

## BUKTI KORESPONDENSI

### JURNAL INTERNASIONAL BEREPUTASI TERAKREDITASI Q2

Judul Artikel : Diversity and abundance of plankton community in Tawang and Prigi Bays, natural settlement habitats of Spiny Lobster larvae in East Java, Indonesia

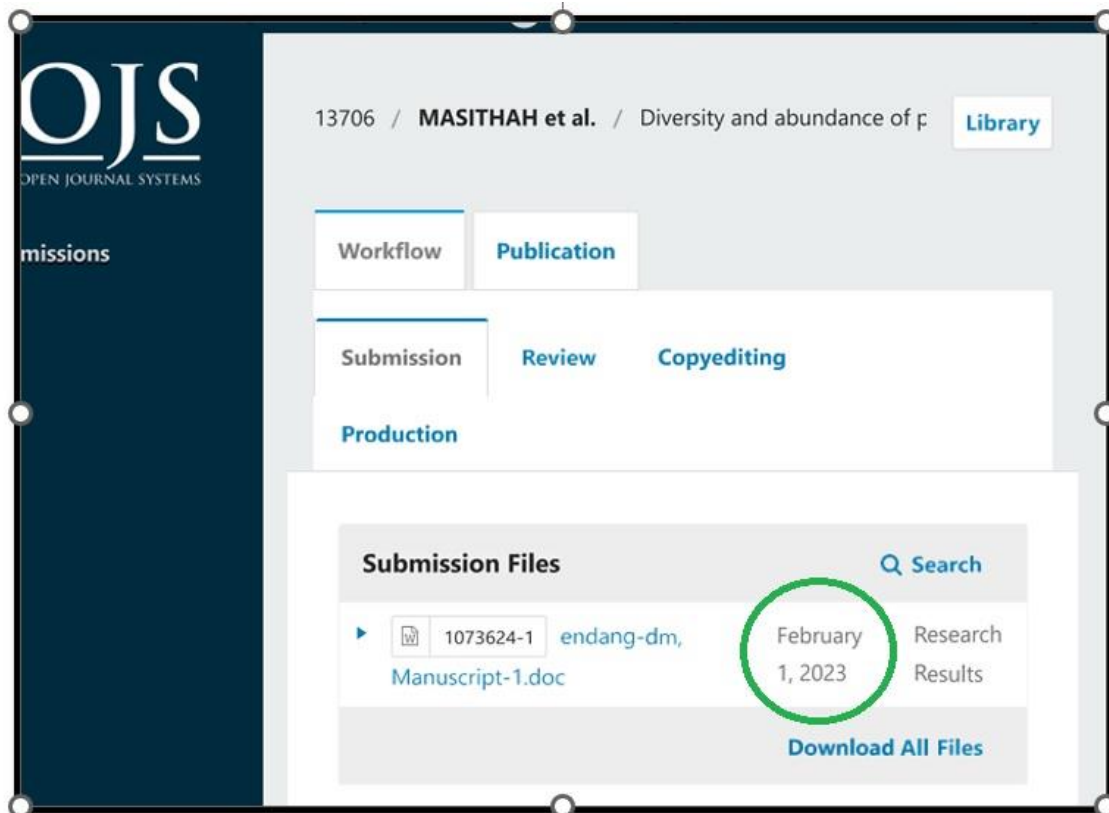
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Penulis : ENDANG DEWI MASITHAH, MUHAMMAD GIANO FADHILAH, MUHAMAD AMIN, KURNIATI UMRAH NUR, LAILA MUSDALIFAH, SHIFANIA HANIFA SAMARA, YUDI CAHYOKO, ALIMUDDIN, SAHRUL ALIM, BAGUS DWI HARI SETYONO

No	Perihal	Tanggal	Halaman
1.	Bukti submit dan artikel yang disubmit	1 Februari 2023	2-17
2.	Bukti komentar reviewer (round 1)	3 Maret 2023	18-38
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4.	Bukti komentari reviewer (round 3)	11 Maret 2023	53-65
5.	Bukti respon kepada reviewer round 3, dan artikel yang diresubmit	11 Maret 2023	66-78
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7.	Bukti published	30 Maret 2023	80-89

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A. Submit naskah awal oleh author



B. Editor mengkonfirmasi bahwa naskah telah diterima untuk proses review 1

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1 message

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To: Endang Masithah <endang\_dm@fpk.unair.ac.id>

Wed, Feb 1, 2023 at 11:48 PM

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**Title:**

**Diversity and Abundance of Plankton Community in the Natural Settlement Habitats of Spiny Lobster Larvae (*Panulirus spp.*)**

**Author(s) name:**

Endang Dewi Masithah<sup>1\*</sup>, Muhammad Giano Fadhilah<sup>2</sup>, Muhamad Amin<sup>3</sup>, Kurniati Umrah Nur<sup>4</sup>, Laila Musdalifah<sup>5</sup>, Sao Mai Dang Thi<sup>6</sup>, Shifania Hanifa Samara<sup>2</sup>, Alimuddin Alimuddin<sup>7</sup>, Yudi Cahyoko<sup>3</sup>

**Address**

(Fill in your institution's name and address, your personal cellular phone and email)

1. Department of Marine, Faculty of Fisheries and Marine, Universitas Airlangga, Campus C UNAIR Mulyorejo, Jl. Mulyorejo Surabaya 60115 Indonesia, Tel./fax.: +62-31-315911541, email: endang\_dm@fpk.unair.ac.id
2. The Aquaculture Study Program, Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga, Campus C UNAIR Mulyorejo, Jl. Mulyorejo Surabaya 60115 Indonesia.
3. Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga, Campus C UNAIR Mulyorejo, Jl. Mulyorejo Surabaya 60115 Indonesia. Tel./fax.: +62-31-315911541,
4. Aquaculture Study Program, Fisheries Department, Faculty of Marine Science and Fisheries, Universitas Hasanudin, Makassar, Sulawesi Selatan, Indonesia.
5. National Research and Innovation Agency, Republic of Indonesia, Jakarta, Indonesia
6. Institute of Veterinary Research and Development of Central Vietnam, Vietnam
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The manuscript is the first study to report diversity, and abundance of planktons in two most common natural settlement habitat of lobster larvae in east java Indonesia (Tawang Bay and Karanggongso Bay).

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Endang Dwi Masithah

# Diversity and Abundance of Plankton Community in the Natural Settlement Habitats of Spiny Lobster Larvae

ENDANG DEWI MASITHAH<sup>1,✉</sup>, MUHAMMAD GIANO FADHILAH<sup>2</sup>, MUHAMAD AMIN<sup>3</sup>, KURNIATI UMRAH NUR<sup>4</sup>, LAILA MUSDALIFAH<sup>5</sup>, SAO MAI DANG THI<sup>6</sup>, SHIFANIA HANIFA SAMARA<sup>2</sup>, ALIMUDDIN ALIMUDDIN<sup>7</sup>, YUDI CAHYOKO<sup>3</sup>

<sup>1</sup>Department of Marine, Faculty of Fisheries and Marine, Universitas Airlangga, Campus C UNAIR Mulyorejo, Jl. Mulyorejo Surabaya 60115 Indonesia, ✉email: endang\_dm@fpk.unair.ac.id.

<sup>2</sup>The Aquaculture Study Program, Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga, Campus C UNAIR Mulyorejo, Jl. Mulyorejo Surabaya 60115 Indonesia.

<sup>3</sup>Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga, Campus C UNAIR Mulyorejo, Jl. Mulyorejo Surabaya 60115 Indonesia.

<sup>4</sup>Aquaculture Study Program, Fisheries Department, Faculty of Marine Science and Fisheries, Universitas Hasanudin, Makassar, Sulawesi Selatan, Indonesia.

<sup>5</sup>National Research and Innovation Agency, Republic of Indonesia, Jakarta, Indonesia

<sup>6</sup>Institute of Veterinary Research and Development of Central Vietnam, Vietnam

<sup>7</sup>Faculty of Animal Science, University of Mataram, West-Nusa Tenggara Indonesia

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**Abstract.** Tawang Bay and Karranggongso Bay have been well-known as settlement areas for lobster larvae in East Java Indonesia, which may suggest that the location are suitable environments including diet availability for lobster larvae. Therefore, the study aimed to investigate the abundance and diversity of plankton in the both locations to discover potential live diets for lobster larvae. Plankton samples were collected in both locations using a plankton net at four different depths: 0.3m, 2.5m, m, and 20m with three replicates. The result revealed that 17 plankton species were identified from the 0.30m depth, 13 species at a depth of 2.5m, 11 species at a depth of 5m, and 13 species at 20m at Karanggongso Bay. While, 17 plankton species were discovered on the surface of Tawang Bay waters: 11 species at a 2.5m, 12 species at 5m, and 12 species at 20m. The diversity index and uniformity indices of plankton in both locations were considered at a moderate. While there were no dominant species at both locations, indicated by the dominance index values ranged from 0.13-0.30. Among the identified plankton species, *Oithona* sp., and *Acartia* sp. are considered potential live feed for lobster larvae, and thus should be further studied.

**Key words:** diversity, diets, dominance, lobster, plankton, uniformity.

**Abbreviations** (if any): -

**Running title:** Plankton diversity in lobster natural habitat

## INTRODUCTION

Lobster is an important fishery commodity in Indonesia due to its high price, high nutritional contents as well as high market demands. According to the Indonesian Central Bureau of Statistics, the total export value of lobsters in 2020 reached USD 8.1 million (BPS 2020). The high export value and continuously increasing marketing demands at national or global markets indicate that lobster is a high-potential fisheries commodity. However, the lobster supply has been highly dependent on the wild catch because lobster aquaculture has not been well developed yet. One of the main issues faced in lobster aquaculture is larval production, which currently relies on the availability of seeds in nature. Many studies have been conducted to study various factors relating to larval production of larvae including spawning-inducing technology and rearing condition, yet the success rates are very low. Several authors have succeeded to breed and producing larvae. Yet, the larvae can live only 7-14 days after hatching. It is hypothesized that the main challenge is in diet availability and suitability. According to Amin et al. (2022b), one way to start domesticating wild species is firstly by collecting information on their natural habitat as much as possible. Similarly, Kashinskaya et al. (2018) suggest that profiling certain animals' natural habitat may reveal their diets.

Environmental conditions including physical, chemical, and biological factors in natural habitats highly determine the recruitment rates of lobster larvae (Keulder 2005). Several authors have previously reported the physical and chemical characteristics of the natural settlement areas of lobster larvae (Amin et al. 2022c; Boudreau et al. 1992; Lillis and Snelgrove 2010). However, studies investigating biological aspects of settlement habitat in the natural environment of lobster larvae are still very limited. Meanwhile, many studies conclude that biological factors hold important information

49 for the lobster larvae, especially for diets (O'Rorke et al. 2014). Accordingly, biological aspects such as natural dietary  
 50 aspects and lobster predation processes that occur in nature during larval and post-larval stages could be critical  
 51 information that must be considered for hatchery production. In their natural settlement habitat, plankton might be a  
 52 natural diet source for various types of fish seeds, including lobster seeds. Raza'i et al. (2018) added that the availability of  
 53 plankton as a natural diet source has a significant impact on the dependence and growth of marine organisms such as fish,  
 54 crabs, shrimp, and lobsters.

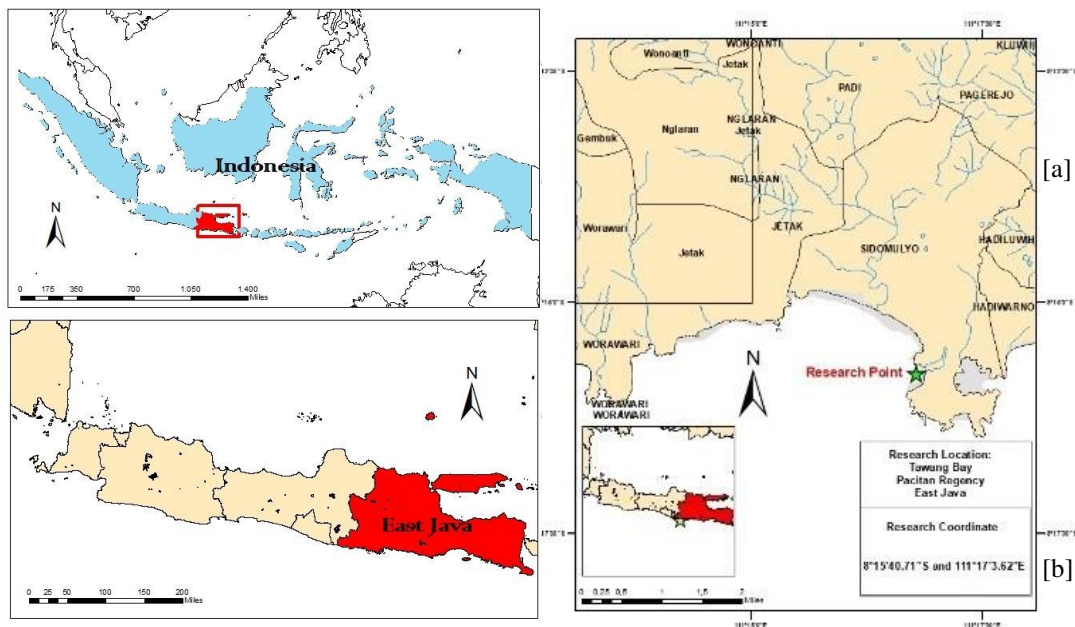
55 Profiling plankton diversity and abundance might reveal potential diets for lobster larvae. A similar approach has been  
 56 done in some studies. For instance, Ihsan et al. (2019) conducted research on plankton as a natural feed for lobster larvae  
 57 and post-larvae in natural habitats in Teluk Awang, Central Lombok. Trijoko and Pasaribu (2003) conducted another study  
 58 in Wedi Ombo Bay, Gunung Kidul, Yogyakarta. The study results in general suggest that each location has a different  
 59 structure and abundance, although some species were the same between the area. All these results raise questions about  
 60 whether lobster larvae are opportunistic feeders or specific feeders. To answer these questions more studies are required by  
 61 collecting more information in more settlement areas of lobster.

62 Tawang Bay been well-known as one of the most settlement areas for lobster larvae in East Java Indonesia (Amin et al.  
 63 2022a); therefore, it is assumed to have important suitable diet availability for lobster larvae. However, studies on the  
 64 biological aspects of both locations areas are still very limited. Thus, the objective of this research is to investigate the  
 65 plankton diversity, abundance, uniformity, and dominance indices in the natural settlement habitat of lobster larvae at  
 66 Karanggongso and Tawang Bays. The study results are expected to enrich the information on potential diets for lobster  
 67 larvae for hatchery development.

## 68 MATERIALS AND METHODS

### 69 Study area

70 The collection of plankton samples was carried out in two common settlement areas of lobster larvae in East Java  
 71 Indonesia (Tawang Bay) with a protocol as previously described by Amin et al. (2022c). The sampling location  
 72 was performed at ordinate points: 8°15'57.4"S 111°17'46.0" E (L1), 8°15'54.3"S 111°17'48.2"E (L2) and 8°15'51.5"S  
 73 111°17'46.2"E (L3), (Figure 1). Plankton sampling was conducted at three different sampling points with four different  
 74 depths: 0-0.3 m, 2.5 m, 5 m, and 20 m. The water samples were filtered using a plankton net and placed in sterile bottles.  
 75 The filtered sample was then immediately given Lugol which acts as a plankton preservative, up to 1% of the total filtering  
 76 and wrapped in Styrofoam. The samples were then examined in the Microbiology Laboratory, Faculty of Fisheries and  
 77 Marine Science at Airlangga University.  
 78



79 Figure 1 Two sampling locations: Karanggongso Bay, Trenggalek Regency [a], and Tawang Bay, Pacitan Regency [b], East Java,  
 80 Indonesia.

82 Karanggongso Bay waters have temperatures ranging from 27-28 °C, a DO content of 7.48 mg/L, a salinity of 26 ppt, a  
 83 pH of 7-8, a NO<sub>3</sub> content of 0.01 mg/L, and a muddy substrate. Tawang Bay waters temperatures are slightly warmer than  
 84 Karanggongso Bay, with water temperature ranging from 28.2-28.3 °C, with a significantly lower, DO content of 3.35



85 mg/L. moreover, Tawang Bay has a higher salinity of 35 ppt, a pH of 8, a NO<sub>3</sub> content of 0.01, a depth of 15 m, and a  
86 sandy substrate

### 87 **Abundance and Identification of planktons**

88 Firstly, plankton identity and their abundances were analyzed using a protocol of LeGresley and McDermott (2010). In  
89 brief, plankton samples were placed on a Sedgewick Rafter Counting Cell and observed under a binocular microscope with  
90 a magnification of 1000x. Thereafter each plankton found in each sample was counted, photographed, and identified  
91 according to an identification book guide by Mazzocchi et al. (2012). Then, the abundance index was calculated according  
92 to the following formula (Fachrul 2012)::

$$N = \frac{a}{b} \times \frac{c}{d} \times \frac{Vb}{Vsrc} \times \frac{1}{Vs}$$

93 Where “N” represents the abundance of plankton (plankton/L), “a” represents the number of SRC boxes, “b” is the area of  
94 one field of view (mm<sup>2</sup>), “c” denotes the number of individuals observed, and “d” indicates the number of boxes observed.  
95 “Vb” is the volume of water in the sample bottle (ml), “Vsrc” is the volume of water in the SRC (ml), and “Vs” represents  
96 the volume of water filtered in the Field (L).  
97

### 98 **Diversit, Uniformity and dominant indices**

99 The diversity index value (H') was calculated using the following formula (Fachrul 2012):

100 
$$H' = -\sum Pi \ln Pi, \text{ where } Pi = \frac{ni}{N}$$

101 Where H' is Shannon Wiener Diversity Index, pi is the number of individuals of the i-th species, ni is the  
102 number of species, and N is the total individual number.

103 The uniformity index (E') was calculated using the “Evenness Index” formula (Ulfah et al. 2019):

$$E' = \frac{104 H'}{105 S} \text{ where, } E' \text{ is uniformity index, } H': \text{ Shannon Wiener Diversity Index, } S: \text{ Total number of species}$$

106

107 The dominance index (d) was calculated using the following equation (Berger and Parker 1970):

108 
$$d = \frac{N_{max}}{N}$$
 where, “d”: Simpson Dominance Index, N<sub>max</sub>: The most abundant number of individual species, dan  
109 N = Total individual

number.110

## 111 **RESULTS AND DISCUSSION**

### 112 **Plankton Abundance in Karanggongso Bay**

113 Samples of water were obtained from Karanggongso Bay at three designated locations, each with four different levels  
114 of depth. A total of 17 plankton species were identified from the surface water (0.0-0.3 m). The top six most abundant  
115 species were *Paracyclops* sp. with 21.21%, followed by *Acartia* sp. (18.18%), *Pteropods* sp. (9.09%), *Prorocentrum* sp.  
116 (6.06%), *Dinophysis* sp. (6.06%), and *Sagitta* sp. (2.13%). Other species and their percentage was presented in Table 1. In  
117 addition, at a 2.5 m depth, 13 plankton species were identified and the top 6 most abundant species were *Acartia* sp.  
118 (26.47%), followed by *Paracyclops* sp. (23.53%), *Ceratium* sp. (8.82%), *Microsetella* sp. (8.82%), *Dinophysis* sp.  
119 (5.8%), and *Oncaea* sp. (5.88%). The rest species with their abundance were presented in Table 1.

120 Furthermore, at 5 m depth, the Bay is home to 11 plankton species. The top 4 most abundant species were *Acartia* sp.  
121 (30.77%), followed by *Paracyclops* sp. (23.08%), *Sagitta* sp. (11.54%), and *Oithona* sp. (7.69%). While the other 7  
122 species including *Synedra* sp., *Oikopleura* sp., *Coscinodiscus* sp., *Ceratium* sp., *Pteropods* sp., *Microsetella* sp., and  
123 unclassified Lucifer which were counted for 3.85% each, Table 1. Meanwhile, a total of 13 plankton species were found at  
124 the depth of 20 m. The top 6 most abundant species were *Acartia* sp. accounted for 24.14%, followed by *Paracyclops*  
125 sp. with 13.79%, *Pteropods* sp. (10.34%), *Dinophysis* sp. (10.34%), *Ceratium* sp. with 6.90%, and *Sagitta* sp. with 6.90%.

126 The rest species were presented in table 1.

127  
128  
129

**Table 1.** Planktons identified from two natural settlement habitats of spiny lobster larvae (Karanggongso Bay and Trenggalek Regency, East Java Indonesia) at four different depths of the water column.

Depth	Species	Cell density (Indiv/L)
0.3 m (Surface)	<i>Cyclotella</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Noctiluca</i> sp.	8
	<i>Prorocentrum</i> sp.	16
	<i>Dinophysis</i> sp.	16
	<i>Ceratium</i> sp.	8
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	24
	<i>Paracyclops</i> sp.	56
	<i>Acartia</i> sp.	48
	<i>Microsetella</i> sp.	8
	<i>Euphausia</i> sp.	8
	<i>Lucifer</i> sp.	8
	<i>Oithona</i> sp.	8
	<i>Sagitta</i> sp.	16
	<i>Nemateia</i> sp.	8
<i>Actinella</i> larvae	8	
2.5 m	<i>Rizosolenia</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Ceratium</i> sp.	24
	<i>Dinophysis</i> sp.	16
	<i>Paracyclops</i> sp.	64
	<i>Acartia</i> sp.	72
	<i>Microsetella</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Codoneopsis</i> sp.	8
	<i>Oithona</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Actinula</i> sp.	8
	<i>Polychaete</i>	8
5.0 m	<i>Oikopleura</i> sp.	8
	<i>Synedra</i> sp.	8
	<i>Coscinodiscus</i> sp.	8
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	8
	<i>Paracyclops</i> sp.	48
	<i>Acartia</i> sp.	64
	<i>Microsetella</i> sp.	8
	<i>Oithona</i> sp.	16
	<i>Lucifer</i> sp.	8
<i>Sagitta</i> sp.	24	
20.0 m (Bottom)	<i>Synedra</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Noctiluca</i> sp.	8
	<i>Dinophysis</i> sp.	24
	<i>Ceratium</i> sp.	16
	<i>Pteropods</i> sp.	24
	<i>Acartia</i> sp.	56
	<i>Paracyclops</i> sp.	32
	<i>Oithona</i> sp.	8
<i>Microsetella</i> sp.	16	

<i>Euphausia</i> sp.	8
<i>Protopteridinium</i> sp.	8
<i>Sagitta</i> sp.	16

### 131 Plankton Abundance in Tawang Bay

132 A total of 17 plankton species were identified from the water sample at depth of 0.0-0.3 m (surface water) of Tawang  
 133 Bay. The top 9 most abundant species were *Acartia* sp. with an abundance of 12.82%, followed by *Ceratium* sp. (10.26%),  
 134 *Prorocentrum* sp. (10.26%), *Microstella* sp. (10.26%), *Oncaea* sp. (10.26%) *Pteropods* sp. (7.69%), *Calanus* sp., (7.69%),  
 135 *Synedra* sp. (5.13%), and *Oithona* sp. (5.13%). While the rest species were counted for 2.56% each and presented in **Table**  
 136 **2**. In addition, there were 11 species of plankton found in a water sample at a depth of 2.5 m in Tawang Bay. The top 6  
 137 most abundant species were *Calanus* sp. (28.00%), followed by *Prorocentrum* sp. (12.00%), *Paracyclopsina* sp. (12.00%),  
 138 *Microstella* sp. (12.00%), *Oncaea* sp. (8.00%), and *Oithona* sp. with an abundance of 8.00%. While the rest plankton  
 139 species including *Synedra* sp., *Ceratium* sp., *Pteropods* sp., *Macrophthalmus* sp., and *Sagitta* sp. were counted at 4.00%  
 140 each, **Table 2**.

141 Furthermore, a total of 12 plankton species were identified from the water sample at 5 m depth. The top 4 most  
 142 common species were *Calanus* sp. with an abundance of 28.57%, *Oithona* sp. with an abundance of 14.29%, *Copepoda*  
 143 *nauplii* with an abundance of 9.52%, *Prorocentrum* sp. with an abundance of 9.52%. While the rest species including  
 144 *Melosira* sp., *Synedra* sp., *Dinophysis* sp., *Microstella* sp., *Temora* sp., *Oncaea* sp., and *Sagitta* sp., with an abundance of  
 145 5.00% respectively. While in the bottom waters of Tawang Bay (20 m depth), a total of 12 plankton species were  
 146 identified. The top 9 most abundant species were *Prorocentrum* sp. with an abundance of 16.44%, *Acartia* sp. with an  
 147 abundance of 16.44%, *Oithona* sp. with an abundance of 16.44%, *Oncaea* sp. with an abundance of 10.96%, *Dinophysis*  
 148 sp. with an abundance of 5.48%, *Rhizosolenia* sp. with an abundance of 5.48%, *Pleurosigma* sp. with an abundance of the  
 149 abundance of 5.48%, *Ceratium* sp. with 5.48%, *Caridean* sp. (5.48%). While the rest species were presented in table 2.

150 **Table 2.** Planktons identified from the natural habitat of spiny lobster in bottom water at Tawang Bay, East Java Indonesia

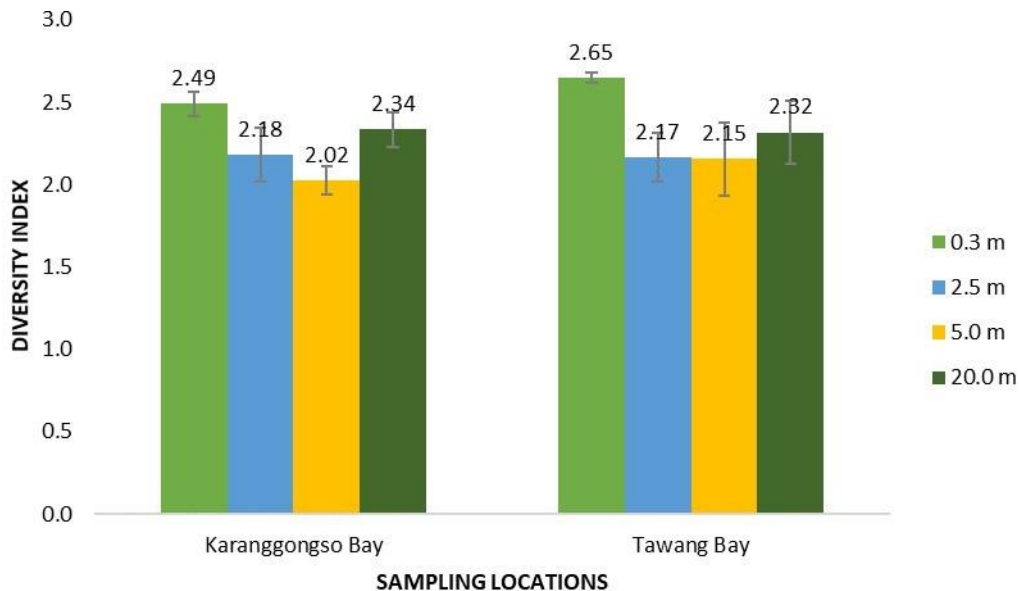
Depth	Species	Density (Indiv/L)
0.3 m (Surface)	<i>Synedra</i> sp.	16
	<i>Oscillatoria</i> sp.	8
	<i>Spirulina</i> sp.	8
	<i>Ceratium</i> sp.	32
	<i>Prorocentrum</i> sp.	32
	<i>Pteropods</i> sp.	24
	<i>Acartia</i> sp.	40
	<i>Microstella</i> sp.	32
	<i>Calanus</i> sp.	24
	<i>Oithona</i> sp.	16
	<i>Oncaea</i> sp.	32
	<i>Euphausia</i> sp.	8
	<i>Macrophthalmus</i> sp.	8
	<i>Clytemnestra</i> sp.	8
	<i>Cypris</i> sp.	8
	Unclassified <i>Fish larvae</i>	8
Unclassified flatworms	8	
2.5 m	<i>Synedra</i> sp.	8
	<i>Prorocentrum</i> sp.	24
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	8
	<i>Paracyclopsina</i> sp.	24
	<i>Calanus</i> sp.	56
	<i>Oithona</i> sp.	16
	<i>Microstella</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Macrophthalmus</i> sp.	8
	<i>Sagitta</i> sp.	8
<i>Melosira</i> sp.	8	
<i>Synedra</i> sp.	8	
<i>Bivalve larvae</i>	8	
<i>Prorocentrum</i> sp.	16	

5 m	<i>Dinophysis</i> sp.	8	
	<i>Microsetella</i> sp.	8	
	<i>Calanus</i> sp.	48	
	<i>Oithona</i> sp.	24	
	<i>Naupli Copepoda</i>	16	
	<i>Temora</i> sp.	8	
	<i>Oncaea</i> sp.	8	
	<i>Sagitta</i> sp.	8	
	20 m (bottom)	<i>Rhizoselenia</i> sp.	8
		<i>Pleurosigma</i> sp.	8
<i>Prorocentrum</i> sp.		24	
<i>Ceratium</i> sp.		8	
<i>Dinophysis</i> sp.		8	
<i>Microsetella</i> sp.		4	
<i>Calanus</i> sp.		6	
<i>Acartia</i> sp.		24	
<i>Oithona</i> sp.		24	
<i>Oncaea</i> sp.		16	
	<i>Caridean</i> sp.	8	
	Unclassified flatworm	8	

151  
152

### 153 Diversity indices

154 The diversity index values obtained in the waters of Karanggongso Bay, Trenggalek Regency East Java were  $2.49 \pm 0.07$  at depth of 0.0-0.3 m depth of water column,  $2.18 \pm 0.16$  at a depth of 2.5 m,  $2.02 \pm 0.08$  at a depth of 5 m, and  $2.34 \pm 0.10$  at the 20 m water column which indicates that the Karanggongso Trenggalek waters have moderate diversity. While the diversity index values obtained in the waters of Tawang Bay were  $2.65 \pm 0.03$  at 0.0 – 0.3 m depth,  $2.17 \pm 0.15$  at the 2.5 m depth,  $2.15 \pm 0.22$  at a 5 m depth, and  $2.32 \pm 0.19$  at a depth of 20 m which indicates that the waters of Tawang Bay have also moderate diversity, Figure 2



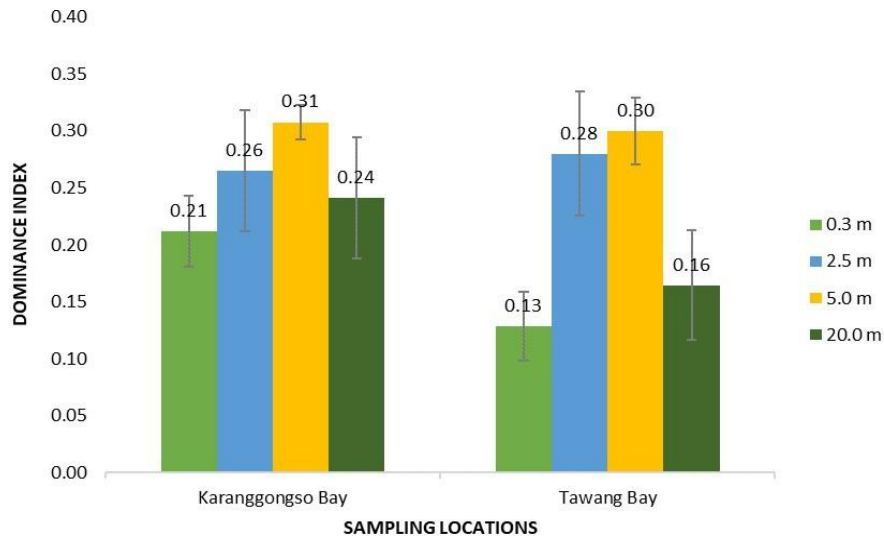
160

161 **Figure 2.** Diversity indices of plankton identified at the water column of Karanggongso Bay and Tawang Bay, East java  
162 Indonesia. Bars are the average values with a standard deviation of three replicates.

### 163 Domination Index

164 The dominance index is a value that indicates whether there are plankton species that dominate certain depths in the  
165 water column. Dominance index values obtained from the waters of Karanggongso Bay were  $0.21 \pm 0.03$  at the 0.0-0.3 m  
166 depth,  $0.26 \pm 0.05$  at a depth of 2.5 m,  $0.31 \pm 0.02$  at a depth of 5 m and  $0.24 \pm 0.05$  at the 20 m water depth. These values  
167 mean that no plankton species were dominant in the natural habitat of spiny lobster larvae (Karanggongso Bay). While the  
168 dominance index values obtained from Tawang Bay waters were  $0.13 \pm 0.03$  at the 0.0-0.3 m depth,  $0.28 \pm 0.05$  at a depth

169 of 2.5 m,  $0.30 \pm 0.03$  at a depth of 5 m, and  $0.16 \pm 0.05$  at the 20 m depth. Similarly, based on the values obtained from the  
 170 surface to the bottom of the waters shows that there are no species that dominate in Tawang Bay, Figure 4.



171  
 172 **Figure 4.** Domination indices of planktons identified at Karanggongso Bay and Tawang Bay, East Java, Indonesia. Bars  
 173 are the average values with a standard deviation of three replicates.

174

## 175 Discussion

176 Environmental conditions including physical, chemical, and biological factors in natural habitats highly determine the  
 177 recruitment rates of lobster larvae (Keulder 2005). Several studies have previously reported the physical and chemical  
 178 characteristics of the settlement area of lobster (Amin et al. 2022c; Boudreau et al. 1992; Lillis and Snelgrove 2010).  
 179 However, studies viewing biological aspects of settlement habitat in natural environment lobster larvae are still very  
 180 limited. Meanwhile, many studies conclude that biological factors such as plankton availability can be important  
 181 information on the natural diets of lobster larvae (O'Rorke et al. 2014). Thus the present study investigated the diversity,  
 182 uniformity, and dominance of plankton in two common settlement areas of lobster larvae in East Java (Karanggongso Bay  
 183 and Tawang Bay) in Indonesia. The sampling was performed in 4 different depths which were 0.3 m, 2.5 m, 5 m, and 20 m  
 184 depth, as lobster larvae vertically migrated from the bottom during the daytime to the surface of the water during the  
 185 nighttime. It was also discovered that the diversity indices of plankton at both locations were 2.02-2.49 at Karanggongso,  
 186 and 2.15-2.65 at Tawang Bay. The diversity index values found at these two locations were all less than 3, which means at  
 187 a moderate level. The high or low value of plankton diversity can be caused by the evenly distributed abundance of each  
 188 individual or in another sense there are no species that have relatively more diversity than other species (Awwaluddin et al.  
 189 2017). As the diversity indices of plankton at Karanggongso Bay and Tawang Bay may which is at a moderate level may  
 190 suggest that plankton communities is in relatively equal distribution of different species, with no one species being  
 191 significantly more prevalent than others (Awwaluddin et al. 2017).

192 Similarly, the uniformity indices of planktons in both settlement areas were classified at a moderate level (0.38-0.45 at  
 193 Karanggongso Bay and 0.41-0.46 at Tawang Bay. The uniformity values found at each location, both Karanggongso  
 194 Beach waters and Tawang Beach waters, are said to have moderate uniformity. The value of uniformity is categorized to  
 195 be moderate if the value ranges from 0.4-0.6 (Ulfah et al. 2019). The availability of nutrients, food, and predation  
 196 processes can affect the high value of uniformity because it affects the type and amount of plankton. Besides that, physical  
 197 and chemical factors also affect the value of uniformity because it will affect the growth of plankton (Nugroho et al. 2020).  
 198 In addition, If the distribution of plankton in both waters is uniform, then a high degree of uniformity can be asserted.  
 199 While the dominance indices were ranging from 0.21 – 0.31 at Karanggongso Bay and 0.13-0.30 in Tawang Bay. The  
 200 result indicates that there were no dominant species at both locations since all values  $< 0.05$ . Dominance index values  
 201 obtained in both waters indicate the absence of plankton which dominates in Karanggongso Bay and also Tawang Bay.  
 202 Whether or not organisms dominate a waters can be seen from the value of the dominance index if the dominance index  
 203 shows a value between 0.5 to 1 then in these waters there are organisms that dominate and if it shows a value less than 0.5  
 204 then in these waters it indicates the absence of organisms dominating (Berger and Parker

1970), 205

## 206 Potential Diet for Lobster Seeds

207 The result also revealed that 17 plankton species were identified from the surface water, 13 species at a depth of 2.5 m,  
 208 11 species at a depth of 5 m, and 13 species at 20m (bottom) of Karanggongso Bay. While, 17 plankton species were

209 discovered on the surface of Tawang Bay waters: 11 species at a depth of 2.5 m, 12 species at a depth of 5 m, and 12  
210 species at the seafloor. The number of plankton species identified in the present study, in general, are higher than in  
211 previous study reported from other settlement habitats of lobster larvae in Awang Bay west Nusa Tenggara (Amin et al.  
212 2022c) and Teluk Wedi Ombo, Yogyakarta (Trijoko and Pasaribu 2004). The most abundant species identified from  
213 Karanggongso Bay were *Paracyclops* sp., *Acartia* sp., *Pteropods* sp., and *Prorocentrum* sp. *Dinophysis* sp., *Sagitta* sp.,  
214 *Ceratium* sp., *Microsetella* sp., *Dinophysis* sp., *Calanus* sp., *Synedra* sp., and *Oithona* sp. (7.69%). While most abundant  
215 species found in Tawang Bay were *Acartia* sp., *Ceratium* sp. *Prorocentrum* sp., *Microsetella* sp., *Oncaea* sp., *Pteropods*  
216 sp., *Calanus* sp., *Synedra* sp., *Oithona* sp., *Calanus* sp., *Paracyclops* sp., *Macrotholmus* sp., *Sagitta* sp., *Dinophysis* sp.,  
217 and *Rhizosolenia* sp. of these identified plankton species, 10 species were found in both locations including *Acartia* sp.,  
218 *Oithona* sp., *Paracyclops* sp., *Pteropods* sp., *Binophysis* sp., *Sagitta* sp., *Microsetella* sp. *Calanus* sp., *Synedra* sp.

219 Among the identified plankton species, few species have been documented as potential live diets in aquaculture  
220 including *Oithona* sp. for live diet of European seabass (*Dicentrarchus labrax*) postlarvae (Magouz et al. 2021a), and  
221 shrimp larvae (Dinesh Kumar et al. 2017), and *Acartia* sp., as a live diet for seabass larvae, *Lates calcarifer* (Rajkumar  
222 2006), fat snook, *Centropomus parallelus* (Barroso et al. 2013), and many other aquatic larvae (Sarkisian et al. 2019). In  
223 fact, some studies also confirmed that these plankton species were identified in the stomach content of lobster larvae. For  
224 instance, *Oithona* sp. has been reported from the stomach content of spiny lobsters at the early life stage (Amin et al.  
225 2022d; Khvorov et al. 2012). *Oithona* sp. has been described as a marine calanoid copepod which has high protein content,  
226 ~59.33% (Santanumurti et al. 2021), therefore frequently used as a live diet for fish or shrimp larvae. Another study has  
227 documented that *Oithona* sp. had a high content of fatty acid profiles including polyunsaturated fatty acids (26.47%) and  
228 omega-3 fatty acids (36.30) which in fact are higher compared to a commercial live diet such as *Artemia* (Magouz et al.  
229 2021b). Furthermore, *Acartia* sp. has been also documented to be a good live diet for aquatic larvae such as seabass larvae,  
230 *Lates calcarifer* (Rajkumar 2006), and fat snook, *Centropomus parallelus* (Barroso et al. 2013). *A. clausi* has been  
231 described to have higher contents of proteins (63.12%) and lipids (16.65%) and is also richer in n-3 fatty acids (33.94%)  
232 than *Artemia* nauplii and rotifers (Rajkumar, 2006). The plankton species has been also identified in the stomach content  
233 of spiny lobster larvae (Amin et al. 2022d). In addition, a member of *Acartia* (*Acartia tonsa*) had been documented to  
234 provide an important nutritional benefit to fat snook larvae undergoing metamorphosis (Vanacor-Barroso et al. 2017).

235 Other potential food sources for lobster larvae identified in the present study are zooplankton and phytoplankton.  
236 According to the results obtained, the plankton found at each station consists of Bacillariophyceae (e.g. *Rizosolenia* sp.,  
237 *Synedra* sp., *Cyclotella* sp.), and Copepoda (e.g. *Oithona* sp., *Acartia* sp., *Calanus* sp.). These plankton groups were  
238 identified at each station, highlighting their potential as a food source for lobster larvae. Diatoms, which belong to the  
239 phytoplankton group Bacillariophyceae, contain essential nutrients required for the growth of lobster larvae, such as  
240 PUFA (Polyunsaturated Fatty Acid). PUFA including EPA (eicosapentaenoic acid, 20:5 n-3) and DHA (docosahexaenoic  
241 acid 22:6 n-3) are the major fatty acids found in diatoms Bacillariophyceae (Pahl et al, 2010). PUFA content of these  
242 diatoms is relatively high, with levels ranging between 23.4 and 60.7% (Valera & Saavedra, 2016). High PUFA content  
243 was identified in several plankton species as potential prey for spiny lobster larvae *Jasus edwardsii*, and these long-chain  
244 fatty acids are an essential nutrient for spiny lobster (Koshio & Kanazawa, 1994; Liddy et al, 2004; Wang, 2013).

245 Copepoda (Hexanauplia) is a rich source of protein, particularly in gastropods, it is also high in calcium content which  
246 is important for lobster during molting (Kirno et al, 2012). Several studies, such as those by Alka (2016), Chow (2011),  
247 and Connel (2007), have reported the presence of copepods in the digestive tracts of lobster larvae. This suggests that  
248 copepods are a preferred food for lobster larvae. Protein is constantly the predominant organic nutrient in the spiny lobster  
249 larvae as well as their preferred prey (Wang, 2013). This is consistent with prior examinations of digestive enzymes of  
250 phyllosoma of *J.edwardsii* and *Panulirus ornatus*, which reveal that they necessitate a high-protein diet and will utilize  
251 protein to generate energy during food deprivation (Johnston et al, 2004a; Johnston et al, 2004b, Johnston et al, 2006).  
252 Copepods contain high protein content, ranging from 28.9 - 84.9 % of dry weight, indicating that lobster larvae consume  
253 prey with high protein content (Wang & Jeffs, 2014). The protein content of the copepods is in accordant with the amount  
254 of protein incorporated into artificial feeds for some of the crustaceans larvae including crab, shrimp, and clawed lobster  
255 species, which is ranging between 30% to 60% protein (Conklin et al, 1980 ; Guillaume, 1997 ; Holme et al, 2009).  
256 Moreover, copepods also high in lipid, ranging from 11.3%-12.4% (Wang & Jeffs, 2014). Rich-lipid diets can be properly  
257 digested by the spiny lobster larvae, and utilize it to supply energy, especially during a food scarcity (Johnston et al, 2004;  
258 Liddy et al , 2003; Liddy et al , 2004; Ritar et al, 2003). Furthermore, late phase phyllosoma of spiny lobster probably  
259 target high lipid prey, as they prepare to accumulate an enormous amount of lipid to fuel their non-feeding post-larval  
260 stage ( Jeffs et al, 2001a; Jeffs et al, 2001b). The presence of copepods especially *Oithona* sp., *Acartia* sp., and *Calanus*  
261 sp in a high abundance value at the Karanggongso and Tawang Bay could provide a significant source of high lipid natural  
262 diets for spiny lobster larvae. These results suggest that these plankton species are a potential diet for spiny lobster larvae,  
263 therefore, should be further studied by in vivo trials using aquatic animals especially for developing ornate spiny lobster  
264 hatcheries.

265 In conclusion, a total of 17 plankton species were identified from the surface water, 13 species at a depth of 2.5 m, 11  
266 species at a depth of 5 m, and 13 species at 20m (bottom) of Karanggongso Bay. While, 17 plankton species were  
267 discovered on the surface of Tawang Bay waters: 11 species at a depth of 2.5 m, 12 species at a depth of 5 m, and 12  
268 species at the seafloor. It was also discovered that the diversity index of plankton was considered at a moderate level at

269 both locations, 2.02-2.49 at Karanggongso, and 2.15-2.65 at Tawang Bay. Similarly, the uniformity index was classified at  
270 a moderate level at both locations (0.38-0.45 at Karanggongso Bay and 0.41-0.46 at Tawang Bay. While the dominance  
271 index was ranging from 0.21 – 0.31 at Karanggongso Bay and 0.13-0.30 in Tawang Bay which indicates that there were no  
272 dominant species at both location. Among the identified plankton species, several members of *Oithona* sp., and *Acartia* sp.  
273 are considered potential live feed for lobster larvae, and thus should be further studied. Among the identified plankton  
274 species, several members of Bacillariophyceae, Copepoda, and Hexanauplia are considered potential live feed for lobster  
275 larvae, and thus should be further studied.

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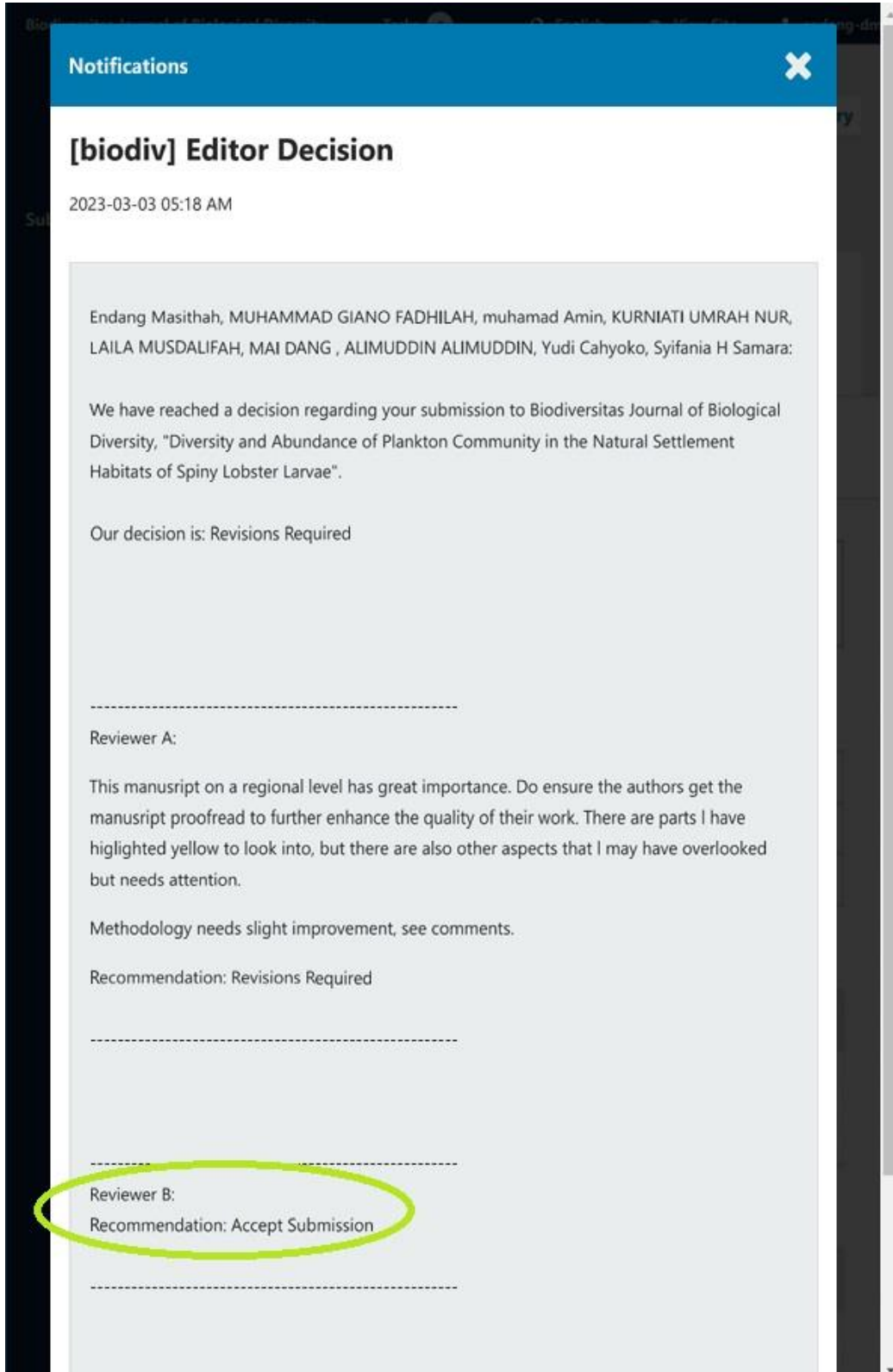
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## 2. Bukti komentar reviewer (round 1) (3 Maret 2023)

### A. Reviewer A meminta mengembangkan metodologi



The image shows a screenshot of a notification email from Biodiversitas Journal of Biological Diversity. The notification is titled "[biodiv] Editor Decision" and is dated 2023-03-03 05:18 AM. The email lists the authors: Endang Masithah, MUHAMMAD GIANO FADHILAH, muhamad Amin, KURNIATI UMRAH NUR, LAILA MUSDALIFAH, MAI DANG, ALIMUDDIN ALIMUDDIN, Yudi Cahyoko, and Syifania H Samara. The decision is "Revisions Required". The email includes a comment from Reviewer A, who states that the manuscript has great importance but needs attention in the methodology section. Reviewer B's comment, "Recommendation: Accept Submission", is circled in green.

**Notifications** ✕

**[biodiv] Editor Decision**

2023-03-03 05:18 AM

Endang Masithah, MUHAMMAD GIANO FADHILAH, muhamad Amin, KURNIATI UMRAH NUR, LAILA MUSDALIFAH, MAI DANG, ALIMUDDIN ALIMUDDIN, Yudi Cahyoko, Syifania H Samara:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Diversity and Abundance of Plankton Community in the Natural Settlement Habitats of Spiny Lobster Larvae".

Our decision is: Revisions Required

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Reviewer A:

This manuscript on a regional level has great importance. Do ensure the authors get the manuscript proofread to further enhance the quality of their work. There are parts I have highlighted yellow to look into, but there are also other aspects that I may have overlooked but needs attention.

Methodology needs slight improvement, see comments.

Recommendation: Revisions Required

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Reviewer B:

Recommendation: Accept Submission

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## B. Artikel yang telah diperbaiki

### Permintaan pengembangan metodologi telah tersedia di bab Material and Method

# Diversity and Abundance of Plankton Community in the Natural Settlement Habitats of Spiny Lobster Larvae

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**Abstract.** Tawang Bay and Karanggongso Bay have been well-known as settlement areas for lobster larvae in East Java Indonesia, which may suggest that the location are suitable environments including diet availability for lobster larvae. Therefore, the study aimed to investigate the abundance and diversity of plankton in the both locations to discover potential live diets for lobster larvae. Plankton samples were collected in both locations using a plankton net at four different depths: 0.3 m, 2.5m, m, and 20 m with three replicates. The results revealed that 17 plankton species were identified from the 0.30 m depth, 13 species at a depth of 2.5m, 11 species at a depth of 5m, and 13 species at 20m at Karanggongso Bay. While, 17 plankton species were discovered on the surface of Tawang Bay waters: 11 species at a 2.5m, 12 species at 5m, and 12 species at 20m. The diversity index and uniformity indices of plankton in both locations were considered at a moderate. While there were no dominant species at both locations, indicated by the dominance index values ranged from 0.13-0.30. Among the identified plankton species, *Oithona* sp., and *Acartia* sp. are considered potential live feed for lobster larvae, and thus should be further studied.

Commented [CC2]: Are there multiple species? Or just one kind present in these areas.

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Commented [CC4]: Authors should mention also then the objective of this paper is to identify the species present at different depths in these two different bays.

Commented [CC5]: Values?

**Key words:** diversity, diets, dominance, lobster, plankton, uniformity.

**Abbreviations** (if any): -

**Running title:** Plankton diversity in lobster natural habitat

## INTRODUCTION

Lobster is an important fishery commodity in Indonesia due to its high price, high nutritional contents as well as high market demands. According to the Indonesian Central Bureau of Statistics, the total export value of lobsters in 2020 reached USD 8.1 million (BPS 2020). The high export value and continuously increasing marketing demands at national or global markets indicate that lobster is a high-potential fisheries commodity. However, the lobster supply has been highly dependent on the wild catch because lobster aquaculture has not been well developed yet. One of the main issues faced in lobster aquaculture is larval production, which currently relies on the availability of seeds in nature. Many studies have been conducted to study various factors relating to larval production of larvae including spawning-inducing technology and rearing condition, yet the success rates are very low. Several authors have succeeded to breed and producing larvae. Yet, the larvae can live only 7-14 days after hatching. It is hypothesized that the main challenge is in diet availability and suitability. According to Amin et al. (2022b), one way to start domesticating wild species is firstly by collecting information on their natural habitat as much as possible. Similarly, Kashinskaya et al. (2018) suggest that profiling certain animals' natural habitat may reveal their diets.

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Environmental conditions including physical, chemical, and biological factors in natural habitats highly determine the recruitment rates of lobster larvae (Keulder 2005). Several authors have previously reported the physical and chemical characteristics of the natural settlement areas of lobster larvae (Amin et al. 2022c; Boudreau et al. 1992; Lillis and Snelgrove 2010). However, studies investigating biological aspects of settlement habitat in the natural environment of lobster larvae are still very limited. Meanwhile, many studies conclude that biological factors hold important information

49 for the lobster larvae, especially for diets (O'Rorke et al. 2014). Accordingly, biological aspects such as natural dietary  
 50 aspects and lobster predation processes that occur in nature during larval and post-larval stages could be critical  
 51 information that must be considered for hatchery production. In their natural settlement habitat, plankton might be a  
 52 natural diet source for various types of fish seeds, including lobster seeds. Raza'i et al. (2018) added that the availability of  
 53 plankton as a natural diet source has a significant impact on the dependence and growth of marine organisms such as fish,  
 54 crabs, shrimp, and lobsters.

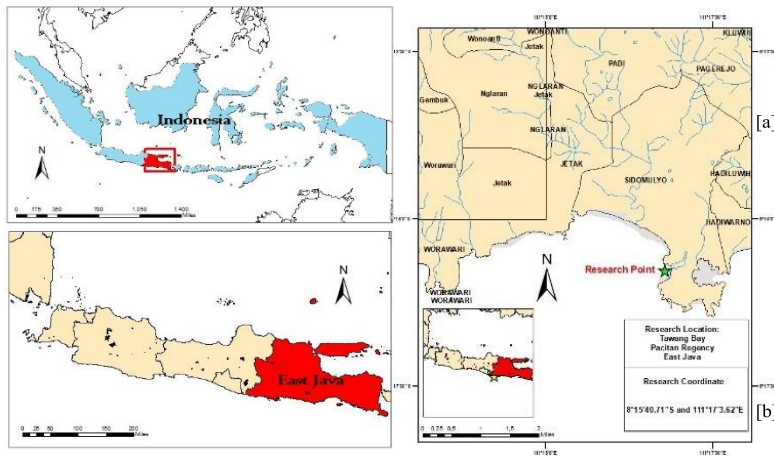
55 Profiling plankton diversity and abundance might reveal potential diets for lobster larvae. A similar approach has been  
 56 done in some studies. For instance, Ihsan et al. (2019) conducted research on plankton as a natural feed for lobster larvae  
 57 and post-larvae in natural habitats in Teluk Awang, Central Lombok. Trijoko and Pasaribu (2003) conducted another study  
 58 in Wedi Ombo Bay, Gunung Kidul, Yogyakarta. The study results in general suggest that each location has a different  
 59 structure and abundance, although some species were the same between the area. All these results raised questions about  
 60 whether lobster larvae are opportunistic feeders or specific feeders. **To answer these questions more studies are required by  
 61 collecting more information in more settlement areas of lobster.**

62 **Tawang Bay been well-known** as one of the most settlement areas for lobster larvae in East Java Indonesia (Amin et al.  
 63 2022a); therefore, it is assumed **to have important suitable diet availability** for lobster larvae. However, studies on the  
 64 biological aspects of both locations areas are still very limited. Thus, the objectives of this research is to investigate the  
 65 plankton diversity, abundance, uniformity, and dominance indices in the natural settlement habitat of lobster larvae at  
 66 Karangongso and Tawang Bays. The study results are expected to enrich the information on potential diets for lobster  
 67 larvae for hatchery development.

## 68 MATERIALS AND METHODS

### 69 Study area

70 The collection of plankton samples was carried out in two common settlement areas of lobster larvae in East Java  
 71 Indonesia (Tawang Bay) with a protocol as previously described by Amin et al. (2022c). The sampling location  
 72 was performed at ordinate points: 8°15'57.4"S 111°17'46.0" E (L1), 8°15'54.3"S 111°17'48.2"E (L2) and 8°15'51.5"S  
 73 111°17'46.2"E (L3), (Figure 1). Plankton sampling was conducted at three different sampling points with four different  
 74 depths: 0-0.3 m, 2.5 m, 5 m, and 20 m. The water samples were filtered using a plankton net and placed in sterile bottles.  
 75 The filtered sample was then immediately given Lugol which acts as a plankton preservative, up to 1% of the total filtering  
 76 and wrapped in Styrofoam. The samples were then examined in the Microbiology Laboratory, Faculty of Fisheries and  
 77 Marine Science at Airlangga University.  
 78



79  
 80 Figure 1 Two sampling locations: Karangongso Bay, Trenggalek Regency [a], and Tawang Bay, Pacitan Regency [b], East Java,  
 81 Indonesia.

82 Karangongso Bay waters have temperatures ranging from 27-28 °C, a DO content of 7.48 mg/L, a salinity of 26 ppt, a  
 83 pH of 7-8, a NO<sub>3</sub> content of 0.01 mg/L, and a muddy substrate. Tawang Bay waters temperatures are slightly warmer than  
 84 Karangongso Bay, with water temperature ranging from 28.2-28.3 °C, with a significantly lower, DO content of 3.35

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85 mg/L. moreover, Tawang Bay has a higher salinity of 35 ppt, a pH of 8, a NO<sub>3</sub> content of 0.01, a depth of 15 m, and a  
86 sandy substrate

### 87 **Abundance and Identification of planktons**

88 Firstly, plankton identity and their abundances were analyzed using a protocol of LeGresley and McDermott (2010). In  
89 brief, plankton samples were placed on a Sedgewick Rafter Counting Cell and observed under a binocular microscope with  
90 a magnification of 1000x. Thereafter each plankton found in each sample was counted, photographed, and identified  
91 according to an identification book guide by Mazzocchi et al. (2012). Then, the abundance index was calculated according  
92 to the following formula (Fachrul 2012)::

$$N = \frac{a}{b} \times \frac{c}{d} \times \frac{Vb}{Vsrc} \times \frac{1}{Vs}$$

93 Where "N" represents the abundance of plankton (plankter/L), "a" represents the number of SRC boxes, "b" is the area of  
94 one field of view (mm<sup>2</sup>), "c" denotes the number of individuals observed, and "d" indicates the number of boxes observed.  
95 "Vb" is the volume of water in the sample bottle (ml), "Vsrc" is the volume of water in the SRC (ml), and "Vs" represents  
96 the volume of water filtered in the Field (L).  
97

### 98 **Diversity, Uniformity and dominant indices**

99 The diversity index value (H') was calculated using the following formula (Fachrul 2012):

$$100 \quad H' = - \sum P_i \ln P_i, \text{ where } P_i = \frac{n_i}{N}$$

101 Where H' is Shannon Wiener Diversity Index, pi is the number of individuals of the i-th species, ni is the  
102 number of species, and N is the total individual number.

103 The uniformity index (E') was calculated using the "Evennes Index" formula (Ulfah et al. 2019):

$$104 \quad E' = \frac{H'}{104^{1/S}}$$

105 where, E' is uniformity index, H': Shannon Wiener Diversity Index, S: Total number of species

106

107 The dominance index (d) was calculated using the following equation (Berger and Parker 1970):

$$108 \quad d = \frac{N_{max}}{N}$$

109 where, "d": Simpson Dominance Index, Nmax: The most abundant number of individual species, dan  
110 N = Total individual

number.110

## 111 **RESULTS AND DISCUSSION**

### 112 **Plankton Abundance in Karanggongso Bay**

113 Samples of water were obtained from Karanggongso Bay at three designated locations, each with four different levels  
114 of depth. A total of 17 plankton species were identified from the surface water (0.0-0.3 m). The top six most abundant  
115 species were *Paracyclops* sp. with 21.21%, followed by *Acartia* sp. (18.18%), *Pteropods* sp. (9.09%), *Prorocentrum* sp.  
116 (6.06%), *Dinophysis* sp. (6.06%), and *Sagitta* sp. (2.13%). Other species and their percentage was presented in Table 1. In  
117 addition, at a 2.5 m depth, 13 plankton species were identified and the top 6 most abundant species were *Acartia* sp.  
118 (26.47%), followed by *Paracyclops* sp. (23.53%), *Ceratium* sp. (8.82%), *Microsetella* sp. (8.82%), *Dinophysis* sp.  
119 (5.8%), and *Oncaea* sp. (5.88%). The rest species with their abundance were presented in Table 1.

120 Furthermore, at 5 m depth, the Bay is home to 11 plankton species. The top 4 most abundant species were *Acartia* sp.  
121 (30.77%), followed by *Paracyclops* sp. (23.08%), *Sagitta* sp. (11.54%), and *Oithona* sp. (7.69%). While the other 7  
122 species including included *Synedra* sp., *Oikopleura* sp., *Coscinodiscus* sp., *Ceratium* sp., *Pteropods* sp., *Microsetella* sp.,  
123 and unclassified Lucifer which were counted for 3.85% each, Table 1. Meanwhile, a total of 13 plankton species were  
124 found at the depth of 20 m. The top 6 most abundant species were *Acartia* sp. accounted for 24.14%), followed by  
125 *Paracyclops* sp. with 13.79%, *Pteropods* sp. (10.34%), *Dinophysis* sp. (10.34%), *Ceratium* sp. with 6.90%, and *Sagitta*  
126 sp. with 6.90%. The rest species were presented in table 1.

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**Table 1.** Planktons identified from two natural settlement habitats of spiny lobster larvae (Karanggongso Bay and Trenggalek Regency, East Java Indonesia) at four different depths of the water column.

Depth	Species	Cell density (Indiv/L)
0.3 m (Surface)	<i>Cyclotella</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Noctiluca</i> sp.	8
	<i>Prorocentrum</i> sp.	16
	<i>Dinophysis</i> sp.	16
	<i>Ceratium</i> sp.	8
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	24
	<i>Paracyclopina</i> sp.	56
	<i>Acartia</i> sp.	48
	<i>Microsetella</i> sp.	8
	<i>Euphausia</i> sp.	8
	<i>Lucifer</i> sp.	8
	<i>Oipheureidea</i> sp.	8
	<i>Sagitta</i> sp.	16
	<i>Nemateia</i> sp.	8
<i>Actinulla larvae</i>	8	
2.5 m	<i>Rizosolenia</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Ceratium</i> sp.	24
	<i>Dinophysis</i> sp.	16
	<i>Paracyclopina</i> sp.	64
	<i>Acartia</i> sp.	72
	<i>Microsetella</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Codoneleopsis</i> sp.	8
	<i>Oipheureidea</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Actinula</i> sp.	8
<i>Polychaete</i>	8	
5.0 m	<i>Oikopleura</i> sp.	8
	<i>Synedra</i> sp.	8
	<i>Coscinodiscus</i> sp.	8
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	8
	<i>Paracyclopina</i> sp.	48
	<i>Acartia</i> sp.	64
	<i>Microsetella</i> sp.	8
	<i>Oithona</i> sp.	16
<i>Lucifer</i> sp.	8	
<i>Sagitta</i> sp.	24	
20.0 m (Bottom)	<i>Synedra</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Noctiluca</i> sp.	8
	<i>Dinophysis</i> sp.	24
	<i>Ceratium</i> sp.	16
	<i>Pteropods</i> sp.	24
	<i>Acartia</i> sp.	56
	<i>Paracyclopina</i> sp.	32
<i>Oithona</i> sp.	8	
<i>Microsetella</i> sp.	16	

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<i>Euphausia</i> sp.	8
<i>Protoperidinium</i> sp.	8
<i>Sagitta</i> sp.	16

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**131 Plankton Abundance in Tawang Bay**

132 A total of 17 plankton species were identified from the water sample at depth of 0.0-0.3 m (surface water) of Tawang  
 133 Bay. The top 9 most abundant species were *Acartia* sp. with an abundance of 12.82%, followed by *Ceratium* sp. (10.26%),  
 134 *Prorocentrum* sp. (10.26%), *Microstella* sp. (10.26%), *Oncaea* sp. (10.26%) *Pteropods* sp. (7.69%), *Calanus* sp., (7.69%),  
 135 *Synedra* sp. (5.13%), and *Oithona* sp. (5.13%). While the rest species were counted for 2.56% each and presented in **Table**  
 136 **2**. In addition, there were 11 species of plankton found in a water sample at a depth of 2.5 m in Tawang Bay. The top 6  
 137 most abundant species were *Calanus* sp. (28.00%), followed by *Prorocentrum* sp. (12.00%), *Paracyclops* sp. (12.00%),  
 138 *Microstella* sp. (12.00%), *Oncaea* sp. (8.00%), and *Oithona* sp. with an abundance of 8.00%. While the rest plankton  
 139 species including *Synedra* sp., *Ceratium* sp., *Pteropods* sp., *Macrophthalmus* sp., and *Sagitta* sp. were counted at 4.00%  
 140 each, **Table 2**.

141 Furthermore, a total of 12 plankton species were identified from the water sample at 5 m depth. The top 4 most  
 142 common species were *Calanus* sp. with an abundance of 28.57%, *Oithona* sp. with an abundance of 14.29%, *Copepoda*  
 143 *nauplii* with an abundance of 9.52%, *Prorocentrum* sp. with an abundance of 9.52%. While the rest species including  
 144 *Melosira* sp., *Synedra* sp., *Dinophysis* sp., *Microstella* sp., *Temora* sp., *Oncaea* sp., and *Sagitta* sp., with an abundance of  
 145 5.00% respectively. While in the bottom waters of Tawang Bay (20 m depth), a total of 12 plankton species were  
 146 identified. The top 9 most abundant species were *Prorocentrum* sp. with an abundance of 16.44%, *Acartia* sp. with an  
 147 abundance of 16.44%, *Oithona* sp. with an abundance of 16.44%, *Oncaea* sp. with an abundance of 10.96%, *Dinophysis*  
 148 sp. with an abundance of 5.48%, *Rhizosolenia* sp. with an abundance of 5.48%, *Pleurosigma* sp. with an abundance of the  
 149 abundance of 5.48%, *Ceratium* sp. with 5.48%, *Caridean* sp. (5.48%). While the rest species were presented in table 2.

**150 Table 2.** Planktons identified from the natural habitat of spiny lobster in bottom water at Tawang Bay, East Java Indonesia

Depth	Species	Density (Indiv/L)
0.3 m (Surface)	<i>Synedra</i> sp.	16
	<i>Oscillatoria</i> sp.	8
	<i>Spirulina</i> sp.	8
	<i>Ceratium</i> sp.	32
	<i>Prorocentrum</i> sp.	32
	<i>Pteropods</i> sp.	24
	<i>Acartia</i> sp.	40
	<i>Microstella</i> sp.	32
	<i>Calanus</i> sp.	24
	<i>Oithona</i> sp.	16
	<i>Oncaea</i> sp.	32
	<i>Euphausia</i> sp.	8
	<i>Macrophthalmus</i> sp.	8
	<i>Clytemnestra</i> sp.	8
	<i>Cypris</i> sp.	8
	Unclassified <i>Fish larvae</i>	8
	Unclassified flatworms	8
2.5 m	<i>Synedra</i> sp.	8
	<i>Prorocentrum</i> sp.	24
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	8
	<i>Paracyclops</i> sp.	24
	<i>Calanus</i> sp.	56
	<i>Oithona</i> sp.	16
	<i>Microstella</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Macrophthalmus</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Melosira</i> sp.	8
<i>Synedra</i> sp.	8	
<i>Bivalve larvae</i>	8	
<i>Prorocentrum</i> sp.	16	

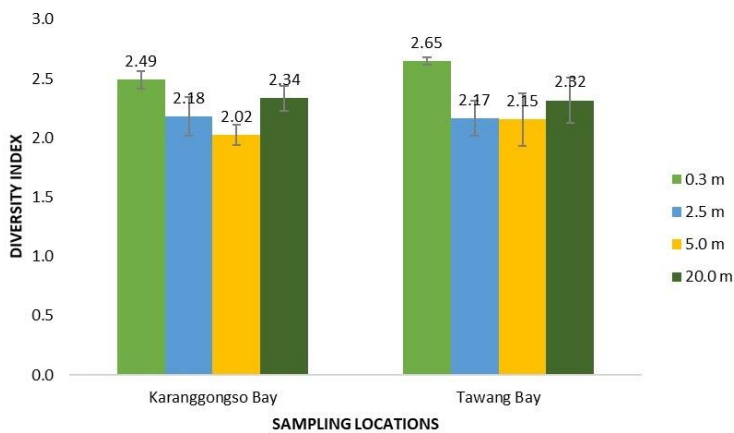
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5 m	<i>Dinophysis</i> sp.	8	
	<i>Microsetella</i> sp.	8	
	<i>Calanus</i> sp.	48	
	<i>Oithona</i> sp.	24	
	<i>Naupli Copepoda</i>	16	
	<i>Temora</i> sp.	8	
	<i>Oncaea</i> sp.	8	
	<i>Sagitta</i> sp.	8	
	<hr/>		
		<i>Rhizoselenia</i> sp.	8
		<i>Pleurosigma</i> sp.	8
		<i>Prorocentrum</i> sp.	24
		<i>Ceratium</i> sp.	8
		<i>Dinophysis</i> sp.	8
	<i>Microsetella</i> sp.	4	
20 m (bottom)	<i>Calanus</i> sp.	6	
	<i>Acartia</i> sp.	24	
	<i>Oithona</i> sp.	24	
	<i>Oncaea</i> sp.	16	
	<i>Caridean</i> sp.	8	
	Unclassified flatworm	8	

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### 153 Diversity indices

154 The diversity index values obtained in the waters of Karanggongso Bay, Trenggalek Regency East Java were  $2.49 \pm$   
155  $0.07$  at depth of 0.0-0.3 m depth of water column,  $2.18 \pm 0.16$  at a depth of 2.5 m,  $2.02 \pm 0.08$  at a depth of 5 m, and  $2.34 \pm$   
156  $0.10$  at the 20 m water column which indicates that the Karanggongso Trenggalek waters have moderate diversity. While  
157 the diversity index values obtained in the waters of Tawang Bay were  $2.65 \pm 0.03$  at 0.0 – 0.3 m depth,  $2.17 \pm 0.15$  at the  
158 2.5 m depth,  $2.15 \pm 0.22$  at a 5 m depth, and  $2.32 \pm 0.19$  at a depth of 20 m which indicates that the waters of Tawang Bay  
159 have also moderate diversity, Figure 2



160

161 **Figure 2.** Diversity indices of plankton identified at the water column of Karanggongso Bay and Tawang Bay, East Java  
162 Indonesia. Bars are the average values with a standard deviation of three replicates.

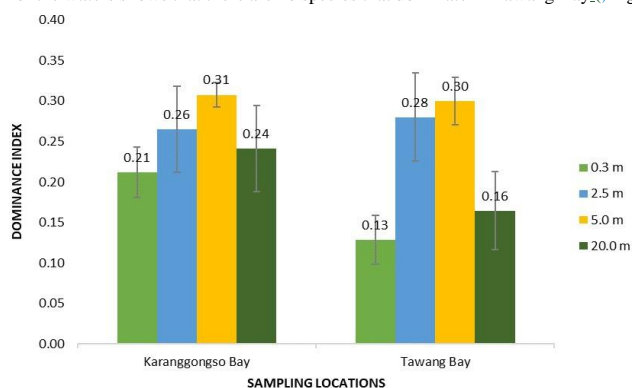
### 163 Domination Index

164 The dominance index is a value that indicates whether there are plankton species that dominate certain depths in the  
165 water column. Dominance index values obtained from the waters of Karanggongso Bay were  $0.21 \pm 0.03$  at the 0.0-0.3 m  
166 depth,  $0.26 \pm 0.05$  at a depth of 2.5 m,  $0.31 \pm 0.02$  at a depth of 5 m and  $0.24 \pm 0.05$  at the 20 m water depth. These values  
167 mean that no plankton species were dominant in the natural habitat of spiny lobster larvae (Karanggongso Bay). While the  
168 dominance index values obtained from Tawang Bay waters were  $0.13 \pm 0.03$  at the 0.0-0.3 m depth,  $0.28 \pm 0.05$  at a depth

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169 of 2.5 m,  $0.30 \pm 0.03$  at a depth of 5 m, and  $0.16 \pm 0.05$  at the 20 m depth. Similarly, based on the values obtained from the  
 170 surface to the bottom of the waters shows that there are no species that dominate in Tawang Bay. (Figure 4).



171  
 172 **Figure 4.** Domination indices of planktons identified at Karanggongso Bay and Tawang Bay, East Java, Indonesia. Bars  
 173 are the average values with a standard deviation of three replicates.

174

#### 175 Discussion

176 Environmental conditions including physical, chemical, and biological factors in natural habitats highly determine the  
 177 recruitment rates of lobster larvae (Keulder 2005). Several studies have previously reported the physical and chemical  
 178 characteristics of the settlement area of lobster (Amin et al. 2022c; Boudreau et al. 1992; Lillis and Snelgrove 2010).  
 179 However, studies viewing biological aspects of settlement habitat in natural environment lobster larvae are still very  
 180 limited. Meanwhile, many studies conclude that biological factors such as plankton availability can be important  
 181 information on the natural diets of lobster larvae (O'Rourke et al. 2014). Thus the present study investigated the diversity,  
 182 uniformity, and dominance of plankton in two common settlement areas of lobster larvae in East Java (Karanggongso Bay  
 183 and Tawang Bay) in Indonesia. The sampling was performed in 4 different depths which were 0.3 m, 2.5 m, 5 m, and 20 m  
 184 depth, as lobster larvae vertically migrated from the bottom during the daytime to the surface of the water during the  
 185 nighttime. It was also discovered that the diversity indices of plankton at both locations were 2.02-2.49 at Karanggongso,  
 186 and 2.15-2.65 at Tawang Bay. The diversity index values found at these two locations were all less than 3, which means at  
 187 a moderate level. The high or low value of plankton diversity can be caused by the evenly distributed abundance of each  
 188 individual or in another sense there are no species that have relatively more diversity than other species (Awwaluddin et al.  
 189 2017). As the diversity indices of plankton at Karanggongso Bay and Tawang Bay may which is at a moderate level may  
 190 suggest that plankton communities is in relatively equal distribution of different species, with no one species being  
 191 significantly more prevalent than others (Awwaluddin et al. 2017).

192 Similarly, the uniformity indices of planktons in both settlement areas were classified at a moderate level (0.38-0.45 at  
 193 Karanggongso Bay and 0.41-0.46 at Tawang Bay. The uniformity values found at each location, both Karanggongso  
 194 Beach waters and Tawang Beach waters, are said to have moderate uniformity. The value of uniformity is categorized to  
 195 be moderate if the value ranges from 0.4-0.6 (Ulfah et al. 2019). The availability of nutrients, food, and predation  
 196 processes can affect the high value of uniformity because it affects the type and amount of plankton. Besides that, physical  
 197 and chemical factors also affect the value of uniformity because it will affect the growth of plankton (Nugroho et al. 2020).  
 198 In addition, if the distribution of plankton in both waters is uniform, then a high degree of uniformity can be asserted.

199 While the dominance indices were ranging from 0.21 – 0.31 at Karanggongso Bay and 0.13-0.30 in Tawang Bay. The  
 200 result indicates that there were no dominant species at both locations since all values < 0.05. Dominance index values  
 201 obtained in both waters indicate the absence of plankton which dominates in Karanggongso Bay and also Tawang  
 202 Bay. Whether or not organisms dominate a waters can be seen from the value of the dominance index if the dominance index  
 203 shows a value between 0.5 to 1 then in these waters there are organisms that dominate and if it shows a value less than 0.5  
 204 then in these waters it indicates the absence of organisms dominating (Berger and Parker  
 1970). 205

#### 206 Potential Diet for Lobster Seeds

207 The result also revealed that 17 plankton species were identified from the surface water, 13 species at a depth of 2.5 m,  
 208 11 species at a depth of 5 m, and 13 species at 20m (bottom) of Karanggongso Bay. While, 17 plankton species were

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209 discovered on the surface of Tawang Bay waters: 11 species at a depth of 2.5 m, 12 species at a depth of 5 m, and 12  
210 species at the seafloor. The number of plankton species identified in the present study, in general, are higher than in  
211 previous study reported from other settlement habitats of lobster larvae in Awang Bay west Nusa Tenggara (Amin et al.  
212 2022c) and Teluk Wedi Ombo, Yogyakarta (Trijoko and Pasaribu 2004). The most abundant species identified from  
213 Karanggongso Bay were *Paracyclops* sp., *Acartia* sp., *Pteropods* sp., and *Prorocentrum* sp. *Dinophysis* sp., *Sagitta* sp.,  
214 *Ceratium* sp., *Microsetella* sp., *Dinophysis* sp., *Calanus* sp., *Synedra* sp., and *Oithona* sp. (7.69%). While most abundant  
215 species found in Tawang Bay were *Acartia* sp., *Ceratium* sp., *Prorocentrum* sp., *Microsetella* sp., *Oncaea* sp., *Pteropods*  
216 sp., *Calanus* sp., *Synedra* sp., *Oithona* sp., *Calanus* sp., *Paracyclops* sp., *Macrophthalmus* sp., *Sagitta* sp., *Dinophysis* sp.,  
217 and *Rhizosolenia* sp. of these identified plankton species, 10 species were found in both locations including *Acartia* sp.,  
218 *Oithona* sp., *Paracyclops* sp., *Pteropods* sp., *Binophysis* sp., *Sagitta* sp., *Microsetella* sp., *Calanus* sp., *Synedra* sp.

219 Among the identified plankton species, few species have been documented as potential live diets in aquaculture  
220 including *Oithona* sp. for live diet of European seabass (*Dicentrarchus labrax*) postlarvae (Magouz et al. 2021a), and  
221 shrimp larvae (Dinesh Kumar et al. 2017), and *Acartia* sp., as a live diet for seabass larvae, *Lates calcarifer* (Rajkumar  
222 2006), fat snook, *Centropomus parallelus* (Barroso et al. 2013), and many other aquatic larvae (Sarkisian et al. 2019). In  
223 fact, some studies also confirmed that these plankton species were identified in the stomach content of lobster larvae. For  
224 instance, *Oithona* sp. has been reported from the stomach content of spiny lobsters at the early life stage (Amin et al.  
225 2022d; Khvorov et al. 2012). *Oithona* sp. has been described as a marine calanoid copepod which has high protein content,  
226 ~59.33% (Santanumurti et al. 2021), therefore frequently used as a live diet for fish or shrimp larvae. Another study has  
227 documented that *Oithona* sp. had a high content of fatty acid profiles including polyunsaturated fatty acids (26.47%) and  
228 omega-3 fatty acids (36.30) which in fact are higher compared to a commercial live diet such as *Artemia* (Magouz et al.  
229 2021b). Furthermore, *Acartia* sp. has been also documented to be a good live diet for aquatic larvae such as seabass larvae,  
230 *Lates calcarifer* (Rajkumar 2006), and fat snook, *Centropomus parallelus* (Barroso et al. 2013). *A. clausi* has been

231 described to have higher contents of proteins (63.12%) and lipids (16.65%) and is also richer in n-3 fatty acids (33.94%)  
232 than *Artemia* nauplii and rotifers (Rajkumar, 2006). The plankton species has been also identified in the stomach content  
233 of spiny lobster larvae (Amin et al. 2022d). In addition, a member of *Acartia* (*Acartia tonsa*) had been documented to

234 provide an important nutritional benefit to fat snook larvae undergoing metamorphosis (Vanacor-Barroso et al. 2017).

235 Other potential food sources for lobster larvae identified in the present study are zooplankton and phytoplankton.  
236 According to the results obtained, the plankton found at each station consists of Bacillariophyceae (e.g. *Rizosolenia* sp.,  
237 *Synedra* sp., *Cyclotella* sp.), and Copepoda (e.g. *Oithona* sp., *Acartia* sp., *Calanus* sp.). These plankton groups were  
238 identified at each station, highlighting their potential as a food source for lobster larvae. Diatoms, which belong to the  
239 phytoplankton group Bacillariophyceae, contain essential nutrients required for the growth of lobster larvae, such as  
240 PUFA (Polyunsaturated Fatty Acid). PUFA including EPA (eicosapentaenoic acid, 20:5 n-3) and DHA (docosahexaenoic  
241 acid 22:6 n-3) are the major fatty acids found in diatoms Bacillariophyceae (Pahl et al., 2010). PUFA content of these  
242 diatoms is relatively high, with levels ranging between 23.4 and 60.7% (Valera & Saavedra, 2016). High PUFA content  
243 was identified in several plankton species as potential prey for spiny lobster larvae *Jasus edwardsii*, and these long-chain  
244 fatty acids are an essential nutrient for spiny lobster (Koshio & Kanazawa, 1994; Liddy et al., 2004; Wang, 2013).

245 Copepoda (Hexanauplia) is a rich source of protein, particularly in gastropods, it is also high in calcium content which  
246 is important for lobster during molting (Kirno et al., 2012). Several studies, such as those by Alka (2016), Chow (2011),  
247 and Connel (2007), have reported the presence of copepods in the digestive tracts of lobster larvae. This suggests that  
248 copepods are a preferred food for lobster larvae. Protein is constantly the predominant organic nutrient in the spiny lobster  
249 larvae as well as their preferred prey (Wang, 2013). This is consistent with prior examinations of digestive enzymes of  
250 phyllosoma of *J.edwardsii* and *Panulirus ornatus*, which reveal that they necessitate a high-protein diet and will utilize  
251 protein to generate energy during food deprivation (Johnston et al., 2004a; Johnston et al., 2004b, Johnston et al., 2006).  
252 Copepods contain high protein content, ranging from 28.9 - 84.9 % of dry weight, indicating that lobster larvae consume  
253 prey with high protein content (Wang & Jeffs, 2014). The protein content of the copepods is in accordant with the amount  
254 of protein incorporated into artificial feeds for some of the crustaceans larvae including crab, shrimp, and clawed lobster  
255 species, which is ranging between 30% to 60% protein (Conklin et al., 1980 ; Guillaume, 1997 ; Holme et al., 2009).  
256 Moreover, copepods also high in lipid, ranging from 11.3%-12.4% (Wang & Jeffs, 2014). Rich-lipid diets can be properly  
257 digested by the spiny lobster larvae, and utilize it to supply energy, especially during a food scarcity (Johnston et al., 2004;  
258 Liddy et al., 2003; Liddy et al., 2004; Ritar et al., 2003). Furthermore, late phase phyllosoma of spiny lobster probably  
259 target high lipid prey, as they prepare to accumulate an enormous amount of lipid to fuel their non-feeding post-larval  
260 stage (Jeffs et al., 2001a; Jeffs et al., 2001b). The presence of copepods especially *Oithona* sp., *Acartia* sp., and *Calanus*  
261 sp in a high abundance value at the Karanggongso and Tawang Bay could provide a significant source of high lipid natural  
262 diets for spiny lobster larvae. These results suggest that these plankton species are a potential diet for spiny lobster larvae,  
263 therefore, should be further studied by in vivo trials using aquatic animals especially for developing ornate spiny lobster  
264 hatcheries.

265 In conclusion, a total of 17 plankton species were identified from the surface water, 13 species at a depth of 2.5 m, 11  
266 species at a depth of 5 m, and 13 species at 20m (bottom) of Karanggongso Bay. While, 17 plankton species were  
267 discovered on the surface of Tawang Bay waters: 11 species at a depth of 2.5 m, 12 species at a depth of 5 m, and 12  
268 species at the seafloor. It was also discovered that the diversity index of plankton was considered at a moderate level at

Commented [CC10]: Please give some context to these plankton. Which phyla are they mainly from, dominance, what group are essential for feed in a wider prospect.

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269 both locations, 2.02-2.49 at Karanggongso, and 2.15-2.65 at Tawang Bay. Similarly, the uniformity index was classified at  
270 a moderate level at both locations (0.38-0.45 at Karanggongso Bay and 0.41-0.46 at Tawang Bay. While the dominance  
271 index was ranging from 0.21 – 0.31 at Karanggongso Bay and 0.13-0.30 in Tawang Bay which indicates that there were no  
272 dominant species at both location. Among the identified plankton species, several members of *Oithona* sp., and *Acartia* sp.  
273 are considered potential live feed for lobster larvae, and thus should be further studied. Among the identified plankton  
274 species, several members of Bacillariophyceae, Copepoda, and Hexanauplia are considered potential live feed for lobster  
275 larvae, and thus should be further studied.

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## C. Artikel yang telah diperbaiki (reviewer A)

# Diversity and Abundance of Plankton Community in the Natural Settlement Habitats of Spiny Lobster Larvae

ENDANG DEWI MASITHAH<sup>1,\*</sup>, MUHAMMAD GIANO FADHILAH<sup>2</sup>, MUHAMAD AMIN<sup>3</sup>, KURNIATI UMRAH NUR<sup>4</sup>, LAILA MUSDALIFAH<sup>5</sup>, SAO MAI DANG THI<sup>6</sup>, SHIFANIA HANIFA SAMARA<sup>2</sup>, ALIMUDDIN ALIMUDDIN<sup>7</sup>, YUDI CAHYOKO<sup>3</sup>

<sup>1</sup>Department of Marine, Faculty of Fisheries and Marine, Universitas Airlangga, Campus C UNAIR Mulyorejo, Jl. Mulyorejo Surabaya 60115 Indonesia, <sup>✉</sup>email: endang\_dm@fpk.unair.ac.id.

<sup>2</sup>The Aquaculture Study Program, Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga, Campus C UNAIR Mulyorejo, Jl. Mulyorejo Surabaya 60115 Indonesia.

<sup>3</sup>Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga, Campus C UNAIR Mulyorejo, Jl. Mulyorejo Surabaya 60115 Indonesia.

<sup>4</sup>Aquaculture Study Program, Fisheries Department, Faculty of Marine Science and Fisheries, Universitas Hasanudin, Makassar, Sulawesi Selatan, Indonesia.

<sup>5</sup>National Research and Innovation Agency, Republic of Indonesia, Jakarta, Indonesia

<sup>6</sup>Institute of Veterinary Research and Development of Central Vietnam, Vietnam

<sup>7</sup>Faculty of Animal Science, University of Mataram, West-Nusa Tenggara Indonesia

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**Abstract.** Tawang Bay and Karanggongso Bay have been well-known as settlement areas for lobster larvae in East Java Indonesia, which may suggest that the location are suitable environments including diet availability for lobster larvae. Therefore, the study aimed to investigate the abundance and diversity of plankton in the both locations to discover potential live diets for lobster larvae. Plankton samples were collected in both locations using a plankton net at four different depths: 0.3m, 2.5m, m, and 20m with three replicates. The result revealed that 17 plankton species were identified from the 0.30m depth, 13 species at a depth of 2.5m, 11 species at a depth of 5m, and 13 species at 20m at Karanggongso Bay. While, 17 plankton species were discovered on the surface of Tawang Bay waters: 11 species at a 2.5m, 12 species at 5m, and 12 species at 20m. The diversity index and uniformity indices of plankton in both locations were considered at a moderate. While there were no dominant species at both locations, indicated by the dominance index values ranged from 0.13-0.30. Among the identified plankton species, *Oithona* sp., and *Acartia* sp. are considered potential live feed for lobster larvae, and thus should be further studied.

**Key words:** diversity, diets, dominance, lobster, plankton, uniformity.

**Abbreviations** (if any): -

**Running title:** Plankton diversity in lobster natural habitat

## INTRODUCTION

Lobster is an important fishery commodity in Indonesia due to its high price, high nutritional contents as well as high market demands. According to the Indonesian Central Bureau of Statistics, the total export value of lobsters in 2020 reached USD 8.1 million (BPS 2020). The high export value and continuously increasing marketing demands at national or global markets indicate that lobster is a high-potential fisheries commodity. However, the lobster supply has been highly dependent on the wild catch because lobster aquaculture has not been well developed yet. One of the main issues faced in lobster aquaculture is larval production, which currently relies on the availability of seeds in nature. Many studies have been conducted to study various factors relating to larval production of larvae including spawning-inducing technology and rearing condition, yet the success rates are very low. Several authors have succeeded to breed and producing larvae. Yet, the larvae can live only 7-14 days after hatching. It is hypothesized that the main challenge is in diet availability and suitability. According to Amin et al. (2022b), one way to start domesticating wild species is firstly by collecting information on their natural habitat as much as possible. Similarly, Kashinskaya et al. (2018) suggest that profiling certain animals' natural habitat may reveal their diets.

Environmental conditions including physical, chemical, and biological factors in natural habitats highly determine the recruitment rates of lobster larvae (Keulder 2005). Several authors have previously reported the physical and chemical characteristics of the natural settlement areas of lobster larvae (Amin et al. 2022c; Boudreau et al. 1992; Lillis and Snelgrove 2010). However, studies investigating biological aspects of settlement habitat in the natural environment of lobster larvae are still very limited. Meanwhile, many studies conclude that biological factors hold important information

49 for the lobster larvae, especially for diets (O'Rorke et al. 2014). Accordingly, biological aspects such as natural dietary  
 50 aspects and lobster predation processes that occur in nature during larval and post-larval stages could be critical  
 51 information that must be considered for hatchery production. In their natural settlement habitat, plankton might be a  
 52 natural diet source for various types of fish seeds, including lobster seeds. Raza'i et al. (2018) added that the availability of  
 53 plankton as a natural diet source has a significant impact on the dependence and growth of marine organisms such as fish,  
 54 crabs, shrimp, and lobsters.

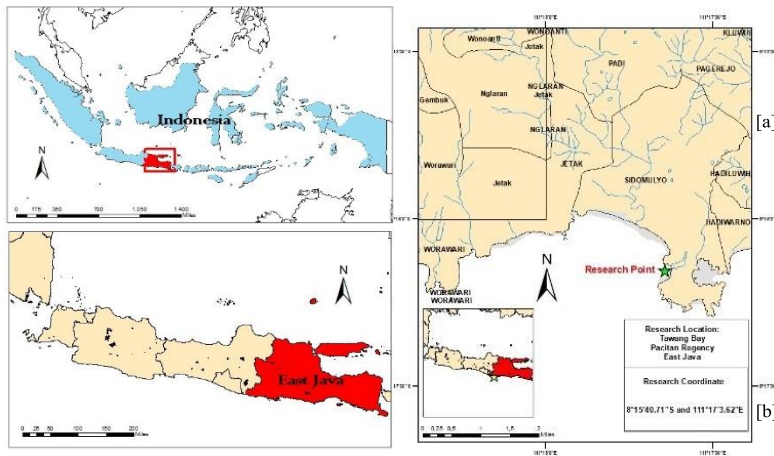
55 Profiling plankton diversity and abundance might reveal potential diets for lobster larvae. A similar approach has been  
 56 done in some studies. For instance, Ihsan et al. (2019) conducted research on plankton as a natural feed for lobster larvae  
 57 and post-larvae in natural habitats in Teluk Awang, Central Lombok. Trijoko and Pasaribu (2003) conducted another study  
 58 in Wedi Ombo Bay, Gunung Kidul, Yogyakarta. The study results in general suggest that each location has a different  
 59 structure and abundance, although some species were the same between the area. All these results raise questions about  
 60 whether lobster larvae are opportunistic feeders or specific feeders. To answer these questions more studies are required by  
 61 collecting more information in more settlement areas of lobster.

62 Tawang Bay been well-known as one of the most settlement areas for lobster larvae in East Java Indonesia (Amin et al.  
 63 2022a); therefore, it is assumed to have important suitable diet availability for lobster larvae. However, studies on the  
 64 biological aspects of both locations areas are still very limited. Thus, the objective of this research is to investigate the  
 65 plankton diversity, abundance, uniformity, and dominance indices in the natural settlement habitat of lobster larvae at  
 66 Karanggongso and Tawang Bays. The study results are expected to enrich the information on potential diets for lobster  
 67 larvae for hatchery development.

68 **MATERIALS AND METHODS**

69 **Study area**

70 The collection of plankton samples was carried out in two common settlement areas of lobster larvae in East Java  
 71 Indonesia (Tawang Bay) with a protocol as previously described by Amin et al. (2022c). The sampling location  
 72 was performed at ordinate points: 8°15'57.4"S 111°17'46.0" E (L1), 8°15'54.3"S 111°17'48.2"E (L2) and 8°15'51.5"S  
 73 111°17'46.2"E (L3), (Figure 1). Plankton sampling was conducted at three different sampling points with four different  
 74 depths: 0-0.3 m, 2.5 m, 5 m, and 20 m. The water samples were filtered using a plankton net and placed in sterile bottles.  
 75 The filtered sample was then immediately given Lugol which acts as a plankton preservative, up to 1% of the total filtering  
 76 and wrapped in Styrofoam. The samples were then examined in the Microbiology Laboratory, Faculty of Fisheries and  
 77 Marine Science at Airlangga University.  
 78



79 Figure 1 Two sampling locations: Karanggongso Bay, Trenggalek Regency [a], and Tawang Bay, Pacitan Regency [b], East Java,  
 80 Indonesia.

81 Karanggongso Bay waters have temperatures ranging from 27-28 °C, a DO content of 7.48 mg/L, a salinity of 26 ppt, a  
 82 pH of 7-8, a NO<sub>3</sub> content of 0.01 mg/L, and a muddy substrate. Tawang Bay waters temperatures are slightly warmer than  
 83 Karanggongso Bay, with water temperature ranging from 28.2-28.3 °C, with a significantly lower, DO content of 3.35  
 84

85 mg/L. moreover, Tawang Bay has a higher salinity of 35 ppt, a pH of 8, a NO<sub>3</sub> content of 0.01, a depth of 15 m, and a  
86 sandy substrate

#### 87 **Abundance and Identification of planktons**

88 Firstly, plankton identity and their abundances were analyzed using a protocol of LeGresley and McDermott (2010). In  
89 brief, plankton samples were placed on a Sedgewick Rafter Counting Cell and observed under a binocular microscope with  
90 a magnification of 1000x. Thereafter each plankton found in each sample was counted, photographed, and identified  
91 according to an identification book guide by Mazzocchi et al. (2012). Then, the abundance index was calculated according  
92 to the following formula (Fachrul 2012)::

$$N = \frac{a}{b} \times \frac{c}{d} \times \frac{Vb}{Vsrc} \times \frac{1}{Vs}$$

93 Where "N" represents the abundance of plankton (plankton/L), "a" represents the number of SRC boxes, "b" is the area of  
94 one field of view (mm<sup>2</sup>), "c" denotes the number of individuals observed, and "d" indicates the number of boxes observed.  
95 "Vb" is the volume of water in the sample bottle (ml), "Vsrc" is the volume of water in the SRC (ml), and "Vs" represents  
96 the volume of water filtered in the Field (L).  
97

#### 98 **Diversit, Uniformity and dominant indices**

99 The diversity index value (H') was calculated using the following formula (Fachrul 2012):

$$100 \quad H' = - \sum P_i \ln P_i, \text{ where } P_i = \frac{n_i}{N}$$

101 Where H' is Shannon Wiener Diversity Index, pi is the number of individuals of the i-th species, ni is the  
102 number of species, and N is the total individual number.

103 The uniformity index (E') was calculated using the "Evenness Index" formula (Ulfah et al. 2019):

$$104 \quad E' = \frac{H'}{1.05^{S^2}} \quad \text{where, } E' \text{ is uniformity index, } H' \text{: Shannon Wiener Diversity Index, } S \text{: Total number of species}$$

106

107 The dominance index (d) was calculated using the following equation (Berger and Parker 1970):

$$108 \quad d = \frac{N_{\max}}{N} \quad \text{where, "d": Simpson Dominance Index, } N_{\max} \text{: The most abundant number of individual species, dan}$$

109 N = Total individual

number.110

## 111 **RESULTS AND DISCUSSION**

### 112 **Plankton Abundance in Karanggongso Bay**

113 Samples of water were obtained from Karanggongso Bay at three designated locations, each with four different levels  
114 of depth. A total of 17 plankton species were identified from the surface water (0.0-0.3 m). The top six most abundant  
115 species were *Paracyclopina* sp. with 21.21%, followed by *Acartia* sp. (18.18%), *Pteropods* sp. (9.09%), *Prorocentrum* sp.  
116 (6.06%), *Dinophysis* sp. (6.06%), and *Sagitta* sp. (2.13%). Other species and their percentage was presented in Table 1. In  
117 addition, at a 2.5 m depth, 13 plankton species were identified and the top 6 most abundant species were *Acartia* sp.  
118 (26.47%), followed by *Paracyclopina* sp. (23.53%), *Ceratium* sp. (8.82%), *Microsetella* sp. (8.82%), *Dinophysis* sp.  
119 (5.8%), and *Oncaea* sp. (5.88%). The rest species with their abundance were presented in Table 1.

120 Furthermore, at 5 m depth, the Bay is home to 11 plankton species. The top 4 most abundant species were *Acartia* sp.  
121 (30.77%), followed by *Paracyclopina* sp. (23.08%), *Sagitta* sp. (11.54%), and *Oithona* sp. (7.69%). While the other 7  
122 species including *Synedra* sp., *Oikopleura* sp., *Coscinodiscus* sp., *Ceratium* sp., *Pteropods* sp., *Microsetella* sp., and  
123 unclassified Lucifer which were counted for 3.85% each, Table 1. Meanwhile, a total of 13 plankton species were found at  
124 the depth of 20 m. The top 6 most abundant species were *Acartia* sp. accounted for 24.14%), followed by *Paracyclopina*  
125 sp. with 13.79%, *Pteropods* sp. (10.34%), *Dinophysis* sp. (10.34%), *Ceratium* sp. with 6.90%, and *Sagitta* sp. with 6.90%.  
126 The rest species were presented in table 1.

127  
128  
129

**Table 1.** Planktons identified from two natural settlement habitats of spiny lobster larvae (Karanggongso Bay and Trenggalek Regency, East Java Indonesia) at four different depths of the water column.

Depth	Species	Cell density (Indiv/L)
0.3 m (Surface)	<i>Cyclotella</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Noctiluca</i> sp.	8
	<i>Prorocentrum</i> sp.	16
	<i>Dinophysis</i> sp.	16
	<i>Ceratium</i> sp.	8
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	24
	<i>Paracyclopina</i> sp.	56
	<i>Acartia</i> sp.	48
	<i>Microstella</i> sp.	8
	<i>Euphausia</i> sp.	8
	<i>Lucifer</i> sp.	8
	<i>Oipheureidea</i> sp.	8
	<i>Sagitta</i> sp.	16
	<i>Nematea</i> sp.	8
<i>Actinulla larvae</i>	8	
2.5 m	<i>Rizosolenia</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Ceratium</i> sp.	24
	<i>Dinophysis</i> sp.	16
	<i>Paracyclopina</i> sp.	64
	<i>Acartia</i> sp.	72
	<i>Microstella</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Codoneleopsis</i> sp.	8
	<i>Oipheureidea</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Actinula</i> sp.	8
<i>Polychaete</i>	8	
5.0 m	<i>Oikopleura</i> sp.	8
	<i>Synedra</i> sp.	8
	<i>Coscinodiscus</i> sp.	8
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	8
	<i>Paracyclopina</i> sp.	48
	<i>Acartia</i> sp.	64
	<i>Microstella</i> sp.	8
	<i>Oithona</i> sp.	16
<i>Lucifer</i> sp.	8	
<i>Sagita</i> sp.	24	
20.0 m (Bottom)	<i>Synedra</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Noctiluca</i> sp.	8
	<i>Dinophysis</i> sp.	24
	<i>Ceratium</i> sp.	16
	<i>Pteropods</i> sp.	24
	<i>Acartia</i> sp.	56
	<i>Paracyclopina</i> sp.	32
<i>Oithona</i> sp.	8	
<i>Microstella</i> sp.	16	



<i>Euphausia</i> sp.	8
<i>Protoperidinium</i> sp.	8
<i>Sagitta</i> sp.	16

130

**131 Plankton Abundance in Tawang Bay**

132 A total of 17 plankton species were identified from the water sample at depth of 0.0-0.3 m (surface water) of Tawang  
 133 Bay. The top 9 most abundant species were *Acartia* sp. with an abundance of 12.82%, followed by *Ceratium* sp. (10.26%),  
 134 *Prorocentrum* sp. (10.26%), *Microstella* sp. (10.26%), *Oncaea* sp. (10.26%) *Pteropods* sp. (7.69%), *Calanus* sp., (7.69%),  
 135 *Synedra* sp. (5.13%), and *Oithona* sp. (5.13%). While the rest species were counted for 2.56% each and presented in **Table**  
 136 **2**. In addition, there were 11 species of plankton found in a water sample at a depth of 2.5 m in Tawang Bay. The top 6  
 137 most abundant species were *Calanus* sp. (28.00%), followed by *Prorocentrum* sp. (12.00%), *Paracyclops* sp. (12.00%),  
 138 *Microstella* sp. (12.00%), *Oncaea* sp. (8.00%), and *Oithona* sp. with an abundance of 8.00%. While the rest plankton  
 139 species including *Synedra* sp., *Ceratium* sp., *Pteropods* sp., *Macrophthalmus* sp., and *Sagitta* sp. were counted at 4.00%  
 140 each, **Table 2**.

141 Furthermore, a total of 12 plankton species were identified from the water sample at 5 m depth. The top 4 most  
 142 common species were *Calanus* sp. with an abundance of 28.57%, *Oithona* sp. with an abundance of 14.29%, *Copepoda*  
 143 *nauplii* with an abundance of 9.52%, *Prorocentrum* sp. with an abundance of 9.52%. While the rest species including  
 144 *Melosira* sp., *Synedra* sp., *Dinophysis* sp., *Microstella* sp., *Temora* sp., *Oncaea* sp., and *Sagitta* sp., with an abundance of  
 145 5.00% respectively. While in the bottom waters of Tawang Bay (20 m depth), a total of 12 plankton species were  
 146 identified. The top 9 most abundant species were *Prorocentrum* sp. with an abundance of 16.44%, *Acartia* sp. with an  
 147 abundance of 16.44%, *Oithona* sp. with an abundance of 16.44%, *Oncaea* sp. with an abundance of 10.96%, *Dinophysis*  
 148 sp. with an abundance of 5.48%, *Rhizosolenia* sp. with an abundance of 5.48%, *Pleurosigma* sp. with an abundance of the  
 149 abundance of 5.48%, *Ceratium* sp. with 5.48%, *Caridean* sp. (5.48%). While the rest species were presented in table 2.

150 **Table 2.** Planktons identified from the natural habitat of spiny lobster in bottom water at Tawang Bay, East Java Indonesia

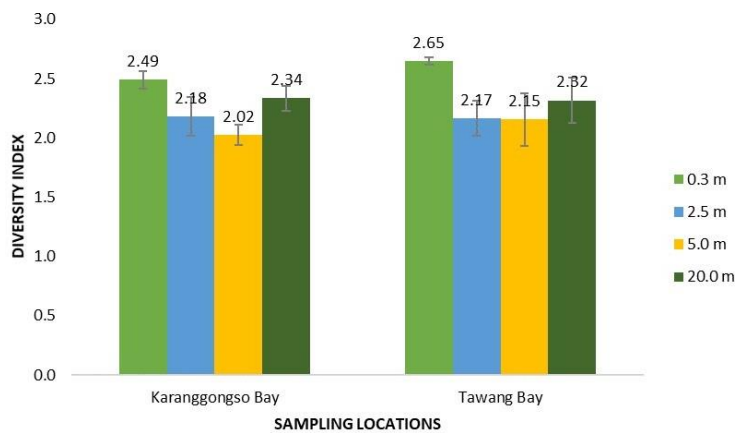
Depth	Species	Density (Indiv/L)
0.3 m (Surface)	<i>Synedra</i> sp.	16
	<i>Oscillatoria</i> sp.	8
	<i>Spirulina</i> sp.	8
	<i>Ceratium</i> sp.	32
	<i>Prorocentrum</i> sp.	32
	<i>Pteropods</i> sp.	24
	<i>Acartia</i> sp.	40
	<i>Microstella</i> sp.	32
	<i>Calanus</i> sp.	24
	<i>Oithona</i> sp.	16
	<i>Oncaea</i> sp.	32
	<i>Euphausia</i> sp.	8
	<i>Macrophthalmus</i> sp.	8
	<i>Clytemnestra</i> sp.	8
	<i>Cypris</i> sp.	8
	Unclassified <i>Fish larvae</i>	8
	Unclassified flatworms	8
2.5 m	<i>Synedra</i> sp.	8
	<i>Prorocentrum</i> sp.	24
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	8
	<i>Paracyclops</i> sp.	24
	<i>Calanus</i> sp.	56
	<i>Oithona</i> sp.	16
	<i>Microstella</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Macrophthalmus</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Melosira</i> sp.	8
<i>Synedra</i> sp.	8	
<i>Bivalve larvae</i>	8	
<i>Prorocentrum</i> sp.	16	

5 m	<i>Dinophysis</i> sp.	8
	<i>Microsetella</i> sp.	8
	<i>Calanus</i> sp.	48
	<i>Oithona</i> sp.	24
	<i>Naupli Copepoda</i>	16
	<i>Temora</i> sp.	8
	<i>Oncaea</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Rhizoselenia</i> sp.	8
	<i>Pleurosigma</i> sp.	8
20 m (bottom)	<i>Prorocentrum</i> sp.	24
	<i>Ceratium</i> sp.	8
	<i>Dinophysis</i> sp.	8
	<i>Microsetella</i> sp.	4
	<i>Calanus</i> sp.	6
	<i>Acartia</i> sp.	24
	<i>Oithona</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Caridean</i> sp.	8
	Unclassified flatworm	8

151  
152

### 153 Diversity indices

154 The diversity index values obtained in the waters of Karanggongso Bay, Trenggalek Regency East Java were  $2.49 \pm$   
155  $0.07$  at depth of 0.0-0.3 m depth of water column,  $2.18 \pm 0.16$  at a depth of 2.5 m,  $2.02 \pm 0.08$  at a depth of 5 m, and  $2.34 \pm$   
156  $0.10$  at the 20 m water column which indicates that the Karanggongso Trenggalek waters have moderate diversity. While  
157 the diversity index values obtained in the waters of Tawang Bay were  $2.65 \pm 0.03$  at 0.0 – 0.3 m depth,  $2.17 \pm 0.15$  at the  
158 2.5 m depth,  $2.15 \pm 0.22$  at a 5 m depth, and  $2.32 \pm 0.19$  at a depth of 20 m which indicates that the waters of Tawang Bay  
159 have also moderate diversity, Figure 2



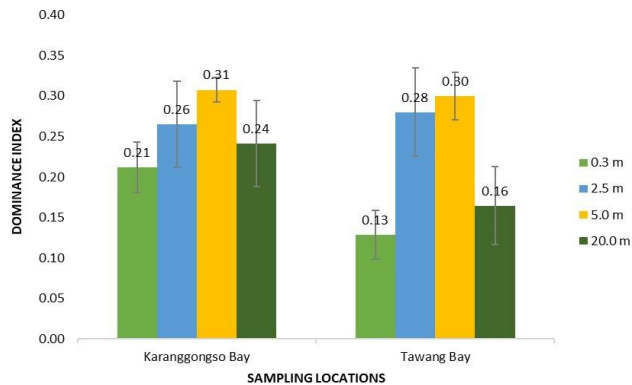
160

161 **Figure 2.** Diversity indices of plankton identified at the water column of Karanggongso Bay and Tawang Bay, East java  
162 Indonesia. Bars are the average values with a standard deviation of three replicates.

### 163 Domination Index

164 The dominance index is a value that indicates whether there are plankton species that dominate certain depths in the  
165 water column. Dominance index values obtained from the waters of Karanggongso Bay were  $0.21 \pm 0.03$  at the 0.0-0.3 m  
166 depth,  $0.26 \pm 0.05$  at a depth of 2.5 m,  $0.31 \pm 0.02$  at a depth of 5 m and  $0.24 \pm 0.05$  at the 20 m water depth. These values  
167 mean that no plankton species were dominant in the natural habitat of spiny lobster larvae (Karanggongso Bay). While the  
168 dominance index values obtained from Tawang Bay waters were  $0.13 \pm 0.03$  at the 0.0-0.3 m depth,  $0.28 \pm 0.05$  at a depth

169 of 2.5 m,  $0.30 \pm 0.03$  at a depth of 5 m, and  $0.16 \pm 0.05$  at the 20 m depth. Similarly, based on the values obtained from the  
 170 surface to the bottom of the waters shows that there are no species that dominate in Tawang Bay, Figure 4.



171  
 172 **Figure 4.** Domination indices of planktons identified at Karanggongso Bay and Tawang Bay, East Java, Indonesia. Bars  
 173 are the average values with a standard deviation of three replicates.

174

175 **Discussion**

176 Environmental conditions including physical, chemical, and biological factors in natural habitats highly determine the  
 177 recruitment rates of lobster larvae (Keulder 2005). Several studies have previously reported the physical and chemical  
 178 characteristics of the settlement area of lobster (Amin et al. 2022c; Boudreau et al. 1992; Lillis and Snelgrove 2010).  
 179 However, studies viewing biological aspects of settlement habitat in natural environment lobster larvae are still very  
 180 limited. Meanwhile, many studies conclude that biological factors such as plankton availability can be important  
 181 information on the natural diets of lobster larvae (O'Rorke et al. 2014). Thus the present study investigated the diversity,  
 182 uniformity, and dominance of plankton in two common settlement areas of lobster larvae in East Java (Karangongso Bay  
 183 and Tawang Bay) in Indonesia. The sampling was performed in 4 different depths which were 0.3 m, 2.5 m, 5 m, and 20 m  
 184 depth, as lobster larvae vertically migrated from the bottom during the daytime to the surface of the water during the  
 185 nighttime. It was also discovered that the diversity indices of plankton at both locations were 2.02-2.49 at Karangongso,  
 186 and 2.15-2.65 at Tawang Bay. The diversity index values found at these two locations were all less than 3, which means at  
 187 a moderate level. The high or low value of plankton diversity can be caused by the evenly distributed abundance of each  
 188 individual or in another sense there are no species that have relatively more diversity than other species (Awwaluddin et al.  
 189 2017). As the diversity indices of plankton at Karangongso Bay and Tawang Bay may which is at a moderate level may  
 190 suggest that plankton communities is in relatively equal distribution of different species, with no one species being  
 191 significantly more prevalent than others (Awwaluddin et al. 2017).

192 Similarly, the uniformity indices of planktons in both settlement areas were classified at a moderate level (0.38-0.45 at  
 193 Karangongso Bay and 0.41-0.46 at Tawang Bay. The uniformity values found at each location, both Karangongso  
 194 Beach waters and Tawang Beach waters, are said to have moderate uniformity. The value of uniformity is categorized to  
 195 be moderate if the value ranges from 0.4-0.6 (Ulfah et al. 2019). The availability of nutrients, food, and predation  
 196 processes can affect the high value of uniformity because it affects the type and amount of plankton. Besides that, physical  
 197 and chemical factors also affect the value of uniformity because it will affect the growth of plankton (Nugroho et al. 2020).  
 198 In addition, If the distribution of plankton in both waters is uniform, then a high degree of uniformity can be asserted.  
 199 While the dominance indices were ranging from 0.21 – 0.31 at Karangongso Bay and 0.13-0.30 in Tawang Bay. The  
 200 result indicates that there were no dominant species at both locations since all values < 0.05. Dominance index values  
 201 obtained in both waters indicate the absence of plankton which dominates in Karangongso Bay and also Tawang Bay.  
 202 Whether or not organisms dominate a waters can be seen from the value of the dominance index if the dominance index  
 203 shows a value between 0.5 to 1 then in these waters there are organisms that dominate and if it shows a value less than 0.5  
 204 then in these waters it indicates the absence of organisms dominating (Berger and Parker  
 1970).

205  
 206 **Potential Diet for Lobster Seeds**

207 The result also revealed that 17 plankton species were identified from the surface water, 13 species at a depth of 2.5 m,  
 208 11 species at a depth of 5 m, and 13 species at 20m (bottom) of Karangongso Bay. While, 17 plankton species were

209 discovered on the surface of Tawang Bay waters: 11 species at a depth of 2.5 m, 12 species at a depth of 5 m, and 12  
210 species at the seafloor. The number of plankton species identified in the present study, in general, are higher than in  
211 previous study reported from other settlement habitats of lobster larvae in Awang Bay west Nusa Tenggara (Amin et al.  
212 2022c) and Teluk Wedi Ombo, Yogyakarta (Trijoko and Pasaribu 2004). The most abundant species identified from  
213 Karangongso Bay were *Paracyclops* sp., *Acartia* sp., *Pteropods* sp., and *Prorocentrum* sp. *Dinophysis* sp., *Sagitta* sp.,  
214 *Ceratium* sp., *Microsetella* sp., *Dinophysis* sp., *Calanus* sp., *Synedra* sp., and *Oithona* sp. (7.69%). While most abundant  
215 species found in Tawang Bay were *Acartia* sp., *Ceratium* sp. *Prorocentrum* sp., *Microsetella* sp., *Oncaea* sp., *Pteropods*  
216 sp., *Calanus* sp., *Synedra* sp., *Oithona* sp., *Calanus* sp., *Paracyclops* sp., *Macrophthalmus* sp., *Sagitta* sp., *Dinophysis* sp.,  
217 and *Rhizosolenia* sp. of these identified plankton species, 10 species were found in both locations including *Acartia* sp.,  
218 *Oithona* sp., *Paracyclops* sp., *Pteropods* sp., *Binophysis* sp., *Sagitta* sp., *Microsetella* sp. *Calanus* sp., *Synedra* sp.

219 Among the identified plankton species, few species have been documented as potential live diets in aquaculture  
220 including *Oithona* sp. for live diet of European seabass (*Dicentrarchus labrax*) postlarvae (Magouz et al. 2021a), and  
221 shrimp larvae (Dinesh Kumar et al. 2017), and *Acartia* sp., as a live diet for seabass larvae, *Lates calcarifer* (Rajkumar  
222 2006), fat snook, *Centropomus parallelus* (Barroso et al. 2013), and many other aquatic larvae (Sarkisian et al. 2019). In  
223 fact, some studies also confirmed that these plankton species were identified in the stomach content of lobster larvae. For  
224 instance, *Oithona* sp. has been reported from the stomach content of spiny lobsters at the early life stage (Amin et al.  
225 2022d; Khvorov et al. 2012). *Oithona* sp. has been described as a marine calanoid copepod which has high protein content,  
226 ~59.33% (Santanumurti et al. 2021), therefore frequently used as a live diet for fish or shrimp larvae. Another study has  
227 documented that *Oithona* sp. had a high content of fatty acid profiles including polyunsaturated fatty acids (26.47%) and  
228 omega-3 fatty acids (36.30) which in fact are higher compared to a commercial live diet such as *Artemia* (Magouz et al.  
229 2021b). Furthermore, *Acartia* sp. has been also documented to be a good live diet for aquatic larvae such as seabass larvae,  
230 *Lates calcarifer* (Rajkumar 2006), and fat snook, *Centropomus parallelus* (Barroso et al. 2013). *A. clausi* has been  
231 described to have higher contents of proteins (63.12%) and lipids (16.65%) and is also richer in n-3 fatty acids (33.94%)  
232 than *Artemia* nauplii and rotifers (Rajkumar, 2006). The plankton species has been also identified in the stomach content  
233 of spiny lobster larvae (Amin et al. 2022d). In addition, a member of *Acartia* (*Acartia tonsa*) had been documented to  
234 provide an important nutritional benefit to fat snook larvae undergoing metamorphosis (Vanacor-Barroso et al. 2017).

235 Other potential food sources for lobster larvae identified in the present study are zooplankton and phytoplankton.  
236 According to the results obtained, the plankton found at each station consists of Bacillariophyceae (e.g. *Rizosolenia* sp.,  
237 *Synedra* sp., *Cyclotella* sp.), and Copepoda (e.g. *Oithona* sp., *Acartia* sp., *Calanus* sp.). These plankton groups were  
238 identified at each station, highlighting their potential as a food source for lobster larvae. Diatoms, which belong to the  
239 phytoplankton group Bacillariophyceae, contain essential nutrients required for the growth of lobster larvae, such as  
240 PUFA (Polyunsaturated Fatty Acid). PUFA including EPA (eicosapentaenoic acid, 20:5 n-3) and DHA (docosahexaenoic  
241 acid 22:6 n-3) are the major fatty acids found in diatoms Bacillariophyceae (Pahl et al., 2010). PUFA content of these  
242 diatoms is relatively high, with levels ranging between 23.4 and 60.7% (Valera & Saavedra, 2016). High PUFA content  
243 was identified in several plankton species as potential prey for spiny lobster larvae *Jasus edwardsii*, and these long-chain  
244 fatty acids are an essential nutrient for spiny lobster (Koshio & Kanazawa, 1994; Liddy et al., 2004; Wang, 2013).

245 Copepoda (Hexanauplia) is a rich source of protein, particularly in gastropods, it is also high in calcium content which  
246 is important for lobster during molting (Kirno et al., 2012). Several studies, such as those by Alka (2016), Chow (2011),  
247 and Connel (2007), have reported the presence of copepods in the digestive tracts of lobster larvae. This suggests that  
248 copepods are a preferred food for lobster larvae. Protein is constantly the predominant organic nutrient in the spiny lobster  
249 larvae as well as their preferred prey (Wang, 2013). This is consistent with prior examinations of digestive enzymes of  
250 phyllosoma of *J.edwardsii* and *Panulirus ornatus*, which reveal that they necessitate a high-protein diet and will utilize  
251 protein to generate energy during food deprivation (Johnston et al., 2004a; Johnston et al., 2004b, Johnston et al., 2006).  
252 Copepods contain high protein content, ranging from 28.9 - 84.9 % of dry weight, indicating that lobster larvae consume  
253 prey with high protein content (Wang & Jeffs, 2014). The protein content of the copepods is in accordant with the amount  
254 of protein incorporated into artificial feeds for some of the crustaceans larvae including crab, shrimp, and clawed lobster  
255 species, which is ranging between 30% to 60% protein (Conklin et al., 1980 ; Guillaume, 1997 ; Holme et al., 2009).  
256 Moreover, copepods also high in lipid, ranging from 11.3%-12.4% (Wang & Jeffs, 2014). Rich-lipid diets can be properly  
257 digested by the spiny lobster larvae, and utilize it to supply energy, especially during a food scarcity (Johnston et al., 2004;  
258 Liddy et al., 2003; Liddy et al., 2004; Ritar et al., 2003). Furthermore, late phase phyllosoma of spiny lobster probably  
259 target high lipid prey, as they prepare to accumulate an enormous amount of lipid to fuel their non-feeding post-larval  
260 stage ( Jeffs et al., 2001a; Jeffs et al., 2001b). The presence of copepods especially *Oithona* sp., *Acartia* sp., and *Calanus*  
261 sp in a high abundance value at the Karangongso and Tawang Bay could provide a significant source of high lipid natural  
262 diets for spiny lobster larvae. These results suggest that these plankton species are a potential diet for spiny lobster larvae,  
263 therefore, should be further studied by in vivo trials using aquatic animals especially for developing ornate spiny lobster  
264 hatcheries.

265 In conclusion, a total of 17 plankton species were identified from the surface water, 13 species at a depth of 2.5 m, 11  
266 species at a depth of 5 m, and 13 species at 20m (bottom) of Karangongso Bay. While, 17 plankton species were  
267 discovered on the surface of Tawang Bay waters: 11 species at a depth of 2.5 m, 12 species at a depth of 5 m, and 12  
268 species at the seafloor. It was also discovered that the diversity index of plankton was considered at a moderate level at

269 both locations, 2.02-2.49 at Karanggongso, and 2.15-2.65 at Tawang Bay. Similarly, the uniformity index was classified at  
270 a moderate level at both locations (0.38-0.45 at Karanggongso Bay and 0.41-0.46 at Tawang Bay. While the dominance  
271 index was ranging from 0.21 – 0.31 at Karanggongso Bay and 0.13-0.30 in Tawang Bay which indicates that there were no  
272 dominant species at both location. Among the identified plankton species, several members of *Oithona* sp., and *Acartia* sp.  
273 are considered potential live feed for lobster larvae, and thus should be further studied. Among the identified plankton  
274 species, several members of Bacillariophyceae, Copepoda, and Hexanauplia are considered potential live feed for lobster  
275 larvae, and thus should be further studied.

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166.350

### 3. Bukti review round 2 (7 Maret 2023)

#### A. Komentar reviewer A (rounde 2): isi tertuang di point B

**Submission** | **Review** | Copyediting | Production

Round 1 | **Round 2** | Round 3

**Round 2 Status**  
A review is overdue.

**Notifications**

<a href="#">[biodiv] Editor Decision</a>	2023-03-03 05:18 AM
<a href="#">[biodiv] Editor Decision</a>	2023-03-11 05:33 AM
<a href="#">[biodiv] Editor Decision</a>	2023-03-30 12:41 PM

**Reviewer's Attachments** Search

1075127-1   REVIEWER_13706-Article Text-1074371-1-4-20230209.doc	February 18, 2023
1076175-1   DONE Review 13706-Article Text-1074371-1-4-20230209.doc	March 2, 2023

**Revisions** Search Upload File

1076636-1   Article Text, 13706-1075127-1-5-20230218-Revision Clean.doc	March 7, 2023	Article Text
1076637-1   Other, 13706-1075127-1-5-20230218_Revision with Track changes.doc	March 7, 2023	Other
1076638-1   Other, Author Responses on Reviewer2.docx	March 7, 2023	Other

## B. Permintaan reviewer A dan respon author (rounde 2)

1. Line 1-3: highlight the two bays here? Otherwise it is too broad.

**Authors' Response:** Title has been revised by adding two bays and presented in line 1-2 in the amended manuscript.

### ABSTRACT

2. Line 17: Are there multiple species? Or just one kind present in these areas.

**Authors' Response:** yes, the habitat provide more than one spiny lobster species.

3. Line-23: A missing value here

**Authors' Response:** Value has been added, and presented in line 23 in the amended manuscript

4. Authors should mention also then the objective of this paper is to identify the species present at different depths in these two different bays.

**Authors' Response:** Objective has been added, ad presented in line 21-23 in the amended manuscript.

5. Line: 31: Values?

**Authors' Response:** values have been added and presented in line 25-29 in the amended manuscript.

6. Highlight the two locations in the methodology

**Authors' Response:** More information on the two selected locations have been added in methodology, and presented in line 74-77 in the amended manuscript.

7. Plural of plankton is still plankton

**Authors' Response:** "planktons" has been replaced with "plankton" and presented in line 139 in the amended manuscript.

8. Line 224: Why if and not since?

**Authors' Response:** if has been replaced with "since"

9. "Artemia" Are you refering to the species or the noun?

**Authors' Response:** "Artemia" has been replaced with "Artemia sp." and presented in line 264 in the amended manuscript.

10. Scientific names at the beginning at the sentence should be spelt full

**Authors' Response:** Full scientific name has been added, and presented in line 269

11. Have a holistic conclusion on what these results implicate with the ecology of Karanggongso and Tawang Bay or for the larvae of these lobsters, or human benefits?

**Authors' Response:** Conclusion has been rewritten and the higher uniformity indexed compared to dominance index indicated that the was no dominant species in each study locations, this information is stated in line 291-294



### c. Artikel yang sudah diperbaiki (rounde 2)

## Diversity and Abundance of Plankton Community in Tawang Bay and Karangongso Bay, the Natural Settlement Habitats of Spiny Lobster Larvae

Commented [CC1]: Perhaps highlight the two bays here? Otherwise it is too broad

Commented [mA2R1]: Title has been revised by adding two bays

**Abstract.** Tawang Bay and Karangongso Bay have been well-known as settlement areas for lobster larvae *Panulirus spp.* in East Java Indonesia, which may suggest that the location are suitable environments including diet availability for lobster larvae. Therefore, the study aimed to investigate the types, abundance and diversity of plankton in the both locations to discover potential live diets for lobster larvae. Plankton samples were collected in both locations using a plankton net at four different depths: 0.3 m, 2.5m, 5 m and 20 m with three replicates. The objectives of this study are to explore the diversity, abundance, uniformity and dominance indices of plankton in the natural settlement ground of lobster larvae at Karangongso and Tawang Bay. The results revealed that 17 plankton species were identified from the 0.30 m depth, 13 species at a depth of 2.5m, 11 species at a depth of 5m, and 13 species at 20m at Karangongso Bay. While, 17 plankton species were discovered on the surface of Tawang Bay waters: 11 species at a 2.5m, 12 species at 5m, and 12 species at 20m. The diversity indices observed in Karangongso and Tawang bay ranged from 2.02-2.49 and 2.17-2.65, respectively, which fall within the moderate range. Similarly, the uniformity indices observed at both locations were also moderate, with values ranging from 0.38-0.45 at Karangongso bay and 0.41-0.46 at Tawang bay. While there were no dominant species at both locations, indicated by the dominance index values ranged from 0.13-0.30. Among the identified plankton species, *Oithona sp.*, and *Acartia sp.* are considered potential live feed for lobster larvae, and thus should be further studied.

Commented [CC3]: Are there multiple species? Or just one kind present in these areas.

Commented [mA4R3]: Yes, there are multiple species

found in this places

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Commented [mA6R5]: Value has been added

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Commented [CC7]: Authors should mention also then the objective of this paper is to identify the species present at different depths in these two different bays.

Commented [mA8R7]: Objective has been added in line 21-23

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Commented [mA10R9]: Values have been added in line 27-31

**Key words:** diversity, diets, dominance, lobster, plankton, uniformity.

**Abbreviations** (if any): -

**Running title:** Plankton diversity in lobster natural habitat

### INTRODUCTION

Lobster is an important fishery commodity in Indonesia due to its high price, high nutritional contents as well as high market demands. According to the Indonesian Central Bureau of Statistics, the total export value of lobsters in 2020 reached USD 8.1 million (BPS 2020). The high export value and continuously increasing marketing demands at national or global markets indicate that lobster is a high-potential fisheries commodity. However, the lobster supply has been highly dependent on the wild catch because lobster aquaculture has not been well developed yet. One of the main issues faced in lobster aquaculture is larval production, which currently relies on the availability of seeds in nature. Many studies relating to larval production of larvae have been conducted to study various factors including spawning-inducing technology and rearing condition, yet the success rates are very low. Several authors have succeeded to breed and producing larvae. Yet, the larvae can live only 7-14 days after hatching. It is hypothesized that the main challenge is in diet availability and suitability. According to Amin et al. (2022b), one way to start domesticating wild species is firstly by

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48 collecting information on their natural habitat as much as possible. Similarly, Kashinskaya et al. (2018) suggest that  
49 profiling certain animals' natural habitat may reveal their diets.

50 Environmental conditions including physical, chemical, and biological factors in natural habitats highly determine the  
51 recruitment rates of lobster larvae (Keulder 2005). Several authors have previously reported the physical and chemical  
52 characteristics of the natural settlement areas of lobster larvae (Amin et al. 2022c; Boudreau et al. 1992; Lillis and  
53 Snelgrove 2010). However, studies investigating biological aspects of settlement habitat in the natural environment of  
54 lobster larvae are still very limited. Meanwhile, many studies conclude that biological factors hold important information  
55 for the lobster larvae, especially for diets (O'Rorke et al. 2014). Accordingly, biological aspects such as natural dietary  
56 aspects and lobster predation processes that occur in nature during larval and post-larval stages could be critical  
57 information that must be considered for hatchery production. In their natural settlement habitat, plankton might be a  
58 natural diet source for various types of fish seeds, including lobster seeds. Raza'i et al. (2018) added that the availability of  
59 plankton as a natural diet source has a significant impact on the dependence and growth of marine organisms such as fish,  
60 crabs, shrimp, and lobsters.

61 Profiling plankton diversity and abundance might reveal potential diets for lobster larvae. A similar approach has been  
62 done in some studies. For instance, Ihsan et al. (2019) conducted research on plankton as a natural feed for lobster larvae  
63 and post-larvae in natural habitats in Teluk Awang, Central Lombok. Trijoko and Pasaribu (2003) conducted another study  
64 in Wedi Ombo Bay, Gunung Kidul, Yogyakarta. The study results in general suggest that each location has a different  
65 structure and abundance, although some species were the same between the area. All these results raised questions about  
66 whether lobster larvae are opportunistic feeders or specific feeders. **To answer these questions more studies are required by  
67 collecting more information in more settlement areas of lobster.**

68 **Tawang Bay** been well-known as one of the most settlement areas for lobster larvae in East Java Indonesia (Amin et al.  
69 2022a); therefore, it is assumed **to have important suitable diet availability** for lobster larvae. However, studies on the  
70 biological aspects of both locations areas are still very limited. Thus, the objectives of this research is to investigate the  
71 plankton diversity, abundance, uniformity, and dominance indices in the natural settlement habitat of lobster larvae at  
72 Karanggongso and Tawang Bays. The study results are expected to enrich the information on potential diets for lobster  
73 larvae for hatchery development.

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## 74 MATERIALS AND METHODS

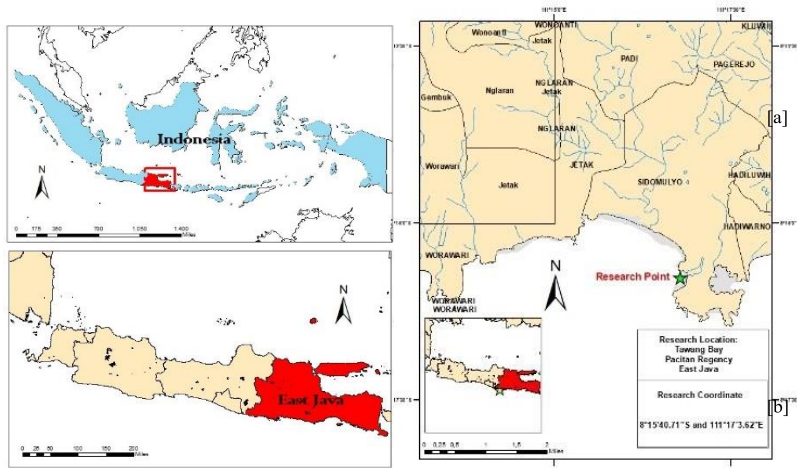
### 75 Study area

76 The collection of plankton samples was carried out in two common settlement areas of lobster larvae in East Java  
77 Indonesia (Tawang Bay) with a protocol as previously described by Amin et al. (2022c). The sampling location  
78 was performed at ordinate points: 8°15'57.4"S 111°17'46.0" E (L1), 8°15'54.3"S 111°17'48.2"E (L2) and 8°15'51.5"S

79 111°17'46.2"E (L3), (Figure 1). Plankton sampling was conducted at three different sampling points with four different  
80 depths: 0-0.3 m, 2.5 m, 5 m, and 20 m. The water samples were filtered using a plankton net and placed in sterile bottles.

81 The filtered sample was then immediately given Lugol which acts as a plankton preservative, up to 1% of the total filtering  
82 and wrapped in Styrofoam. The samples were then examined in the Microbiology Laboratory, Faculty of Fisheries and  
83 Marine Science at Airlangga

University.84



85  
86 Figure 1 Two sampling locations: Karanggongso Bay, Trenggalek Regency [a], and Tawang Bay, Pacitan Regency [b], East Java,  
87 Indonesia.

88 Karanggongso Bay waters have temperatures ranging from 27-28 °C, a DO content of 7.48 mg/L, a salinity of 26 ppt, a  
89 pH of 7-8, a NO<sub>3</sub> content of 0.01 mg/L, and a muddy substrate. Tawang Bay waters temperatures are slightly warmer than  
90 Karanggongso Bay, with water temperature ranging from 28.2-28.3 °C, with a significantly lower, DO content of 3.35  
91 mg/L. moreover, Tawang Bay has a higher salinity of 35 ppt, a pH of 8, a NO<sub>3</sub> content of 0.01, a depth of 15 m, and a  
92 sandy substrate.

93 **Abundance and Identification of planktons**

94 Firstly, plankton identity and their abundances were analyzed using a protocol of LeGresley and McDermott (2010). In  
95 brief, plankton samples were placed on a Sedgewick Rafter Counting Cell and observed under a binocular microscope with  
96 a magnification of 1000x. Thereafter each plankton found in each sample was counted, photographed, and identified  
97 according to an identification book guide by Mazzocchi et al. (2012). Then, the abundance index was calculated according  
98 to the following formula (Fachrul 2012):

$$N = \frac{a}{b} \times \frac{c}{d} \times \frac{Vb}{Vsrc} \times \frac{1}{Vs}$$

101 Where “N” represents the abundance of plankton (plankton/L), “a” represents the number of SRC boxes, “b” is the area of  
102 one field of view (mm<sup>2</sup>), “c” denotes the number of individuals observed, and “d” indicates the number of boxes observed.  
103 “Vb” is the volume of water in the sample bottle (ml), “Vsrc” is the volume of water in the SRC (ml), and “Vs” represents  
104 the volume of water filtered in the Field (L).  
105

106 **Diversity, Uniformity and dominant indices**

107 The diversity index value (H') was calculated using the following formula (Fachrul 2012):

$$108 \quad H' = - \sum P_i \ln P_i, \text{ where } P_i = \frac{n_i}{N}$$

109 Where H' is Shannon Wiener Diversity Index, pi is the number of individuals of the i-th species, ni is the  
110 number of species, and N is the total individual number.

111 The uniformity index (E') was calculated using the “Evenness Index” formula (Ulfah et al. 2019):

$$E' = \frac{112}{Lns}$$

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113 where, 'E' is uniformity index, 'H': Shannon Wiener Diversity Index, 'S': Total number of species

114

115 The dominance index (d) was calculated using the following equation (Berger and Parker 1970):

116 
$$d = \frac{N_{max}}{N}$$
 where, "d": Simpson Dominance Index, Nmax: The most abundant number of individual species, dan  
 117 N = Total individual

number.118

119 **RESULTS AND DISCUSSION**

120 **Results**

121 **Plankton Abundance in Karanggongso Bay**

122 ~~Water~~ Samples ~~samples of water were obtained~~ collected two locations, from Karanggongso Bay at three designated  
 123 ~~locations~~ and Tawang Bay at each with four different levels of depths (0.3m, 2.5m, 5m, and 20m). The two bays were  
 124 located at southern part of East Java Province and both areas are facing to the Indian Ocean, Figure 1. The results showed  
 125 that a total of 17 plankton species were identified from the surface water (0.0-0.3 m). The top six most abundant species were  
 126 *Paracyclops* sp. with 21.21%, followed by *Acartia* sp. (18.18%), *Pteropods* sp. (9.09%), *Prorocentrum* sp. (6.06%),  
 127 *Dinophysis* sp. (6.06%), and *Sagitta* sp. (2.13%). Other species and their percentage was presented in Table 1. In addition,  
 128 at a 2.5 m depth, 13 plankton species were identified and the top 6 most abundant species were *Acartia* sp. (26.47%),  
 129 followed by *Paracyclops* sp. (23.53%), *Ceratium* sp. (8.82%), *Microstella* sp. (8.82%), *Dinophysis* sp. (5.8%), and  
 130 *Oncaea* sp. (5.88%). The rest species with their abundance were presented in Table 1.

131 Furthermore, at 5 m depth, the Bay is home to 11 plankton species. The top 4 most abundant species were *Acartia* sp.  
 132 (30.77%), followed by *Paracyclops* sp. (23.08%), *Sagitta* sp. (11.54%), and *Oithona* sp. (7.69%). While the other 7  
 133 species ~~including~~ ~~included~~ *Synedra* sp., *Oikopleura* sp., *Coscinodiscus* sp., *Ceratium* sp., *Pteropods* sp., *Microstella* sp., and  
 134 unclassified *Lucifer* which were counted for 3.85% each, Table 1. Meanwhile, a total of 13 plankton species were found  
 135 at the depth of 20 m. The top 6 most abundant species were *Acartia* sp. accounted for 24.14%, followed by *Paracyclops*  
 136 sp. with 13.79%, *Pteropods* sp. (10.34%), *Dinophysis* sp. with 6.90%, and *Sagitta* sp. with 6.90%.  
 137 The rest species were presented in table 1.

138  
 139 **Table 1.** Planktons identified from two natural settlement habitats of spiny lobster larvae (Karanggongso Bay and  
 140 Trenggalek Regency, East Java Indonesia) at four different depths of the water column.

Depth	Species	Cell density (Indiv/L)
0.3 m (Surface)	<i>Cyclotella</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Noctiluca</i> sp.	8
	<i>Prorocentrum</i> sp.	16
	<i>Dinophysis</i> sp.	16
	<i>Ceratium</i> sp.	8
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	24
	<i>Paracyclops</i> sp.	56
	<i>Acartia</i> sp.	48
	<i>Microstella</i> sp.	8
	<i>Euphausia</i> sp.	8
	<i>Lucifer</i> sp.	8
	<i>Oipheureidea</i> sp.	8
<i>Sagitta</i> sp.	16	
<i>Nematea</i> sp.	8	
<i>Actinulla larvae</i>	8	
2.5 m	<i>Rizosolenia</i> sp.	8
	<i>Penilia</i> sp.	8

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Commented [CC11]: Highlight this in the methodology

Commented [mA12R11]: More information on the two selected locations have been added in line124-127

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Commented [CC13]: Plural of plankton is still plankton

Commented [mA14R13]: Thank you for the correction

	<i>Ceratium</i> sp.	24
	<i>Dinophysis</i> sp.	16
	<i>Paracyclopina</i> sp.	64
	<i>Acartia</i> sp.	72
	<i>Microstella</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Codoneleopsis</i> sp.	8
	<i>Oipheureidea</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Actinula</i> sp.	8
	<i>Polychaete</i>	8
5.0 m	<i>Oikopleura</i> sp.	8
	<i>Synedra</i> sp.	8
	<i>Coscinodiscus</i> sp.	8
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	8
	<i>Paracyclopina</i> sp.	48
	<i>Acartia</i> sp.	64
	<i>Microstella</i> sp.	8
	<i>Oithona</i> sp.	16
	<i>Lucifer</i> sp.	8
	<i>Sagitta</i> sp.	24
20.0 m (Bottom)	<i>Synedra</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Noctiluca</i> sp.	8
	<i>Dinophysis</i> sp.	24
	<i>Ceratium</i> sp.	16
	<i>Pteropods</i> sp.	24
	<i>Acartia</i> sp.	56
	<i>Paracyclopina</i> sp.	32
	<i>Oithona</i> sp.	8
	<i>Microstella</i> sp.	16
	<i>Euphausia</i> sp.	8
	<i>Protoperidinium</i> sp.	8
	<i>Sagitta</i> sp.	16

141

#### 142 Plankton Abundance in Tawang Bay

143 A total of 17 plankton species were identified from the water sample at depth of 0.0-0.3 m (surface water) of Tawang  
144 Bay. The top 9 most abundant species were *Acartia* sp. with an abundance of 12.82%, followed by *Ceratium* sp. (10.26%),  
145 *Prorocentrum* sp. (10.26%), *Microstella* sp. (10.26%), *Oncaea* sp. (10.26%), *Pteropods* sp. (7.69%), *Calanus* sp., (7.69%),  
146 *Synedra* sp. (5.13%), and *Oithona* sp. (5.13%). While the rest of the species were counted for 2.56% each and presented in

147 **Table 2.** In addition, there were 11 species of plankton found in a water sample at a depth of 2.5 m in Tawang Bay. The  
148 top 6 most abundant species were *Calanus* sp. (28.00%), followed by *Prorocentrum* sp. (12.00%), *Paracyclopina* sp.  
149 (12.00%), *Microstella* sp. (12.00%), *Oncaea* sp. (8.00%), and *Oithona* sp. with an abundance of 8.00%. While the rest  
150 plankton species including *Synedra* sp., *Ceratium* sp., *Pteropods* sp., *Macrophthalmus* sp., and *Sagitta* sp. were counted at  
151 4.00% each, **Table 2.**

152 Furthermore, a total of 12 plankton species were identified from the water sample at 5 m depth. The top 4 most  
153 common species were *Calanus* sp. with an abundance of 28.57%, *Oithona* sp. with an abundance of 14.29%, *Copepoda*  
154 *nauplii* with an abundance of 9.52%, *Prorocentrum* sp. with an abundance of 9.52%. While the rest of the species  
155 including *Melosira* sp., *Synedra* sp., *Dinophysis* sp., *Microstella* sp., *Temora* sp., *Oncaea* sp., and *Sagitta* sp., with an  
156 abundance of 5.00% respectively. While in the bottom waters of Tawang Bay (20 m depth), a total of 12 plankton species  
157 were identified. The top 9 most abundant species were *Prorocentrum* sp. with an abundance of 16.44%, *Acartia* sp. with  
158 an abundance of 16.44%, *Oithona* sp. with an abundance of 16.44%, *Oncaea* sp. with an abundance of 10.96%,  
159 *Dinophysis* sp. with an abundance of 5.48%, *Rhizosolenia* sp. with an abundance of 5.48%, *Pleurosigma* sp. with  
160 an abundance of the abundance of 5.48%, *Ceratium* sp. with 5.48%, *Caridean* sp. (5.48%). While the rest species were  
161 presented in table 2.

162 **Table 2.** Planktons identified from the natural habitat of spiny lobster in bottom water at Tawang Bay, East Java Indonesia

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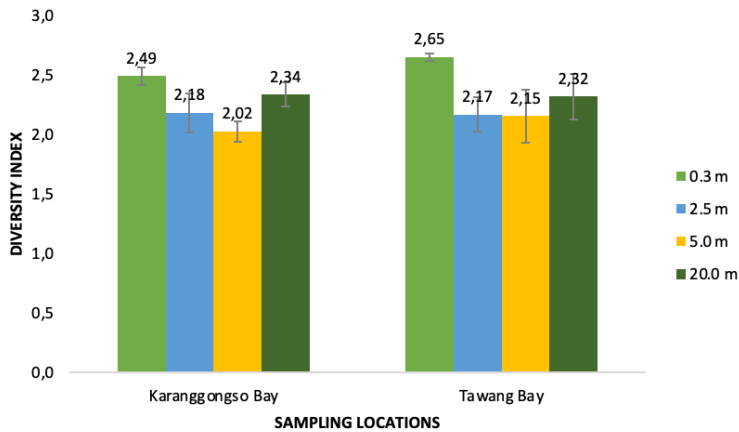
Depth	Species	Density (Indiv/L)
0.3 m (Surface)	<i>Synedra</i> sp.	16
	<i>Oscillatoria</i> sp.	8
	<i>Spirulina</i> sp.	8
	<i>Ceratium</i> sp.	32
	<i>Prorocentrum</i> sp.	32
	<i>Pteropods</i> sp.	24
	<i>Acartia</i> sp.	40
	<i>Microsetella</i> sp.	32
	<i>Calanus</i> sp.	24
	<i>Oithona</i> sp.	16
	<i>Oncaea</i> sp.	32
	<i>Euphausia</i> sp.	8
	<i>Macrophthalmus</i> sp.	8
	<i>Clytemnestra</i> sp.	8
	<i>Cypris</i> sp.	8
	Unclassified <i>Fish larvae</i>	8
	Unclassified flatworms	8
2.5 m	<i>Synedra</i> sp.	8
	<i>Prorocentrum</i> sp.	24
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	8
	<i>Paracyclops</i> sp.	24
	<i>Calanus</i> sp.	56
	<i>Oithona</i> sp.	16
	<i>Microsetella</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Macrophthalmus</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Melosira</i> sp.	8
	<i>Synedra</i> sp.	8
5 m	<i>Bivalve larvae</i>	8
	<i>Prorocentrum</i> sp.	16
	<i>Dinophysis</i> sp.	8
	<i>Microsetella</i> sp.	8
	<i>Calanus</i> sp.	48
	<i>Oithona</i> sp.	24
	<i>Naupli Copepoda</i>	16
	<i>Temora</i> sp.	8
	<i>Oncaea</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Rhizoselenia</i> sp.	8
20 m (bottom)	<i>Pleurosigma</i> sp.	8
	<i>Prorocentrum</i> sp.	24
	<i>Ceratium</i> sp.	8
	<i>Dinophysis</i> sp.	8
	<i>Microsetella</i> sp.	4
	<i>Calanus</i> sp.	6
	<i>Acartia</i> sp.	24
	<i>Oithona</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Caridean</i> sp.	8
Unclassified <i>flatworm</i>	8	

163  
164

**165 Diversity indices**

166 The diversity index values obtained in the waters of Karanggongso Bay, Trenggalek Regency East Java were  $2.49 \pm$   
167  $0.07$  at depth of 0.0-0.3 m depth of water column,  $2.18 \pm 0.16$  at a depth of 2.5 m,  $2.02 \pm 0.08$  at a depth of 5 m, and  $2.34 \pm$

168 0.10 at the 20 m water column which indicates that the Karanggongso Trenggalek waters have moderate diversity. While  
 169 the diversity index values obtained in the waters of Tawang Bay were  $2.65 \pm 0.03$  at 0.0 – 0.3 m depth,  $2.17 \pm 0.15$  at the  
 170 2.5 m depth,  $2.15 \pm 0.22$  at a 5 m depth, and  $2.32 \pm 0.19$  at a depth of 20 m which indicates that the waters of Tawang Bay  
 171 have also moderate diversity, Figure 2

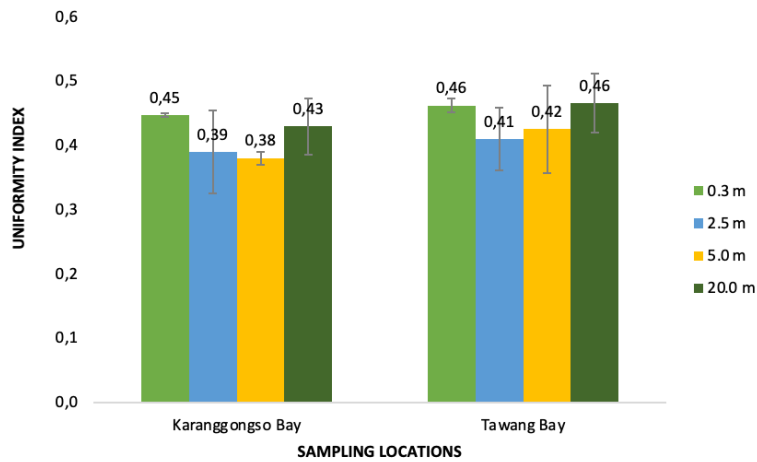


172  
 173 **Figure 2.** Diversity indices of plankton identified at the water column of Karanggongso Bay and Tawang Bay, East Java  
 174 Indonesia. Bars are the average values with a standard deviation of three replicates.

175  
 176 **Uniformity indices**

178 The uniformity index values obtained in the water column of Karanggongso Bay were  $0.45 \pm 0.01$  at 0.0-0.3 m  
 179 depth (surface water column),  $0.39 \pm 0.06$  at a depth of 2.5 m,  $0.38 \pm 0.01$  at a depth of 5 m and  $0.43 \pm 0.04$  at the 25m  
 180 depth or bottom of the water column. These index values indicated that the uniformity of plankton in Karanggongso Bay  
 181 was at a moderate level. While the uniformity values obtained in Tawang Bay were  $0.46 \pm 0.01$  at 0.0-0.3 m depth,  $0.41 \pm$   
 182  $0.05$  at a depth of 2.5 m,  $0.42 \pm 0.07$  at a depth of 5 m, and  $0.46 \pm 0.05$  at 25 m depth or bottom of the water column.  
 183 Similarly, uniformity indices of plankton in Tawang Bay were considered also at a moderate level, **Figure 3.**

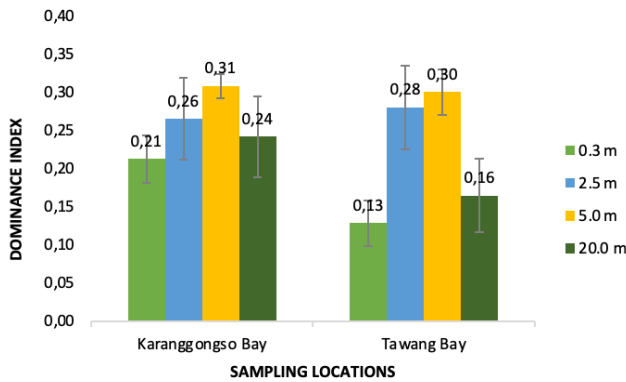
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184  
185 **Figure 3.** Uniformity indices of planktons identified in Karanggongso Bay and Tawang Bay, East Java Indonesia. Bars are  
186 the average values with a standard deviation of three replicates.

187  
188 **Domination Index**

189 The dominance index is a value that indicates whether there are plankton species that dominate certain depths in the  
190 water column. Dominance index values obtained from the waters of Karanggongso Bay were  $0.21 \pm 0.03$  at the 0.0-0.3 m  
191 depth,  $0.26 \pm 0.05$  at a depth of 2.5 m,  $0.31 \pm 0.02$  at a depth of 5 m and  $0.24 \pm 0.05$  at the 20 m water depth. These values  
192 mean that no plankton species were dominant in the natural habitat of spiny lobster larvae (Karanggongso Bay). While the  
193 dominance index values obtained from Tawang Bay waters were  $0.13 \pm 0.03$  at the 0.0-0.3 m depth,  $0.28 \pm 0.05$  at a depth  
194 of 2.5 m,  $0.30 \pm 0.03$  at a depth of 5 m, and  $0.16 \pm 0.05$  at the 20 m depth. Similarly, based on the values obtained from the  
195 surface to the bottom of the waters shows that there are no species that dominate in Tawang Bay. (Figure 4)  
196



197  
198 **Figure 4.** Domination indices of planktons identified at Karanggongso Bay and Tawang Bay, East Java, Indonesia. Bars  
199 are the average values with a standard deviation of three replicates.

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## 201 Discussion

202 Environmental conditions including physical, chemical, and biological factors in natural habitats highly determine the  
 203 recruitment rates of lobster larvae (Keulder 2005). Several studies have previously reported the physical and chemical  
 204 characteristics of the settlement area of lobster (Amin et al. 2022c; Boudreau et al. 1992; Lillis and Snelgrove 2010).  
 205 However, studies viewing biological aspects of settlement habitat in natural environment lobster larvae are still very  
 206 limited. Meanwhile, many studies conclude that biological factors such as plankton availability can be important  
 207 information on the natural diets of lobster larvae (O'Rorke et al. 2014). Thus the present study investigated the diversity,  
 208 uniformity, and dominance of plankton in two common settlement areas of lobster larvae in East Java (Karanggongso Bay  
 209 and Tawang Bay) in Indonesia. The sampling was performed in 4 different depths which were 0.3 m, 2.5 m, 5 m, and 20 m  
 210 depth, as lobster larvae vertically migrated from the bottom during the daytime to the surface of the water during the  
 211 nighttime . It was also discovered that the diversity indices of plankton at both locations were 2.02-2.49 at Karangongso,  
 212 and 2.15-2.65 at Tawang Bay. The diversity index values found at these two locations were all less than 3, which means at  
 213 a moderate level. The high or low value of plankton diversity can be caused by the evenly distributed abundance of each  
 214 individual or in another sense there are no species that have relatively more diversity than other species (Awwaluddin et al.  
 215 2017). As the diversity indices of plankton at Karangongso Bay and Tawang Bay may which is at a moderate level may  
 216 suggest that plankton communities is in relatively equal distribution of different species, with no one species being  
 217 significantly more prevalent than others (Awwaluddin et al. 2017).  
 218 Similarly, the uniformity indices of planktons in both settlement areas were classified at a moderate level (0.38-0.45 at  
 219 Karangongso Bay and 0.41-0.46 at Tawang Bay. The uniformity values found at each location, both Karangongso  
 220 Beach waters and Tawang Beach waters, **are said to have moderate uniformity**. The value of uniformity is categorized to  
 221 be moderate if the value ranges from 0.4-0.6 (Ulfah et al. 2019). The availability of nutrients, food, and predation  
 222 processes can affect the high value of uniformity because it affects the type and amount of plankton. Besides that, physical  
 223 and chemical factors also affect the value of uniformity because it will affect the growth of plankton (Nugroho et al. 2020).  
 224 In addition, ~~if since~~ the distribution of plankton in both waters is uniform, then a high degree of uniformity can be

225 asserted. While the dominance indices were ranging from 0.21 – 0.31 at Karangongso Bay and 0.13-0.30 in Tawang  
 226 Bay. The result indicates that there were no dominant species at both locations since all values < 0.05. Dominance index  
 227 values **obtained in both waters indicate the absence of plankton which dominates in Karangongso Bay and also Tawang**  
 228 Bay. The dominance index value indicates whether organisms are dominant in a water environment. A value between 0.5  
 229 to 1 on the dominance index shows the presence of dominant organisms in the water. On the other hand, a value less than  
 230 0.5 indicates that there are no dominant organisms present in the water. ~~Whether or not organisms dominate a waters can be~~  
 231 ~~seen from the value of the dominance index if the dominance index shows a value between 0.5 to 1 then in these waters~~  
 232 ~~there are organisms that dominate and if it shows a value less than 0.5 then in these waters it indicates the absence of~~  
 233 ~~organisms dominating~~ (Berger and Parker 1970).

### 234 Potential Diet for Lobster Seeds

235 The result also revealed that 17 plankton species were identified from the surface water, 13 species at a depth of 2.5 m, 11  
 236 species at a depth of 5 m, and 13 species at 20m (bottom) of Karangongso Bay. While, 17 plankton species were  
 237 discovered on the surface of Tawang Bay waters: 11 species at a depth of 2.5 m, 12 species at a depth of 5 m, and 12  
 238 species at the seafloor. The number of plankton species identified in the present study, in general, are higher than in  
 239 previous study reported from other settlement habitats of lobster larvae in Awang Bay west Nusa Tenggara (Amin et al.  
 240 2022c) and Teluk Wedi Ombo, Yogyakarta (Trijoko and Pasaribu 2004). The most abundant species identified from  
 241 Karangongso bay are mainly from Phylum Arthropoda including *Paracyclops* sp., *Oithona* sp., *Acartia* sp., and *Calanus*  
 242 sp. Other prominent species included *Prorocentrum* sp., *Dinophysis* sp., and *Ceratium* sp. are belonged to phylum  
 243 Dinoflagellata, ~~most abundant species identified from Karangongso Bay were *Paracyclops* sp., *Acartia* sp., *Pteropods*~~  
 244 ~~sp., and *Prorocentrum* sp., *Dinophysis* sp., *Sagitta* sp., *Ceratium* sp., *Microsetella* sp., *Dinophysis* sp., *Calanus* sp., *Synedra*~~  
 245 ~~sp., and *Oithona* sp. (7.69%).~~ While most abundant species found in Tawang Bay were **also dominated by phylum**  
 246 **Arthropoda, including *Acartia* sp., *Oithona* sp., *Oncaea* sp., *Calanus* sp., *Paracyclops* sp., and *Macrotholmus* sp.** Plankton  
 247 **species in this area also dominated by phylum Dinoflagellata such as *Ceratium* sp., *Prorocentrum* sp., and *Dinophysis* sp.**  
 248 ***Microsetella* sp., *Oncaea* sp., *Pteropods* sp., *Calanus* sp., *Synedra* sp., *Oithona* sp., *Calanus* sp., *Paracyclops* sp.,**  
 249 ***Macrotholmus* sp., *Sagitta* sp., *Dinophysis* sp., and *Rhizosolenia* sp.** Of these identified plankton species, 10 species were  
 250 found in both locations including *Acartia* sp., *Oithona* sp., *Paracyclops* sp., *Pteropods* sp., *Dinophysis* sp., *Sagitta* sp.,  
 251 *Microsetella* sp., *Calanus* sp., *Synedra* sp. These findings suggest that the planktonic community in both bays is dominated  
 252 by species belonging to the phylum Arthropoda and Dinoflagellata, which are known to be important components of the  
 253 marine food web.

254 Among the identified plankton species, few species have been documented as potential live diets in aquaculture  
 255 including *Oithona* sp. for live diet of European seabass (*Dicentrarchus labrax*) postlarvae (Magouz et al. 2021a), and  
 256 shrimp larvae (Dinesh Kumar et al. 2017), and *Acartia* sp., as a live diet for seabass larvae, *Lates calcarifer* (Rajkumar  
 257 2006), fat snook, *Centropomus parallelus* (Barroso et al. 2013), and many other aquatic larvae (Sarkisian et al. 2019). In

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Commented [CC17]: Rephrase whole sentence and break it down.

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259 fact, some studies also confirmed that these plankton species were identified in the stomach content of lobster larvae. For  
260 instance, *Oithona* sp. has been reported from the stomach content of spiny lobsters at the early life stage (Amin et al.  
261 2022d; Khvorov et al. 2012). *Oithona* sp. has been described as a marine calanoid copepod which has high protein content,  
262 ~59.33% (Santanumurti et al. 2021), therefore frequently used as a live diet for fish or shrimp larvae. Another study has  
263 documented that *Oithona* sp. had a high content of fatty acid profiles including polyunsaturated fatty acids (26.47%) and  
264 omega-3 fatty acids (36.30) which in fact are higher compared to a commercial live diet such as *Artemia* sp. (Magouz et

265 al. 2021b). Furthermore, *Acartia* sp. has been also documented to be a good live diet for aquatic larvae such as seabass  
266 larvae, *Lates calcarifer* (Rajkumar 2006), and fat snook, *Centropomus parallelus* (Barroso et al. 2013). *Acartia clausi* has

267 been described to have higher contents of proteins (63.12%) and lipids (16.65%) and is also richer in n-3 fatty acids  
268 (33.94%) than *Artemia* nauplii and rotifers (Rajkumar, 2006). The plankton species has been also identified in the stomach  
269 content of spiny lobster larvae (Amin et al. 2022d). In addition, a member of *Acartia* (*Acartia tonsa*) had been documented  
270 to provide an important nutritional benefit to fat snook larvae undergoing metamorphosis (Vanacor-Barroso et al. 2017).

271 Other potential food sources for lobster larvae identified in the present study are zooplankton and phytoplankton.  
272 According to the results obtained, the plankton found at each station consists of Bacillariophyceae (e.g. *Rizosolenia* sp.,  
273 *Synedra* sp., *Cyclotella* sp.), and Copepoda (e.g. *Oithona* sp., *Acartia* sp., *Calanus* sp.). These plankton groups were  
274 identified at each station, highlighting their potential as a food source for lobster larvae. Diatoms, which belong to the  
275 phytoplankton group Bacillariophyceae, contain essential nutrients required for the growth of lobster larvae, such as  
276 PUFA (Polyunsaturated Fatty Acid). PUFA including EPA (eicosapentaenoic acid, 20:5 n-3) and DHA (docosahexaenoic  
277 acid 22:6 n-3) are the major fatty acids found in diatoms Bacillariophyceae (Pahl et al., 2010). PUFA content of these  
278 diatoms is relatively high, with levels ranging between 23.4 and 60.7% (Valera & Saavedra, 2016). High PUFA content  
279 was identified in several plankton species as potential prey for spiny lobster larvae *Jasus edwardsii*, and these long-chain  
280 fatty acids are an essential nutrient for spiny lobster (Koshio & Kanazawa, 1994; Liddy et al., 2004; Wang, 2013).

281 Copepoda (Hexanauplia) is a rich source of protein, particularly in gastropods, it is also high in calcium content which  
282 is important for lobster during molting (Kirno et al., 2012). Several studies, such as those by Alka (2016), Chow (2011),  
283 and Connel (2007), have reported the presence of copepods in the digestive tracts of lobster larvae. This suggests that  
284 copepods are a preferred food for lobster larvae. Protein is constantly the predominant organic nutrient in the spiny lobster  
285 larvae as well as their preferred prey (Wang, 2013). This is consistent with prior examinations of digestive enzymes of  
286 phyllosoma of *J. edwardsii* and *Panulirus ornatus*, which reveal that they necessitate a high-protein diet and will utilize  
287 protein to generate energy during food deprivation (Johnston et al., 2004a; Johnston et al., 2004b, Johnston et al., 2006).  
288 Copepods contain high protein content, ranging from 28.9 - 84.9 % of dry weight, indicating that lobster larvae consume  
289 prey with high protein content (Wang & Jeffs, 2014). The protein content of the copepods is in accordant with the amount  
290 of protein incorporated into artificial feeds for some of the crustaceans larvae including crab, shrimp, and clawed lobster  
291 species, which is ranging between 30% to 60% protein (Conklin et al., 1980 ; Guillaume, 1997 ; Holme et al., 2009).  
292 Moreover, copepods also high in lipid, ranging from 11.3%-12.4% (Wang & Jeffs, 2014). Rich-lipid diets can be properly  
293 digested by the spiny lobster larvae, and utilize it to supply energy, especially during a food scarcity (Johnston et al., 2004;  
294 Liddy et al., 2003; Liddy et al., 2004; Ritar et al., 2003). Furthermore, late phase phyllosoma of spiny lobster probably  
295 target high lipid prey, as they prepare to accumulate an enormous amount of lipid to fuel their non-feeding post-larval  
296 stage ( Jeffs et al., 2001a; Jeffs et al., 2001b). The presence of copepods especially *Oithona* sp., *Acartia* sp., and *Calanus*  
297 sp in a high abundance value at the Karangongso and Tawang Bay could provide a significant source of high lipid natural  
298 diets for spiny lobster larvae. These results suggest that these plankton species are a potential diet for spiny lobster larvae,  
299 therefore, should be further studied by in vivo trials using aquatic animals especially for developing ornate spiny lobster  
300 hatcheries.

301 In conclusion, the number of plankton species found in both locations was more abundant in the surface water (0-0.3m)  
302 compared to the deeper water column. A total of 17 plankton species were identified from the surface water, 13 species at  
303 a depth of 2.5 m, 11 species at a depth of 5 m, and 13 species at 20 m (bottom) of Karangongso Bay. Similarly, 17  
304 plankton species were discovered from the water surface of Tawang Bay: 11 species at a depth of 2.5 m, 12 species at a  
305 depth of 5 m, and 12 species at the seafloor. Based on the diversity, uniformity, and dominance indices, both locations had  
306 moderate plankton diversity, and no specific species was dominant over the others. Among the identified plankton species,  
307 several members of Bacillariophyceae, Copepoda, and Hexanauplia such as *Oithona* sp., *Calanus* sp., *Paracyclops* sp.,  
308 and *Acartia* sp. are considered potential live feed for lobster larvae, and thus should be further studied. A total of 17 plankton  
309 species were identified from the surface water, 13 species at a depth of 2.5 m, 11 species at a depth of 5 m, and 13 species  
310 at 20m (bottom) of Karangongso Bay. While, 17 plankton species were discovered on the surface of Tawang Bay waters:  
311 11 species at a depth of 2.5 m, 12 species at a depth of 5 m, and 12 species at the seafloor. It was also discovered that the  
312 diversity index of plankton was considered at a moderate level at both locations, 2.02-2.49 at Karangongso, and 2.15-2.65  
313 at Tawang Bay. Similarly, the uniformity index was classified at a moderate level at both locations (0.38-0.45 at  
314 Karangongso Bay and 0.41-0.46 at Tawang Bay. While the dominance index was ranging from 0.21-0.31 at  
315 Karangongso Bay and 0.13-0.30 in Tawang Bay which indicates that there were no dominant species at both location.  
316 Among the identified plankton species, several members of *Oithona* sp., and *Acartia* sp. are considered potential live feed  
317 for lobster larvae, and thus should be further studied. Among the identified plankton species, several members of

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318 ~~Bacillariophyceae, Copepoda, and Hexanauplia are considered potential live feed for lobster larvae, and thus should be~~  
319 ~~further studied.~~

## 320 ACKNOWLEDGEMENTS

321 The authors thank all colleges at the Fish Nutrition Group, Department of Aquaculture, Faculty of Fisheries and  
322 Marine, Universitas Airlangga who have provided help and technical advice during the experiment.

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Commented [CC25]: Have a holistic conclusion on what these results implicate with the ecology of Karanggongso and Tawang Bay or for the larvae of these lobsters, or human benefits?

Commented [mA26R25]: Conclusion has been rewritten and the higher uniformity indexed compared to dominance index indicated that the was no dominant species in each study locations, this information is stated in line 291-294

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#### 4. Bukti komentari reviewer (round 3) (11 Maret 2023)

A. Bukti reviewer A meminta melakukan revisi rounde 3. Detail permintaan reviewer terdapat pada draft artikel di point C

The screenshot displays the 'Round 3 Status' as 'Submission accepted.' Below this, the 'Notifications' section lists three '[biodiv] Editor Decision' messages with timestamps: 2023-03-03 05:18 AM, 2023-03-11 05:33 AM, and 2023-03-30 12:41 PM. The 'Reviewer's Attachments' section shows a file upload for '1077001-1' with the filename '13706-Article Text-1076667-1-4-20230307 xo.doc' dated March 11, 2023. The 'Revisions' section includes two entries: '1077068-1' for 'Article Text, 13706-1077001-1-5-20230311-R2-Clean.doc' and '1077069-1' for 'Article Text, 13706-1077001-1-5-20230311-R2-Track changes.doc', both dated March 11, 2023. A green circle highlights the date and file type for the second revision entry.

B. Bukti author memenuhi saran yang diberikan reviewer A rounde 3

Reviewer suggestion:

1. Revise the title
2. Rephrase the abstract
3. Revise the introduction, method, and discussion according to the reviewer's suggestion. See the manuscript

Answers:

1. We revised the title according to the reviewer's suggestion
2. We revised the abstract
3. We revised the introduction, method, and discussion according to the reviewer's suggestion. See the new manuscript

## C. Artikel yang telah diperbaiki sesuai arahan reviewer A (rounde 3)

### Diversity and Abundance of Plankton Community in Tawang Bay and Karangongso Bays, the Natural Settlement Habitats of Spiny Lobster Larvae in East Java Indonesia

**Abstract.** Tawang Bay and Karangongso Bay have been well-known as settlement areas for spiny lobster larvae, *Panulirus* spp., in East Java, Indonesia. Therefore, these locations, which may suggest that the location are suitable environments, including diet availability for lobster larvae. Furthermore, the present study aimed to investigate the types and abundance and diversity of plankton in the both locations to discover potential live diets for lobster larvae. Plankton samples were collected in both locations using a plankton net at four different depths: 0.3 m, 2.5m, 5<sup>m</sup>, and 20 m with three replicates. The objectives of this study also are to

explored plankton's diversity, uniformity, and dominance indices the diversity, abundance, uniformity, and dominance indices of plankton in the natural settlement ground of lobster larvae at both locations Karangongso and Tawang Bay. Plankton samples were collected using a plankton net at four different depths: 0.3 m, 2.5 m, 5 m, and 20 m. The results revealed that 17 plankton species were identified from the 0.30-m depth, 13 species at a 2.5m depth of 2.5m, 11 species at a 5m depth of 5m, and 13 species at 2.5 m, 11 at 5 m, and 13 at 20 m at depth at Karangongso Bay. While, 17 plankton species were discovered on the surface of Tawang Bay waters: 11 species at a 2.5m, 12 species at 5m, and 12 species at 20m. In addition, 17 plankton species were discovered in at 0.3 m depth, 11 species at 2.5m, 12 species at 5m, and 12 species at 2.5 m, 12 at 5 m, and 12 at 20 m at Tawang Bay. Among the most abundant species were *Acartia* sp., *Calanus* sp., *Paracyclops* sp., and *Oithona* sp. The diversity indices observed in Karangongso and Tawang bay ranged from 2.02-2.49 and 2.17-2.65, respectively, which fall within the moderate range. Similarly, the uniformity indices observed at both locations were also moderate, with values ranging from 0.38-0.45 at Karangongso bay and 0.41-0.46 at Tawang bay. While there were no dominant species at both locations, as indicated by, as the dominance index values ranged from 0.13-0.30. Among the identified plankton species, *Oithona* sp., *Calanus* sp., and *Acartia* sp. are considered potential live feed for lobster larvae, and thus should be further studied.

**Key words:** diversity, diets, dominance, lobster, plankton, uniformity.

**Abbreviations** (if any): -

**Running title:** Plankton diversity in lobster natural habitat

#### INTRODUCTION

Lobster is an important fishery commodity in Indonesia due to its high price, high nutritional contents as well as, and high market demands. According to the Indonesian Central Bureau of Statistics, the total export value of lobsters in 2020 reached USD 8.1 million (BPS 2020). The high export value and continuously increasing marketing demands at national or global markets indicate that lobster is a high-potential fisheries commodity. However, the lobster supply has been highly dependent on the wild catch because lobster aquaculture has not yet been well developed yet depended highly on the wild catch because lobster aquaculture has not yet been well developed. One of the main issues faced in lobster aquaculture is larval production, which currently relies on the availability of seeds in nature natural seeds. Many studies have been conducted to study various factors relating to larval production of larvae's larval production, including spawning-inducing technology and rearing condition, yet the success rates are very low. Several authors have succeeded to

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49 **breeding and producing larvae.** Yet, the larvae can live only 7-14 days after hatching. ~~Therefore, it is~~  
50 hypothesized that the main challenge is ~~in~~ diet availability and suitability. According to Amin et al. (2022b), ~~one way to~~  
51 ~~start domesticating wild species is firstly by collecting information on their natural habitat as much as possible~~first, one  
52 ~~way to start domesticating wild species is by collecting information on their natural habitat as much as possible.~~ Similarly,  
53 Kashinskaya et al. (2018) suggest ~~that profiling certain animals' natural habitat~~profiling certain animals' natural habitats  
54 may reveal their diets.

55 Environmental conditions, including physical, chemical, and biological factors in natural habitats, highly determine the  
56 recruitment rates of lobster larvae (Keulder 2005). Several authors have previously reported the physical and chemical  
57 characteristics of the natural settlement areas of lobster larvae (Amin et al. 2022c; Boudreau et al. 1992; Lillis and  
58 Snelgrove 2010). However, studies investigating biological aspects of settlement habitat in the natural environment of  
59 lobster larvae are ~~still~~very limited. Meanwhile, many studies conclude that biological factors ~~have~~old important  
60 information for the lobster larvae, especially for diets (O'Rourke O'Rourke et al. 2014). Accordingly, biological aspects such  
61 as natural dietary aspects and lobster predation processes that occur in nature during larval and post-larval stages could be  
62 critical information that must be considered for hatchery production. ~~In~~For example, plankton might be a natural diet  
63 source for various fish seeds, including lobster seeds, in their natural settlement habitat~~their natural settlement habitat,~~  
64 ~~plankton might be a natural diet source for various types of fish seeds, including lobster seeds.~~ Raza'i et al. (2018) added  
65 that the availability of plankton as a natural diet source ~~has a significant impact on~~significantly impacts the dependence  
66 and growth of marine organisms such as fish, crabs, shrimp, and lobsters.

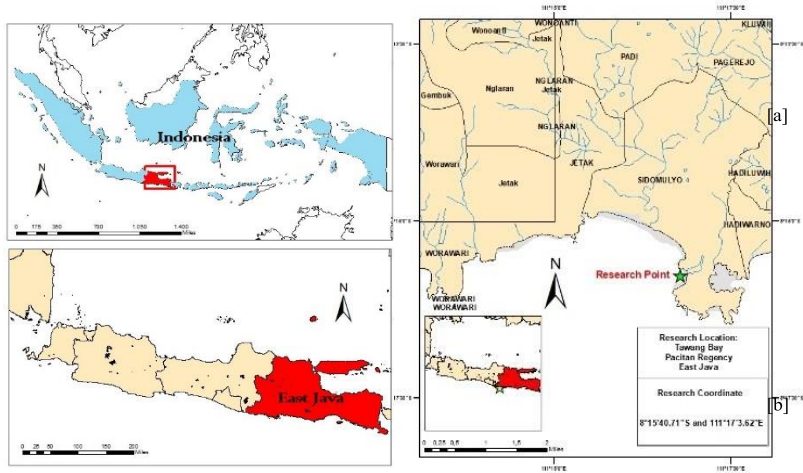
67 Profiling plankton diversity and abundance might reveal potential diets for lobster larvae. A similar approach has been  
68 done in some studies. For instance, Ihsan et al. (2019) conducted research on plankton as a natural feed for lobster larvae  
69 and post-larvae in natural habitats in Teluk Awang, Central Lombok. Trijoko and Pasaribu (2003) conducted another study  
70 in Wedi Ombo Bay, Gunung Kidul, Yogyakarta. ~~Generally, this study's results in general~~ suggest that each location has  
71 a different structure and abundance, although some species were the same between the area. All these results raised  
72 questions about whether lobster larvae are opportunistic ~~feeders~~or specific feeders. **Therefore, to answer these questions,**  
73 **more studies are required by collecting more information in more settlement areas of lobster.**

74 Tawang Bay ~~has been~~s well-known as one of the most settlement areas for lobster larvae in East Java Indonesia (Amin  
75 et al. 2022a); therefore, it is assumed **to have important suitable diet availability** for lobster larvae. However, studies on the  
76 biological aspects of both locations areas are still very limited. Thus, ~~the objectives of this research is~~ research aims to  
77 investigate the plankton diversity, abundance, uniformity, and dominance indices in the natural settlement habitat of  
78 lobster larvae at Karanggongso and Tawang Bays. The study results are expected to enrich the information on potential  
79 diets for lobster larvae for hatchery development.

## 80 MATERIALS AND METHODS

### 81 Study area

82 ~~The collection of plankton samples was carried out~~Plankton samples were collected in two common settlement areas of  
83 lobster larvae in East Java, Indonesia (Tawang Bay), with a protocol as previously described by Amin et al. (2022c).  
84 The sampling location was performed at ordinate points: 8°15'57.4"S 111°17'46.0" E (L1), 8°15'54.3"S 111°17'48.2"E  
(L2),  
85 and 8°15'51.5"S 111°17'46.2"E (L3), (Figure 1). Plankton sampling was conducted at three different sampling points with  
86 four different depths: 0-0.3 m, 2.5 m, 5 m, and 20 m. ~~The First, the~~ water samples were filtered using a plankton net and  
87 placed in sterile bottles. The filtered sample was then immediately given Lugol which acts as a plankton preservative, up  
88 to 1% of the total filtering, and wrapped in Styrofoam. The samples were then examined in the Microbiology Laboratory,  
89 Faculty of Fisheries and Marine Science at Airlangga University.



90 Figure 1 Two sampling locations: Karanggongso Bay, Trenggalek Regency [a], and Tawang Bay, Pacitan Regency [b], East Java,  
 91 Indonesia.

92  
 93 Karanggongso Bay waters have temperatures ranging from 27-28 °C, a DO content of 7.48 mg/L, a salinity of 26 ppt, a  
 94 pH of 7-8, a NO<sub>3</sub> content of 0.01 mg/L, and a muddy substrate. On the other hand, Tawang Bay waters temperatures are  
 95 slightly warmer than Karanggongso Bay, with water temperature ranging from 28.2-28.3 °C, with a significantly lower,  
 96 DO content of 3.35 mg/L. moreover, Tawang Bay has a higher salinity of 35 ppt, a pH of 8, a NO<sub>3</sub> content of 0.01, a depth  
 97 of 15 m, and a sandy substrate.

98 **Abundance and Identification of planktons**

99 Firstly, plankton identity and their abundances were analyzed using a protocol of LeGresley and McDermott (2010). In  
 100 brief, plankton samples were placed on a Sedgewick Rafter Counting Cell and observed under a binocular microscope with  
 101 a magnification of 1000x. Thereafter Afterward, plankton found in each sample was counted, photographed, and identified  
 102 according to an identification book guide by Mazzocchi et al. (2012). Then, the abundance index was calculated according  
 103 to the following formula (Fachrul

2012):104

105

$$N = \frac{a}{b} \times \frac{c}{d} \times \frac{Vb}{Vsrc} \times \frac{1}{Vs}$$

106

107

108 Where "N" represents the abundance of plankton (plankter/L), "a" represents the number of SRC boxes, "b" is the  
 109 area of one field of view (mm<sup>2</sup>), "c" denotes the number of individuals observed, and "d" indicates the number of  
 110 boxes observed. "Vb" is the volume of water in the sample bottle (ml), "Vsrc" is the volume of water in the SRC  
 111 (ml), and "Vs" represents the volume of water filtered in the Field (L). -

112

112 **Diversity, Uniformity uniformity, and dominant indices**

113 The diversity index value (H') was calculated using the following formula (Fachrul 2012):

$$114 \quad H' = - \sum P_i \ln P_i, \text{ where } P_i = \frac{n_i}{N}$$

115 Where H' is Shannon Wiener Diversity Index, pi is the number of individuals of the i-th species, ni is the  
 116 number of species, and N is the total individual number.

117 The uniformity index (E') was calculated using the "Evennes Index" formula (Ulfah et al. 2019):

$$118 \quad E' = \frac{H'}{\ln S}$$



where, 'E' is the uniformity index, 'H' is the Shannon Wiener Diversity Index, 'S' is the Total number of species

121

122 The dominance index (d) was calculated using the following equation (Berger and Parker 1970):

$$d = \frac{N_{max}}{N}$$

123 where, where, "d": Simpson Dominance Index, Nmax: The most abundant number of individual  
124 species, dan N = Total individual

number.125

## 126 RESULTS AND DISCUSSION

### 127 Results

#### 128 Plankton Abundance in Karanggongso Bay

129 Water samples were collected from two locations, Karanggongso Bay and Tawang Bay at four different depths (0.3 m,  
130 2.5 m, 5 m, and 20 m). The two bays were located at in the Southern part of East Java Province, and both areas are  
131 facing face to the Indian Ocean, Figure 1. The results showed that a total of 17 plankton species were identified from the  
132 surface water (0.0-0.3 m). The top six most abundant species were *Paracyclops* sp. with 21.21%, followed by *Acartia*  
133 sp. (18.18%), *Pteropods* sp. (9.09%), *Prorocentrum* sp. (6.06%), *Dinophysis* sp. (6.06%), and *Sagitta* sp. (2.13%). Other  
134 species and their percentage was are presented in Table 1. In addition, at a 2.5 m depth, 13 plankton species were  
135 identified. Again, the top 6 most abundant species were *Acartia* sp. (26.47%), followed by *Paracyclops* sp.  
136 (23.53%), *Ceratium* sp. (8.82%), *Microsetella* sp. (8.82%), *Dinophysis* sp. (5.8%), and *Oncaea* sp. (5.88%). The rest  
137 species with their abundance were presented in Table 1.

138 Furthermore, at 5 m depth, the Bay is home to 11 plankton species. The top 4 most abundant species were *Acartia* sp.  
139 (30.77%), followed by *Paracyclops* sp. (23.08%), *Sagitta* sp. (11.54%), and *Oithona* sp. (7.69%). While the other 7  
140 species included *Synedra* sp., *Oikopleura* sp., *Coscinodiscus* sp., *Ceratium* sp., *Pteropods* sp., *Microsetella* sp., and  
141 unclassified Lucifer, which were counted for 3.85% each (Table 1). Meanwhile, a total of 13 plankton species were found  
142 at the a depth of 20 m. The Again, the top 6 most abundant species were *Acartia* sp. accounted for 24.14%), followed by  
143 *Paracyclops* sp. with 13.79%, *Pteropods* sp. (10.34%), *Dinophysis* sp. (10.34%), *Ceratium* sp. with 6.90%, and *Sagitta*  
144 sp. with 6.90%. The rest species were are presented in  
table 1.145

146 **Table 1.** Plankton identified from two natural settlement habitats of spiny lobster larvae (Karanggongso Bay and  
147 Trenggalek Regency, East Java Indonesia) at four different depths of the water column was identified from two  
148 natural settlement habitats of spiny lobster larvae (Karanggongso Bay and Trenggalek Regency, East Java  
149 Indonesia) at four different water column depths.

Depth	Species	Cell density (Indiv/L)
0.3 m (Surface)	<i>Cyclotella</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Noctiluca</i> sp.	8
	<i>Prorocentrum</i> sp.	16
	<i>Dinophysis</i> sp.	16
	<i>Ceratium</i> sp.	8
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	24
	<i>Paracyclops</i> sp.	56
	<i>Acartia</i> sp.	48
	<i>Microsetella</i> sp.	8
	<i>Euphausia</i> sp.	8
	<i>Lucifer</i> sp.	8
	<i>Oipheureidea</i> sp.	8
	<i>Sagitta</i> sp.	16
	<i>Nematea</i> sp.	8
	<i>Actinulla larvae</i>	8

2.5 m	<i>Rizosolenia</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Ceratium</i> sp.	24
	<i>Dinophysis</i> sp.	16
	<i>Paracyclopina</i> sp.	64
	<i>Acartia</i> sp.	72
	<i>Microsetella</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Codoneleopsis</i> sp.	8
	<i>Oipheureidea</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Actinula</i> sp.	8
<i>Polychaete</i>	8	
5.0 m	<i>Oikopleura</i> sp.	8
	<i>Synedra</i> sp.	8
	<i>Coscinodiscus</i> sp.	8
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	8
	<i>Paracyclopina</i> sp.	48
	<i>Acartia</i> sp.	64
	<i>Microsetella</i> sp.	8
	<i>Oithona</i> sp.	16
	<i>Lucifer</i> sp.	8
<i>Sagitta</i> sp.	24	
20.0 m (Bottom)	<i>Synedra</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Noctiluca</i> sp.	8
	<i>Dinophysis</i> sp.	24
	<i>Ceratium</i> sp.	16
	<i>Pteropods</i> sp.	24
	<i>Acartia</i> sp.	56
	<i>Paracyclopina</i> sp.	32
	<i>Oithona</i> sp.	8
	<i>Microsetella</i> sp.	16
	<i>Euphausia</i> sp.	8
	<i>Proto-peridinium</i> sp.	8
<i>Sagitta</i> sp.	16	

150

#### 151 Plankton Abundance in Tawang Bay

152 A total of 17 plankton species were identified from the water sample at a depth of 0.0-0.3 m (surface water) of Tawang  
153 Bay. The top 9 most abundant species were *Acartia* sp.<sub>2</sub> with an abundance of 12.82%, followed by *Ceratium* sp.  
154 (10.26%), *Prorocentrum* sp. (10.26%), *Microsetella* sp. (10.26%), *Oncaea* sp. (10.26%), *Pteropods* sp. (7.69%), *Calanus*  
155 sp.<sub>1</sub> (7.69%), *Synedra* sp. (5.13%), and *Oithona* sp. (5.13%). While at the same time, the rest of the species were counted  
156 for 2.56% each and presented in Table 2. In addition, there were 11 species of plankton 11 species of plankton were found  
157 in a water sample at a depth of 2.5 m in Tawang Bay. The top 6 most abundant species were *Calanus* sp. (28.00%),  
158 followed by *Prorocentrum* sp. (12.00%), *Paracyclopina* sp. (12.00%), *Microsetella* sp. (12.00%), *Oncaea* sp. (8.00%), and  
159 *Oithona* sp. with an abundance of 8.00%. While the rest plankton species, including *Synedra* sp., *Ceratium* sp., *Pteropods*  
160 sp., *Macrophthalmus* sp., and *Sagitta* sp.<sub>2</sub> were counted at 4.00% each, Table 2.

161 Furthermore, a total of 12 plankton species were identified from the water sample at 5 m depth. The top 4 most  
162 common species were *Calanus* sp. with an abundance of 28.57%, *Oithona* sp. with an abundance of 14.29%, *Copepoda*  
163 *nauplii* with an abundance of 9.52%, *Prorocentrum* sp. with an abundance of 9.52%. While the rest of the species,  
164 including *Melosira* sp., *Synedra* sp., *Dinophysis* sp., *Microsetella* sp., *Temora* sp., *Oncaea* sp., and *Sagitta* sp., with an  
165 abundance of 5.00%, respectively. While in the bottom waters of Tawang Bay (20 m depth), a total of 12 plankton species  
166 were identified. The top 9 most abundant species were *Prorocentrum* sp. with an abundance of 16.44%, *Acartia* sp. with  
167 an abundance of 16.44%, *Oithona* sp. with an abundance of 16.44%, *Oncaea* sp. with an abundance of 10.96%,  
168 *Dinophysis* sp. with an abundance of 5.48%, *Rhizosolenia* sp. with an abundance of 5.48%, *Pleurosigma* sp. with an

169 abundance of the abundance of 5.48%, *Ceratium* sp. with 5.48%, *Caridean* sp. (5.48%). While At the same time, the rest  
 170 species were are presented in table 2.

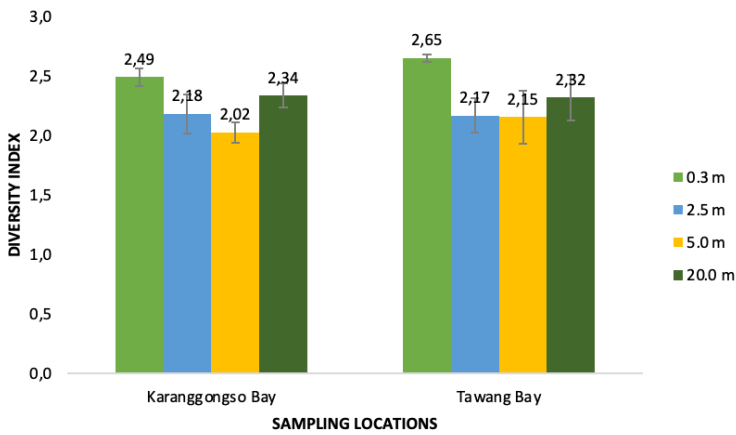
171 **Table 2.** Planktons identified from the natural habitat of spiny lobster in bottom water at Tawang Bay, East Java Indonesia

Depth	Species	Density (Indiv/L)
0.3 m (Surface)	<i>Synedra</i> sp.	16
	<i>Oscillatoria</i> sp.	8
	<i>Spirulina</i> sp.	8
	<i>Ceratium</i> sp.	32
	<i>Prorocentrum</i> sp.	32
	<i>Pteropods</i> sp.	24
	<i>Acartia</i> sp.	40
	<i>Microsetella</i> sp.	32
	<i>Calanus</i> sp.	24
	<i>Oithona</i> sp.	16
	<i>Oncaea</i> sp.	32
	<i>Euphausia</i> sp.	8
	<i>Macrophthalmus</i> sp.	8
	<i>Clytemnestra</i> sp.	8
	<i>Cypris</i> sp.	8
	Unclassified <i>Fish larvae</i>	8
Unclassified flatworms	8	
2.5 m	<i>Synedra</i> sp.	8
	<i>Prorocentrum</i> sp.	24
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	8
	<i>Paracyclops</i> sp.	24
	<i>Calanus</i> sp.	56
	<i>Oithona</i> sp.	16
	<i>Microsetella</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Macrophthalmus</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Melosira</i> sp.	8
	<i>Synedra</i> sp.	8
	<i>Bivalve larvae</i>	8
5 m	<i>Prorocentrum</i> sp.	16
	<i>Dinophysis</i> sp.	8
	<i>Microsetella</i> sp.	8
	<i>Calanus</i> sp.	48
	<i>Oithona</i> sp.	24
	<i>Naupli Copepoda</i>	16
	<i>Temora</i> sp.	8
	<i>Oncaea</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Rhizoselenia</i> sp.	8
<i>Pleurosigma</i> sp.	8	
20 m (bottom)	<i>Prorocentrum</i> sp.	24
	<i>Ceratium</i> sp.	8
	<i>Dinophysis</i> sp.	8
	<i>Microsetella</i> sp.	4
	<i>Calanus</i> sp.	6
	<i>Acartia</i> sp.	24
	<i>Oithona</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Caridean</i> sp.	8
	Unclassified flatworm	8

172  
 173

174 **Diversity indices**

175 The diversity index values obtained in the waters of Karanggongso Bay, Trenggalek Regency East Java, were  $2.49 \pm$   
176  $0.07$  at a depth of 0.0-0.3 m depth of water column,  $2.18 \pm 0.16$  at a depth of 2.5 m,  $2.02 \pm 0.08$  at a depth of 5 m, and  $2.34$   
177  $\pm 0.10$  at the 20 m water column. Those which indicate that the Karanggongso Trenggalek waters have moderate  
178 diversity. While the diversity index values obtained in the waters of Tawang Bay were  $2.65 \pm 0.03$  at 0.0 – 0.3 m depth,  
179  $2.17 \pm 0.15$  at the 2.5 m depth,  $2.15 \pm 0.22$  at a 5 m depth, and  $2.32 \pm 0.19$  at a depth of 20 m which indicates that the  
180 waters of Tawang Bay have also moderate diversity, Figure 2

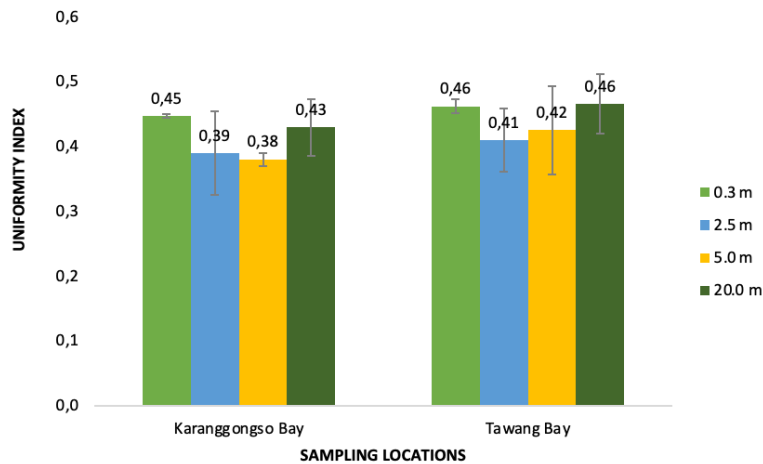


181 **Figure 2.** Diversity indices of plankton identified at the water column of Karanggongso Bay and Tawang Bay, East  
182 [Java](#), Indonesia. Bars are the average values with a standard deviation of three replicates.

184 **Uniformity indices**

187 The uniformity index values obtained in the water column of Karanggongso Bay were  $0.45 \pm 0.01$  at 0.0-0.3 m  
188 depth (surface water column),  $0.39 \pm 0.06$  at a depth of 2.5 m,  $0.38 \pm 0.01$  at a depth of 5 m and  $0.43 \pm 0.04$  at the 25m  
189 depth or bottom of the water column. These index values indicated that the uniformity of plankton in Karanggongso Bay  
190 was at a moderate level/moderate. While At the same time, the uniformity values obtained in Tawang Bay were  $0.46 \pm 0.01$   
191 at 0.0-0.3 m depth,  $0.41 \pm 0.05$  at a depth of 2.5 m,  $0.42 \pm 0.07$  at a depth of 5 m, and  $0.46 \pm 0.05$  at 25 m depth or bottom  
192 of the water column. Similarly, uniformity indices of plankton in Tawang Bay were considered also considered at a  
193 moderate level, Figure 3.

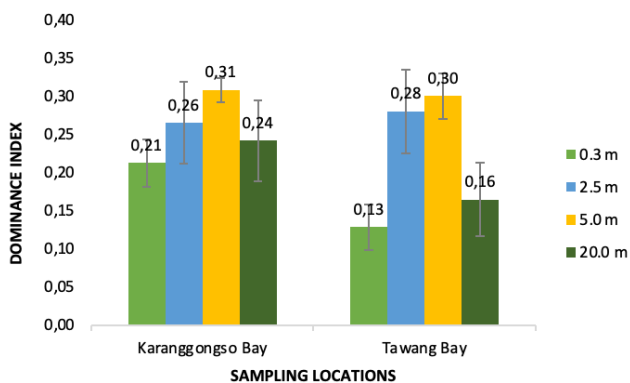
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194  
195 **Figure 3.** Uniformity indices of planktons identified in Karanggongso Bay and Tawang Bay, East Java, Indonesia. Bars  
196 are the average values with a standard deviation of three replicates.

197  
198 **Domination Index**

199 Domination index values obtained from the waters of Karanggongso Bay were  $0.21 \pm 0.03$  at the 0.0-0.3 m depth,  $0.26 \pm 0.05$   
200  $\pm 0.05$  at a depth of 2.5 m,  $0.31 \pm 0.02$  at a depth of 5 m and  $0.24 \pm 0.05$  at the 20 m water depth. These values mean that  
201 no plankton species were dominant in the natural habitat of spiny lobster larvae (Karanggongso Bay). While the  
202 dominance index values obtained from Tawang Bay waters were  $0.13 \pm 0.03$  at the 0.0-0.3 m depth,  $0.28 \pm 0.05$  at a depth  
203 of 2.5 m,  $0.30 \pm 0.03$  at a depth of 5 m, and  $0.16 \pm 0.05$  at the 20 m depth. Similarly, based on the values obtained from the  
204 surface to the bottom of the waters shows that there are no species that the values obtained from the surface to the bottom  
205 of the waters show that no species dominate in Tawang Bay (Figure 4).



206  
207 **Figure 4.** Domination indices of planktons identified at Karanggongso Bay and Tawang Bay, East Java, Indonesia. Bars  
208 are the average values with a standard deviation of three replicates.

## 210 Discussion

211 Environmental conditions, including physical, chemical, and biological factors in natural habitats, highly determine the  
 212 recruitment rates of lobster larvae (Keulder 2005). Several studies have previously reported the physical and chemical  
 213 characteristics of the settlement area of lobster (Amin et al. 2022c; Boudreau et al. 1992; Lillis and Snelgrove 2010).  
 214 However, studies viewing biological aspects of settlement habitat in natural environment lobster larvae are still very  
 215 limited. Meanwhile, many studies conclude that biological factors such as plankton availability ~~can~~ would be important  
 216 information on the natural diets of lobster larvae (O'Rourke O'Rourke et al. 2014). Thus the present study investigated the  
 217 diversity, uniformity, and dominance of plankton in two common settlement areas of lobster larvae in East Java  
 218 (Karanggongso Bay and Tawang Bay) in Indonesia. The sampling was performed in 4 different depths, which were 0.3 m,  
 219 2.5 m, 5 m, and 20 m depth, as lobster larvae vertically migrated from the bottom during the daytime to the surface of the  
 220 water during the nighttime. It was also discovered that the diversity indices of plankton at both locations were 2.02-2.49 at  
 221 Karanggongso, and 2.15-2.65 at Tawang Bay. The diversity index values found at these two locations were all less than 3,  
 222 which means at a moderate level. The high or low value of plankton diversity can be caused by the evenly distributed  
 223 abundance of each individual ~~or in another sense there are no species that~~. In another sense, no species have relatively  
 224 more diversity than other species (Awwaluddin et al. 2017). ~~As the diversity indices of plankton at Karanggongso Bay and~~  
 225 ~~Tawang Bay which is are at a moderate level may suggest that plankton communities is are in relatively equal~~  
 226 ~~distribution of different species, with no one~~ Therefore, the diversity indices of plankton at Karanggongso Bay and Tawang  
 227 Bay, which are at a moderate level may suggest that plankton communities are in relatively equal distribution of different  
 228 species, with no species being significantly more prevalent than others (Awwaluddin et al. 2017).  
 229 Similarly, the uniformity indices of planktons in both settlement areas were classified at a moderate level (0.38-0.45 at  
 230 Karanggongso Bay and 0.41-0.46 at Tawang Bay). The uniformity values found at each location, both Karanggongso  
 231 Beach waters and Tawang Beach waters, are categorized ~~and to have as moderate uniformity~~. The value of uniformity is  
 232 categorized to be uniformity value is categorized as moderate if the value ranges from 0.4-0.6 (Ulfah et al. 2019). The  
 233 availability of nutrients, food, and predation processes can affect the high value of uniformity because it affects the type  
 234 and amount of plankton. Besides that, physical and chemical factors also affect the value of uniformity because it will  
 235 affect the growth of plankton (Nugroho et al. 2020). In addition, since the distribution of plankton in both waters ~~samples~~  
 236 is uniform, ~~t~~ then a high degree of uniformity can be asserted. While the dominance indices were ranging ~~ran~~ged from 0.21 –  
 237 0.31 at Karanggongso Bay and 0.13-0.30 in Tawang Bay. The result indicates ~~that there were~~ no dominant species at both  
 238 locations since all values < 0.05. Dominance index values obtained in both waters indicate the absence of plankton which  
 239 dominates in Karanggongso Bay and also Tawang Bay. The dominance index value indicates whether organisms are  
 240 dominant in a water environment. A value between 0.5 to 1 on the dominance index shows the presence of dominant  
 241 organisms in the water. On the other hand, a value less than 0.5 indicates ~~t~~ hat there are no dominant organisms ~~no dominant~~  
 242 ~~organisms are~~ present in the water (Berger and Parker,  
 1970). 243

### 244 Potential Diet for Lobster Seeds

245 The result also revealed that 17 plankton species were identified from the surface water, 13 species at a depth of 2.5 m, 11  
 246 species at a depth of 5 m, and 13 species at a depth of 5 m, and 13 at 20m (bottom) of Karanggongso Bay. ~~While~~ At the  
 247 same time, 17 plankton species were discovered on the surface of Tawang Bay waters: 11 species at a depth of 2.5 m, 12  
 248 species at a depth of 5 m, and 12 species at the seafloor. ~~The number of plankton species identified in the present study, in~~  
 249 ~~general~~. In general, the number of plankton species identified in the present study are is higher than in previous study  
 250 reported from other settlement habitats of lobster larvae ~~es~~ reported from other lobster larvae settlement habitats in Awang  
 251 Bay west Nusa Tenggara (Amin et al. 2022c) and Teluk Wedi Ombo, Yogyakarta (Trijoko and Pasaribu 2004). The most  
 252 abundant species identified from Karanggongso bay are mainly from Phylum Arthropoda, including *Paracyclops* sp.,  
 253 *Oithona* sp., *Acartia* sp., and *Calanus* sp. Other prominent species included *Prorocentrum* sp., *Dinophysis* sp., and  
 254 *Ceratium* sp., which are belonged to the phylum Dinoflagellata. ~~While most abundant species found in Tawang Bay~~  
 255 ~~were also dominated by phylum Arthropoda, including Acartia sp., Oithona sp., Oncaea sp., Calanus sp.,~~  
 256 ~~Paracyclops phylum Arthropoda, including Acartia sp., Oithona sp., Oncaea sp., Calanus sp., Paracyclops, and~~  
 257 ~~Macrotholmus sp., also dominated the most abundant species found in Tawang Bay, and Macrotholmus sp.~~ Plankton  
 258 species in this area are also dominated by phylum Dinoflagellata such as *Ceratium* sp., *Prorocentrum* sp., and *Dinophysis*  
 259 sp. Of these identified plankton species, ~~10~~ ~~t~~ en species were found in both locations, including *Acartia* sp., *Oithona* sp.,  
 260 *Paracyclops* sp., *Pteropods* sp., *Binophysis* sp., *Sagitta* sp., *Microstellas* sp., *Calanus* sp., *Synedra* sp. These findings  
 261 suggest that the planktonic community in both bays is dominated by species belonging to the phylum Arthropoda and  
 262 Dinoflagellata, which are known to be important components of the marine food web.

263 Among the identified plankton species, few species have been documented as potential live diets in aquaculture,  
 264 including *Oithona* sp., for a live diet of European seabass (*Dicentrarchus labrax*) postlarvae (Magouz et al. 2021a), and  
 265 shrimp larvae (Dinesh Kumar et al. 2017). ~~Therefore, and Acartia sp. could possess as a live diet for seabass larvae,~~  
 266 *Lates calcarifer* (Rajkumar 2006), fat snook, *Centropomus parallelus* (Barroso et al. 2013), and many other aquatic larvae  
 267 (Sarkisian et al. 2019). ~~In fact,~~ Some studies also confirmed that these plankton species were identified in the content

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268 stomach content of lobster larvae. For instance, *Oithona* sp. has been reported from the stomach content of spiny lobsters  
269 at the early life stage (Amin et al. 2022d; Khvorov et al. 2012). Furthermore, *Oithona* sp. has been described as a marine  
270 calanoid copepod which with high protein content, ~59.33% (Santanumurti et al. 2021), therefore frequently used as a  
271 live diet for fish or shrimp larvae. Another study has documented that *Oithona* sp. had a high content of fatty acid profiles  
272 including polyunsaturated fatty acids (26.47%) and omega-3 fatty acids (36.30), which in fact are higher compared to than  
273 a commercial live diet such as *Artemia* sp. (Magouz et al. 2021b). Furthermore, *Acartia* sp. has been also been  
274 documented to be a good live diet for aquatic larvae such as seabass larvae, *Lates calcarifer* (Rajkumar 2006), and fat  
275 snook, *Centropomus parallelus* (Barroso et al. 2013). *Acartia clausi* has been described to have higher contents of proteins  
276 (63.12%) and lipids (16.65%) and is also richer in n-3 fatty acids (33.94%) than *Artemia* nauplii and rotifers (Rajkumar,  
277 2006). The plankton species has have been also identified in the stomach content of spiny lobster larvae also been  
278 identified in spiny lobster larvae's stomach content (Amin et al. 2022d). In addition, a member of *Acartia* (*Acartia tonsa*)  
279 had been documented to provide an important nutritional benefit to fat snook larvae undergoing metamorphosis (Vanacor-  
280 Barroso et al. 2017).

281 Other potential food sources for lobster larvae identified in the present study are zooplankton and phytoplankton.  
282 According to the results obtained, the plankton found at each station consists The plankton results found at each station  
283 consist of Bacillariophyceae (e.g., *Rizosolenia* sp., *Synedra* sp., *Cyclotella* sp.-) and Copepoda (e.g., *Oithona* sp., *Acartia*  
284 sp., *Calanus* sp.). These plankton groups were identified at each station, highlighting their potential as a food source for  
285 lobster larvae. Diatoms, which belong to the phytoplankton group Bacillariophyceae, contain essential nutrients required  
286 for the growth of lobster larvae, such as PUFA (Polyunsaturated Fatty Acid). The PUFA PUFA is the major fatty acid in  
287 Bacillariophyceae diatoms (Pahl et al. 2010), including EPA (eicosapentaenoic acid, 20:5 n-3) and DHA (docosahexaenoic  
288 acid 22:6 n-3). Therefore, PUFA are is the major fatty acids found in diatoms Bacillariophyceae diatoms (Pahl et al., 2010).  
289 PUFA content of these diatoms is relatively high, with levels ranging between 23.4 and 60.7% (Valera & Saavedra, 2016).  
290 High PUFA content was identified in several plankton species as potential prey for spiny lobster larvae *Jasus edwardsii*,  
291 and these long-chain fatty acids are an essential nutrient for spiny lobster (Koshio & Kanazawa, 1994; Liddy et al.,  
2004; Wang, 2013).

293 Copepoda (Hexanauplia) is a rich source of protein, particularly in gastropods- it is also high in calcium content which  
294 is important for lobster during molting (Kirno et al., 2012). Several studies, such as those by Alka (2016), Chow (2011),  
295 and Connel (2007), have reported the presence of copepods in the digestive tracts of lobster larvae. That suggests that  
296 copepods are a preferred food for lobster larvae. Protein is constantly the predominant organic nutrient in the spiny lobster  
297 larvae as well as and their preferred prey (Wang, 2013). This is consistent with with prior examinations of digestive  
298 enzymes of phyllosoma of *J. edwardsii* and *Panulirus ornatus*, which reveal that they necessitate a high-protein diet and  
299 will utilize protein to generate energy during food deprivation (Johnston et al., 2004a; Johnston et al., 2004b; Johnston et  
300 al., 2006). Copepods contain high protein content, ranging from 28.9 - 84.9 % of dry weight, indicating that lobster larvae  
301 consume prey with high protein content (Wang & Jeffs, 2014). The protein content of the copepods is in accordant  
302 with follows the amount of protein incorporated into artificial feeds for some of the crustaceans larvae, including crab,  
303 shrimp, and clawed lobster species, which is ranging ranges between 30% to 60% protein (Conklin et al., 1980 ; Guillaume,  
304 1997; Holme et al., 2009). Moreover, copepods are also high in lipids, ranging from 11.3%-12.4% (Wang & Jeffs, 2014).  
305 Rich-lipid diets can be properly digested by the spiny lobster larvae, and utilized to supply energy, especially during a  
306 food scarcity (Johnston et al., 2004; Liddy et al., 2003; Liddy et al., 2004; Ritar et al., 2003). Furthermore, late-ate phase  
307 phyllosoma of spiny lobster probably targets high lipid prey, as they prepare to accumulate an enormous amount of lipid to  
308 fuel their non-feeding post-larval stage (Jeffs et al., 2001a; Jeffs et al., 2001b). The presence of copepods, especially  
309 *Oithona* sp., *Acartia* sp., and *Calanus* sp., in a high abundance value at the Karanggongso and Tawang Bay could provide  
310 a significant source of high lipid natural diets for spiny lobster larvae. These results suggest that these plankton species are  
311 a potential diet for spiny lobster larvae, therefore, should be further studied by in vivo trials using aquatic animals  
312 especially for developing ornate spiny lobster hatcheries. Therefore, in vivo trials using aquatic animals especially for  
313 developing ornate lobster hatcheries, should be further studied.

314 In conclusion, the number of plankton species found in both locations was more abundant in the surface water (0-0.3  
315 m) compared to the deeper water column. A total of a total of 17 plankton species were identified from the surface water,  
316 13 species at a depth of 2.5 m, 11 species at a depth of 5 m, and 13 species at 20 m (bottom) of Karanggongso Bay.  
317 Similarly, While, 17 plankton species were discovered on from the water surface of Tawang Bay waters: 11 species at a  
318 depth of 2.5 m, 12 species at a depth of 5 m, and 12 species at the seafloor. Based on the diversity, uniformity, and  
319 dominance indices, at both locations had, plankton species which are available at both location were moderate plankton  
320 quite variety diversity, and no specific species was dominant over the others, which suggest there were no dominant  
321 species in both locations. Among the identified plankton species, several members of Bacillariophyceae, Copepoda, and  
322 Hexanauplia, such as *Oithona* sp., *Calanus* sp., *Paracyclopina* sp., and *Acartia* sp., are considered potential live feed for  
323 lobster larvae, and thus should be further studied.

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326 Marine, Universitas Airlangga, who have provided help and technical advice during the  
327 experiment.

328 **AUTHORS' CONTRIBUTIONS**

- 329 1. Endang Dwi Masitah :funding acquisition, data analysis, writing draft, supervision  
330 2. Muhamad Amin :Experimental design, data collection, data analysis, writing the draft  
331 3. Anis Fitria: data collection, data analysis, writing draft.  
332 4. Andi Baso Manguntungi ÷ Experimental design, data collection, data analysis, writing draft, data validation,  
333 submission.  
334 5. Shafwan Amrullah ÷ Experimental design, data collection, data analysis, writing draft, data validation,  
335 submission.  
336 6. Laila Musdalifah: Experimental design, data collection, data analysis, writing the draft  
337 7. Sahrul Alim : Experimental design, data collection, data analysis, writing draft, data validation.

submission.338

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## 5. Bukti respon kepada reviewer rounde 3, dan artikel yang diresubmit (11 Maret 2023)

### A. Author mengirim Kembali artikel yang sudah direvisi

The screenshot displays a submission management interface with the following components:

- Submission Progress:** A horizontal bar at the top shows stages: Submission, Review, Copyediting, and Production. Below this, three tabs for Round 1, Round 2, and Round 3 are visible, with Round 3 being the active tab.
- Round 2 Status:** A box indicating "Round 2 Status: A review is overdue."
- Round 3 Status:** A box indicating "Round 3 Status: Submission accepted."
- Notifications:** A table listing three notifications, each with a "[biodiv] Editor Decision" link and a timestamp.
- Reviewer's Attachments:** A section at the bottom showing a document attachment with a file icon, the name "1077001-1\_13706-Article Text-1076667-1-4-20230307 xo.doc", and a date stamp "March 11, 2023" which is circled in green.

Notification	Timestamp
[biodiv] Editor Decision	2023-03-03 05:18 AM
[biodiv] Editor Decision	2023-03-11 05:33 AM
[biodiv] Editor Decision	2023-03-30 12:41 PM

Attachment	Date
1077001-1_13706-Article Text-1076667-1-4-20230307 xo.doc	March 11, 2023

## B. Bukti artikel yang diperbaiki rounde 3

### Diversity and Abundance of Plankton Community in Tawang Bay and Karanggongso Bays, the Natural Settlement Habitats of Spiny Lobster Larvae in East Java Indonesia

**Abstract.** Tawang and Karanggongso Bays have been well-known as settlement areas for spiny lobster larvae, *Panulirus* spp., in East Java, Indonesia. These locations may suggest that these locations, which may suggest that the location are suitable environments including diet availability for lobster larvae. Therefore, the present study aimed to investigate types and abundance and diversity of plankton in the both locations to discover potential live diets for lobster larvae. Plankton samples were collected in both locations using a plankton net at four different depths: 0.3 m, 2.5 m, 5 m, and 20 m with three replicates. The objectives of this study

also are to explore plankton's diversity, uniformity, and dominance indices the diversity, abundance, uniformity and dominance indices of plankton in the natural settlement ground of lobster larvae at both locations Karanggongso and Tawang Bay. Plankton samples in each location was collected using a plankton net at four different depths: 0.3 m, 2.5 m, 5 m, and 20 m with three replicates. The results revealed that 17 plankton species were identified from the 0.30 m depth, 13 species at a 2.5 m depth, 11 species at a 5 m depth, and 13 species at 2.5 m, 11 at 5 m, and 13 at 20 m at depth at Karanggongso Bay. While, 17 plankton species were discovered on the surface of Tawang Bay waters: 11 species at a 2.5 m, 12 species at 5 m, and 12 species at 20 m. In addition, 17 plankton species were discovered in at 0.3 m depth, 11 species at 2.5 m, 12 species at 5 m, and 12 species at 2.5 m, 12 at 5 m, and 12 at 20 m at Tawang Bay. Among the most abundant species were *Acartia* sp., *Calanus* sp., *Paracyclops* sp., and *Oithona* sp. The diversity indices observed in Karanggongso and Tawang bay ranged from 2.02-2.49 and 2.17-2.65, respectively, which fall within the moderate range. Similarly, the uniformity indices observed at both locations were also moderate, with values ranging from 0.38-0.45 at Karanggongso Bay and 0.41-0.46 at Tawang Bay. While there were no dominant species at both locations, as indicated by, as the dominance index values ranged from 0.13-0.30. Among the identified plankton species, *Oithona* sp., *Calanus* sp., *Paracyclops* sp., and *Acartia* sp. are considered potential live feed for lobster larvae, and thus should be further studied.

**Key-words:** diversity, diets, dominance, lobster, plankton, uniformity.

**Abbreviations** (if any): -

**Running title:** Plankton diversity in lobster natural habitat

#### INTRODUCTION

Lobster is an important fishery commodity in Indonesia due to its high price, high nutritional contents as well as, and high market demands. According to the Indonesian Central Bureau of Statistics, the total export value of lobsters in 2020 reached USD 8.1 million (BPS 2020). The high export value and continuously increasing marketing demands at national or global markets indicate that lobster is a high-potential fisheries commodity. However, the lobster supply has been highly dependent on the wild catch because lobster aquaculture has not been well developed yet depended highly on the wild catch because lobster aquaculture has not yet been well developed. One of the main issues faced in lobster

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49 aquaculture is larval production, which currently relies on the availability of ~~seeds in nature~~ natural seeds. Many studies  
50 have been conducted to study various factors ~~relating to larval production of larvae's larval production,~~ including  
51 spawning-inducing technology and rearing condition, yet the success rates are very low. Several authors have succeeded ~~the~~  
52 ~~breedi n breeding and producing larvae.~~ Yet, the larvae can live only 7-14 days after hatching. ~~H-Therefore, it is~~  
53 hypothesized that the main challenge is ~~i-n~~ diet availability and suitability. According to Amin et al. (2022b), ~~one-way-to~~  
54 ~~start domesticating wild species is firstly by collecting information on their natural habitat as much as possible~~ first, one  
55 way to start domesticating wild species is by collecting information on their natural habitat as much as possible. Similarly,  
56 Kashinskaya et al. (2018) suggest ~~t-hat profiling certain animals' natural habitat~~ profiling certain animals' natural habitats  
57 may reveal their diets.

58 Environmental conditions, including physical, chemical, and biological factors in natural habitats, highly determine the  
59 recruitment rates of lobster larvae (Keulder 2005). Several authors have previously reported the physical and chemical  
60 characteristics of the natural settlement areas of lobster larvae (Amin et al. 2022b; Boudreau et al. 1992; Lillis and  
61 Snelgrove 2010). However, studies investigating biological aspects of settlement habitat in the natural environment of  
62 lobster larvae are ~~still~~ very limited. Meanwhile, many studies conclude that biological factors ~~have old~~ important  
63 information for the lobster larvae, especially for diets (O'Rorke et al. 2014). Accordingly, biological aspects such as  
64 natural dietary aspects and lobster predation processes that occur in nature during larval and post-larval stages could be  
65 critical information that must be considered for hatchery production. ~~In-For example, plankton might be a natural diet~~  
66 ~~source for various fish seeds, including lobster seeds, in their natural settlement habitat~~ ~~heir natural settlement habitat,~~  
67 ~~plankton might be a natural diet sourcee for various types of fish seeds, including lobster seeds.~~ Raza'i et al. (2018) added  
68 that the availability of plankton as a natural diet source ~~has a significant impact on~~ significantly impacts the dependence  
69 and growth of marine organisms such as fish, crabs, shrimp, and lobsters.

70 Profiling plankton diversity and abundance might reveal potential diets for lobster larvae. A similar approach has been  
71 done in some studies. For instance, Ihsan et al. (2019) conducted research on plankton as a natural feed for lobster larvae  
72 and post-larvae in natural habitats in Teluk Awang, Central Lombok. Trijoko and Pasaribu (2003) conducted another study  
73 in Wedi Ombo Bay, Gunung Kidul, Yogyakarta. ~~Generally, t-hi se study's results in general~~ suggest that each location has  
74 a different structure and abundance, although some species were the same between the area. All these results raised  
75 questions about whether lobster larvae are opportunistic ~~feeders~~ or specific feeders. ~~Therefore, to answer these questions,~~  
76 ~~more studies are required by collecting more information in more settlement areas of lobster.~~

77 ~~Karanggongso bay and Tawang Bay has been~~ have been well-known as one of the most settlement areas for lobster  
78 larvae in East Java Indonesia (Amin et al. 2022a); therefore, it is assumed to ~~have important suitable diet availability~~ for  
79 lobster larvae. However, studies on the biological aspects of both locations areas are still very limited. Thus, ~~the objectives~~  
80 ~~of this research ii s research aims~~ to investigate the plankton diversity, abundance, uniformity, and dominance indices in the  
81 natural settlement habitat of lobster larvae at Karanggongso and Tawang Bays. The study results are expected to enrich the  
82 information on potential diets for lobster larvae for hatchery development.

## 83 MATERIALS AND METHODS

### 84 Study area

85 ~~The collection of plankton samples was carried out~~ Plankton samples were collected in two common settlement areas of  
86 lobster larvae in East Java, Indonesia (Karanggongso Bay and Tawang Bay), with a protocol as previously described by  
87 Amin et al. (2022b). ~~At Karanggongso Bay, The sampling location was performed at three different ordinate points at~~  
88 ~~ordinate points as repetitions:~~ 8°18'13.8"S 111°44'28.4"E (R1), 8°18'16.3"S 111°44'21.6"E (R2), and 8°18'23.0"S  
89 111°44'26.8"E (R3). While at Tawang Bay, the sampling pointes were 8°15'57.4"S 111°17'46.0"E (R1), 8°15'54.3"S  
90 111°17'48.2"E (R2), and 8°15'51.5"S 111°17'46.2"E (R3) 8°15'57.4"S 111°17'46.0"E (L1), 8°15'54.3"S 111°17'48.2"E  
91 (L2) and 8°15'51.5"S 111°17'46.2"E (L3), (Figure 1). Plankton sampling in each sampling point was collected at ~~Plankton~~  
92 ~~sampling was conducted at three different sampling points with~~ four different depths: 0-0.3 -m, 2.5 -m, 5 -m, and 20 -m.  
93 ~~First, T~~he water samples collected from three sampling points with the same depth were mixed and filtered using a  
94 plankton net and placed in sterile bottles. The filtered sample was then immediately given Lugol which acts as a plankton  
95 preservative, up to 1% of the total filtering, and wrapped in Styrofoam. The samples were then examined in the  
96 Microbiology Laboratory, Faculty of Fisheries and Marine Science at Airlangga University.

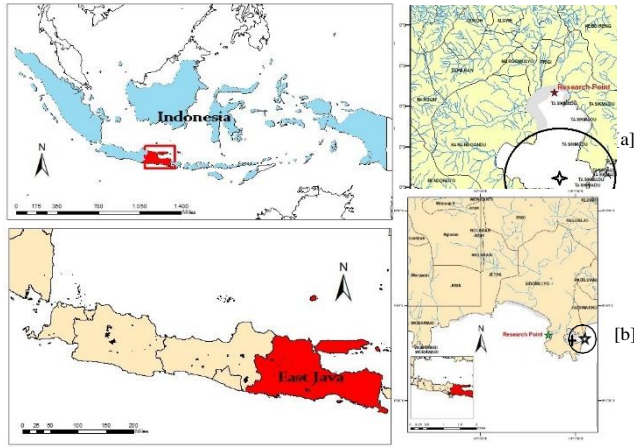


Figure 1 Two sampling locations: Karanggongso Bay, Trenggalek Regency [a], and Tawang Bay, Pacitan Regency [b], East Java, Indonesia.

Karanggongso Bay waters have had temperatures ranging from 27-28 °C, a DO content of 7.48 mg/L, a salinity of 26 ppt, a pH of 7-8, a NO<sub>3</sub> content of 0.01 mg/L, and a muddy substrate. On the other hand, Tawang Bay waters temperatures are were slightly warmer than Karanggongso Bay, with water temperature ranging from 28.2-28.3 °C, with a significantly lower DO content of 3.35 mg/L. moreover, Tawang Bay has a higher salinity of 35 ppt, a pH of 8, a NO<sub>3</sub> content of 0.01, a depth of 15 m, and a sandy substrate.

#### 105 Abundance and Identification of plankton

106 Firstly, plankton identity and their abundances were analyzed using a protocol of LeGresley and McDermott (2010). In  
 107 brief, plankton samples were placed on a Sedgewick Rafter Counting (SRC) Cell and observed under a binocular  
 108 microscope with a magnification of 1000x. Thereafter-Afterward, plankton found in each sample was counted,  
 109 photographed, and identified according to an identification book guide by Mazzocchi et al. (2012). Then, the abundance  
 110 index was calculated according to the following formula (Fachrul

2012):

$$N = \frac{a}{b} \times \frac{c}{d} \times \frac{Vb}{Vsrc} \times \frac{1}{Vs}$$

112  
 113 Where "N" represents the abundance of plankton (plankter/L), "a" represents the number of SRC boxes, "b" is the  
 114 area of one field of view (mm<sup>2</sup>), "c" denotes the number of individuals observed, and "d" indicates the number of  
 115 boxes observed. "Vb" is the volume of water in the sample bottle (ml), "Vsrc" is the volume of water in the SRC  
 116 (ml), and "Vs" represents the volume of water filtered in the Field (L).

#### 119 Diversity, Uniformity, and dominant indices

120 The diversity index value (H') was calculated using the following formula (Fachrul 2012):

$$H' = -\sum p_i \ln p_i, \text{ where } p_i = \frac{n_i}{N} \quad H' = -\sum p_i \ln p_i, \text{ where } p_i = \frac{n_i}{N}$$

122 Where H' is Shannon Wiener Diversity Index, pi is the number of individuals of the i-th species, ni is the  
 123 number of species, and N is the total individual number.

124 The uniformity index (E') was calculated using the "Evenness Index" formula (Ulifah et al. 2019):

$$E' = \frac{125}{126} \frac{H'}{S} \quad \text{where, } E' \text{ is the uniformity index, } H' \text{ is the Shannon Wiener Diversity Index, } S \text{ is}$$

127 the Total total number of species

128

129 The dominance index (d) was calculated using the following equation (Berger and Parker 1970):

130 
$$d = \frac{N_{max}}{N}$$
 where, where, "d": Simpson Dominance Index, Nmax: The most abundant number of individual  
131 species, dan N = Total individual

number.132

## 133 RESULTS AND DISCUSSION

### 134 Results

#### 135 Plankton Abundance in Karanggongso Bay

136 Water samples were collected from two locations, Karanggongso Bay and Tawang Bay at four different depths (0.3 m,  
137 2.5 m, 5 m, and 20 m). The two bays were located at in the Southern part of East Java Province, and both areas are  
138 facing face to the Indian Ocean, Figure 1. The results showed that a total of 17 plankton species were identified from the  
139 surface water (0.0-0.3 m). The top six most abundant species were *Paracyclops* sp. with 21.21%, followed by *Acartia*  
140 sp. (18.18%), *Pteropods* sp. (9.09%), *Prorocentrum* sp. (6.06%), *Dinophysis* sp. (6.06%), and *Sagitta* sp. (2.13%). Other  
141 species and their percentage was are presented in Table 1. In addition, at a 2.5 m depth, 13 plankton species were  
142 identified. Again, the top 6 most abundant species were *Acartia* sp. (26.47%), followed by *Paracyclops* sp.  
143 (23.53%), *Ceratium* sp. (8.82%), *Microsetella* sp. (8.82%), *Dinophysis* sp. (5.8%), and *Oncaea* sp. (5.88%). The rest  
144 species with their abundance were presented in Table 1.

145 Furthermore, at 5 m depth, the Bay is home to 11 plankton species. The top 4 most abundant species were *Acartia* sp.  
146 (30.77%), followed by *Paracyclops* sp. (23.08%), *Sagitta* sp. (11.54%), and *Oithona* sp. (7.69%). While the other 7  
147 species included *Synedra* sp., *Oikopleura* sp., *Coscinodiscus* sp., *Ceratium* sp., *Pteropods* sp., *Microsetella* sp., and  
148 unclassified *Lucifer*, which were counted for 3.85% each (Table 1). Meanwhile, a total of 13 plankton species were found  
149 at the a depth of 20 m. The Again, the top 6 most abundant species were *Acartia* sp. accounted for 24.14%), followed by  
150 *Paracyclops* sp. with 13.79%, *Pteropods* sp. (10.34%), *Dinophysis* sp. (10.34%), *Ceratium* sp. with 6.90%, and *Sagitta*  
151 sp. with 6.90%. The rest species were are presented in  
table 1.152

153 **Table 1.** Plankton species identified from two natural settlement habitats of spiny lobster larvae (Karanggongso Bay and  
154 Trenggalek Regency, East Java Indonesia) at four different depths of the water column was identified from two  
155 natural settlement habitats of spiny lobster larvae (Karanggongso Bay and Trenggalek Regency, East Java  
156 Indonesia) at four different depth of water column depths.

Depth	Species	Cell density (Indiv/L)
0.3 m (Surface)	<i>Cyclotella</i> sp.	8
	<i>Penilia</i> sp.	8
	<i>Noctiluca</i> sp.	8
	<i>Prorocentrum</i> sp.	16
	<i>Dinophysis</i> sp.	16
	<i>Ceratium</i> sp.	8
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	24
	<i>Paracyclops</i> sp.	56
	<i>Acartia</i> sp.	48
	<i>Microsetella</i> sp.	8
	<i>Euphausia</i> sp.	8
	<i>Lucifer</i> sp.	8
	<i>Oipheureidea</i> sp.	8
	<i>Sagitta</i> sp.	16
<i>Nermatea</i> sp.	8	
<i>Actinulla larvae</i>	8	
2.5 m	<i>Rizosolenia</i> sp.	8

	<i>Penilia</i> sp.	8
	<i>Ceratium</i> sp.	24
	<i>Dinophysis</i> sp.	16
	<i>Paracyclopina</i> sp.	64
	<i>Acartia</i> sp.	72
	<i>Microstella</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Codoneleopsis</i> sp.	8
	<i>Oipheureidea</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Actinula</i> sp.	8
	<i>Polychaete</i>	8
5.0 m	<i>Oikopleura</i> sp.	8
	<i>Synedra</i> sp.	8
	<i>Coscinodiscus</i> sp.	8
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	8
	<i>Paracyclopina</i> sp.	48
	<i>Acartia</i> sp.	64
	<i>Microstella</i> sp.	8
	<i>Oithona</i> sp.	16
	<i>Lucifer</i> sp.	8
	<i>Sagitta</i> sp.	24
	20.0 m (Bottom)	<i>Synedra</i> sp.
<i>Penilia</i> sp.		8
<i>Noctiluca</i> sp.		8
<i>Dinophysis</i> sp.		24
<i>Ceratium</i> sp.		16
<i>Pteropods</i> sp.		24
<i>Acartia</i> sp.		56
<i>Paracyclopina</i> sp.		32
<i>Oithona</i> sp.		8
<i>Microstella</i> sp.		16
<i>Euphausia</i> sp.		8
<i>Protoperidinium</i> sp.		8
	<i>Sagitta</i> sp.	16

157

#### 158 Plankton Abundance in Tawang Bay

159 A total of 17 plankton species were identified from the water sample at a depth of 0.0-0.3-m (surface water) of Tawang  
160 Bay. The top 9 most abundant species were *Acartia* sp., with an abundance of 12.82%, followed by *Ceratium* sp.  
161 (10.26%), *Prorocentrum* sp. (10.26%), *Microstella* sp. (10.26%), *Oncaea* sp. (10.26%), *Pteropods* sp. (7.69%), *Calanus*  
162 sp., (7.69%), *Synedra* sp. (5.13%), and *Oithona* sp. (5.13%). While At the same time, the rest of the species were counted  
163 for 2.56% each and presented in Table 2. In addition, there were 11 species of plankton 11 species of plankton were found  
164 in a water sample at a depth of 2.5 m in Tawang Bay. The top 6 most abundant species were *Calanus* sp. (28.00%),  
165 followed by *Prorocentrum* sp. (12.00%), *Paracyclopina* sp. (12.00%), *Microstella* sp. (12.00%), *Oncaea* sp. (8.00%), and  
166 *Oithona* sp. with an abundance of 8.00%. While the rest plankton species, including *Synedra* sp., *Ceratium* sp., *Pteropods*  
167 sp., *Macrophthalmus* sp., and *Sagitta* sp., were counted at 4.00% each, Table 2.

168 Furthermore, a total of 12 plankton species were identified from the water sample at 5-m depth. The top 4 most  
169 common species were *Calanus* sp. with an abundance of 28.57%, *Oithona* sp. with an abundance of 14.29%, *Copepoda*  
170 *nauplii* with an abundance of 9.52%, *Prorocentrum* sp. with an abundance of 9.52%. While the rest of the species,  
171 including *Melosira* sp., *Synedra* sp., *Dinophysis* sp., *Microstella* sp., *Temora* sp., *Oncaea* sp., and *Sagitta* sp., with an  
172 abundance of 5.00%, respectively. While in the bottom waters of Tawang Bay (20 m depth), a total of 12 plankton species  
173 were identified. The top 9 most abundant species were *Prorocentrum* sp. with an abundance of 16.44%, *Acartia* sp. with  
174 an abundance of 16.44%, *Oithona* sp. with an abundance of 16.44%, *Oncaea* sp. with an abundance of 10.96%,  
175 *Dinophysis* sp. with an abundance of 5.48%, *Rhizosolenia* sp. with an abundance of 5.48%, *Pleurosigma* sp. with an  
176 abundance of 5.48%, *Ceratium* sp. with 5.48%, *Caridean* sp. (5.48%). While At the same time, the rest  
177 species were are presented in table 2.

178

179

180

**Table 2.** Plankton species identified from the natural habitat of spiny lobster in bottom water at Tawang Bay, at four different depth of water column, East Java Indonesia

Depth	Species	Density (Indiv/L)
0.3 m (Surface)	<i>Synedra</i> sp.	16
	<i>Oscillatoria</i> sp.	8
	<i>Spirulina</i> sp.	8
	<i>Ceratium</i> sp.	32
	<i>Prorocentrum</i> sp.	32
	<i>Pteropods</i> sp.	24
	<i>Acartia</i> sp.	40
	<i>Microsetella</i> sp.	32
	<i>Calanus</i> sp.	24
	<i>Oithona</i> sp.	16
	<i>Oncaea</i> sp.	32
	<i>Euphausia</i> sp.	8
	<i>Macrophthalmus</i> sp.	8
	<i>Clytemnestra</i> sp.	8
	<i>Cypris</i> sp.	8
Unclassified Fish larvae	8	
Unclassified flatworms	8	
2.5 m	<i>Synedra</i> sp.	8
	<i>Prorocentrum</i> sp.	24
	<i>Ceratium</i> sp.	8
	<i>Pteropods</i> sp.	8
	<i>Paracyclops</i> sp.	24
	<i>Calanus</i> sp.	56
	<i>Oithona</i> sp.	16
	<i>Microsetella</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Macrophthalmus</i> sp.	8
	<i>Sagitta</i> sp.	8
	<i>Melosira</i> sp.	8
5 m	<i>Synedra</i> sp.	8
	<i>Bivalve larvae</i>	8
	<i>Prorocentrum</i> sp.	16
	<i>Dinophysis</i> sp.	8
	<i>Microsetella</i> sp.	8
	<i>Calanus</i> sp.	48
	<i>Oithona</i> sp.	24
	<i>Naupli Copepoda</i>	16
	<i>Temora</i> sp.	8
	<i>Oncaea</i> sp.	8
	<i>Sagitta</i> sp.	8
20 m (bottom)	<i>Rhizoselenia</i> sp.	8
	<i>Pleurosigma</i> sp.	8
	<i>Prorocentrum</i> sp.	24
	<i>Ceratium</i> sp.	8
	<i>Dinophysis</i> sp.	8
	<i>Microsetella</i> sp.	4
	<i>Calanus</i> sp.	6
	<i>Acartia</i> sp.	24
	<i>Oithona</i> sp.	24
	<i>Oncaea</i> sp.	16
	<i>Caridean</i> sp.	8
Unclassified flatworm	8	

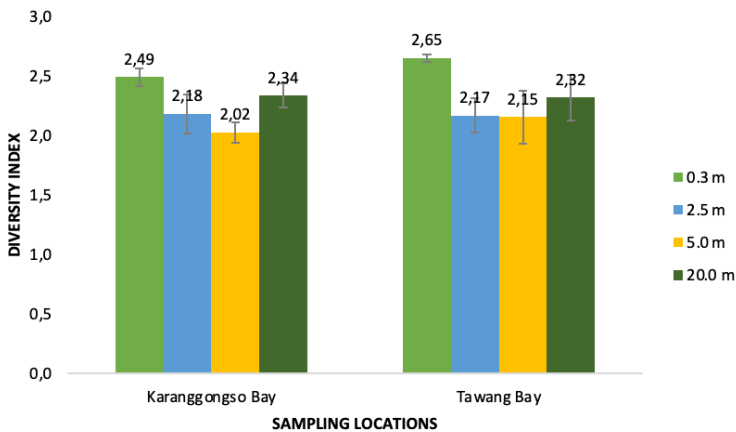
181

182



183 **Diversity indices**

184 The diversity index values obtained in the waters of Karanggongso Bay, Trenggalek Regency East Java, were  $2.49 \pm$   
185  $0.07$  at a depth of 0.0-0.3 m depth of water column,  $2.18 \pm 0.16$  at a depth of 2.5 m,  $2.02 \pm 0.08$  at a depth of 5 m, and  $2.34$   
186  $\pm 0.10$  at the 20 m water column. Those which indicate that the Karanggongso Trenggalek waters have moderate  
187 diversity. While the diversity index values obtained in the waters of Tawang Bay were  $2.65 \pm 0.03$  at 0.0 – 0.3 m depth,  
188  $2.17 \pm 0.15$  at the 2.5 m depth,  $2.15 \pm 0.22$  at a 5 m depth, and  $2.32 \pm 0.19$  at a depth of 20 m which indicates that the  
189 waters of Tawang Bay have also have moderate diversity, Figure 2

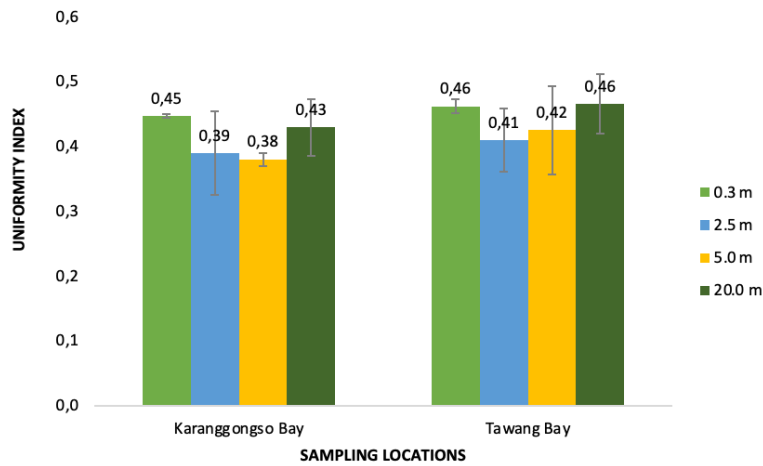


190  
191 **Figure 2.** Diversity indices of plankton identified at the water column of Karanggongso Bay and Tawang Bay, East  
192 [Java](#), Indonesia. Bars are the average values with a standard deviation of three replicates.

193  
194  
195 **Uniformity indices**

196 The uniformity index values obtained in the water column of Karanggongso Bay were  $0.45 \pm 0.01$  at 0.0-0.3 m  
197 depth (surface water column),  $0.39 \pm 0.06$  at a depth of 2.5 m,  $0.38 \pm 0.01$  at a depth of 5 m and  $0.43 \pm 0.04$  at the 25m  
198 depth or bottom of the water column. These index values indicated that the uniformity of plankton in Karanggongso Bay  
199 was at a moderate level/moderate. While At the same time, the uniformity values obtained in Tawang Bay were  $0.46 \pm 0.01$   
200 at 0.0-0.3 m depth,  $0.41 \pm 0.05$  at a depth of 2.5 m,  $0.42 \pm 0.07$  at a depth of 5 m, and  $0.46 \pm 0.05$  at 25 m depth or bottom  
201 of the water column. Similarly, uniformity indices of plankton in Tawang Bay were considered also considered at a  
202 moderate level, Figure 3.

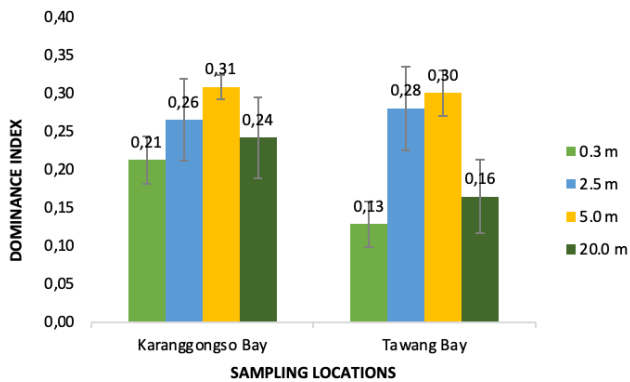
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203  
204 **Figure 3.** Uniformity indices of plankton identified in Karanggongso Bay and Tawang Bay, East Java, Indonesia. Bars are  
205 the average values with a standard deviation of three replicates.

206  
207 **Domination Index**

208 Domination index values obtained from the waters of Karanggongso Bay were  $0.21 \pm 0.03$  at the 0.0-0.3 m depth,  $0.26 \pm 0.05$  at a depth of 2.5 m,  $0.31 \pm 0.02$  at a depth of 5 m and  $0.24 \pm 0.05$  at the 20 m water depth. These values mean that  
209 no plankton species were dominant in the natural habitat of spiny lobster larvae (Karanggongso Bay). While the  
210 dominance index values obtained from Tawang Bay waters were  $0.13 \pm 0.03$  at the 0.0-0.3 m depth,  $0.28 \pm 0.05$  at a depth  
211 of 2.5 m,  $0.30 \pm 0.03$  at a depth of 5 m, and  $0.16 \pm 0.05$  at the 20 m depth. Similarly, based on the values obtained from the  
212 surface to the bottom of the waters shows that there are no species that the values obtained from the surface to the bottom  
213 of the waters show that no species dominate in Tawang Bay (Figure 4).  
214



215  
216 **Figure 4.** Domination indices of plankton identified at Karanggongso Bay and Tawang Bay, East Java, Indonesia. Bars are  
217 the average values with a standard deviation of three replicates.

## 219 Discussion

220 Environmental conditions, including physical, chemical, and biological factors in natural habitats, highly determine the  
 221 recruitment rates of lobster larvae (Keulder 2005). Several studies have previously reported the physical and chemical  
 222 characteristics of the settlement area of lobster (Amin et al. 2022b; Boudreau et al. 1992; Lillis and Snelgrove 2010).  
 223 However, studies viewing biological aspects of settlement habitat in natural environment lobster larvae are still very  
 224 limited. Meanwhile, many studies conclude that biological factors such as plankton availability ~~can~~ would be important  
 225 information on the natural diets of lobster larvae (O'Rorke et al. 2014). Thus the present study investigated the diversity,  
 226 uniformity, and dominance of plankton in two common settlement areas of lobster larvae in East Java (Karanggongso Bay  
 227 and Tawang Bay) in Indonesia. The sampling was performed in 4 different depths, which were 0.3 m, 2.5 m, 5 m, and 20  
 228 m depth, as lobster larvae vertically migrated from the bottom during the daytime to the surface of the water during the  
 229 nighttime. It was also discovered that the diversity indices of plankton at both locations were 2.02-2.49 at Karangongso,  
 230 and 2.15-2.65 at Tawang Bay. The diversity index values found at these two locations were all less than 3, which means at  
 231 a moderate level. The high or low value of plankton diversity can be caused by the evenly distributed abundance of each  
 232 individual ~~or in another sense there are no species that~~. ~~In another sense, no species~~ have relatively more diversity than  
 233 other species (Awwaluddin et al. 2017). ~~As the diversity indices of plankton at Karangongso Bay and Tawang Bay may~~  
 234 ~~which is are at a moderate level may suggest that plankton communities is are in relatively equal distribution of different~~  
 235 ~~species, with no one~~ Therefore, the diversity indices of plankton at Karangongso Bay and Tawang Bay, which are at a  
 236 moderate level may suggest that plankton communities are in relatively equal distribution of different species, with no  
 237 species being significantly more prevalent than others (Awwaluddin et al. 2017).

238 Similarly, the uniformity indices of plankton in both settlement areas were classified at a moderate level (0.38-0.45 at  
 239 Karangongso Bay and 0.41-0.46 at Tawang Bay). The uniformity values found at each location, both Karangongso  
 240 Beach waters and Tawang Beach waters, are categorized ~~said to have as~~ moderate uniformity. The value of uniformity is  
 241 categorized to be ~~uniformity~~ value is categorized as moderate if the value ranges from 0.4-0.6 (Ulfah et al. 2019). The  
 242 availability of nutrients, food, and predation processes can affect the high value of uniformity because it affects the type  
 243 and amount of plankton. Besides that, physical and chemical factors also affect the value of uniformity because it will  
 244 affect the growth of plankton (Nugroho et al. 2020). In addition, since the distribution of plankton in both waters ~~samples~~  
 245 is uniform, ~~t-hen~~ a high degree of uniformity can be asserted. While the dominance indices ~~were ranging~~ ranged from 0.21 –  
 246 0.31 at Karangongso Bay and 0.13-0.30 in Tawang Bay. The result indicates ~~that there were~~ no dominant species at both  
 247 locations since all values < 0.05. Dominance index values obtained in both waters indicate the absence of plankton which  
 248 dominates in Karangongso Bay and also Tawang Bay. The dominance index value indicates whether organisms are  
 249 dominant in a water environment. A value between 0.5 to 1 on the dominance index shows the presence of dominant  
 250 organisms in the water. On the other hand, a value less than 0.5 indicates ~~t-hat there are no dominant organisms~~ no dominant  
 251 organisms are present in the water (Berger and Parker 1970).

## 252 Potential Diet for Lobster Seeds

253 The result also revealed that 17 plankton species were identified from the surface water, 13 species at a depth of 2.5 m, 11  
 254 species at a depth of 5 m, and 13 species at a depth of 5 m, and 13 at 20m (bottom) of Karangongso Bay. ~~While~~ At the  
 255 same time, 17 plankton species were discovered on the surface of Tawang Bay waters: 11 species at a depth of 2.5 m, 12  
 256 species at a depth of 5 m, and 12 species at the seafloor. ~~The number of plankton species identified in the present study, in~~  
 257 ~~general,~~ In general, the number of plankton species identified in the present study are is higher than in previous study  
 258 reported from other settlement habitats of lobster larvae ~~ies reported from other lobster larvae settlement habitats in Awang~~  
 259 Bay west Nusa Tenggara (Amin et al. 2022b) and Teluk Wedi Ombo, Yogyakarta (Trijoko and Pasaribu 2004). The most  
 260 abundant species identified from Karangongso bay are mainly from Phylum Arthropoda, including *Paracyclops* sp,  
 261 *Oithona* sp, *Acartia* sp, and *Calanus* sp. Other prominent species included *Prorocentrum* sp., *Dinophysis* sp., and *Ceratium*  
 262 sp., which are belonged to the phylum Dinoflagellata. While ~~most abundant species found in Tawang Bay were also~~  
 263 ~~dominated by phylum Arthropoda, including~~ *Acartia* sp., *Oithona* sp., *Oncaea* sp., *Calanus* sp., *Paracyclops* phylum  
 264 Arthropoda, including *Acartia* sp., *Oithona* sp., *Oncaea* sp., *Calanus* sp., *Paracyclops*, and *Macrotholmus* sp., also  
 265 dominated the most abundant species found in Tawang Bay, and *Macrotholmus* sp. Plankton species in this area are also  
 266 dominated by phylum Dinoflagellata such as *Ceratium* sp., *Prorocentrum* sp., and *Dinophysis* sp. Of these identified  
 267 plankton species, ~~10~~ 11 species were found in both locations, including *Acartia* sp., *Ceratium*  
 268 sp., *Dinophysis* sp., *Euphausia* sp., *Microsetella* sp., *Oithona* sp., *Paracyclops* sp., *Pteropods* sp., *Rizosolenia* sp.,  
 269 *Binophysis* sp., *Sagitta* sp., *Microsetella* sp., *Calanus* sp., *Synedra* sp. These findings suggest that the planktonic  
 270 community in both bays is dominated by species belonging to the phylum Arthropoda and Dinoflagellata, which are  
 271 known to be important components of the marine food web.

272 Among the identified plankton species, few species have been documented as potential live diets in aquaculture,  
 273 including *Oithona* sp., for a live diet of European seabass (*Dicentrarchus labrax*) postlarvae (Magouz et al. 2021a), and  
 274 shrimp larvae (Dinesh Kumar et al. 2017). Therefore, and *Acartia* sp., could possess as a live diet for seabass larvae, *Late*  
 275 *calcarifer* (Rajkumar 2006), fat snook, *Centropomus parallelus* (Barroso et al. 2013), and many other aquatic larvae  
 276

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Commented [X03]: This species summary is only nine, one species short of ten

Commented [mA4R3]: We have rechecked our list and found 11 species. All these species have been added in the text.

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277 (Sarkisian et al. 2019). ~~In fact,~~ Some studies also confirmed that these plankton species were identified in the content  
278 stomach ~~content~~ of lobster larvae. For instance, *Oithona* sp. has been reported from the stomach content of spiny lobsters  
279 at the early life stage (Amin et al. 2022c; Khvorov et al. 2012). ~~Furthermore,~~ *Oithona* sp. has been described as a marine  
280 calanoid copepod ~~which with~~ has high protein content, ~59.33% (Santanumurti et al. 2021), therefore frequently used as a  
281 live diet for fish or shrimp larvae. Another study has documented that *Oithona* sp. had a high content of fatty acid profiles  
282 including polyunsaturated fatty acids (26.47%) and omega-3 fatty acids (36.30), which ~~i-n-fact~~ are higher ~~compared to~~ han  
283 a commercial live diet such as *Artemia* sp. (Magouz et al. 2021b). Furthermore, *Acartia* sp. has ~~been also~~ been  
284 documented to be a good live diet for aquatic larvae such as seabass larvae, *Lates calcarifer* (Rajkumar 2006), and fat  
285 snook, *Centropomus parallelus* (Barroso et al. 2013). *Acartia clausi* has been described to have higher contents of proteins  
286 (63.12%) and lipids (16.65%) and is also richer in n-3 fatty acids (33.94%) than *Artemia* nauplii and rotifers (Rajkumar,  
287 2006). The plankton species ~~has have been also identified in the stomach content of spiny lobster larvae also been~~  
288 identified in spiny lobster larvae's stomach content (Amin et al. 2022b; Amin et al. 2022c). In addition, a member of  
289 *Acartia* (*Acartia tonsa*) had been documented to provide an important nutritional benefit to fat snook larvae undergoing  
290 metamorphosis (Vanacor-Barroso et al. 2017).

291 Other potential food sources for lobster larvae identified in the present study are zooplankton and phytoplankton.  
292 ~~According to the results obtained, the plankton found at each station consists~~ The plankton results found at each station  
293 consist of Bacillariophyceae (e.g., *Rizosolenia* sp., *Synedra* sp., *Cyclotella* sp.), and Copepoda (e.g., *Oithona* sp., *Acartia*  
294 sp., *Calanus* sp.). These plankton groups were identified at each station, highlighting their potential as a food source for  
295 lobster larvae. Diatoms, which belong to the phytoplankton group Bacillariophyceae, contain essential nutrients required  
296 for the growth of lobster larvae, such as PUFA (Polyunsaturated Fatty Acid). ~~The PUFA~~ PUFA is the major fatty acid in  
297 Bacillariophyceae diatoms (Pahl et al. 2010), including EPA (eicosapentaenoic acid, 20:5 n-3) and DHA (docosahexaenoic  
298 acid 22:6 n-3). ~~Therefore, PUFA are i s~~ the major fatty acids ~~found in diatoms~~ Bacillariophyceae diatoms (Pahl et al., 2010).  
299 PUFA content of these diatoms is relatively high, with levels ranging between 23.4 and 60.7% (Valera & Saavedra, 2016).  
300 High PUFA content was identified in several plankton species as potential prey for spiny lobster larvae  *Jasus edwardsii*,  
301 and these long-chain fatty acids are an essential nutrient for spiny lobster (Koshio & Kanazawa, 1994; Liddy et al.,  
2004; Wang, 2013).

303 Copepoda (Hexanauplia) is a rich source of protein, particularly in gastropods, ~~it~~ is also high in calcium content which  
304 is important for lobster during molting (Kirno et al., 2012). Several studies, such as those by Alka (2016), Chow (2011),  
305 and Connel (2007), have reported the presence of copepods in the digestive tracts of lobster larvae. ~~That i s~~ suggests ~~t hat~~  
306 copepods are a preferred food for lobster larvae. Protein is ~~constantly~~ the predominant organic nutrient in the spiny lobster  
307 larvae ~~as well as~~ and their preferred prey (Wang, 2013). This is consistent ~~with~~ with prior examinations of digestive  
308 enzymes of phyllosoma of *J. edwardsii* and *Panulirus ornatus*, which reveal that they necessitate a high-protein diet and  
309 will utilize protein to generate energy during food deprivation (Johnston et al., 2004a; Johnston et al., 2004b, Johnston et  
310 al., 2006). Copepods contain high protein content, ranging from 28.9 - 84.9 % of dry weight, indicating that lobster larvae  
311 consume prey with high protein content (Wang & Jeffs, 2014). The protein content of the copepods ~~i s i n~~ accordant  
312 with follows the amount of protein incorporated into artificial feeds for some of the crustaceans larvae, including crab,  
313 shrimp, and clawed lobster species, which ~~i s~~ ranging between 30% to 60% protein (Conklin et al., 1980 ; Guillaume,  
314 1997 ; Holme et al., 2009). Moreover, copepods ~~are~~ also high in lipids, ranging from 11.3%-12.4% (Wang & Jeffs, 2014).  
315 Rich-lipid diets can be properly digested by the spiny lobster larvae, and utilized ~~i t~~ to supply energy, especially during a  
316 food scarcity (Johnston et al., 2004; Liddy et al., 2003; Liddy et al., 2004; Ritar et al., 2003). Furthermore, ~~late l ate~~ phase  
317 phyllosoma of spiny lobster probably targets high lipid prey, as they prepare to accumulate an enormous amount of lipid to  
318 fuel their non-feeding post-larval stage ( Jeffs et al., 2001a; Jeffs et al., 2001b). The presence of copepods, especially  
319 *Oithona* sp., *Acartia* sp., and *Calanus* sp., in a high abundance value at the Karanggongso and Tawang Bay could provide  
320 a significant source of high lipid natural diets for spiny lobster larvae. These results suggest that these plankton species are  
321 a potential diet for spiny lobster larvae, ~~therefore, should be further studied by in vivo trials using aquatic animals~~  
322 especially for developing ornate spiny lobster hatcheries. ~~Therefore, in vivo trials using aquatic animals especially for~~  
323 developing ornate lobster hatcheries, should be further studied.

324 In conclusion, ~~t he~~ number of plankton species found in both locations was more abundant in the surface water (0-0.3  
325 m) compared to the deeper water column. A total of ~~a total of~~ 17 plankton species were identified from the surface water,  
326 13 species at a depth of 2.5 m, 11 species at a depth of 5 m, and 13 species at 20 m (bottom) of Karanggongso Bay.  
327 Similarly, While, 17 plankton species were discovered ~~on from the water surface of Tawang Bay~~ waters: 11 species at a  
328 depth of 2.5 m, 12 species at a depth of 5 m, and 12 species at the seafloor. Based on the diversity, uniformity, and  
329 dominance indices, ~~at both locations had~~ plankton species which are available at both location were moderate plankton  
330 quite variety diversity, and no specific species was dominant over the others, ~~which suggest there were no dominant~~  
331 species in both locations. Among the identified plankton species, several members of Bacillariophyceae, Copepoda, and  
332 Hexanauplia, such as *Oithona* sp., *Calanus* sp., *Paracyclops* sp., and *Acartia* sp., are considered potential live feed for  
333 lobster larvae, and thus should be further studied.

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337 experiment.337

338 **AUTHORS' CONTRIBUTIONS**

- 339 1. Endang Dwi Masitah : funding acquisition, data analysis, writing draft, supervision.
- 340 2. Muhammad Giano Fadilah: data collection, data analysis, writing draft.
- 341 3. Muhamad Amin : Experimental design, data collection, data analysis, writing draft, validation, supervision,
- 342 submission.
- 343 4. Kurniati Umrah Nur: data collection, data analysis, writing draft, validation.
- 344 5. Laila Musdalifah: Experimental design, data collection, data analysis, writing the draft.
- 345 6. Shifania Hanifa Samara: Data collection, data analysis, writing draft, data validation.
- 346 7. Yudi Cahyoko: Experimental design, data collection, data analysis, writing draft, data validation, submission.
- 347 8. Alimuddin: Experimental design, data collection, data analysis, writing the draft.
- 348 9. Sahrul Alim: Experimental design, data collection, data analysis, writing the draft.
- 349 10. Bagus Dwi Hari Setyono: Experimental design, data collection, data analysis, writing draft, data

validation350

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Notifications

**[biodiv] Editor Decision**

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ENDANG DEWI MASITHAH, MUHAMMAD GIANO FADHILAH, MUHAMAD AMIN, KURNIATI UMRAH NUR, LAILA MUSDALIFAH, SHIFANIA HANIFA SAMARA, YUDI CAHYOKO, ALIMUDDIN, SAHRUL ALIM, BAGUS DWI HARI SETYONO:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Diversity and abundance of plankton community in Tawang and Prigi Bays, natural settlement habitats of Spiny Lobster larvae in East Java, Indonesia".

Our decision is to: Accept Submission

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[Biodiversitas Journal of Biological Diversity](#)

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# Diversity and abundance of plankton community in Tawang and Prigi Bays, natural settlement habitats of Spiny Lobster larvae in East Java, Indonesia



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Articles



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ENDANG DEWI MASITHAH ▼

Department of Marine, Faculty of Fisheries and Marine, Universitas Airlangga. Jl. Dr. Ir. H. Soekarno, Mulyorejo, Surabaya 60115, East Java, Indonesia

MUHAMMAD GIANO FADHILAH

Aquaculture Study Program, Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga. Jl. Dr. Ir. H. Soekarno, Mulyorejo, Surabaya 60115, East Java, Indonesia

MUHAMAD AMIN

Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga. Jl. Dr. Ir. H. Soekarno, Mulyorejo, Surabaya 60115, East Java, Indonesia

KURNIATI UMRAH NUR

Aquaculture Study Program, Fisheries Department, Faculty of Marine Science and Fisheries, Universitas Hasanudin. Jl. Perintis Kemerdekaan Km. 10, Tamalanrea, Makassar 90245, South Sulawesi, Indonesia

LAILA MUSDALIFAH

Research Center for Fishery, National Research and Innovation Agency. Jl. Pasir Putih II No. 3, Ancol, Jakarta Utara 14430, Jakarta, Indonesia

SHIFANIA HANIFA SAMARA

Aquaculture Study Program, Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga. Jl. Dr. Ir. H. Soekarno, Mulyorejo, Surabaya 60115, East Java, Indonesia

YUDI CAHYOKO

Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga. Jl. Dr. Ir. H. Soekarno, Mulyorejo, Surabaya 60115, East Java, Indonesia

ALIMUDDIN

Microbiology and Biotechnology Laboratory, Faculty of Animal Sciences, Universitas Mataram. Jl. Majapahit No. 62, Mataram 83115, West Nusa Tenggara, Indonesia

SAHRUL ALIM

Program of Aquaculture, Faculty of Agriculture, Universitas Mataram. Jl. Majapahit No. 62, Mataram 83115, West Nusa Tenggara, Indonesia

BAGUS DWI HARI SETYONO

Program of Aquaculture, Faculty of Agriculture, Universitas Mataram. Jl. Majapahit No. 62, Mataram 83115, West Nusa Tenggara, Indonesia

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# Diversity and abundance of plankton community in Prigi and Tawang Bays, natural settlement habitats of Spiny Lobster larvae in East Java, Indonesia

ENDANG DEWI MASITHAH<sup>1,\*</sup>, MUHAMMAD GIANO FADHILAH<sup>2</sup>, MUHAMMAD AMIN<sup>3</sup>,  
KURNIATI UMRAH NUR<sup>4</sup>, LAILA MUSDALIFAH<sup>5</sup>, SHIFANIA HANIFA SAMARA<sup>2</sup>, YUDI CAHYOKO<sup>3</sup>,  
ALIMUDDIN<sup>6</sup>, SAHRUL ALIM<sup>7</sup>, BAGUS DWI HARI SETYONO<sup>7</sup>

<sup>1</sup>Department of Marine, Faculty of Fisheries and Marine, Universitas Airlangga. Jl. Dr. Ir. H. Soekarno, Mulyorejo, Surabaya 60115, East Java, Indonesia. \*email: endang\_dm@fpk.unair.ac.id

<sup>2</sup>Aquaculture Study Program, Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga. Jl. Dr. Ir. H. Soekarno, Mulyorejo, Surabaya 60115, East Java, Indonesia

<sup>3</sup>Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga. Jl. Dr. Ir. H. Soekarno, Mulyorejo, Surabaya 60115, East Java, Indonesia

<sup>4</sup>Aquaculture Study Program, Fisheries Department, Faculty of Marine Science and Fisheries, Universitas Hasanudin. Jl. Perintis Kemerdekaan Km. 10, Tamalanrea, Makassar 90245, South Sulawesi, Indonesia

<sup>5</sup>Research Center for Fishery, National Research and Innovation Agency. Jl. Pasir Putih II No. 3, Ancol, Jakarta Utara 14430, Jakarta, Indonesia

<sup>6</sup>Microbiology and Biotechnology Laboratory, Faculty of Animal Sciences, Universitas Mataram. Jl. Majapahit No. 62, Mataram 83115, West Nusa Tenggara, Indonesia

<sup>7</sup>Program of Aquaculture, Faculty of Agriculture, Universitas Mataram. Jl. Majapahit No. 62, Mataram 83115, West Nusa Tenggara, Indonesia

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**Abstract.** Masithah ED, Fadhilah MG, Amin M, Nur KU, Musdalifah L, Samara SH, Cahyoko Y, Alimuddin, Alim S, Setyono BDH. 2023. Diversity and abundance of plankton community in Prigi and Tawang Bays, natural settlement habitats of Spiny Lobster larvae in East Java, Indonesia. *Biodiversitas* 24: 1642-1649. Prigi and Tawang Bays have been well-known as settlement areas for spiny lobster larvae, *Panulirus* spp., in East Java, Indonesia. These locations may suggest suitable environments including diet availability for lobster larvae. Therefore, the present study aimed to investigate the type and abundance of plankton in both locations to discover potential live diets for lobster larvae. This study also explored plankton's diversity, uniformity, and dominance indices in both locations. Plankton samples in each location were collected using a plankton net at four depths: 0.3 m, 2.5 m, 5 m, and 20 m with three replicates. The results revealed that 17 plankton species were identified from 0.30 m depth, 13 at 2.5 m, 11 at 5 m, and 13 at 20 m depth at Prigi Bay. In addition, 17 plankton species were discovered at 0.3 m depth, 11 at 2.5 m, 12 at 5 m, and 12 at 20 m at Tawang Bay. Among the most abundant species were *Acartia* sp., *Calanus* sp., *Paracyclops* sp., and *Oithona* sp. The diversity indices observed in Karangongso of Prigi Bay and Tawang Bay ranged from 2.02-2.49 and 2.17-2.65, respectively, within the moderate range. Similarly, the uniformity indices observed at both locations were moderate, ranging from 0.38-0.45 at Prigi Bay and 0.41-0.46 at Tawang Bay. There were no dominant species at both locations, as the dominance index values ranged from 0.13-0.30. Among the identified plankton species, *Oithona* sp., *Calanus* sp., *Paracyclops* sp., and *Acartia* sp. are considered potential live feed for lobster larvae, and thus should be further studied.

**Keywords:** Diets, diversity, dominance, lobster, plankton, uniformity

## INTRODUCTION

Lobster is an important fishery commodity in Indonesia due to its high price, high nutritional contents, and high market demands. According to the Indonesian Central Bureau of Statistics, the total export value of lobsters in 2020 reached USD 8.1 million (BPS 2020). The high export value and continuously increasing marketing demands at national or global markets indicate that lobster is a high-potential fisheries commodity. However, the lobster supply has depended highly on the wild catch because lobster aquaculture has not yet been well developed. One of the main issues faced in lobster aquaculture is larval production, which currently relies on the availability of natural seeds. Many studies have been conducted to study various factors relating to larval

production, including spawning-inducing technology and rearing condition, yet the success rates are very low. Several authors have succeeded in breeding and producing larvae. Yet, the larvae can live only 7-14 days after hatching. Therefore, it is hypothesized that the main challenge is diet availability and suitability. According to Amin et al. (2022b), first, one way to start domesticating wild species is by collecting information on their natural habitat as much as possible. Similarly, Kashinskaya et al. (2018) suggest profiling certain animals' natural habitats may reveal their diets.

Environmental conditions, including physical, chemical, and biological factors in natural habitats, highly determine the recruitment rates of lobster larvae (Keulder 2005). Several authors have previously reported the physical and chemical characteristics of the natural

settlement areas of lobster larvae (Amin et al. 2022b; Boudreau et al. 1992; Lillis and Snelgrove 2010). However, studies investigating biological aspects of settlement habitat in the natural environment of lobster larvae are very limited. Meanwhile, many studies conclude that biological factors have important information for the lobster larvae, especially for diets (O'Rorke et al. 2014). Accordingly, biological aspects such as natural dietary aspects and lobster predation processes that occur in nature during larval and post-larval stages could be critical information that must be considered for hatchery production. For example, plankton might be a natural diet source for various aquatic species (Amin et al. 2022d), including lobster seeds, in their natural settlement habitat. Raza'i et al. (2018) added that the availability of plankton as a natural diet source significantly impacts the dependence and growth of marine organisms such as fish, crabs, shrimp, and lobsters.

Profiling plankton diversity and abundance might reveal potential diets for lobster larvae. A similar approach has been done in some studies. For instance, Ihsan et al. (2019) conducted research on plankton as a natural feed for lobster larvae and post-larvae in natural habitats in Teluk Awang, Central Lombok. Trijoko and Pasaribu (2003) conducted another study in Wedi Ombo Bay, Gunungkidul, Yogyakarta. Generally, this study's results suggest that each location has a different structure and abundance, although some species were the same between the area. All these results raised questions about whether lobster larvae are opportunistic or specific feeders. Therefore, to answer these questions, more studies are required by collecting more information in more settlement areas of lobster.

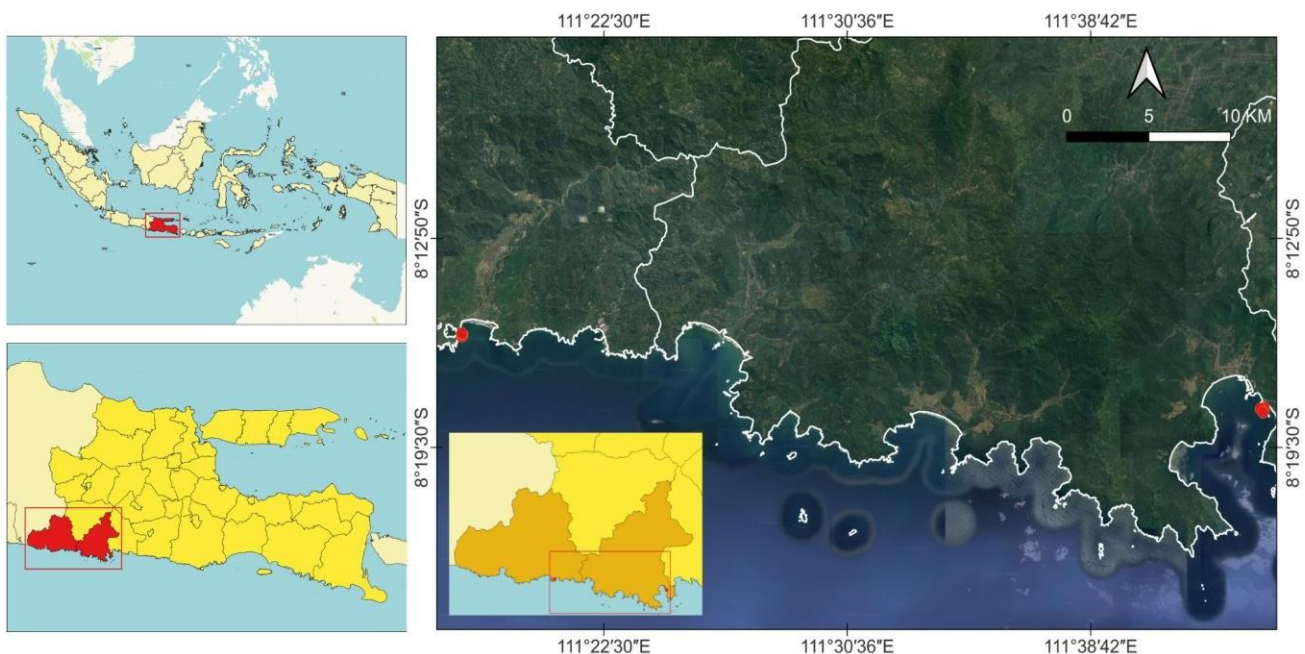
Prigi Bay and Tawang Bay have been well-known as the top two settlement areas for lobster larvae in East Java Indonesia (Amin et al. 2022a); therefore, it is assumed to

have important suitable diet availability for lobster larvae. However, studies on the biological aspects of both locations areas are still very limited. Thus, this research aims to investigate the plankton diversity, abundance, uniformity, and dominance indices in the natural settlement habitat of lobster larvae at Prigi Bay and Tawang Bay. The study results are expected to enrich the information on potential diets for lobster larvae for hatchery development.

## MATERIALS AND METHODS

### Study area

Plankton samples were collected in two common settlement areas of lobster larvae in East Java, Indonesia (Prigi Bay and Tawang Bay), with a protocol as previously described by Amin et al. (2022b). At Karanggongso of Prigi Bay, sampling was performed at three different ordinate points as repetitions: 8°18'13.8"S 111°44'28.4"E (R1), 8°18'16.3"S 111°44'21.6"E (R2), and 8°18'23.0"S 111°44'26.8"E (R3). While at Tawang Bay, the sampling points were 8°15'57.4"S 111°17'46.0"E (R1), 8°15'54.3"S 111°17'48.2"E (R2), and 8°15'51.5"S 111°17'46.2"E (R3) (Figure 1). Plankton sampling in each sampling point was collected at four different depths: 0-0.3 m, 2.5 m, 5 m, and 20 m. First, the water samples collected from three sampling points with the same depth were mixed and filtered using a plankton net and placed in sterile bottles. The filtered sample was then immediately given Lugol which acts as a plankton preservative, up to 1% of the total filtering, and wrapped in Styrofoam. The samples were then examined in the Microbiology Laboratory, Faculty of Fisheries and Marine Science at Airlangga University.



**Figure 1.** Two sampling locations in Prigi Bay, Trenggalek District, and Tawang Bay, Pacitan District, East Java, Indonesia

Prigi Bay water had temperatures ranging from 27- 28°C, a DO content of 7.48 mg/L, a salinity of 26 ppt, a pH of 7-8, a nitrate (NO<sub>3</sub>) content of 0.01 mg/L, and a muddy substrate. On the other hand, Tawang Bay water temperatures were slightly warmer than Prigi Bay, with water temperature ranging from 28.2-28.3°C, with a lower DO concentration (3.35 mg/L). Moreover, Tawang Bay has a higher salinity (35 ppt), a pH of 8, a NO<sub>3</sub> concentration of 0.01 mg/L, a depth of 20 m, and a sandy substrate.

### Abundance and identification of plankton

Firstly, plankton identity and abundance were analyzed using a protocol of LeGresley and McDermott (2010). In brief, plankton samples were placed on a Sedgewick Rafter Counting (SRC) Cell and observed under a binocular microscope with a magnification of 1,000x. Afterward, plankton found in each sample was counted, photographed, and identified according to an identification book guide by Mazzocchi et al. (2012). Then, the abundance index was calculated according to the following formula (Fachrul 2012):

$$N = \frac{a}{b} \times \frac{c}{d} \times \frac{Vb}{Vsrc} \times \frac{1}{Vs}$$

Where: "N" represents the abundance of plankton (plankton/L), "a" represents the number of SRC boxes, "b" is the area of one field of view (mm<sup>2</sup>), "c" denotes the number of individuals observed, and "d" indicates the number of boxes observed. "Vb" is the volume of water in the sample bottle (ml), "Vsrc" is the volume of water in the SRC (ml), and "Vs" represents the volume of water filtered in the Field (L).

### Diversity, uniformity, and dominant indices

The diversity index value (*H'*) was calculated using the following formula (Fachrul 2012):

$$H' = -\sum P_i \ln P_i, \text{ where } P_i = \frac{n_i}{N}$$

Where: *H'* is Shannon Wiener Diversity Index, *p<sub>i</sub>* is the number of individuals of the *i*-th species, *n<sub>i</sub>* is the number of species, and *N* is the total individual number. The uniformity index (*E'*) was calculated using the "Evenness Index" formula (Ulfah et al. 2019):

$$E' = \frac{H'}{\ln S}$$

Where: *E'* is the uniformity index, *H'* is the Shannon-Wiener diversity index, *S* is the total number of species. The dominance index (*d*) was calculated using the following equation (Berger and Parker 1970):

$$d = \frac{N_{max}}{N}$$

Where: "d": Simpson Dominance Index, *N<sub>max</sub>*: The most abundant number of individual species, dan *N* = Total individual number.

## RESULTS AND DISCUSSION

### Plankton abundance in Prigi Bay

Water samples were collected from Prigi Bay and Tawang Bay at four depths (0.3 m, 2.5 m, 5 m, and 20 m). The two bays were located in the Southern part of East Java Province, and both areas face the Indian Ocean, Figure 1. The results showed that 17 plankton species were identified from the surface water (0.0-0.3 m). The top six most abundant species were *Paracyclops* sp. with 21.21%, followed by *Acartia* sp. (18.18%), *Pteropods* sp. (9.09%), *Prorocentrum* sp. (6.06%), *Dinophysis* sp. (6.06%), and *Sagitta* sp. (2.13%). Other species and their percentage are presented in Table 1. In addition, at a 2.5 m depth, 13 plankton species were identified. Again, the top 6 most abundant species were *Acartia* sp. (26.47%), followed by *Paracyclops* sp. (23.53%), *Ceratium* sp. (8.82%), *Microsetella* sp. (8.82%), *Dinophysis* sp. (5.8%), and *Oncaea* sp. (5.88%). The rest species with their abundance were presented in Table 1.

Furthermore, at 5 m depth, the bay is home to 11 plankton species. The top 4 most abundant species were *Acartia* sp. (30.77%), followed by *Paracyclops* sp. (23.08%), *Sagitta* sp. (11.54%), and *Oithona* sp. (7.69%). While the other 7 species included *Synedra* sp., *Oikopleura* sp., *Coscinodiscus* sp., *Ceratium* sp., *Pteropods* sp., *Microsetella* sp., and unclassified Lucifer, which were counted for 3.85% each (Table 1). Meanwhile, 13 plankton species were found at a depth of 20 m. Again, the top 6 most abundant species were *Acartia* sp. accounted for 24.14%, followed by *Paracyclops* sp. with 13.79%, *Pteropods* sp. (10.34%), *Dinophysis* sp. (10.34%), *Ceratium* sp. with 6.90%, and *Sagitta* sp. with 6.90%. The rest species are presented in table 1.

### Plankton abundance in Tawang Bay

A total of 17 plankton species were identified from the water sample at a depth of 0.0-0.3m (surface water) of Tawang Bay. The top 9 most abundant species were *Acartia* sp. with an abundance of 12.82%, followed by *Ceratium* sp. (10.26%), *Prorocentrum* sp. (10.26%), *Microsetella* sp. (10.26%), *Oncaea* sp. (10.26%), *Pteropods* sp. (7.69%), *Calanus* sp., (7.69%), *Synedra* sp. (5.13%), and *Oithona* sp. (5.13%). At the same time, the rest of the species were counted for 2.56% each and presented in Table 2. In addition, 11 species of plankton were found in a water sample at a depth of 2.5 m in Tawang Bay.

The top 6 most abundant species were *Calanus* sp. (28.00%), followed by *Prorocentrum* sp. (12.00%), *Paracyclops* sp. (12.00%), *Microsetella* sp. (12.00%), *Oncaea* sp. (8.00%), and *Oithona* sp. with an abundance of 8.00%. While the rest plankton species, including *Synedra* sp., *Ceratium* sp., *Pteropods* sp., *Macrophthalmus* sp., and *Sagitta* sp., were counted at 4.00% each, Table 2.

**Table 1.** Plankton species identified from Prigi Bay at four depths of water column**Table 2.** Plankton species identified from Tawang Bay at four depths of water column

Depth	Species	Density (ind./L)	Depth	Species	Density (ind./L)
0.3 m (surface)	<i>Cyclotella</i> sp.	8	0.3 m (surface)	<i>Synedra</i> sp.	16
	<i>Penilia</i> sp.	8		<i>Oscillatoria</i> sp.	8
	<i>Noctiluca</i> sp.	8		<i>Spirulina</i> sp.	8
	<i>Prorocentrum</i> sp.	16		<i>Ceratium</i> sp.	32
	<i>Dinophysis</i> sp.	16		<i>Prorocentrum</i> sp.	32
	<i>Ceratium</i> sp.	8		<i>Pteropods</i> sp.	24
	<i>Ceratium</i> sp.	8		<i>Acartia</i> sp.	40
	<i>Pteropods</i> sp.	24		<i>Microsetella</i> sp.	32
	<i>Paracyclopsina</i> sp.	56		<i>Calanus</i> sp.	24
	<i>Acartia</i> sp.	48		<i>Oithona</i> sp.	16
	<i>Microsetella</i> sp.	8		<i>Oncaea</i> sp.	32
	<i>Euphausia</i> sp.	8		<i>Euphausia</i> sp.	8
	<i>Lucifer</i> sp.	8		<i>Macrophthalmus</i> sp.	8
	<i>Oipheureidea</i> sp.	8		<i>Clytemnestra</i> sp.	8
<i>Sagitta</i> sp.	16	<i>Cypris</i> sp.	8		
<i>Nematea</i> sp.	8	Unclassified Fish larvae	8		
<i>Actinulla larvae</i>	8	Unclassified flatworms	8		
2.5 m	<i>Rizosolenia</i> sp.	8	2.5 m	<i>Synedra</i> sp.	8
	<i>Penilia</i> sp.	8		<i>Prorocentrum</i> sp.	24
	<i>Ceratium</i> sp.	24		<i>Ceratium</i> sp.	8
	<i>Dinophysis</i> sp.	16		<i>Pteropods</i> sp.	8
	<i>Paracyclopsina</i> sp.	64		<i>Paracyclopsina</i> sp.	24
	<i>Acartia</i> sp.	72		<i>Calanus</i> sp.	56
	<i>Microsetella</i> sp.	24		<i>Oithona</i> sp.	16
	<i>Oncaea</i> sp.	16		<i>Microsetella</i> sp.	24
	<i>Codonopsis</i> sp.	8		<i>Oncaea</i> sp.	16
	<i>Oipheureidea</i> sp.	8		<i>Macrophthalmus</i> sp.	8
	<i>Sagitta</i> sp.	8		<i>Sagitta</i> sp.	8
<i>Actinula</i> sp.	8				
<i>Rotylnaete</i>	8	5 m	<i>Melosira</i> sp.	8	
5.0 m	<i>Oikopleura</i> sp.		8	<i>Synedra</i> sp.	8
	<i>Synedra</i> sp.		8	Bivalve larvae	8
	<i>Coscinodiscus</i> sp.		8	<i>Prorocentrum</i> sp.	16
	<i>Ceratium</i> sp.		8	<i>Dinophysis</i> sp.	8
	<i>Pteropods</i> sp.		8	<i>Microsetella</i> sp.	8
	<i>Paracyclopsina</i> sp.		48	<i>Calanus</i> sp.	48
	<i>Acartia</i> sp.		64	<i>Oithona</i> sp.	24
	<i>Microsetella</i> sp.		8	Naupli Copepoda	16
	<i>Oithona</i> sp.		16	<i>Temora</i> sp.	8
	<i>Lucifer</i> sp.	8	<i>Oncaea</i> sp.	8	
<i>Sagitta</i> sp.	24	<i>Sagitta</i> sp.	8		
20.0 m (Bottom)	<i>Synedra</i> sp.	8	20 m (bottom)	<i>Rhizosolenia</i> sp.	8
	<i>Penilia</i> sp.	8		<i>Pleurosigma</i> sp.	8
	<i>Noctiluca</i> sp.	8		<i>Prorocentrum</i> sp.	24
	<i>Dinophysis</i> sp.	24		<i>Ceratium</i> sp.	8
	<i>Ceratium</i> sp.	16		<i>Dinophysis</i> sp.	8
	<i>Pteropods</i> sp.	24		<i>Microsetella</i> sp.	4
	<i>Acartia</i> sp.	56		<i>Calanus</i> sp.	6
	<i>Paracyclopsina</i> sp.	32		<i>Acartia</i> sp.	24
	<i>Oithona</i> sp.	8		<i>Oithona</i> sp.	24
	<i>Microsetella</i> sp.	16		<i>Oncaea</i> sp.	16
	<i>Euphausia</i> sp.	8		<i>Caridean</i> sp.	8
<i>Protoperidinium</i> sp.	8	Unclassified flatworm	8		
<i>Sagitta</i> sp.	16				

Furthermore, 12 plankton species were identified from the water sample at 5 m depth. The top 4 most common species were *Calanus* sp. with an abundance of 28.57%, *Oithona* sp. with an abundance of 14.29%, *Copepoda nauplii* with an abundance of 9.52%, *Prorocentrum* sp. with an abundance of 9.52%. While the rest of the species, including *Melosira* sp., *Synedra* sp., *Dinophysis* sp., *Microsetella* sp., *Temora* sp., *Oncaea* sp., and *Sagita* sp., with an abundance of 5.00%, respectively. While in the bottom waters of Tawang Bay (20 m depth), 12 plankton species were identified. The top 9 most abundant species were *Prorocentrum* sp. with an abundance of 16.44%, *Acartia* sp. with an abundance of 16.44%, *Oithona* sp. with an abundance of 16.44%, *Oncaea* sp. with an abundance of 10.96%, *Dinophysis* sp. with an abundance of 5.48%, *Rhizoselenia* sp. with an abundance of 5.48%, *Pleurosigma* sp. with an abundance of 5.48%, *Ceratium* sp. with 5.48%, *Caridean* sp. (5.48%). At the same time, the rest species are presented in table 2.

### Diversity indices

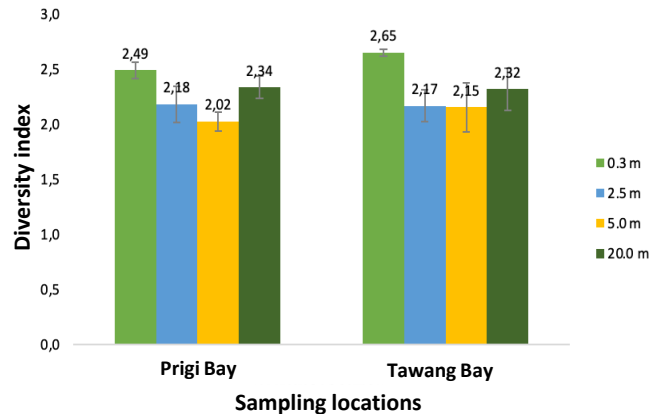
The diversity index values obtained in the waters of Prigi Bay, Trenggalek District, were  $2.49 \pm 0.07$  at a depth of 0.0-0.3 m depth of water column,  $2.18 \pm 0.16$  at a depth of 2.5 m,  $2.02 \pm 0.08$  at a depth of 5 m, and  $2.34 \pm 0.10$  at the 20 m water column. Those indicate that the Prigi Bay waters have moderate diversity. While the diversity index values obtained in the waters of Tawang Bay, Pacitan District were  $2.65 \pm 0.03$  at 0.0 - 0.3 m depth,  $2.17 \pm 0.15$  at the 2.5 m depth,  $2.15 \pm 0.22$  at a 5 m depth, and  $2.32 \pm 0.19$  at a depth of 20 m which indicates that the waters of Tawang Bay also have moderate diversity, Figure 2.

### Uniformity indices

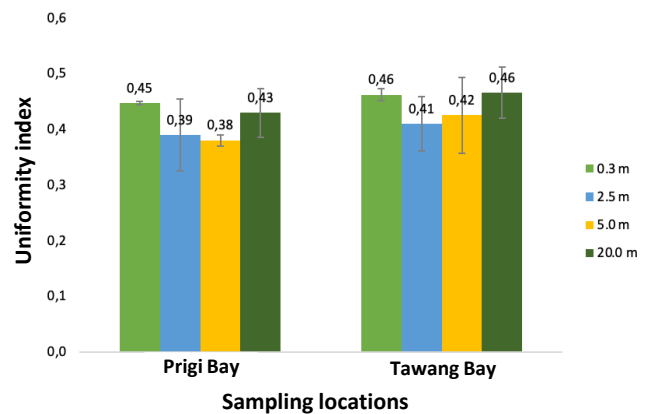
The uniformity index values obtained in the water column of Prigi Bay were  $0.45 \pm 0.01$  at 0.0-0.3 m depth (surface water column),  $0.39 \pm 0.06$  at a depth of 2.5 m,  $0.38 \pm 0.01$  at a depth of 5 m and  $0.43 \pm 0.04$  at the 25m depth or bottom of the water column. These index values indicated that the uniformity of plankton in Prigi Bay was moderate. At the same time, the uniformity values obtained in Tawang Bay were  $0.46 \pm 0.01$  at 0.0-0.3 m depth,  $0.41 \pm 0.05$  at a depth of 2.5 m,  $0.42 \pm 0.07$  at a depth of 5 m, and  $0.46 \pm 0.05$  at 25 m depth or bottom of the water column. Similarly, uniformity indices of plankton in Tawang Bay were also considered at a moderate level, Figure 3.

### Dominance index

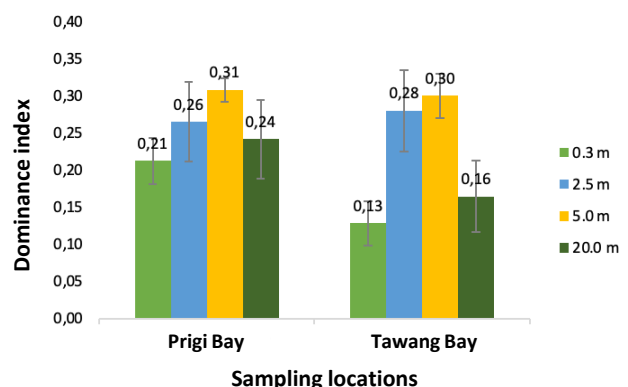
Dominance index values obtained from the waters of Prigi Bay were  $0.21 \pm 0.03$  at the 0.0-0.3 m depth,  $0.26 \pm 0.05$  at a depth of 2.5 m,  $0.31 \pm 0.02$  at a depth of 5 m and  $0.24 \pm 0.05$  at the 20 m water depth. These values mean no plankton species were dominant in the natural habitat of spiny lobster larvae (Prigi Bay). While the dominance index values obtained from Tawang Bay waters were  $0.13 \pm 0.03$  at the 0.0-0.3 m depth,  $0.28 \pm 0.05$  at a depth of 2.5 m,  $0.30 \pm 0.03$  at a depth of 5 m, and  $0.16 \pm 0.05$  at the 20 m depth. Similarly, the values obtained from the surface to the bottom of the waters show that no species dominate in Tawang Bay (Figure 4).



**Figure 2.** Diversity indices of plankton identified at the water column of Prigi Bay and Tawang Bay, East Java, Indonesia. Bars are the average values with a standard deviation of three replicates



**Figure 3.** Uniformity indices of plankton identified in Prigi Bay and Tawang Bay, East Java, Indonesia. Bars are the average values with a standard deviation of three replicates



**Figure 4.** Dominance indices of plankton identified at Prigi Bay and Tawang Bay, East Java, Indonesia. Bars are the average values with a standard deviation of three replicates

## Discussion

Environmental conditions, including physical, chemical, and biological factors in natural habitats, highly determine the recruitment rates of lobster larvae (Keulder 2005). Several studies have previously reported the physical and chemical characteristics of the settlement area of lobster (Amin et al. 2022b; Boudreau et al. 1992; Lillis and Snelgrove 2010). However, studies viewing biological aspects of settlement habitat in natural environment lobster larvae are still very limited. Meanwhile, many studies conclude that biological factors such as plankton availability would be important information on the natural diets of lobster larvae (O'Rorke et al. 2014). Thus, the present study investigated the diversity, uniformity, and dominance of plankton in two common settlement areas of lobster larvae in East Java (Karanggongso of Prigi Bay and Tawang Bay) in Indonesia. The sampling was performed in 4 different depths, which were 0.3 m, 2.5 m, 5 m, and 20 m depth, as lobster larvae vertically migrated from the bottom during the daytime to the surface of the water during the nighttime. It was also discovered that the diversity indices of plankton at both locations were 2.02-2.49 at Karangongso of Prigi Bay, and 2.15-2.65 at Tawang Bay. The diversity index values found at these two locations were all less than 3, which means at a moderate level. The high or low value of plankton diversity can be caused by the evenly distributed abundance of each individual. In another sense, no species have relatively more diversity than other species (Awwaluddin et al. 2017). Therefore, the diversity indices of plankton at Prigi Bay and Tawang Bay, which are at a moderate level may suggest that plankton communities are in relatively equal distribution of different species, with no species being significantly more prevalent than others (Awwaluddin et al. 2017).

Similarly, the uniformity indices of plankton in both settlement areas were classified at a moderate level (0.38-0.45 at Prigi Bay and 0.41-0.46 at Tawang Bay). The uniformity values found at each location, Karangongso of Prigi Bay water and Tawang Bay water, are categorized as moderate uniformity. The uniformity value is categorized as moderate if the value ranges from 0.4-0.6 (Ulfah et al. 2019). The availability of nutrients, food, and predation processes can affect the high value of uniformity because it affects the type and amount of plankton. Besides that, physical and chemical factors also affect the value of uniformity because it will affect the growth of plankton (Nugroho et al. 2020). In addition, since the distribution of plankton in both water samples is uniform, a high degree of uniformity can be asserted. While the dominance indices ranged from 0.21-0.31 at Prigi Bay and 0.13-0.30 in Tawang Bay. The result indicates no dominant species at both locations since all values < 0.05. Dominance index values obtained in both waters indicate the absence of plankton which dominates in Prigi Bay and Tawang Bay. The dominance index value indicates whether organisms are dominant in a water environment. A value between 0.5 to 1 on the dominance index shows the presence of dominant organisms in the water. On the other hand, a value less than 0.5 indicates no dominant organisms are present in the water (Berger and Parker 1970).

## Potential diet for lobster seeds

The result also revealed that 17 plankton species were identified from the surface water, 13 species at a depth of 2.5 m, 11 at a depth of 5 m, and 13 at 20 m (bottom) of Prigi Bay. At the same time, 17 plankton species were discovered on the surface of Tawang Bay waters: 11 species at a depth of 2.5 m, 12 species at a depth of 5 m, and 12 species at the seafloor. In general, the number of plankton species identified in the present study is higher than in previous studies reported from other lobster larvae settlement habitats in Awang Bay, West Nusa Tenggara (Amin et al. 2022b) and Wedi Ombo Bay, Yogyakarta (Trijoko and Pasaribu 2004). The most abundant species identified from Prigi Bay are mainly from Phylum Arthropoda, including *Paracyclops* sp., *Oithona* sp., *Acartia* sp., and *Calanus* sp. Other prominent species included *Prorocentrum* sp., *Dinophysis* sp., and *Ceratium* sp., which belonged to the phylum Dinoflagellata. While phylum Arthropoda, including *Acartia* sp., *Oithona* sp., *Oncaea* sp., *Calanus* sp., *Paracyclops*, and *Macrophthalmus* sp., also dominated the most abundant species found in Tawang Bay. Plankton species in this area are also dominated by phylum Dinoflagellata such as *Ceratium* sp., *Prorocentrum* sp., and *Dinophysis* sp. Of these identified plankton species, 11 species were found in both locations, including *Acartia* sp., *Ceratium* sp., *Dinophysis* sp., *Euphausia* sp., *Microsetella* sp., *Oithona* sp., *Paracyclops* sp., *Pteropods* sp., *Rizosolenia* sp., *Sagitta* sp., *Synedra* sp. These findings suggest that the planktonic community in both bays is dominated by species belonging to the phylum Arthropoda and Dinoflagellata, which are known to be important components of the marine food web.

Among the identified plankton species, few species have been documented as potential live diets in aquaculture, including *Oithona* sp., for a live diet of European seabass (*Dicentrarchus labrax*) postlarvae (Magouz et al. 2021a) and shrimp larvae (Dinesh Kumar et al. 2017). Therefore, *Acartia* sp. could possess a live diet for seabass larvae, *Lates calcarifer* (Rajkumar 2006), fat snook, *Centropomus parallelus* (Barroso et al. 2013), and many other aquatic larvae (Sarkisian et al. 2019). Some studies also confirmed that these plankton species were identified in the content stomach of lobster larvae. For instance, *Oithona* sp. has been reported from the stomach content of spiny lobsters at the early life stage (Amin et al. 2022c; Khvorov et al. 2012). Furthermore, *Oithona* sp. has been described as a marine calanoid copepod with high protein content, ~59.33% (Santanumurti et al. 2021), therefore frequently used as a live diet for fish or shrimp larvae. Another study has documented that *Oithona* sp. had a high content of fatty acid profiles including polyunsaturated fatty acids (26.47%) and omega-3 fatty acids (36.30), which are higher than a commercial live diet such as *Artemia* sp. (Magouz et al. 2021b). Furthermore, *Acartia* sp. has also been documented to be a good live diet for aquatic larvae such as seabass larvae, *Lates calcarifer* (Rajkumar 2006), and fat snook, *Centropomus parallelus* (Barroso et al. 2013). *Acartia clausi* has been described to have higher contents of proteins (63.12%) and lipids

(16.65%) and is also richer in n - 3 fatty acids (33.94%) than *Artemia nauplii* and rotifers (Rajkumar 2006). The plankton species have also been identified in spiny lobster larvae's stomach content (Amin et al. 2022b; Amin et al. 2022c). In addition, a member of *Acartia* (*Acartia tonsa*) had been documented to provide an important nutritional benefit to fat snook larvae undergoing metamorphosis (Vanacor-Barroso et al. 2017).

Other potential food sources for lobster larvae identified in the present study are zooplankton and phytoplankton. The plankton results found at each station consist of Bacillariophyceae (e.g., *Rizosolenia* sp., *Synedra* sp., *Cyclotella* sp.) and Copepoda (e.g., *Oithona* sp., *Acartia* sp., *Calanus* sp.). These plankton groups were identified at each station, highlighting their potential as a food source for lobster larvae. Diatoms, which belong to the phytoplankton group Bacillariophyceae, contain essential nutrients required for the growth of lobster larvae, such as PUFA (Polyunsaturated Fatty Acid). The PUFA is the major fatty acid in Bacillariophyceae diatoms (Pahl et al. 2010), including EPA (eicosapentaenoic acid, 20:5 n-3) and DHA (docosahexaenoic acid 22:6 n-3). Therefore, PUFA is the major fatty acid in Bacillariophyceae diatoms (Pahl et al. 2010). PUFA content of these diatoms is relatively high, with levels ranging between 23.4 and 60.7% (Valera and Saavedra, 2016). High PUFA content was identified in several plankton species as potential prey for spiny lobster larvae *Jasus edwardsii*, and these long-chain fatty acids are an essential nutrient for spiny lobster (Koshio and Kanazawa 1994; Liddy et al. 2004; Wang 2013).

Copepoda (Hexanauplia) is a rich source of protein, particularly in gastropods; it is also high in calcium content which is important for lobster during molting (Kirno et al. 2012). Several studies, such as those by Alka (2016), Chow (2011), and Connel (2007), have reported the presence of copepods in the digestive tracts of lobster larvae. That suggests copepods are a preferred food for lobster larvae. Protein is the predominant organic nutrient in the spiny lobster larvae and their preferred prey (Wang 2013). This is consistent with prior examinations of digestive enzymes of phyllosoma of *J.edwardsii* and *Panulirus ornatus*, which reveal that they necessitate a high-protein diet and will utilize protein to generate energy during food deprivation (Johnston et al. 2004a, 2004b, 2006). Copepods contain high protein content, ranging from 28.9-84.9 % of dry weight, indicating that lobster larvae consume prey with high protein content (Wang and Jeffs 2014). The protein content of the copepods follows the amount of protein incorporated into artificial feeds for some of the crustacean's larvae, including crab, shrimp, and clawed lobster species, which ranges between 30% to 60% protein (Conklin et al. 1980; Guillaume 1997; Holme et al. 2009). Moreover, copepods are also high in lipids, ranging from 11.3-12.4% (Wang and Jeffs 2014). Rich-lipid diets can be properly digested by the spiny lobster larvae and utilized to supply energy, especially during a food scarcity (Johnston et al. 2004; Liddy et al. 2003; Liddy et al. 2004; Ritar et al. 2003). Furthermore, late-phase phyllosoma of spiny lobster probably targets high lipid prey as they prepare to

accumulate an enormous amount of lipid to fuel their non-feeding post-larval stage (Jeffs et al. 2001a, 2001b). The presence of copepods, especially *Oithona* sp., *Acartia* sp., and *Calanus* sp., in a high abundance value at the Karanggongso of Prigi Bay and Tawang Bay could provide a significant source of high lipid natural diets for spiny lobster larvae. These results suggest that these plankton species are a potential diet for spiny lobster larvae. Therefore, in vivo trials using aquatic animals especially for developing ornate lobster hatcheries, should be further studied.

In conclusion, the number of plankton species found in both locations was more abundant in the surface water (0-0.3 m) compared to the deeper water column. A total of 17 plankton species were identified from the surface water, 13 species at a depth of 2.5 m, 11 species at a depth of 5 m, and 13 species at 20 m (bottom) of Prigi Bay. Similarly, 17 plankton species were discovered from the water surface of Tawang Bay: 11 species at a depth of 2.5 m, 12 species at a depth of 5 m, and 12 species at the seafloor. Based on the diversity, uniformity, and dominance indices, both locations had moderate plankton diversity, and no specific species was dominant over the others. Among the identified plankton species, several members of Bacillariophyceae, Copepoda, and Hexanauplia, such as *Oithona* sp., *Calanus* sp., *Paracyclops* sp., and *Acartia* sp., are considered potential live feed for lobster larvae, and thus should be further studied.

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