy 2002). The diameter of the eggs of *O. bengalensis* (45 ± 8 μm) is little more than that of *E. acutifrons* (37 ± 6 μm).

The incubation period (egg to nauplius) is 3 days in *O. bengalensis*, 2.6 days in *T. fulvus* (Carli et al. 1989) and 1 – 4 days in *Tisbe* sp. (Vilela 1969).

In comparison with *Artemia* and *Brachionus,* the nauplii stages of *O.bengalensis* are of particular interest on account of their size range of 62 to 164 μm (first nauplius to sixth nauplius). Furthermore these nauplii swim around in the water and thus are attractive to early fish larvae. They have the potential as a first feed organism due to its availability in the water column, fish larval survival and growth.

The total length of first nauplius of *O. bengalensis* is 62 μm which was much smaller than that of *Artemia* nauplius (450 μm). In fact the nauplii of *O. bengalensis* are smaller than the nauplii of many harpacticoid species. For example nauplii of *T. fulvus* are 125 μm in length (Carli and Fiori 1977), *Tisbe cucumariae* 72 μm (Dahms et al. 1991), *E. acutifrons* 107 μm (Goswami 1976), *Paraleptastacus brevicaudatus* 67 μm (Dahms 1990), *Drescheriella glacialis* 77 μm in length (Dahms 1987). The small size is highly suitable for the commercially important finfish and shellfish larvae with small gapes.

The larval growth in *O.bengalensis* was faster than some other species of harpacticoids, probably due to its ambient temperature and its genetic constitution (Saboor 2003). The total duration of naupliar development in this species from hatching to sixth nauplius was 6-7 days whereas it was 10 days in *T. californicus* (Powlik et al. 1997) and *E. acutifrons* (Goswami 1976). Moreover the copepodite developmental duration of *O. bengalensis* was only 3-4 days, which was very less when compared to *T. fulvus* having 6 days and *T. californicus* (Powlik et al. 1997) 11 days. This faster growth was one of the important essential characters required for the use as live feed organism.

The sex ratio in *O. bengalensis* was 0.63 but in *T. japonicus* it was only 0.44 (Hagiwara et al. 1995). This female dominant population of *O. bengalensis* will increase the amount of nauplii produced.

The interclutch period (period between formation of ovisac to next ovisac) in *O. bengalensis* was 4 days, whereas in *Tisbe* it was 3.5 days (Vilela 1969), in *Amphiascoides atopus* it was 3–4 days. The period from the hatching to the formation of next ovisac was just one day in *O. bengalensis* but it was 2.3 – 2.6 days in *T. fulvus* (Carli et al. 1989). The number of clutches produced in the life span of *O. bengalensis* is 10. In *Tisbe* the number is same (Vilela 1969) whereas it is 6 in *T. fulvus* (Pane et al. 1996). However, *T. japonicus* produced 11–15 clutches, but after the reproductive period, the ovisacs did not mature or they produced 1–4 nauplii only.

The generation time (egg to egg) in *O. bengalensis* was 15 days whereas it was same in *Tisbe* (Vilela 1969) and 21 days in *T. californicus* (Powlik et al. 1997). This shorter generation time would result in higher population growth.

Lifespan of *O. bengalensis* female was about 52 days. However the lifespan of *T. fulvus* was 76 days and *T. japonicus* was 56 – 101 days.

O. bengalensis being an estuarine harpacticoid, tolerated a wide range of salinity and was not affected even by lower salinities. However marine harpacticoids are more affected by lower salinities as in the case of *P. fulvofasciata* (Dahms 1991). Like other harpacticoids such as *Cleotocamptus dietersi* (Dexter 1995) it also produced all life history stages in different salinities. The ease at which *O. bengalensis* was cultured in the lab at various salinities, without the presence of sediment, suggested it as a good candidate for aquaculture. It can be raised for an unlimited number of generations in the lab.

The maximum lifespan of female of *O. bengalensis* in the laboratory culture experiment was 69 ± 23 days in 24ppt salinity whereas *T. japonicus* (Hagiwara et al. 1995) required 32ppt for longer lifespan which was 101 ± 50 days. The maximum brood size (32 ± 2.21 eggs) in *O. bengalensis* was obtained in 16ppt salinity whereas *T. californicus* produced a maximum number of only 17 ± 4.2 eggs in 20 – 25pt (Powlik et al. 1997). However, *T. japonicus* produced the maximum number 52 ± 6.6 in 32ppt (Hagiwara et al. 1995). *O. bengalensis* formed maximum number of clutches (9.8) in 24ppt salinity, whereas *T. japonicus* spawned 11-15 times. However after the reproductive period the ovisacs did not mature in *T. japonicus* (Hagiwara et al. 1995). In the present experiment all the eggs of *O. bengalensis* hatched into nauplii in all the experimental salinities and the survival of those that reached maturity was highest (91 %) at 24ppt. In the case of *T. japonicus* the maximum survival (84 %) was at 32 ppt (Hagiwara et al. 1995). The sex ratio showed that the highest number of females (71 %) in 16ppt, whereas in *T. japonicus* it was highest (44 %) in 32ppt. Harpacticoids are generally tolerant to environment fluctuations but they do have temperature and salinity optima, and these will be species- and strain- dependent (Cutts 2003).

Harpacticoids feed on all types of foods. In the present laboratory culture experiment it produced the highest (36) number of eggs per ovisac, when fed with the diatom, *Amphora ovalis*. However, *Nitocra spinipes* produced only 10 – 20 eggs in a brood when fed with detritus and phytoplankton (Abraham and Gopalan 1975), *T. japonicus* produced 52 eggs when fed with *Tetraselmis tertathele* (Hagiwara et al. 1995). The strain dependent variations in egg numbers have been reported in harpacticoids (Zaleha and Jamaludin 2010). Female sex ratio (0.7) as well as percentage of ovigerous females of *O. bengalensis* (50 ± 5.33) was highest in diatom food regime. However, *T. brevicornis* produced the higher number of ovigerous females with mixed diet (Vilela 1984). The interclutch period of *O. bengalensis* was minimum in the diatom medium, whereas it was 72 to 96 hours in *A. atopus* with *Chaetoceros muelleri* and artificial fish food (Sun and Fleeger 1995). *O. bengalensis* fed with diatoms produced more number of clutches as seen in *Tisbe* sp. (Vilela 1969). However, *T. japonicus* produced 11–15 clutches in *Tertraselmis tetrathele* medium in its lifetime (Hagiwara et al. 1995). The generation time was about 14 days in *O. bengalensis* in yeast, shrimp meal as well as diatom media. It was same in *T. brevicornis* fed with *Platymonas suecica*, *Nannochloris*, artificial food and vegetables (Vilela 1984) and also *T. holothuriae* fed with dried mantle meat of *Mytilus edulis*. Naupliar hatching success of *O. bengalensis* was 100 % with yeast, diatom and shrimp meal food media. The survival rate was highest (93 %) with the diatom diet, whereas the nauplii of *T. furcata* showed only 50 % survival rate with *Skeletonema costatum* diet, 30–40 % with *Rhinomonas reticulata* and only 20–30 % with *Paulova lutheri* (Abu-Rezq et al. 1997). The average lifespan is 52 days in *O. bengalensis* in yeast, diatom and shrimp meal diets. However, it is 90 days in *A. atopus* fed with *Chaetoceros muelleri* and commercial fish flake food (Sun and Fleeger 1995) and 101 days in *T. japonicus* with *Tetraselmis tetrathele* diet (Hagiwara et al. 1995).

Conclusion

The present study suggests that *O. bengalensis* possesses all the required demographic characteristics such as higher fecundity, larger brood size, shorter interclutch period, longer reproductive period, shorter generation time and higher survival rate. Its size, from nauplius to adult, is suitable as a starter zooplanktonic live food organism for commercially important shell fish and fin fish. It also satisfies the basic aquacultural demands. The euryhaline nature, the survival at low oxygen levels and the adaptability to laboratory conditions make this species an ideal candidate for aquaculture.

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