Effect of salinity on the larvae of an edible estuarine crab
*Thalamita crenata* (Crustacea, Decapoda, Portunidae)

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Tolerance of the larvae of *Thalamita crenata* to salinity stress was studied in the laboratory at different salinities ranging from 5 to 40 × 10\(^3\). Complete larval development from hatching through metamorphosis to first crab instar occurred only in salinities from 20 to 35 × 10\(^3\). Though 3% of the larvae at 40 × 10\(^3\) were able to moult up to zoea V instar, they did not successfully moult to megalopa stage. The total duration for the successful completion of larval development was 34.63, 26.66, 25.31 and 31.75 days respectively in the salinities of 20, 25, 30 and 35 × 10\(^3\). There was a variation in the development rate of larvae at different salinities, i.e. 0.029, 0.038, 0.40 and 0.031% respectively in the salinities of 20, 25, 30 and 35 × 10\(^3\). The salinity tolerance was ranged from 20 to 35 × 10\(^3\) and optimum salinity was found to be 30 × 10\(^3\).

Although the study of salinity tolerance of the brachyuran crabs has been started as much earlier as 1944 for the temperate species\(^5\), only recently it has gained its momentum in the tropical waters\(^4\). Hence the present study was attempted to find out the influence of salinity on development rate, survival and the optimum salinity for each larval developmental stage of the edible estuarine portunid crab *Thalamita crenata* (Latreille), which has potential for coastal aquaculture.

Ovigerous females of *T. crenata* (Crustacea: Decapoda:Portunidae) were collected from the Vellar estuary and maintained individually in the laboratory in plastic troughs containing estuarine water of salinity 30±1 × 10\(^3\) and a controlled temperature 27±1°C. They were fed with shrimps and clam meat and the water was changed daily until the eggs hatched into zoea. The larvae were tested at 8 different salinities\(^6\) of 5, 10, 15, 20, 25, 30, 35 and 40 × 10\(^3\). The tests were conducted by using small glass finger bowls containing 100 ml water and 10 larvae per bowl. Hundred larvae were subjected to each test salinity in the range 5 to 40 × 10\(^3\). Hence freshly hatched larvae were separated into 8 groups of 100 individuals each. Three groups of larvae were placed directly in bowls containing seawater of salinities 25, 30 and 35 × 10\(^3\). The other groups were gradually acclimated in steps of 5 × 10\(^3\), for 2 hours to their final rearing salinities: 40, 20, 15, 10, 5 × 10\(^3\). Each treatment was carried out in 10 bowls, with 10 larvae reared in each glass bowl. Experimental salinities were obtained by filtering seawater (35 × 10\(^3\)) and diluting it with glass-distilled water. Seawater of 40 × 10\(^3\) was obtained by evaporating seawater.

Daily counts of exuvia and surviving larvae were noted down. The larvae were transferred daily to clean bowls containing freshly filtered seawater of the same salinity. Newly hatched Brazilian strain of *Artemia* nauplii was added to each bowl as larval feed, and each day freshly hatched *Artemia* nauplii were given. Experiments were terminated when all larvae had either moulted to first crab instar or died.

Intermoult period varied among larval stages of *T. crenata* in different test salinities. Table 1 summarizes the intermoult period of different stages of larval development at various salinities tested and mortalities (%) at different stages of development. The zoea I showed a decrease in the intermoult duration (7.00±0.00 to 3.68±0.47 days) with increasing salinities from 15 to 40 × 10\(^3\). But in the lower salinities of 15 × 10\(^3\) no zoea I was metamorphosed to the subsequent larval stage.

Whereas the zoea IV, V and megalopa showed a
Table 1—Intermoult period (days) of different stages of *Thalamita crenata* larval development at various salinities (mortality in % is provided in parenthesis)

<table>
<thead>
<tr>
<th>Developmental stage</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoa I</td>
<td>7.00±0.00</td>
<td>4.70±0.66</td>
<td>4.77±0.75</td>
<td>4.00±0.45</td>
<td>3.80±0.75</td>
<td>3.68±0.47</td>
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<tr>
<td></td>
<td>(97)</td>
<td>(27)</td>
<td>(16)</td>
<td>(23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zoa II</td>
<td>4.36±0.61</td>
<td>3.69±0.46</td>
<td>3.71±0.67</td>
<td>3.71±0.45</td>
<td>3.22±0.43</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>(4)</td>
<td>(14)</td>
<td>(3)</td>
<td>(59)</td>
<td></td>
</tr>
<tr>
<td>Zoa III</td>
<td>3.50±0.50</td>
<td>3.55±0.58</td>
<td>3.11±0.32</td>
<td>3.61±0.92</td>
<td>3.46±0.88</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(9)</td>
<td>(4)</td>
<td>(15)</td>
<td>(5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zoa IV</td>
<td>3.75±0.97</td>
<td>3.51±0.50</td>
<td>3.26±0.44</td>
<td>3.74±0.44</td>
<td>5.00±0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(20)</td>
<td>(15)</td>
<td>(3)</td>
<td>(17)</td>
<td>(10)</td>
<td></td>
</tr>
<tr>
<td>Zoa V</td>
<td>5.32±0.62</td>
<td>3.51±0.95</td>
<td>3.68±0.54</td>
<td>5.39±0.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(20)</td>
<td>(5)</td>
<td>(10)</td>
<td>(12)</td>
<td>(3)</td>
<td></td>
</tr>
<tr>
<td>Megalopa</td>
<td>13.00±0.00</td>
<td>7.63±0.48</td>
<td>7.55±0.62</td>
<td>11.50±0.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(34)</td>
<td>(5)</td>
<td>(5)</td>
<td>(10)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

reduction in the intermoult duration in the salinities from 20 to $40 \times 10^3$. But for zoa II and III, though the same trend was observed for the salinities from 20 to $35 \times 10^3$ the intermoult duration was further decreased in $40 \times 10^3$ salinity.

*Survival*—As the salinity increases the larvae survived only for 2 h, 24 h and 12 days in 5, 10 and $15 \times 10^3$ respectively (Fig. 1). Up to $15 \times 10^3$ salinity, all the larvae (zoa I) died showing different percentage of mortality and survival duration in the salinities of 5, 10 and $15 \times 10^3$. In $20 \times 10^3$ salinity, overall 99% of the larvae died before metamorphose into the first crab instar. Further in the higher salinities of 25, 30 and $35 \times 10^3$, the larvae completed their metamorphosis into I crab instar with a percentage of survival of 44%, 79% and 46% respectively. Whereas in $40 \times 10^3$ salinity, no larvae survived to complete metamorphosis (Table 1).

*Development*—From the results it is evident that no metamorphosis was recorded in 5 and $10 \times 10^3$ salinity (Fig. 2). In $15 \times 10^3$ salinity also minimum (3%) number of individuals only metamorphosed to zoa II, but no further development could be seen. In the salinities of 20, 25, 30 and $35 \times 10^3$, the development was complete in different percentage (Table 1) and the total duration for complete development was 34.63, 26.66, 25.31 and 31.75 days respectively. The time taken for complete metamorphosis of 25.31 days was observed in $30 \times 10^3$ salinity. But in the $25 \times 10^3$ salinity one extra zoael stage (zoa VI) has appeared which did not moult to megalopa stage. In the highest salinity of $40 \times 10^3$ no larvae survived to complete metamorphosis. The development was noticed only up to the zoa V stage.

*Optimum salinity*—The optimum salinity for each zoael stage and megalopal stage varies (Fig. 2). The optimum salinity or range of salinity for the zoa I was $35 \times 10^3$, for zoa II was 30-$35 \times 10^3$, for zoa III was $30 \times 10^3$, for zoa IV was $30 \times 10^3$, for zoa V was 25-30 $\times 10^3$ and for megalopa was 25 to $30 \times 10^3$. However, the larvae...
in $30 \times 10^3$ salinity show high development and survival rate and hence the $30 \times 10^3$ salinity was found to be the optimum salinity for the complete larval development of *T. crenata*.

*Thalamita crenata* breeds from April through September, as berried females were collected during this period. In Vellar estuary the water salinity ranges from $30 \times 10^3$ in April to $35 \times 10^3$ in September. Laboratory experiments on the salinity of hatching of eggs of *T. crenata* showed that it can release larvae in waters of the salinity ranging 25-35 $\times 10^3$. The tested salinities from 5 to 40 $\times 10^3$ show a strong influence of salinity on the larval survival and development rate.

Larval mortality in low salinity (5 to 20 $\times 10^3$) is possibly due to imbalance in osmoregulatory mechanism. Gills are the important site of active ion-transport in adult decapods. Larvae lack gills or develop gills in the penultimate or ultimate zoeal stages. Most crabs do not develop gills until the penultimate or ultimate zoeal stage and megalopal stage of the families Xanthidae, Grapsidae, Ocypodidae and Portunidae possesses well-developed gills. The presence of these potential salt absorbing tissues would be advantageous for the survival of larval and postlarval forms in low salinities, occurring in estuaries or more brackish and freshwater environments. Larvae with advanced morphological features (e.g. gills) could experience greater survivorship and development in low salinities. Salinity tolerance of larvae without necessary osmoregulatory tissues and/or regulatory mechanisms is more restrictive and survivorship lowers beyond a limited range. Larval susceptibility to low salinity can be a major limiting factor in the distribution of a species.

Mortality at higher salinity ($40 \times 10^3$) is likely to be due to the inability of the larvae to osmoregulate and it is also suggested that since larvae lack a heavy exoskeleton, hyper-osmoticity in all salinities may be necessary to provide turgor pressure to insure integrity of the thin larval cuticle. Mortality at high and low salinities may perhaps be attributed to osmotic stress, i.e. rupture of cells at low salinity due to hyperosmosis and shrinkage of cells at higher salinity.

Development at low salinity is slower, which is probably due to increased rate of excretion. At stressful salinity (both higher and lower salinities) protein is used as a source of energy. The crustacean larvae have protein as the major portion of their biochemical composition. Utilization of dietary and body protein as energy source diverts this resource from growth to maintenance needs. Thus development is delayed at stressful salinities. Development at higher salinity is quicker because high salinity may accelerate decomposition of the cuticle which is little quicker in the tropics owing to high temperature.

Variation in the number of zoeal stages or the appearance of supernumerary zoeal stages in $25 \times 10^3$ salinity is probably the result of non-uniform rates of internal growth coupled with a more or less regular moulting cycle, malfunction of endocrine systems in the larvae, poor feeding (with poor feeding, longer time is needed to reach the post-larval stage, which at the same time will often increase the number of larval stage), environmental factors, laboratory-induced factors and inherent variability.

In the natural environment, the larvae of this species may escape from unfavourable dilute media by sinking to deeper water layers of high salinity as a kind of avoidance behaviour. Further it appears to be a general response of decapod larvae to low salinity stress. The zoea V and megalopa of this species have a range of salinity tolerance i.e., $25-30 \times 10^3$ may be due to the well-developed gills. Similar pattern of tolerance of low salinity by the later stages of development, viz., megalopa has been reported in *Callinectes sapidus* and *Neopipesarma (Neopipesarma) mederi*. The salinity requirements of a species may change with the stage in its life history.
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