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Profiling the natural settlement habitat of spiny lobster, *Panulirus* spp. to determine potential diets and rearing conditions in a lobster hatchery

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Abstract. *Amin M, Harlyan LI, Achmad K, Diantari R. 2022. Profiling the natural settlement habitat of spiny lobster,* Panulirus *spp. to determine potential diets and rearing conditions in a lobster hatchery. Biodiversitas 23: 2893-2898.* The high demand for spiny lobster seeds has triggered research on seed production in a hatchery system. However, the remaining challenges are still in determining suitable live diets and environmental conditions at the early life stages. Thus, the present study investigated the natural settlement habitat of lobster larvae as basic information for developing diets and rearing conditions in an indoor system. One of the most common natural settlement habitats for lobster larvae in Indonesia, indicated by the high catching rates, Gerupuk Bay located in West-Nusa Tenggara, was selected as a studied area. Physicochemical and biological parameters were investigated to obtain the habitat profiles. The results showed that Gerupuk Bay was 18-30 m water depth, 5-6 m transparency, a sandy, and rocky bottom, 27-31ºC temperature, 0.1-0.2 $m.s^{-1}$ current, 5-6 mg/L dissolved oxygen, <0.01 mg/L nitrate, 0.4-0.6 mg/m^3 chlorophyll concentration, and salinity of 30-34 practical salinity unit (psu). Furthermore, the present study found at least 16 zooplankton species and 25 phytoplankton species at 0-5 m water depth. The most dominant species dominant species was *Echinocamptus hiemalis elongates* (90 indiv/L) in the surface water (0-0.3m), followed by *Tortanus derjugin* (20 indv/L) at 2.5 m and *Oithona* sp. with 46 indv/L at 5 m depth. While the most dominant phytoplankton was *Oscilatoria* sp. (9 ind/L) in the surface water, followed by *Rhizosolenia* sp. (4 indv/L) at 2.5 m depth, and *Favella ehrenbergii* (13 ind./L).

Keywords: Ecology, natural habitat, post-larval stage, recruitment

INTRODUCTION

Indonesia is well known as a lobster larvae-exporting country for aquaculture purposes. The lobster larvae were widely caught from several southern coastal regions of Indonesia, such as Lampung in Sumatra Island, Pangandaran in West Java (Mukhtar et al. 2021), Tawang and Kili-Kili Bay in the East Java, and Gerupuk Bay in Lombok Island West-Nusa Tenggara Indonesia (Priyambodo et al. 2015). Few studies reported the status of lobster-larvae catching in these fishing-ground areas, such as in Awang Bay, Lombok Island, in 2016 exceeded the maximum allowable fishing status (maximum sustainable yield, MSY) (Sibeni and Calderini 2013; Nurfiarini et al. 2016). This is caused by the recruitment rate of lobster seeds in marine water being relatively small (<0.1%). Therefore, the Indonesian Government, through The Ministry of Marine Affairs and Fisheries, has nowadays banned fishermen to catch/trade lobster larvae. However, as the demand for lobster larvae is continuously increasing, it has been caught illegally (Priyono et al. 2009). The fact that the lobster larvae could not be produced artificially yet may worsen the lobster stock in nature and might lead to extinction in the future.

Many studies have been done to develop a lobster hatchery to produce lobster larvae artificially by an indoor system (Shanks and Jones 2015). Several researchers reported successfully breeding adult lobsters and producing a million larvae per female brood-stock. Nonetheless, the larvae experienced mass mortality about 7 days after hatching. Some putative possibilities are rearing conditions and the availability of suitable diets for the larval stage. Important factors of rearing conditions as well as diet availability to the survival rate of aquatic animals have been described by several authors (Powell et al. 2017; Mir et al. 2020). Snakehead (*Channa striata*) larvae, for instance, are very sensitive to the temperature of rearing water thus significantly affecting their survival rates (Muslim et al. 2018).

Furthermore, the environmental temperature has been viewed as a critical factor in the survival rate of marine fish larvae (Downie et al. 2020). Based on these facts, knowledge and information about the favorable environmental conditions of the rearing system, as well as suitable diets, are critically important in order to develop lobster larvae artificially by an indoor system.

One way to gain knowledge and information on favorable rearing conditions and potential diets for lobster larvae is by profiling the natural habitat in which they are mostly caught or live (Kashinskaya et al. 2018). The abundance of lobster larvae in certain areas can represent a high recruitment rate which indirectly suggests physical, chemical and biological characteristics of the areas are favorable for the lobster larvae. Acknowledging this, Indonesia has many fishing-ground areas for lobster larvae, profiling physical, chemical, and biological environmental characteristics may provide basic knowledge and information to produce lobster larvae in the future. Therefore, the present study aims at profiling the natural habitat of lobster larvae. A selected location was Gerupuk Bay in Lombok Island, West Nusa Tenggara Indonesia, which is considered one of the most common areas for lobster-larvae catching in Indonesia.

MATERIALS AND METHODS

Study area

This study was conducted on 18-20 August 2021, which was considered one of the most abundant larval seasons in Gerupuk Bay (Junaidi et al. 2019). The sampling site was determined as previously described by Jawahar and Venkataramani (2007). The present study was Gerupuk Bay, Lombok Island, West-Nusa Tenggara, Indonesia with an ordinate point at 8°92'18.29" S, 116°35'72.79" E, Figure 1. The location was selected due to being considered one of the most abundant fishing ground areas for lobster larvae (*Panulirus homarus* and *Panulirus ornatus*) in Indonesia. Profiling ecological characteristics of the fishing ground may provide preliminary knowledge on developing favorable rearing conditions for an artificial lobster hatchery in the future.

Procedures

Physicochemical characteristics

The present study started by investigating the physical and chemical parameters of the fishing ground area to get an overview of the natural habitat for lobster puerulus. The physical parameters included the bottom substrate of the fishing ground areas (sandy, rocky or muddy), depth, current direction and speed, temperature, transparency, and dissolved oxygen (DO). The water depth was measured by fishfinder (LAWRENCE HOOK4x), current direction and speed were taken from the data of Stace of the Ocean (https://podaac-tools.jpl.nasa.gov) on 10 June 2021. Furthermore, the water transparency was measured using a Secchi disc. Temperature and dissolved oxygen (DO) were measured with a digital instrument (HI 98199 digital portable meter). While chemical parameters measured in the present study were pH, salinity, and nitrate. These parameters were measured using a commercial kit and digital probes; NO_3 Test (Hanna HI96728 Instrument) for nitrate, PH meter AS218 (Intel InstrumentTM Pro) for pH, and refractometer (Refractometer Salinity Test).

Biological characteristics

Water samples and plankton identification was carried out according to the protocol of Shirota (1966), with slight modification. In brief, seawater was collected from three different depths (0-0.3 m, 2.5 m, and 5 m) using a water sampler (Water Sampler Horizontal, Type: WSH-BIT 22) with a capacity of 2.2 L. The collected water was afterward filtered through a plankton net (diameter 20 cm with a mesh size of 50 microns). The water samples were collected at night as the lobster puerulus are also nocturnal animals. To preserve the plankton, the water samples were stored in a plastic bottle sample and followed by the addition of Lugol solution to reach a final concentration of 1%. Meanwhile, Chlorophyll-A concentration in the selected location was obtained from data of "State of the Ocean (https://podaac-tools.jpl.nasa.gov) on 10 June 2021".

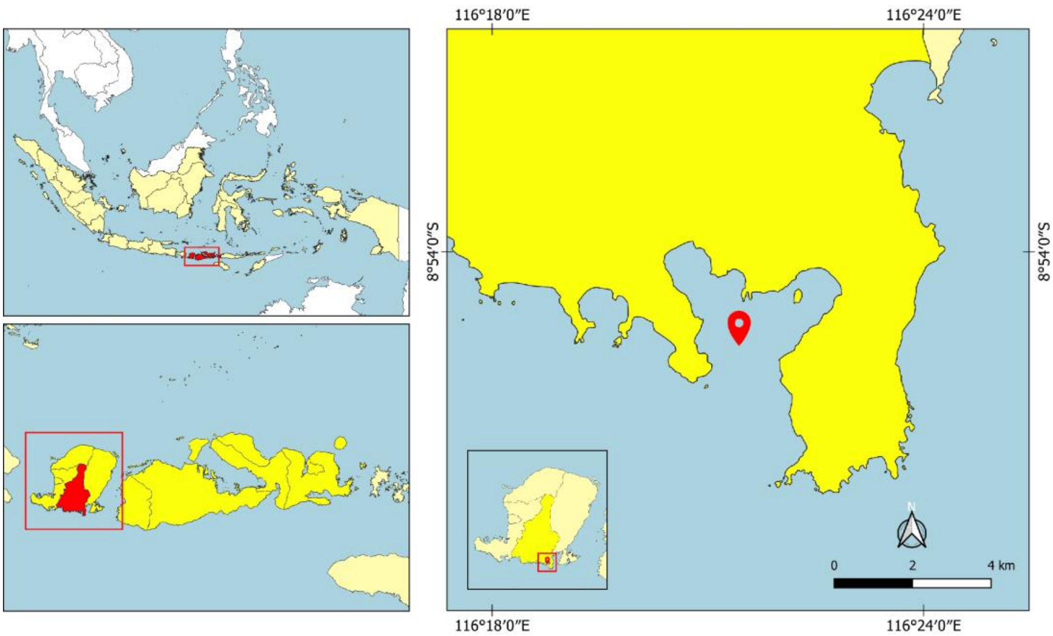

Figure 1. The sampling location of lobster-larvae fishing ground, Gerupuk Bay, Lombok Island, West-Nusa Tenggara, Indonesia. Sampling point (8°92'18.29" S, 116°35'72.79" E)

Identification of plankton

Furthermore, the abundance of plankton in the water samples was calculated according to the protocol of Shirota (1966). In brief, pictures of phytoplankton and zooplankton obtained from the water samples were taken under a binocular microscope with a digital camera (MEIJI Techno M4000 series), and the obtained pictures were compared to the pictures in The Plankton of South Vietnam. Afterward, the data were analysed descriptively by comparing the present result with other previous studies.

RESULTS AND DISCUSSION

Physical and chemical characteristics

Gerupuk Bay was a bay, a coastal body of water that directly connects to the southern of the Indian Ocean in the south. The bottom substrate was mostly sandy and rocky. In addition, the water depth ranged from 18-25 m, 5.7 m transparency, the temperature of 29-31ºC, and dissolved oxygen of ~5.14 mg. L^{-1}. The surface current taken from State of the Ocean data showed that the surface current seems to flow from the Indian Ocean from the south to the north. The current speed was 0.2-0.30 m/s. In addition, pH was recorded at 8.5, and 0.01 mg. L^{-1} nitrate concentration and salinity of ~34 psu, Table 1.

Biological factor

The present study identified both phytoplankton and zooplankton in the fishing ground of puerulus lobster. The result showed that at least 16 species of zooplankton were identified, Table 2. Based on water depth, the diversity of zooplankton decreased as the depth increased. As presented in table 2, there were 6 zooplankton genera in the water depth of 0-0.3 m and 2.5 m, but drastically decreased to only 2 species in the depth of 5 m.

The result also showed that the most abundant zooplankton species found in the surface water (0-0.3 m) were *Echinocamptus hiemalis elongates* (53%) followed by *Penilia avirostris* (24%), *Tortanus derjugini* (9%), *Acartia pacifica* (6%), *Caloceolanus* sp. (5%), and the least was *Rotaria* sp. (3%), Table 2. While, *Apocyclops royi* was the most dominant species found at 2.5 m water depth (45%). The rest species were *Penilia avirostris* (20%), followed by *Labidocera pava* (12%), *Lopadorhynchus* sp. (10%), and *Apocyclops* sp. (7%). The least abundant zooplankton species at the water of 2.5 m depth was *Tortanus derjugini* with 5%. Furthermore, the most dominant zooplankton species identified from water samples at 5m was *Oithona* sp. (85%), followed by *Polychaeta* with ~15%. In terms of cell density, the number of zooplankton species detected in the water samples appeared to decrease with the water depths. The density of zooplankton recorded from the water sample was ~211 ind./L water at surface water, decreased to 87 ind./L water at 2.5 m depth and became 80 ind./L water at a depth of 5m.

Table 1. Physical and chemical characteristics of fishing ground for lobster larvae in Gerupuk Bay, Indonesia

Parameters	Values
Transparency (m)	5.7
Depth (m)	30
Substrate types	Sandy and Rocky
T (°C)	29-31
DO (mg/L)	5.14
Salinity (psu)	34-34.5
pH	8.1-8.3
NO_3 (mg/L)	<0.01
Current speed (m/s)	0.21-0.22
Chlorophyll-A (mg/m)	0.44-0.45

Note: T is temperature; DO is dissolved oxygen. PSU is a practical salinity unit.

Table 2. Diversity of Zooplanktons collected from fishing grounds of lobsters at different water depths.

Zooplankton species	Depth (m)	Density (Ind./L)	Abund. (%)
Rotaria sp.	0-0.3 (Surface)	8.5	3
Caloceolanus sp.	0-0.3 (Surface)	20.5	5
Echinocamptus hiemalis elongatus	0-0.3 (Surface)	90.3	53
Tortanus derjugin	0-0.3 (Surface)	63.1	9
Penilia avirostris	0-0.3 (Surface)	11.9	24
Acartia pacifica	0-0.3 (Surface)	17.0	6
Lopadorhynchus sp.	2.5	17.1	10
Tortanus derjugin	2.5	20.5	5
Apocyclopas royi	2.5	11.9	45
Apocyclopas sp.	2.5	17.1	7
Labidocera pava	2.5	8.50	12
Penilia avirostris	2.5	11.9	20
Oithona sp.	5.0	46.0	85
Polychaeta sp.	5.0	34.1	15

Other results showed that at least 25 phytoplankton species were detected from water samples collected from the three different depths, Table 3. In contradiction to zooplankton species, the diversity of phytoplankton increased with the water depth. As presented in table 3, there were 5 phytoplankton genera detected in the water of 0-0.3 m depth, increased to 8 species at 2.5 m, and became 10 species in the depth of 5 m.

The most abundant species found in the surface water (0-0.3m) was *Oscillatoria* sp. (47%), followed by *Rhizosolenia* sp. (33%), *Colotrix* sp. (11%), *Xyatonellopsis* sp. (6%), and the least percentage was *Bellerochea* sp. (3%). While at a depth of 2.5 m, the most dominant species was *Rhizosolenia* sp. (27%), followed by *FaIvella* sp. (12%), and *Bacillaria* sp., *Colotrix* sp., *Nitzschia* sp. with 10% of each, Figure 4. While at a depth of 5.0 m, the most 5 dominant species were *Favella ehrenbergii* with 12.78 cells/L (38%), followed by *Oscillatoria* sp. with 5.46 cells/L (16%), *Coscinodiscus* sp. with 4.26 cells/L (13%), *Rhabdonella* sp. with 3.41 cells/L (10%) and *Synedra* sp. with 2.05 cells/L (6%). While the rest 5 less dominant species were *Striatella* sp. with 1.71 cells/L (5%), followed by *Rhizosolenia* sp. with 1.19 cells/L (4%). The least three species, including *Coscinodiscus* sp., *Helicostomella* sp., and *Salpingella* sp. accounted for 1.01 cells/L or equal to `~3% of each. The next fewer species were *Grammatophora* sp. and *Pleurosigma* sp. with 7 % of each, followed *Triceratium* sp. (6%), and *Oscillatoria* sp. and *Xystonella* sp. with 5% of each. In addition, there were 10 phytoplankton species were identified from water samples at the 5 m depth, Table 3 and Figure 4.

In terms of density, the number of phytoplankton species detected in the water sample also appeared to increase with the water depths. The density of phytoplankton recorded from the water sample at the surface was ~27.08 cells/L water, and slightly decreased to 15.0 indv/L water at 2.5 m depth and dramatically increased to 36.82 cells/L water at a depth of 5 m.

Discussion

Environmental conditions of settlement areas play critical roles in the recruitment rate of marine fish larvae (Kashinskaya et al. 2018; Mazur et al. 2022). The fact that lobster larvae are highly abundant throughout the year in several bay areas of Indonesia, may suggest that those areas might provide favorable rearing conditions as well as good natural diet viability, which allows the high recruitment rate for the lobster larvae (Priyambodo et al. 2020). Thus, the present study reported physicochemical and biological conditions at one of the most common Indonesian lobster fishing grounds, which may be critical information for developing artificial lobster hatcheries in the future.

Table 3. Diversity of phytoplankton collected from fishing grounds of lobsters at different water depths

Phytoplankton species	Water depth (m)	Density (cells/ L)
Bellerochea sp.	0-0.3 (Surface)	8.50
Colotrix sp.	0-0.3 (Surface)	2.05
Oscillatoria sp.	0-0.3 (Surface)	9.03
Rhizosolenia sp.	0-0.3 (Surface)	6.31
Xyatonellopsis sp.	0-0.3 (Surface)	1.19
Bacillaria sp.	2.5	1.70
Colotrix sp.	2.5	1.71
Favella sp.	2.5	2.05
Grammatophora sp.	2.5	1.19
Nitzschia sp.	2.5	1.71
Oscillatoria sp.	2.5	0.85
Pleurosigma sp	2.5	1.19
Rhizosolenia sp.	2.5	4.60
Rhabdonella sp.	5.0	3.41
Coscinodiscus sp.	5.0	4.26
Favella ehrenbergii	5.0	12.78
Helicostomella sp.	5.0	0.85
Oscillatoria sp.	5.0	5.46
Rhizosolenia sp	5.0	1.19
Salpingella sp.	5.0	0.85
Striatella sp.	5.0	1.71
Synedra sp.	5.0	2.05
Tintinnopsis sp.	5.0	4.26

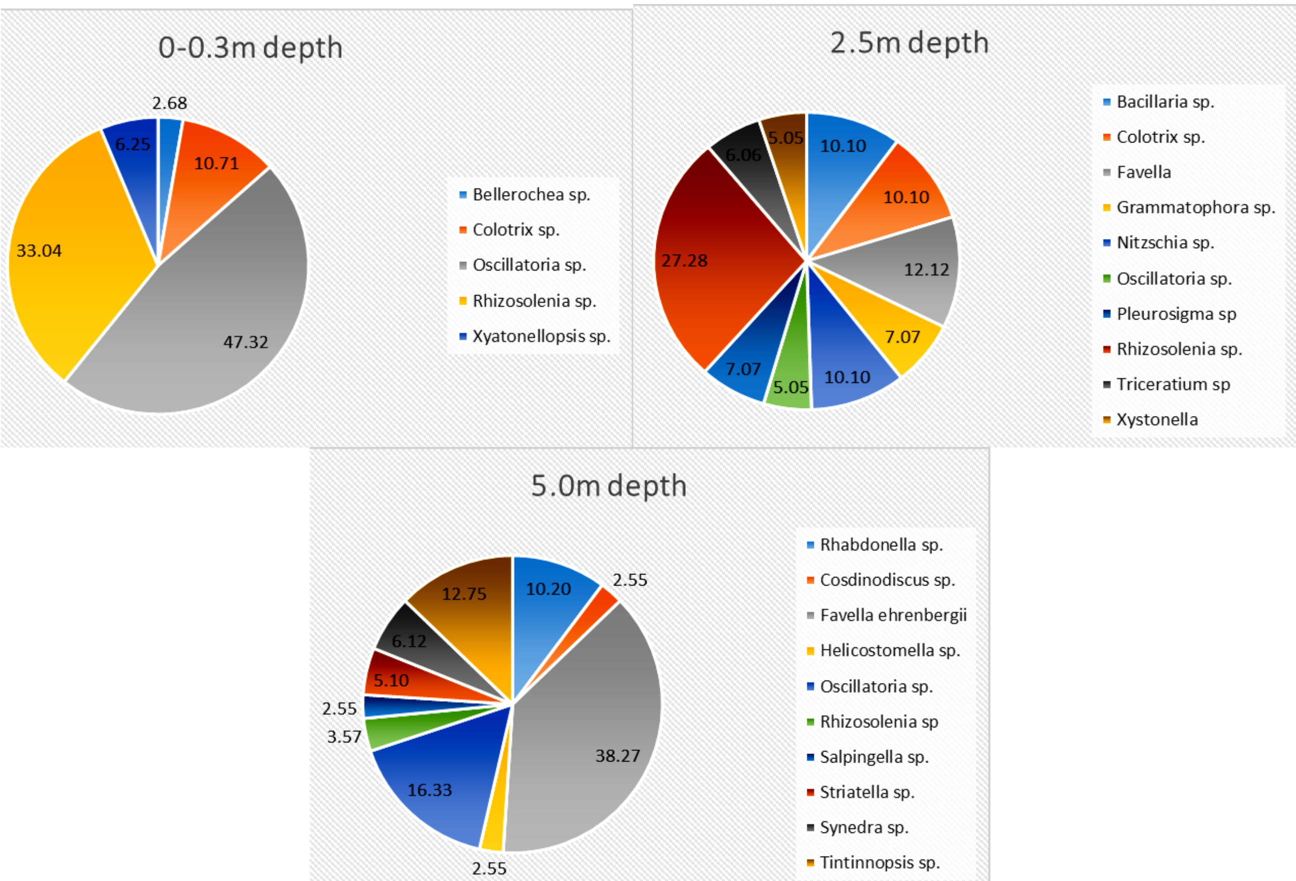

Figure 4. An abundance of phytoplankton species obtained from water samples at different depths, surface water (0-0.3 m), 2.5 m water depth, and 5 m water depth. Values are a percentage of each phytoplankton found in the water samples

Geographically, the selected area in the present study was protected (bay), a coastal body of water that directly connects to the Indian Ocean in the south. A similar type of geographic location (a bay) has been reported as a lobster fishing ground by Jawahar and Venkataramani (2007) in the Gulf of Mannar India. Some studies hypothesized that the lobsters naturally spawn in the deep sea, and as soon as hatching, the larvae are planktonic and driven by favorable shoreward currents, which help in transporting the larvae to their settlement grounds which are mostly in bays (Alborés et al. 2019). The direction of ocean current obtained in the present study confirmed that the ocean water flowing from the Indian ocean may carry lobster larvae shoreward at a speed of 0.1 m/s to 0.2-0.30 m/s. The bottom substrates were mostly a combination of sandy and rocky or sandy and corals that are relatively similar to what has been previously described by Priyambodo et al. (2020). However, this result differs from what has been reported in Booth and Phillips (1994), where lobster puerulus were mostly settled in mangrove and weed bottom areas. In addition, the water depth ranged from 18-30 m in both East Java locations. Lower water depth has been reported from several other fishing grounds of lobster peurulii by Priyambodo et al. (2015), which ranged from 5-17 m depth. Other parameters include transparency (5-6 m), temperature (28-29ºC), and dissolved oxygen (5-6 mg/L). The water temperature was slightly higher than the optimal temperature (25ºC), but it was also described that warmer temperature leads to better growth and onset maturity of crabs (Azra et al. 2020). While pH ranged from 7.8 to 85, which is very normal marine water, and nitrate concentration was less than 0.01 mg/L. These physicochemical characteristics are still in an optimal range for several aquatic animals at larval or adult stages (Amir et al. 2018; Amin et al. 2020). All this information can be used as basic knowledge to set up an artificial environment for breeding lobsters in the future.

Regarding the natural diets, some studies reported that plankton is one of the main natural diets for lobster larvae (O'Rorke et al. 2014). As lobster larvae vertically migrated to the surface of the water during the night (Booth and Phillips 1994), the present study also investigated the presence and density of plankton in the water column, 0-5 m depth. In general, the result showed that a total of 16 zooplankton species were identified, consisting of 6 zooplankton genera from the water depth of 0-0.3 m, 6 genera from the depth of 2.5m, and only 2 genera from the depth of 5m. The most abundant zooplankton species found in the surface water (0-0.3 m) were *Echinocamptus hiemalis elongates* (53%), followed by *Penilia avirostris* (24%), *Tortanus derjugini* (9%), *Acartia pacifica* (6%), *Caloceolanus* sp. (5%), and the least was *Rotaria* sp. (3%). While *Apocyclops royi* was the most dominant species found at 2.5 m water depth (45%). The rest species were *Penilia avirostris* (20%), followed by *Labidocera pava* (12%), *Lopadorhynchus* sp. (10%), and *Apocyclops* sp. (7%). The least abundant zooplankton species at the water of 2.5 m depth was *Tortanus derjugini* with 5%. Furthermore, the most dominant zooplankton species identified from water samples at 5m was *Oithona* sp. (85%), followed by *Polychaeta* with ~15 %.

However, in terms of cell density, the number of zooplankton species detected in the water sample appeared to decrease with the water depths. The density of zooplankton recorded from each water sample was decrease with the water depths. The density of zooplankton recorded from the water sample was ~211 ind./L at the surface water, decreased to 87 ind./L at 2.5 m depth, and became 80 ind./L water at a depth of 5m. According to Alka (2016), lobster larvae feed mostly on copepods, decapod larvae, fish eggs, and insect parts, indicating a predominantly carnivorous feeding habit. Another study by Chow et al. (2011) documented the potential diet of lobster larvae by unveiling the stomach content of lobster larvae and found metazoans such as Ctenophora, Cnidaria, Crustacea, and worms. Furthermore, O'Rorke et al. (2014) reported zooplankton, including Siphonophora (Cnidaria), Tetraodontiformes (ray-finned fish: Chordata), Lobata (Ctenophora), Siphonophora (Cnidaria), Tetraodontiformes (ray-finned fish: Chordata) and Siphonophoracalanoid copepod (Arthropoda), was identified in the stomach of lobster at phyllosoma stage. This study showed that at least 13 zooplankton genera detected belonged to Arthropoda (e.g., *Echinocamptus hiemalis*, *Penilia avirostris*, *Acartia pacifica*), which might be potential candidates for the diets of lobster larvae. However, this putative conclusion should be further investigated.

Another study by Carloni et al. (2018) reported that lobster larvae also fed on marine phytoplankton. Phillips (2008) explained that phytoplankton could be the source of essential polyunsaturated fatty acids (PUFA) such as eicosapentaenoic acid, linoleic acid, docosahexaenoic acid, and arachidonic acids. The present study found several species of diatom, including *Nitzia* sp., *Rhizosolenia* sp., *Bacillaria* sp., and *Synedra* sp. These species have been commonly known as live diets for several aquaculture species, including Sardine (*Sardinella longiceps*) (Shah et al. 2019) and mackerel (Aye 2020). Among the diatoms, *Synedra* sp. *Rhizosolenia* sp., and *Bacillaria* sp., were previously reported to be found in the stomach of spiny lobster (Ihsan et al. 2019). These results might suggest that the diatom could be a potential diet for spiny lobster larvae. However, further studies are still required to confirm such a conclusion.

In conclusion, the settlement habitat of lobster larvae (*P. homarus* and *P. ornatus*) is located in a bay facing the Indian Ocean, with sandy, rocky, or corals bottom substrates, 18-30m water depth, transparency (5-6 m), temperature (27-31ºC), dissolved oxygen (5-6 mg/L), and current speed (0.1-0.2 m/s), nitrate <0.01, and chlorophyll concentration at 0.4-0.6 mg/m. Furthermore, the surface current data seems to flow from the Indian ocean in the south to the north (Indonesia Islands), moving from west to east with a speed of 0.1 m/s to 0.2-0.30 m/s. pH ranged from 7.8 to 85, nitrate concentration was less than 0.01 mg/L and salinity of 30 psu-34 psu.

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