

Abundance and spatial distribution of blue swimming crab (*Portunus pelagicus*) larvae during east monsoon in the East Lampung waters, Indonesia

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Abstract. Kembaren DD, Zairion, Kamal MM, Wardiatno Y. 2018. Abundance and spatial distribution of blue swimming crab (*Portunus pelagicus*) larvae during east monsoon in the East Lampung waters, Indonesia. *Biodiversitas* 19: 1326-1333. The blue swimming crab/BSC, *Portunus pelagicus*, is an economically important species in fishery industry and continuously being exploited, particularly in the East Lampung waters. BSC research in Indonesia during the last decade was only restricted to the adult phase, while research on their larval dynamics in nature has not been done yet. This study aimed to assess the abundance and the distribution of BSC larvae, and to describe their correlation to its environmental conditions. This study was conducted in June 2017 (during east monsoon) in the East Lampung waters. Sampling was done in surface water during the daylight hours on nine sites with three replicates on each site. Plankton abundance and oceanographic profile were also recorded from the same sampling site. The result from this study showed that the water quality from the environment was suitable for the development of BSC larvae. The abundance of the early-stage larvae (Z1-Z3) was relatively higher than the late-stage larvae (Z4 and M). The larval stages of BSC were dispersed and completed their development in the mid-shore and offshore waters. There was a tendency that the early-stage was more abundant in the northern part, while the late-stage was more abundant in the southern part of the study area. The highest larval abundance was found in the mid-shore, particularly in site number five, which was influenced by the water mass density and current direction during the east monsoon. Moreover, oxygen concentration and salinity of the water environment influenced the early-stage larvae abundance more than the late-stages abundance.

Keywords: Abundance, blue swimming crab, decapods, early stages, east Lampung

INTRODUCTION

The blue swimming crab/BSC, *Portunus pelagicus* is a species of the Decapods crustacean, member of Brachyuran crab from family Portunidae. Previously, the BSC is known as *P. pelagicus* "sensu lato" and found in the shallow tropical water as well as in the coastal and estuarine temperate water throughout the Indo-West Pacific (Ng 1998). Recently, this species is known as *P. pelagicus* "sensu stricto" and distributed across Southeast and East Asia (Lai et al. 2010). In the Indonesian waters, this species is widely distributed across the eastern coast of Sumatra, northern coast of Java, south and east Kalimantan, south-eastern of Sulawesi and south-western of Papua. The BSC is economically important species in fishery sector throughout its distribution areas.

Due to its high economic value and diversity, the Decapods species were often used as study objects. In the last decade, BSC research in Indonesia have covered different aspects of BSC such as growth, reproduction, population dynamics, stock and catches dynamic (Kembaren et al. 2012; Ernawati et al. 2014, 2015, 2017; Wiyono and Ihsan 2015; Zairion et al. 2015; Sara et al. 2016; Hamid et al. 2016a,b; Pane et al 2017; Kembaren and Surahman 2018), however these research were restricted to

the adult phase. Research on the larval dynamics as an early life history of BSC has not been done yet, including BSC from East Lampung waters. The East Lampung waters are one of potential BSC fishing grounds in Indonesia. The BSC from this area has been exploited by small-scale fisherman using set gill-net and trap (Zairion et al. 2014a). □

The peak reproduction periods of BSC in East Lampung waters occur in April to June and October to November (Zairion et al. 2015) and largely depends on the environmental condition such as temperature (Johnson et al. 2010; Kamrani et al. 2010; Jazayeri et al. 2011) and salinity (Ikhwanuddin et al. 2016). The female BSC carries and incubates the eggs on their abdominal flap for eight days at the temperature of 26-27°C and salinity of 30-32 PSU (Arshad et al. 2006). To release the hatched eggs, the female of Portunidae moves to the coastal water with higher salinity and the larvae generally occur in the open ocean (Sforza et al. 2010; Sant'anna et al. 2012; Alberts-Hubatsch et al. 2016).

Planktonic larval phase, also called as meroplankton is an early life phase of the aquatic organism, especially marine organism, which morphologically different from their juvenile and adult phases (Anger 2001). This phase is the most critical phase of an organism, since it has a high

mortality rate due to the larval susceptibility against predators, food availability, and environmental changes (Anger 2001). Survival and growth rate of the Portunidae larval phase determine the recruitment to the next phase (juvenile and adult) and this condition affected by the environmental dynamics such as temperature, salinity, and oxygen (Bryars and Havenhand 2004; Baylon 2010; Ikhwanuddin et al. 2012a; Yamamoto et al. 2014).

During their planktonic life, BSC passes through four zoeal stages (Z1 to Z4) and one megalopa stage; then it metamorphoses to a juvenile which has the same morphology as adult crabs (Juwana et al. 1987; Arshad et al. 2006). In the laboratory condition, the total duration of BSC larval development is about 12 to 17 days. The first and second zoea stages span is two to four days each, the third and fourth stages need two to three days each, while the megalopa needs three to four days (Juwana et al. 1987; Arshad et al. 2006). Based on the previous field studies of the BSC larvae and other Portunidae, the zoeal stages were found mostly in the surface water (Bryars and Havenhand 2004; Breckenridge and Bollens 2011; Vieira and Calazans 2015).

This paper reports the result of field investigation on the abundance and spatial distribution of BSC larvae and their correlation to its environmental condition in the East Lampung waters, Indonesia during the east monsoon. The information gathered from this study would be useful as a basic input for management of the BSC fishery in the East Lampung.

MATERIALS AND METHODS

Study area

This research was conducted in East Lampung coastal waters, along-side the East Lampung Region, Lampung Province, Indonesia. The East Lampung coastal is characterized as shallow bathymetry with 20 m depth of isobath and 12 nm width from the seashore (Figure 1). The surface current speed in the east monsoon ranged from 1.2 m. s⁻¹ to 2.7 m. s⁻¹, with the average of 1.8 m. s⁻¹. The water mass in this area was greatly influenced by the Java Sea in the south and Natuna Sea in the north site. Sampling occurred at nine sites (ST1 to ST9), adjacent to Labuhan Maringgai regency and Way Kambas National Park. In the northern part (ST7-ST9), the Way Kambas River loaded fresh water from Way Kambas National Park, while in the middle part (ST4-ST6) fresh water was loaded from Way Penet River. Both sites were covered by slight mangrove forest. Beach land in the southern part (ST1-ST3) had minimum vegetation and utilized for pond, wet rice field, people settlement, and fish landing base. Individual sites were positioned in the range depth contour of less than 5 m (ST3, ST4, and ST9; 'inshore'), 5-10 m (ST2, ST5, and ST8; 'mid-shore'), and 10-15 m (ST1, ST6 and ST7; 'offshore', Figure 1 and Table 1).

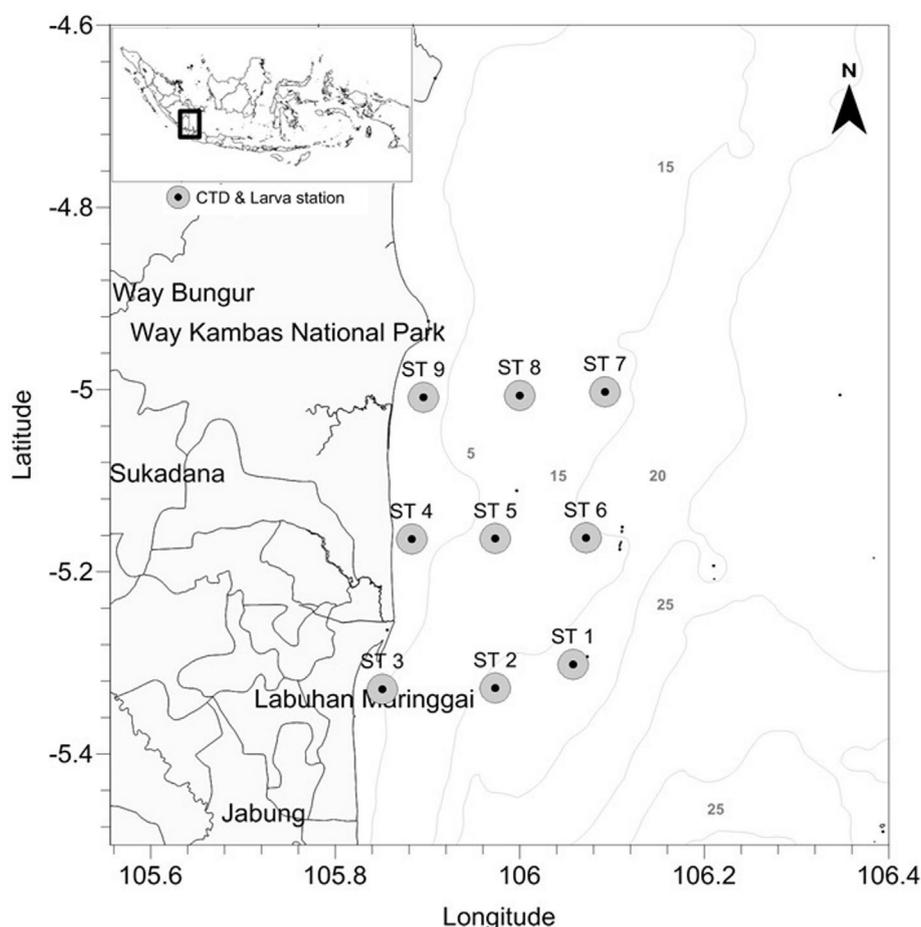


Figure 1. Sampling sites of larvae, plankton and oceanographic profile in the East Lampung waters, Sumatra, Indonesia

Table 1. The *Portunus pelagicus* larval number and abundance in East Lampung waters, Indonesia during the east monsoon

Site	Site category	Larval numbers (ind.)					Total	Mean of larval abundance (ind. per 100 m ³)				
		Z1	Z2	Z3	Z4	M		Z1	Z2	Z3	Z4	M
ST1	Offshore	15	8	4	1	1	29	3.7	1.9	1.0	0.2	0.3
ST2	Midshore	0	3	5	11	3	22	0.0	1.3	3.3	8.1	2.4
ST3	Inshore	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
ST4	Inshore	3	2	0	1	5	11	0.9	0.7	0.0	0.4	1.7
ST5	Midshore	34	26	35	17	17	129	37.3	31.0	40.2	18.9	19.2
ST6	Offshore	13	4	6	0	3	26	5.6	1.8	2.3	0.0	1.0
ST7	Offshore	8	31	15	2	0	56	2.6	10.4	5.0	0.6	0.0
ST8	Midshore	4	1	0	0	0	5	3.1	0.8	0.0	0.0	0.0
ST9	Inshore	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
	Total	77	75	65	32	29	278	53.17	47.83	51.71	28.30	24.64

Note: Z1-Z4 = zoeal stages 1-4, M = megalopa

Sampling procedures

Site procedures

Sampling was conducted in June 2017 (east monsoon), after the peak spawning season of BSC had occurred (Zairion et al. 2015). Sampling was done during the daylight time between 06.00 and 17.00 hours of local time. Larval samples were collected using a 0.6 m diameter, 3 m long, and 500 μ m mesh of conical larval (bongo) net, and preserved in 96% ethanol. The mouth of the net was fitted with a mechanical flow meter (model 2030 R, General Oceanic Inc., Miami, FL) to estimate the volume of water passing through the net during each tow. For each site, three replicates sampling was conducted. Considering that mostly zoea stage have been found in surface water (Bryars and Havenhand 2004; Breckenridge and Bollens 2011; Vieira and Calazans 2015), samples were collected from the surface area at 1-3 m in depth. The larval net was towed at the speed of 1-2.5 knot for seven to ten minutes.

Zooplankton samples were collected using a net with 0.45 m in diameter, 1.8 m in length and 300 μ m of mesh size, while phytoplankton samples were collected using a net with 0.3 m in diameter, 1 m in length and 80 μ m of mesh size. Zooplankton and phytoplankton samples were collected from the surface area with horizontal haul performed as long as 10 m. Zooplankton and phytoplankton samples were preserved with 4% formaldehyde in seawater. Oceanographic profiles such as temperature, salinity, dissolved oxygen, density, and fluorescence, were measured using a Conductivity Temperature Depth (CTD, SBE 19 plus V2 model), while the current speed and profile were recorded with an Acoustic Doppler Current Profiler (ADCP, SONTEK 250 kHz).

Laboratory procedures

In the laboratory, the whole preserved larval samples were transferred to a sorting tray for further analysis. The *P. pelagicus* larvae were separated from the others species and debris. Detail identification and examination of larvae were conducted using an optical microscope at 4x and 10x magnification. The larvae were mounted with glycerin. The *P. pelagicus* larvae were identified using the morphological characters as described in Juwana et al. (1987). The *P. pelagicus* larvae have five developmental stages consisting

of zoea 1-4 (Z1-Z4) and megalopa (M). The numbers of *P. pelagicus* from each stage in the sample were enumerated and recorded. Zooplankton and phytoplankton samples were enumerated and identified under a light microscope by transferring the sample onto the Sedgewick rafter counting chamber.

Data analysis

Larval densities were standardized as a function of the water volume filtered in each tow and expressed in a number of individual larvae per 100 m³. The means of volume of water filtered by the net for all samples were 94.1 ± 9.7 m³. The composition of *P. pelagicus* larval stages was expressed as a percentage of abundance each stage at each sampling site and plotted in a graph using Microsoft Office Excel 2013 software. A two-way ANOVA was used to test the differences in larval abundance between sites and location categories (inshore, mid-shore and offshore). Larval abundance data were log (x+1) transformed before analyses to meet the assumption of normality and homogeneity of variance. The spatial distribution maps of each larval stages of the *P. pelagicus* were prepared using the Surfer 10.0 software based on their abundance. To describe the relationship between larval abundance and environmental condition, the principal component analyses were performed based on the Euclidean distance similarity index using program XLSTAT 2014.5.03. All hydrographic data from CTD were analyzed using SBE data processing software and Ocean Data View (ODV), while data from ADCP were analyzed using current surveyor ADP software. Zooplankton abundance was standardized to zooplankton density defined as an individual per cubic meters (ind. m⁻³), while phytoplankton defines as cells per cubic meters (cell.m⁻³).

RESULTS AND DISCUSSION

Environmental condition

The water temperatures ranged from 29.6°C to 30.5°C, with the average of 29.9°C. Temperature in offshore sites was higher than in north-west and lower than in south-west inshore sites. Water salinity ranged from 29.7 PSU to 32.8

PSU, with the average of 31.3 PSU. The distribution of the salinity indicated that offshore sites had higher salinity than mid-shore and inshore sites. The dissolved oxygen concentration ranged from 5.0 mg.L^{-1} to 5.5 mg.L^{-1} , with the average of 5.4 mg.L^{-1} . The dissolved oxygen recorded in the inshore sites were higher than mid-shore and offshore sites. The water density distribution showed a similar pattern to the salinity because density was greatly influenced by salinity, temperature and pressure. The southern and northern part of the offshore sites had higher water density than the other sites. This condition indicated that water mass in this area was influenced by water mass from the Java Sea in the south and Natuna Sea in the north. The water density ranged from 1017.8 kg.m^{-3} to 1020.1 kg.m^{-3} , with the average of 1019.0 kg.m^{-3} . Water turbidity in the inshore sites was higher than mid-shore and offshore sites, because it was influenced by freshwater loads from the stream. The fluorescence analysis indicated the chlorophyll-a concentration (Kalaji et al. 2014). The fluorescence values ranged from 0.3 mg.L^{-1} to 2.2 mg.L^{-1} , with the average of 1.0 mg.L^{-1} . Higher concentration of chlorophyll-a was found in the inshore site. The water current flow from the northern, eastern and southern sites of the study area. The surface current speed ranged from 1.2 m.s^{-1} to 2.7 m.s^{-1} , with the average of 1.8 m.s^{-1} . The current speed from northern and eastern sites was faster than southern sites. All of those oceanographic profiles are presented in Figure 2.

Larval abundance and stage composition

A total of 278 *P. pelagicus* larvae were caught from nine sampling sites, with the total abundance of Z1, Z2, Z3, Z4, and M were 53.17, 47.83, 51.71, 28.30 and 24.64 ind. per 100 m^3 , respectively (Tabel 1). There was no significant difference among larval stages ($F_{4,32} = 1.27$; $P > 0.05$). The mean of Z1 larvae abundance ranged from 2.6 ind. per 100 m^3 to 37.3 ind. per 100 m^3 . The highest abundance of Z1 larvae was found at sampling site ST5, while there were no Z1 found at ST2, ST3 and ST9. The mean of Z2 larvae abundance ranged from 0.8 ind. per 100 m^3 to 31.0 ind. per 100 m^3 . The highest abundance of Z2 larvae was found at ST5 and no larvae found at ST3 and ST9. The mean of Z3 larvae abundance ranged from 1.0 ind. per 100 m^3 to 40.2 ind. per 100 m^3 . The highest abundance of Z3 larvae was found at ST5 and no larvae found at ST3, ST4, ST8, and ST9. The mean of Z4 larvae abundance ranged from 0.2 ind. per 100 m^3 to 18.9 ind. per 100 m^3 . The highest abundance of Z4 larvae was found at ST5 and no larvae found at ST3, ST6, ST8, and ST9. The mean of M larvae abundance ranged from 0.3 ind. per 100 m^3 to 19.2 ind. per 100 m^3 . The highest abundance of M larvae was found at ST5 and no larvae found at ST3, ST7, ST8, and ST9. The majority of the larvae were captured from ST5 that reached to 46.4% of the total larvae. Larval abundance of each stages were significantly different between the sampling site ($F_{8,32} = 10.05$; $P < 0.05$).

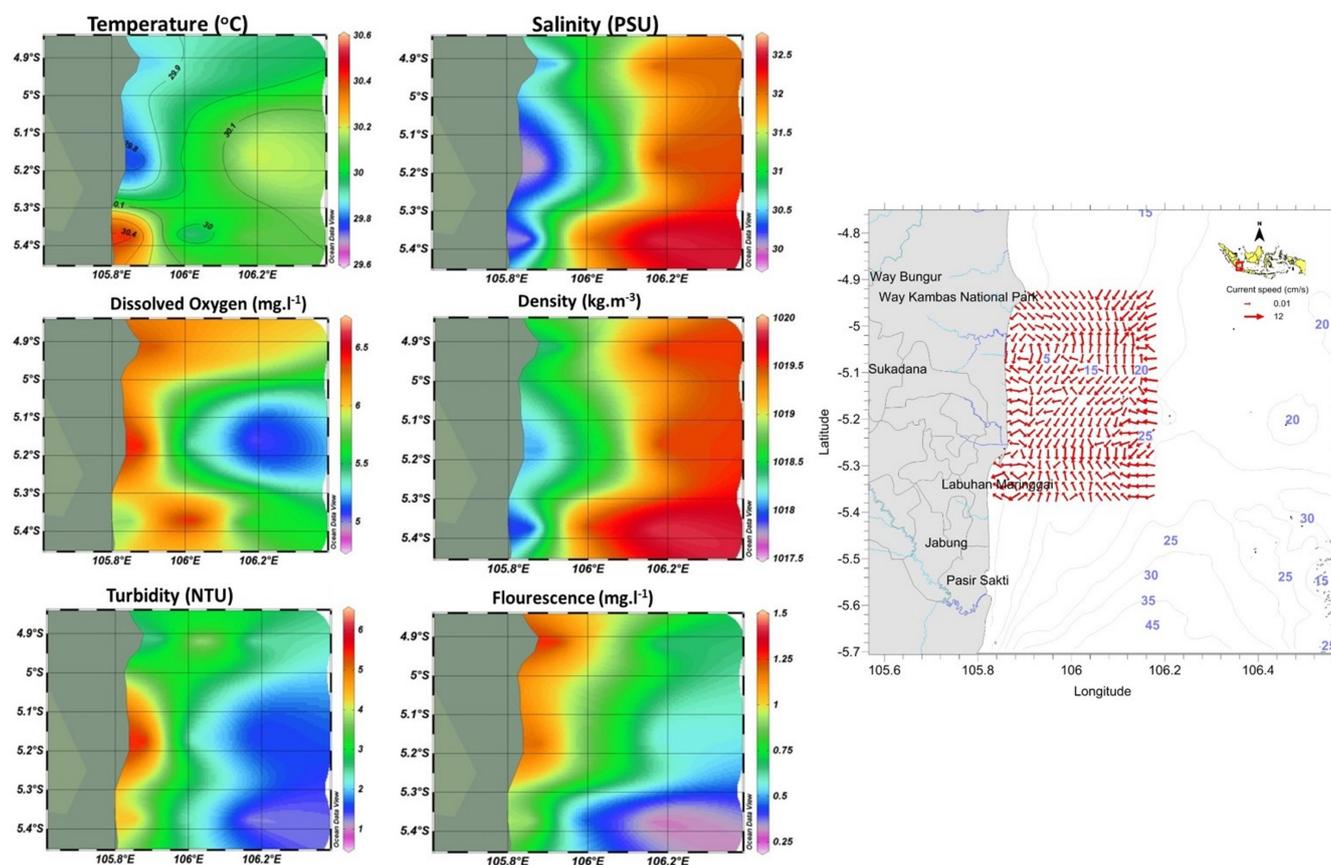


Figure 2. Oceanographic profile in the East Lampung waters, Indonesia during east monsoon

Larval stages composition of Z1, Z2, Z3, Z4, and M were 28, 27, 23, 12 and 10% of the total larvae, respectively. These result showed that early and mid-stage larvae (Z1-Z3) composed 78% of the total larvae, while late-stage larvae (Z4 and M) were composed only 22% of the total larvae. All larval stages were found at ST1 and ST5, but the larval composition at ST1 was dominated by Z1 while at ST5 no stage dominant was found. No larvae were found at ST3 and ST9. More than 60% of larval stages composition at ST1, ST5, ST6, ST7, and ST8 were dominated by early-stage larvae (Z1-Z3), while late-stage larvae (Z4 and M) were found more dominant at ST2 and ST4 (more than 50% on each site). The Z1 as the first stages after hatching was found to be dominant at the ST1, ST6, and ST8, with the highest percentage at ST8 (Figure 3).

Spatial distribution

All stages of *P. pelagicus* larvae were found in the surface water throughout the study area during the east monsoon. Each larvae stage have a different pattern of their distribution, even though they appeared to be most abundant at ST5. Early stages of *P. pelagicus* larvae (Z1 and Z2) showed a similar distribution pattern where they were more abundant in the northern than the southern part. Different distribution patterns appeared at later stages (Z4 and M), where the abundance was higher in the southern part. Moreover, Z3 had a transition distribution patterns from the northern to southern part of the study area (Figure 4).

The larval abundance for all stages, based on the site categories, showed that the highest abundance was found in the mid-shore site, while the lowest abundance was found in the inshore site. The larval abundance in the offshore site was higher than in the inshore site (Table 2). The abundance of Z1 and Z2 stages in the mid-shore site were 98% higher than in the inshore and approximately 71% and 57% higher than in the offshore. The abundances of Z4 and M stages in the mid-shore were 99% and 92% higher than in the inshore and 97% and 94% higher than in the offshore, respectively. No Z3 stage was found in the inshore site. The abundance of Z1, Z2, and Z4 stages in the offshore were 92%, 95%, and 54% higher, respectively, than in the inshore site. The abundances of M stages in the inshore were 25% higher than in the offshore site. The larval abundance was significantly different ($F_{2,8} = 51.14, P < 0.05$) between sites.

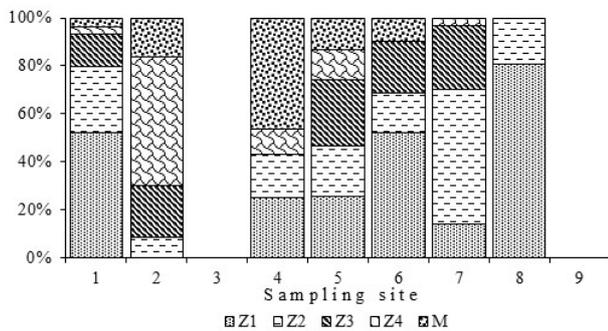


Figure 3. Larval stages composition at each sampling site in East Lampung waters, Indonesia during the east monsoon



Figure 4. Spatial distribution of *P. pelagicus* larval abundance (ind. per 100 m³) in East Lampung waters, Indonesia during the east monsoon. Z1-Z4 = Zoal stages 1-4, M = Megalopa

Table 2. Abundance (ind. per 100 m³) of *P. pelagicus* larvae at inshore, mid-shore, and offshore in East Lampung waters, Indonesia during the east monsoon. Data are means value \pm 1 s.e from each site category

Larval stages	Site category		
	Inshore	Mid-shore	Offshore
Z1	0.3 \pm 0.3	13.5 \pm 12.0	3.9 \pm 0.9
Z2	0.2 \pm 0.2	11.0 \pm 10.0	4.7 \pm 2.9
Z3	0.0 \pm 0.0	14.5 \pm 12.9	2.7 \pm 1.2
Z4	0.1 \pm 0.1	9.0 \pm 5.5	0.3 \pm 0.2
M	0.6 \pm 0.6	7.2 \pm 6.1	0.4 \pm 0.3

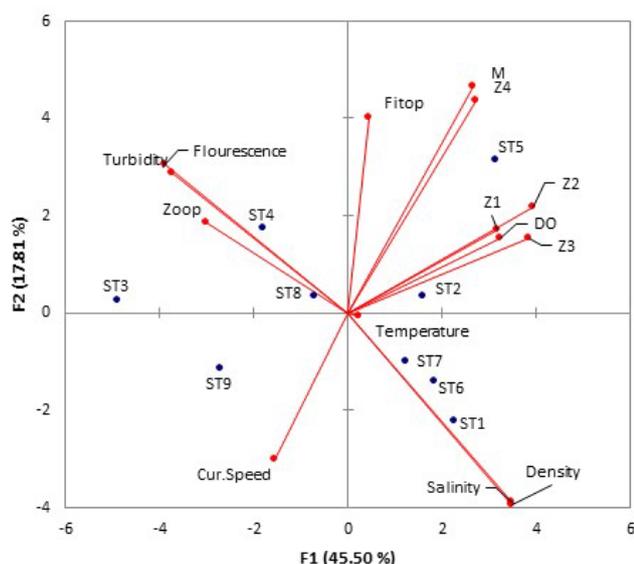


Figure 5. Biplot diagram of larval abundance, environmental conditions, and site location in the East Lampung waters, Indonesia during the east monsoon. Z1-Z4 = zoeal stages 1 to 4, M = megalopa, ST1-ST9 = sampling site 1 to 9

Relationship between larval abundance and environmental condition

A principal component analysis was used to describe the relationship between larval abundance and environmental condition across the study area. Larval abundance at each stage and environmental conditions were used as variables, while sampling sites were used as observations. The result showed that the first principal component (factor in XLSTAT) showed 45.50% of the variability and cumulatively with second principal component showed 63.31% variability. The first principal component had strong correlation with variable salinity, dissolved oxygen (DO), density, fluorescence, turbidity, zooplankton, and early-mid larval stages (Z1-Z3). Meanwhile, the second principal component had a correlation with variable phytoplankton, current speed and late-stage larval (Z4 and M). The temperature had a weak correlation with the first and second principal components and explained the third principal component. The biplots diagram from the variables and observation showed that early-mid larval stage of *P. pelagicus* (Z1-Z3) had the closest similarity distance to variable DO and ST2 and

ST5. The later larval stage (Z4 and M) had the closest similarity distance to ST5. Biplot diagram also represented the closest similarity between ST2 and ST5 as mid-shore area category and ST1, ST6, and ST7 as offshore area category. Offshore area of East Lampung waters was characterized by the high salinity and density. ST4 and ST8 were characterized by turbidity and fluorescence, while the ST3 and ST9 were characterized by the other condition (Figure 5).

Discussion

During their planktonic phase, larvae are exposed to the variation of numerous ecological factors including physical and chemical factors, such as temperature, salinity, oxygen concentration, water density, and current speed and direction, as well as biotic factors such as food, and predation. The temperature, salinity, oxygen concentration, food, and predation are ecologically important factors of the decapod larval growth and development (Anger 2001; Bryars and Havenhand 2004; Baylon 2010; Ikhwanuddin et al. 2012a; Yamamoto et al. 2014; Epifanio and Cohen 2016). The oceanographic profiles, temperature, and salinity reported in this study were similar to those reported by CRMP (1998) and Zairion (2014b). There was no extreme condition of all oceanographical parameters in this study, and overall range of water quality was suitable for the development of *P. pelagicus* larvae. However, some oceanographic profiles may have important roles for the larvae distribution. Torres et al. (2014) found that fluorescence and food availability had the highest power for explaining the distribution of the decapod larvae in the Balearic Sea, western Mediterranean. In the Yangtze Estuary, China, Geng et al (2018) found that water temperature and depth had significant impacts on the Chinese mitten crab larvae densities.

The mean batch fecundity of female *P. pelagicus* in this study area was estimated to be 926.638 eggs (Zairion et al. 2015). In the rearing system, hatching rate of *P. pelagicus* was about 50% (Oniam et al. 2012). Assuming the hatching rate of *P. pelagicus* from this study is 20%-50%, the numbers of larvae release by a female can be estimated at hundreds of thousands. Given the presence of ovigerous females in this study area from previous studies (Zairion et al. 2014b), Z1 larvae abundance found in this present study appeared to be low (53.17 ind. per 100 m³). The similar abundance of *P. pelagicus* larvae (< 100 ind. per 100 m³) is found in the Gulf of Saint Vincent, Southern Australia (Bryars and Havenhand 2004). In contrast, Gaughan and Potter (1994) reported that in the confined waters from lower Swan Estuary, South Australia, *P. pelagicus* larvae has abundance up to 20-99 zoea per m³ (= 2,000-9,900 zoea per 100 m³); however, the zoea stages of this study was not classified. Aggregating ovigerous female before releasing the larval was contributed to the high early larvae abundance. However, aggregation of berried female *P. pelagicus* did not occur in East Lampung waters because the berried females were widespread from inshore (depth < 5 m) to offshore (depth > 10 m) (Zairion et al. 2014b).

The late-stage zoea (Z4) and megalopa (M) were captured in a relatively few portions of this current study,

i.e. 12% and 10% of the total larvae, respectively. The abundance of megalopa in this study was considerably higher than the study reported by Bryars and Havenhand (2004), where the abundance of megalopa which was only 0.05%. The difference of the late-stage and megalopa abundance could be explained by the difference in the speed tows during sampling. Tow with higher speed is more effective to catch the older and faster swimming stages of decapods crustacean. Furthermore, the low portion of *P. pelagicus* at later-stages probably reflected the mortality rates and/or dispersal of later-stage larvae away from the sampling area (Bryars and Havenhand 2004). The survival rates of crab larvae are generally very low. In the rearing system, the highest survival rate of *P. pelagicus* first zoea was 21.82% with a certain feed (Ikhwanuddin et al. 2013). However, this survival rate in the natural habitat could be lower than in the rearing system, due to predation and feed availability.

The ovigerous female of *P. pelagicus* generally made a movement from shallow coastal water to deeper oceanic water or higher saline water for spawning (Christy 2011; Ikhwanuddin et al. 2012b; Kunsook et al. 2014). Furthermore, the study from Epifanio and Dittel (1984) showed that the Portunidae zoea needs higher salinity to complete their larval development, and this behavior is known as an ecological strategy to find optimum development condition. In this present study, the highest abundance of Z1 *P. pelagicus* larvae was found from sampling site ST5 (mid-shore), where the salinity concentration was lower than offshore site (Figure 2 and Figure 4). This phenomenon contrasts with the study from Epifanio and Dittel (1984), but consistent with the previous study from Zairion et al. (2014b). Study from Zairion et al. (2014b) has a similar study area with our study, where the highest proportion of BSC berried female is found in the open water with depth more than 5 m. The study from Epifanio and Dittel (1984) is conducted at the estuary water where the salinity is more fluctuate than open water.

The spatial distribution of the BSC larvae indicated that the highest abundance of larvae was found at ST5 (mid-shore). This phenomenon was influenced by water density and current pattern. The water mass in southern part was influenced by the water mass from the Java Sea, while in the northern part was influenced by the Natuna Sea, where the density from the Java Sea greater than Natuna Sea. Furthermore, during the east monsoon, current direction flows from north-east, east and south-east (Figure 2). This condition created water circulation in this study area with the center was occurred on site ST5. Therefore, the larval stages of *P. pelagicus* showed in this study were dispersed and completed their development in mid-shore and offshore area. There was a tendency that early-stage larvae were more abundant in the northern part, while the late-larvae were more abundant in the southern part of the study area.

The *P. pelagicus* larval abundance showed positive correlations to salinity, oxygen concentration (DO), and density, and negative correlations to fluorescence and turbidity. These variables were presented in the first principal component and descriptively explained

environmental factors that influence the larval abundance. Temperature, current speed, phytoplankton and zooplankton abundances positioned on the second principal component were not able to explain the larval abundance. Oxygen concentration and salinity had greater influence on the early-mid stage larvae (Z1-Z3) than late-stage larvae (Z4 and M). This condition reinforced that the later larval stages of decapod larvae more tolerant to the environmental changes, particularly DO and salinity than early larva stage (Anger 2001; Baylon 2010).

In summary, this study showed that water quality conditions in this study area were suitable for the development of *P. pelagicus* larvae. The abundance of the early-mid stage larvae (Z1-Z3) was relatively higher than late-stages larvae (Z4 and M). The larval stages of *P. pelagicus* were dispersed and complete their development on the mid-shore and offshore waters. There was a tendency that early-larvae were more abundant at the northern part, while the late larvae stage was more abundant in the southern part of the study area. The highest larval abundance was found in the mid-shore, particularly site ST5 and was influenced by the water mass density and current direction during the east monsoon. Descriptively, oxygen concentration and salinity were better to explain the larvae abundance at the early-stage than at the late stages.

□

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