*Asian Fisheries Science* **19**(2006):331-347
ISSN: 0116-6514
https://doi.org/10.33997/j.afs.2006.19.4.002

Asian Fisheries Society, Manila, Philippines

# Abundance and Distribution Patterns of *Scylla* spp. Larvae in the Lawele Bay, Southeast Sulawesi, Indonesia

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## Abstract

A study on the dynamics of the zoeae larvae of *Scylla* spp. was conducted in Lawele Bay, Southeast Sulawesi from November 1999 to September 2000, to determine the spatial and temporal patterns of abundance of the zoeae larvae of *Scylla* spp. and to examine their relationship with water parameters. Sampling was done during flood and ebb tides using a modified miller net high speed sampler with 300 μm mesh. Temperature, salinity and pH were measured at the surface and taken parallel to each plankton haul. The results showed that zoeal abundance was higher during flood tide than ebb tide. Seasonal abundance of the zoeae had three peaks belonging to the dry season (south monsoon), one in March as minor peak and the other two in June and in November as major and moderate peaks, respectively.

Water salinity and pH were significantly correlated with zoeal abundance in the respective flood and ebb tides ($p < 0.05$). Zoeal abundance decreased toward less saline waters, and were absent at low salinity stations (0.3 – 17.3 ppt). Our results suggest that zoeal prefer seawater for development to the megalopal stage.

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# Introduction

Mating of adult mud crabs *Scylla* spp. usually occur in estuaries, after which mature females move out of the inshore estuarine area to spawn in seawater (Arriola 1940; Hill 1974). The planktonic larvae of mud crabs (zoeae) develop in seawater, and after the fourth molt, reach the postlarval stage called the megalopae (Sin 1966).

Ingress of brachyuran megalopae to estuaries can be facilitated by selective tidal stream transport (Dittel and Epifanio 1990; Little and Epifanio 1991). This mechanism involves rhythmic increases in swimming activity such that they move to the surface on flood tide currents and then return to or near the bottom on ebb tides (De Vries et al. 1994). Such rhythms in activity might be due to megalopal responses to changes in environmental variables associated with the tidal phase, such as pressure, temperature, salinity, and current speed (De Vries et al. 1994). However, the influence of currents and water circulation seems to be the most important factor in determining the horizontal distribution of the larvae (Ingles and Braum 1989). Among other larval crustaceans, wind-driven surface water may transport in the movement of larvae from offshore to coastal region (McConaugha 1992; Watanabe et al. 1992; Johnson 1995; Johnson and Perry 1999). Since zoeae of *Scylla* spp. are sensitive to high temperature and low salinity (Hill 1974; Lavina 1980), they cannot survive in estuaries. At the Ragay Gulf, Philippines, Ingles and Braum (1989) found relatively low abundance of zoeae of the *Portunus pelagicus* (15 ind•100 $m^{-3}$), whereas upstream with low salinity, no zoeae was collected.

Many studies have examined the abundance and distribution patterns of crab larvae in relation to hydrological parameters (e.g. Ingles and Braum 1989; Mense and Wenner 1989; Dittel and Epifanio 1990; Little and Epifanio 1991; Watanabe et al. 1992; De Vries et al. 1994; Lochmann et al. 1995; Johnson and Perry 1999), but none focused on larvae of *Scylla* spp. The purposes of this study are to investigate the spatial and seasonal variation in abundance of *Scylla* spp. larvae, and to examine the effects of water paremeters on their abundance.

# Materials and Methods

The study was carried out in the Lawele Bay, Southeast Sulawesi, Indonesia (Fig. 1). Six stations were established in different areas that have varying salinity and turbidity. Stations 1, 2, 3, and 4 were located along the Lawele River and near the mouth of the river, whereas stations 5 and 6 were situated in seagrass beds near a coral reef area.

Two samplings during day time were conducted monthly for 10 months using a modified miller net high speed sampler with 300 µm mesh. This sampler has a 20-cm diameter pipe mouth, 100-cm pipe length, 20-cm diameter net mouth and 100-cm net length. The sampler was towed for about 10 - 20 min following a uniform towing speed of three knots. Water volume sampled was calculated following Epifanio et al. (1984). Plankton samples were fixed in 4% buffered formalin solution in seawater immediately upon collection. Temperature, pH, and salinity were measured and taken parallel to each plankton haul. The samplings were done during flood and ebb tide in the day time.

Identification was made in the laboratory following the larval descriptions of Sin (1964) and Lavina (1980). Only number of individuals belonging to each zoeal stage were counted, while plankton were seperated . The number of individuals per tow was standardized by the volume of water filtered (presented as ind•$100m^{-3}$).

The density of zoeae was determined using the following equation: $D = n(100)\bullet V^{-1}$; $V = 2\pi r^2 d$; $d = Rt$; where D is the density of zoeae in ind•$100m^{-3}$, n is the number of zoeae identified, V is the volume of water sampled in $m^3$, r is the radius of sampler, d is the tow distance, R is the boat's speed in knot (1 knot = 1 NM•$h^{-1}$), and t is the duration of tow.

Seasonal abundance was calculated using all the samples collected from all stations during the sampling period, while spatial abundance was calculated using all the samples collected from each station. Differences in zoeal abundance among months and stations during flood and ebb tides were analyzed using one-way ANOVA (Zar 1984). Duncan multiple range test (DRMT) was used when significant differences were detected. Simple regression analysis was used to find out the correlation of zoeal abundance with water parameters.

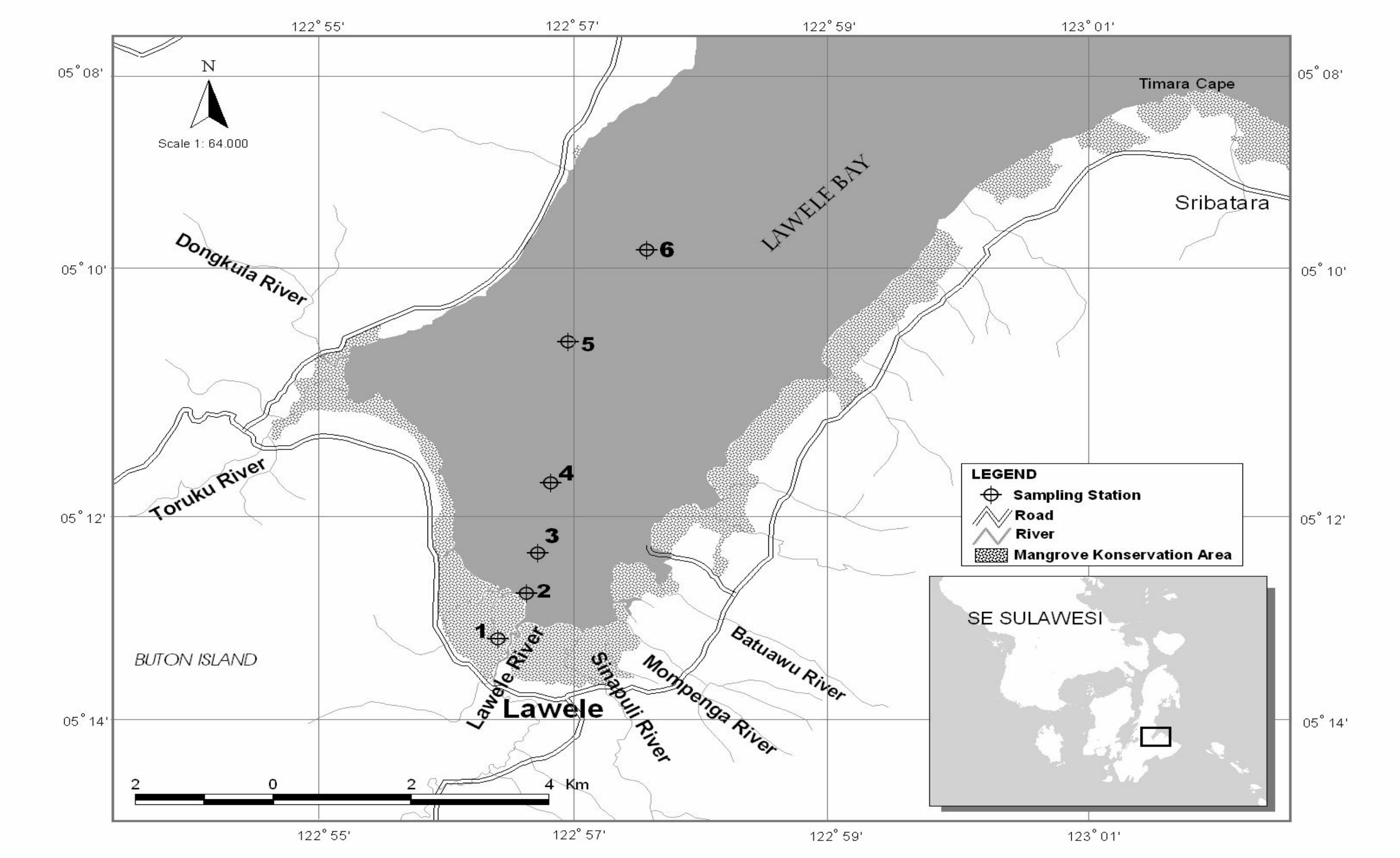

Fig. 1. Sampling stations of mud crab *Scylla* spp. zoeae in Lawele Bay, Southeast Sulawesi

# Results

## *Water parameters*

Stations 1 and 2 had low salinity of 0 – 6 ppt. Water depth depended on tidal cycle and season. It was 3 – 5 m deep during flood tide in dry season and 4 – 6 m in rainy season. During ebb tide, water depth may drop to 2 – 4 m. Since the bottom of the river was littered with toppled trees making sub-surface sampling difficult, sampling was limited to surface tows during times of low water depth.

Stations 3 and 4 were partly influenced by river outflows resulting in wide salinity fluctuations. Water depth ranged from 20 – 30 m. Occasionally, salinity was high during flood tide and dropped to moderate during ebb tide. Stations 5 and 6 which were near seagrass bed and coral reef areas represented seawater condition. Water depth was more than 40 m.

Temperature and pH during flood and ebb tides fluctuated in narrow ranges at all stations throughout the year (Figs. 2 and 3). During flood and ebb tides, temperatures ranged from 27.3 to 31.7ºC and from 27.0 to 31.3ºC, respectively, while pH ranged from 6.96 to 8.40 and from 6.43 to 8.20, respectively. Salinities fluctuated with respect to tidal cycle, sampling station and season. During flood and ebb tides, it ranged from 0 to 33.3 ppt and from 0 to 34.7 ppt, respectively (Fig. 4). The lowest salinity during flood and ebb tides was at Station 1. During the rainy season (November to early March), salinity dropped to 0 ppt particularly at Stations 1 and 2 (Fig. 4).

The highest salinity recorded during flood and ebb tides were at Stations 5 and 6 (Fig. 4). These stations were directly influenced by seawater. However, salinity occasionally dropped to moderate levels (17 ppt ) during the rainy season when there was riverine flooding. Stations 3 and 4 had the greatest variance in salinity, ranging from freshwater to over 30 ppt.

## *Seasonal abundance of Scylla* spp. *zoeae*

Five zoeal stages of *Scylla* spp. were collected during this study. The megalopae stage was not collected during our sampling periods. The

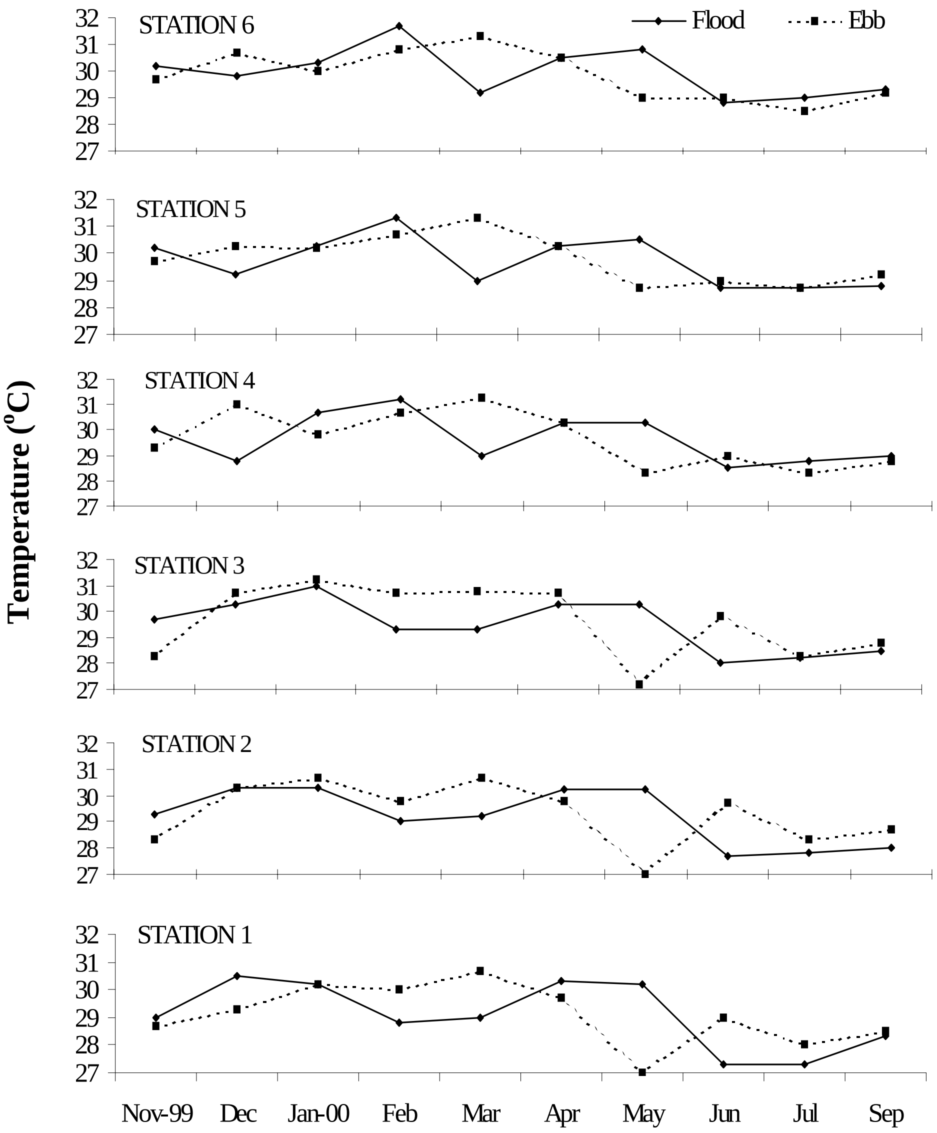

Fig. 2. Temperature fluctuation during flood and ebb tides in Lawele Bay, Southeast Sulawesi

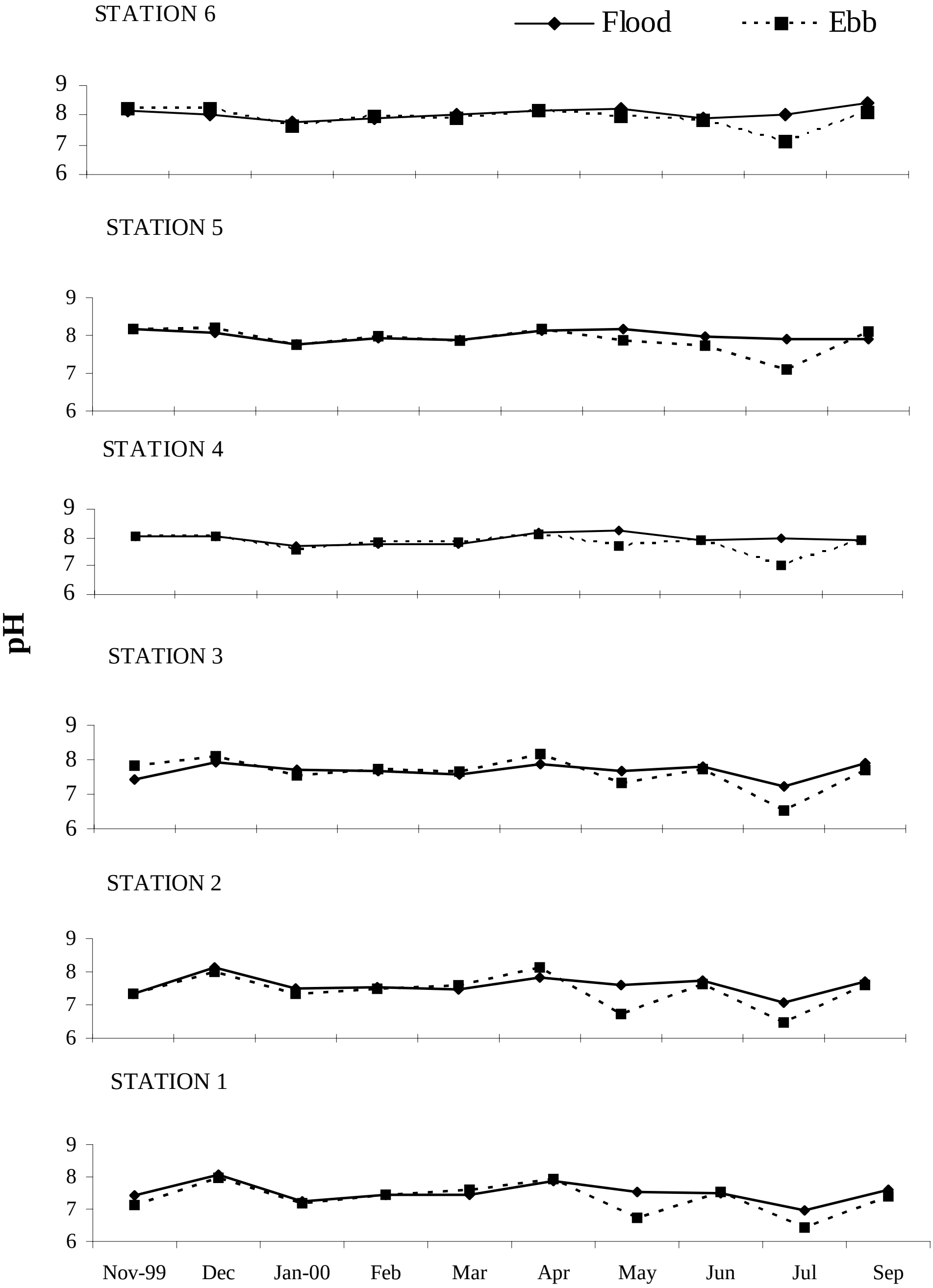

Fig. 3. pH fluctuation during flood and ebb tides in Lawele Bay, Southeast Sulawesi

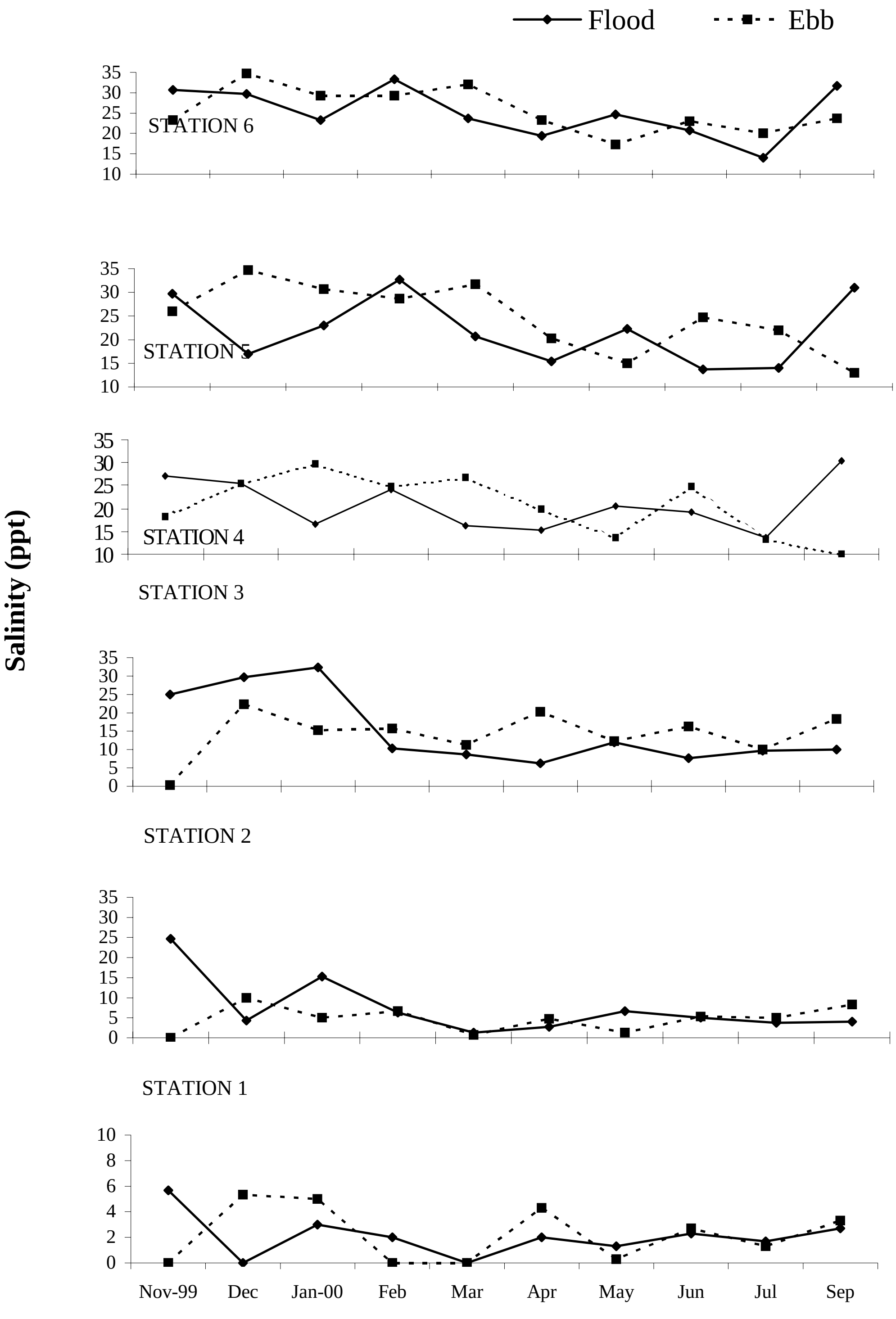

Fig. 4. Salinity fluctuation during flood and ebb tides in Lawele Bay, Southeast Sulawesi

relative abundance of zoea was consistently higher during flood tide than ebb tide (Fig. 5). General trends in abundance were very similar over time and differed only in values. There were three peaks of zoeal abundances, first in March (just at the beginning dry season) with a relatively minor peak of $36.66 \bullet 100m^{-3}$, second in June (dry season) with a relatively high peak of $66.09 \bullet 100m^{-3}$ and third in November with a moderate peak of $47.81 \bullet 100m^{-3}$. Months of low relative abundance were in January ($6.63 \bullet 100m^{-3}$) and in May ($5.93 \bullet 100m^{-3}$). The zoeal abundance were significantly different among months during flood and ebb tides ($p < 0.05$). The DMRT shows the differences of zoeal abundance between months during flood tide and ebb tide (Fig. 5). Correlation of zoeal abundance with water parameters was calculated. However, only salinity during flood tide ($r = 0.74$) and pH during ebb tide ($r = 0.68$) showed significant correlation to the zoeal abundance ($p < 0.05$).

### *Spatial distribution of Scylla spp. zoeae*

In the six stations surveyed, zoeal crabs were mainly collected at Stations 3, 4, 5 and 6. Zoeae were conspicuously absent in the riverine area (Stations 1 and 2). The highest zoeal abundance were at Stations 5 and 6 with $38.41 \bullet 100m^{-3}$ and $43.67 \bullet 100m^{-3}$ during flood tide, and $19.07 \bullet 100m^{-3}$ and $26.12 \bullet 100m^{-3}$ during ebb tide, respectively, and decreased at Stations 3 and 4 with $34.96 \bullet 100m^{-3}$ and $32.15 \bullet 100m^{-3}$ during flood tide, and $9.97 \bullet 100m^{-3}$ and $13.83 \bullet 100m^{-3}$ during ebb tide, respectively (Fig. 6). However, the abundance of zoeae was not significantly different among stations during flood tide ($p > 0.05$), but significantly different during ebb tide ($p < 0.05$). The zoeal abundance at Stations 4, 5 and 6 differed significantly with Station 3, while at Stations 4, 5 and 6 there were not significantly different. Similar results were found at Stations 3 and 4.

## Discussion

### *Seasonal abundance of Scylla spp. zoeae*

The seasonal zoeal abundance of *P. pelagicus* correlated with the seasonality of spawning (Ingles and Braum 1989). However, this cannot be proven for *Scylla* spp. in Lawele Bay because no study has been undertaken yet. The results of this study showed that only zoeae were present, while megalopae were not caught. The absence of megalopae may be due to the shallowness of the water levels sampled (0.5 - 3.0 m). Water

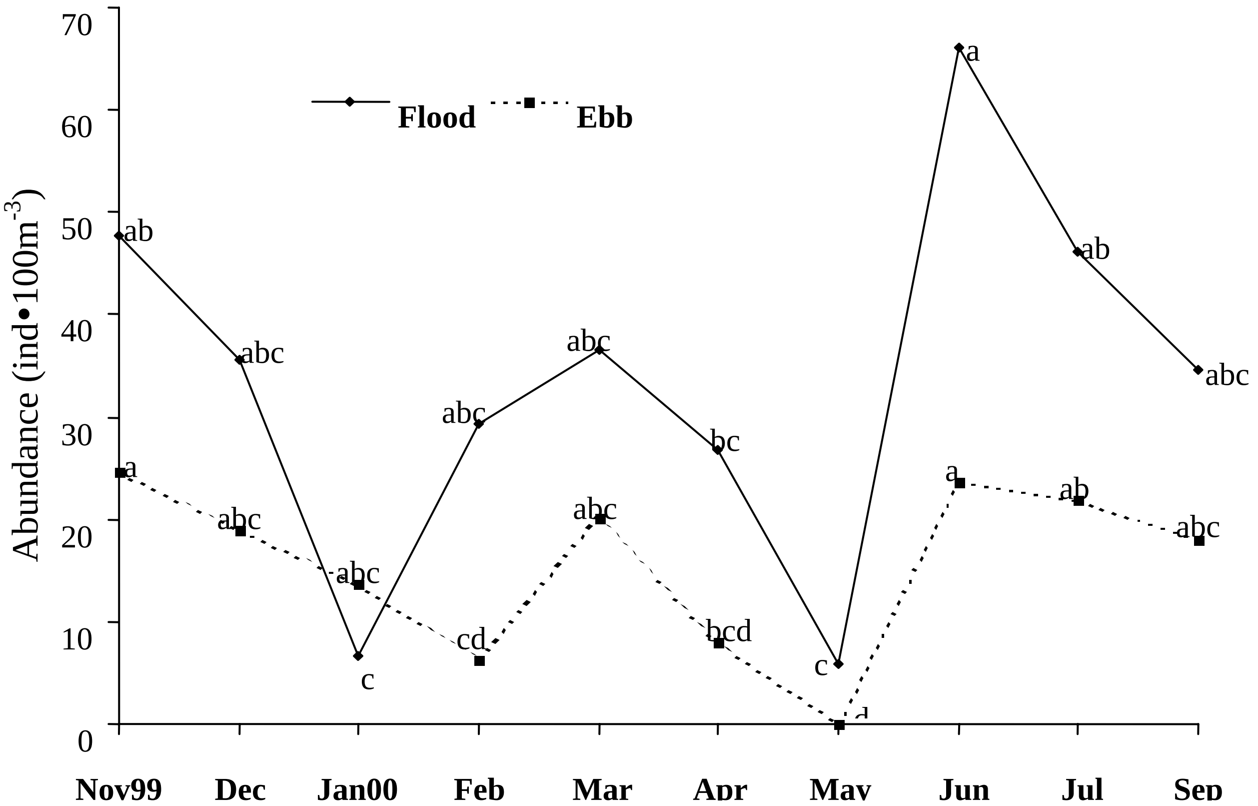

Fig. 5. Seasonal abundance of *Scylla* spp. zoeae during flood and ebb tides from all sampling stations in Lawele Bay, Southeast Sulawesi. The zoeal abundance collected at each month were combined from all stations. Points on the same line are not significantly different

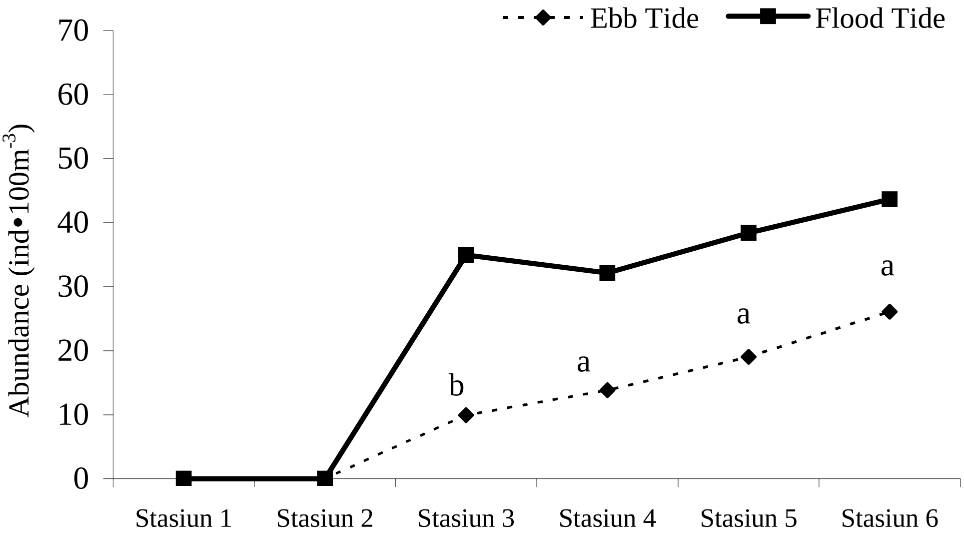

Fig. 6. Spatial distribution of *Scylla* spp. zoeae during flood and ebb tides in Lawele Bay, Southeast Sulawesi. The zoeal abundance collected at each station were combined from all months. Points on the same line are not significantly different.

depth at Stations 5 and 6 was deeper than 40 m, while at Stations 3 and 4 it ranged from 20 – 30 m, where megalopae were not caught by the gear. Another explanation is that megalopae may have an ecological niche found outside the study area, or because zoeae may have been transported away from the parental habitat (Johnson 1985; McConaugha 1992). For instance, wind stress provides an opportunity for blue crab larval dispersion offshore (Johnson and Perry 1999). Laboratory studies showed high mortality rates during early larval stages of *Scylla* spp. (Sin 1964; Djunaidah et al. 1998; Baylon et al. 2001).

Seasonal abundance of zoeae showed three peaks, a minor peak in March, a moderate peak in November and the major peak in June (Fig. 5). The zoeal abundance between flood tide and ebb tide was significantly different. This seasonal trend in abundance may represent the number of mature females with berried eggs that move offshore areas to spawn (Arriola 1940; Sin 1966; Hill 1994). Based on reproduction and larval development (Motoh 1977; Dittel and Epifanio 1990), the peak seasons of zoeal abundance in March and June suggest that mating and spawning of *Scylla* spp in Lawele Bay takes place in months prior to these peaks namely in January, February, April and May.

The peak season of spawning of *Scylla* spp. in Lawele Bay differed with the other regions (Table 1). In tropical estuaries, periods of peak productivity correlate to peak abundance of food organisms available to potential spawners. It generally coincides with summer periods of high nutrient input, i.e. periods of monsoon or cyclonic rainfall (Heasman et al. 1985). However, this may not always be the case. In the present study, the predicted spawning season was from early north monsoon (rainy season, January) to mid north monsoon (dry season, May). The study on *P. pelagicus* showing seasonality of larval catches correlated well with the abundance of berried females (Ingles and Braum 1989) indicating the main breeding population of this species is found within the study area. In Lawele Bay, some berried *Scylla* spp. were obtained swimming away from the study area of about 20 km near a fish aggregating device. Similar results showed that berried crabs migrate 18 to 20 km offshore where their eggs hatch into zoea (Arriola 1940). This might cause the newly hatched masses of eggs or zoeae to spread away from the study area following the current and other physical oceanographic processes (Provenzano et al. 1983; Epifanio 1988; Ingles and Braum 1989; McConaugha 1992; Luckenbach and Orth 1992; De Vries et al. 1994; Tankersley and Forward 1994). Wind-driven process can also spread eggs or zoeae away from spawning areas (McConaugha 1992; Watanabe et al. 1992; Epifanio 1995; Johnson 1995; Johnson and Perry 1999). For instance, wind-driven current carry *C. sapidus* larvae away from potential settlement sites (Epifanio 1995).

High natural mortality of zoeae causes low abundance of postlarva. For instance, salinity and temperature are the main water parameters affecting survival of the zoeae (Sin 1964; 1966; Hill 1974; Baylon et al. 2001). Only 50% of the larvae survived exposure to 17.5 ppt salinity with a temperature of 22.5 to 25ºC, while salinity lower than 14 ppt at a temperature of 15 to 35ºC, almost 100% of the zoeae died (Hill 1974). Laboratory study showed that all zoea2 (Z2) and zoea4 (Z4) larvae were dead after 24 h and 48 h exposure to 12 ppt, respectively (Baylon et al. 2001).

It indicates that zoeal stages of some species are not tolerant of low salinity and high temperatures. In the present study, water temperature showed narrow fluctuations ranging between 27.0 to 31.3°C, while pH was higher than 7.0. Salinity had high fluctuations depending on station and season. Salinity decreased during rainy season as measured at Stations 1, 2 and 3. During this period, zoeal abundance decreased gradually and

Table 1. Reported spawning activity of *Scylla* spp. from different regions

| Location | Latitude | Total spawning season | | Peak spawning activity | Reference |
|---|---|---|---|---|---|
| | | Months | Seasons | | |
| Philippines | 15°N | All months | All seasons | May to September | Arriola (1940)<br>Pagcatipunan (1972) |
| India | 13°N | All months | All seasons | December to February | Pillai & Nair (1968) |
| Thailand | 12°N | Not known | Not known | July to December | Varicul et al (1972) |
| Hawaii | 20°N | Not known | Not known | May to October | Brick (1972) |
| South Africa | 34°S | November to March | Late spring to early autumn | Not known | Hill (1975) |
| Moreton Bay | 28°S | September to March | Early spring to early autumn | November to December | Heasman et al (1985) |
| Lawele Bay | 5°S | All months* | All seasons* | January to May** | Present study |

*based on Fig. 5

**prediction based on Fig. 5

reached low abundance from January (just at the end of rainy season) to February (intermonsoon). The low zoeal abundance may be partly correlated with low salinity (Hill 1974) which was caused by heavy rainfall. Salinity as well as pH were significantly correlated with zoeal abundance ($p < 0.05$). Several studies have revealed the significant effect of rainfall on the abundance of larval crustaceans. For example, migrations of *Penaeus merguiensis* postlarvae were also lower during high rainfall periods, hence low salinity, than during dry periods (Staples and Vance 1985). In the present study zoeae were not found in the riverine area with low salinity of 0.3 - 17.3 ppt. This suggests that low salinity might not be suitable for zoeae. Therefore, low abundance in May was probably influenced by low salinity (0.3 - 17.3 ppt). Alternatively, the major peak of abundance in June correlated with salinity that was still in seawater condition.

## *Spatial distribution of Scylla spp zoeae*

Most brachyuran larvae are incapable of overcoming advective transport by horizontal swimming (Johnson and Gonor 1982). However, vertical migration during flood tide would allow larvae to move into an estuary against a net seaward flow (Johnson and Gonor 1982; Epifanio et al. 1984). The horizontal distribution of blue crab *C. sapidus* larvae at the bay entrance of Chesapeake Bay and surrounding shelf waters was found at the mouth of the bay, while intermediate stages were detected offshore (McConaugha et al. 1981). In the present study, the results showed a decreasing zoeal density toward less saline waters as showed by salinities at Stations 5 and 6 namely 13.7 – 33.3 ppt with relative abundance of $92.54 – 124.78•100m^{-3}$ during flood tide and $44.53 – 55.80•100m^{-3}$ during ebb tide and then density decreased at Station 3 where salinity ranged from 0 to 5.67 ppt. Baylon et al. (2001) reported that high mortality of zoea larvae when transferred to lower salinities of 12 and 16 ppt from 32 ppt. Salinity lower than 14 ppt caused an almost 100% death of zoea1 (Z1) *S. serrata* (Hill 1974). The ability of crustaceans to adapt to a habitat with fluctuating salinity is determined by their capability to either regulate or conform to the osmolality inside their body with that of the medium (Gilles and Pequeux 1983).

## Conclusion

Although there are studies on *Scylla* spp. zoeae that reveal toleration to relatively low salinity, our study shows that survival and development of zoeal stages require high salinity of water in the ocean. This also reflects the life cycle of *Scylla* spp., where berried females migrate from mangroves and less saline water areas to higher salinity offshore to hatch their eggs in the sea. This is an important information to find out the optimum water condition for development of a successful hatchery technology for this economically important species.

## Acknowledgment

This research is part of a dissertation of the first author, which was funded by a scholarship for Ph.D. program by the Higher Education Program (HEP) of Indonesia-ADB-SEARCA. We wish to thank Nur Alam and all the fishermen in Lawele Bay for their dedicated assistance during field collections, and Prof. Joy R. Sumagaysay for the first language editing. We would also like to thank the Japan Society for the Promotion of Science (JSPS) that provided the financial for the preparation of this manuscript at the Department of Aquatic Biosciences, Tokyo University of Fisheries, Tokyo, Japan.

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