Comparison of zooplankton community structure in sea grass ecosystems of Panggang and Semak Daun Islands, Kepulauan Seribu, Indonesia

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Abstract. Research on zooplankton assemblage is indispensable for understanding food web dynamics in marine ecosystems. In this study, we elucidated the composition, spatio-temporal distributions and community structure of zooplankton on the sea grass ecosystem of Panggang and Semak Daun Islands, Kepulauan Seribu National Park. Sampling was conducted monthly at fixed stations by vertical tows of 53 µm plankton net from February 2018 to March 2019. During the study period, a total of 52 genera belonging to 38 families of zooplankton were collected. Copepods and protozoans dominate in the zooplankton communities in both sea grass areas. No significant difference was observed in abundance of zooplankton between two sea grass areas of both islands (p > 0.05), however there were a relatively few significant differences of between day and night time catches of zooplankton (p < 0.05). Day time zooplankton was less abundant than night time. Canonical correspondence analysis underlines that zooplankton assemblages were significantly affected by environmental parameters such as salinity, dissolved oxygen, turbidity, and the percentage of sea grass cover. Moreover, the abundance and zooplankton assemblages were well matched with chlorophyll-a concentrations. Since early stage of fishes feeds directly on the zooplankton assemblage, our findings support that sea grass ecosystem plays an important role as a nursery ground for marine fishes.

1. Introduction
Zooplankton is one of the main components in the sea grass ecosystem and plays a role of importance in energy transfer between phytoplankton and marine fish populations [1, 2]. Moreover, changes in zooplankton community structure and abundance both spatially and temporally are related to the environmental variations [3]. Studies of zooplankton community structure in coastal waters or sea grass ecosystem have been done in many areas of tropical region such as demersal zooplankton communities from tropical habitats [4], zooplankton abundance and community in sea grass and non-sea grass areas of Merambong shoal, Selangor, Malaysia [5], copepod diversity in the Merambong sea grass meadow, Johor, Peninsular Malaysia [6], community structure of zooplankton in natural and artificial sea grass ecosystem, Awur Bay, Jepara, Indonesia [7]. However, there have been few studies on zooplankton composition, spatio-temporal distributions and community structure of zooplankton in
the sea grass ecosystem and its relations to the marine environments in Kepulauan Seribu, National Park, Indonesia [8, 9].

Panggang and Semak Daun Islands are situated in Kepulauan Seribu National Park, Indonesia. The coastal area of both islands is characterized by quite an abundance of sea grass beds [10]. There are different types and densities of sea grass vegetation between coastal waters of Panggang and Semak Daun Islands. Furthermore, Panggang Island is an inhabited island, while Semak Daun Island is uninhabited. Difference in characteristics of both islands may lead to a variety of environmental conditions and then significantly affect zooplankton population [11]. The fluctuation on zooplankton density can influence fish larval and juvenile survival and turn to affect coastal fishery [12]. Thus, in this study, we analyzed composition, spatio-temporal distributions and community structure of zooplankton in the sea grass ecosystem of Panggang and Semak Daun Islands, Kepulauan Seribu National Park.

2. Sampling collection and analysis

2.1. Study area and time
Research was conducted in Panggang and Semak Daun Islands, Kepulauan Seribu National Park, Jakarta, Indonesia. Sampling was carried out at five fixed stations, which spread over both islands, i.e, three stations in Semak Daun Islands and two stations in the Panggang Island (Figure 1). Sampling was conducted monthly at fixed stations from February 2018 to March 2019.

Figure 1. Map of study area in Panggang and Semak Daun Islands, Kepulauan Seribu National Park.
2.2. Zooplankton sampling
Since zooplankton may be distributed in the water column due to water mass mixing [13] in sea grass ecosystem, sampling was conducted by vertical tows of a 53 µm plankton net. Flow meter (TSK) was mounted at the mouth of the plankton net to measure the volume of water filtered. Samples were preserved using 2% of formalin solution. Zooplankton samples were identified to genus level refers to [14, 15]; while zooplankton abundance was expressed as a number of individuals per sample volume (ind/m³) per each sampling time and location. To describe zooplankton community structure, some ecological indices were calculated, namely Shannon-Wiener index, evenness index [16] and dominance index [17]. Comparison of zooplankton abundance and community structure were conducted spatially and temporally. The spatial comparison was carried out between sea grass ecosystems on Panggang and Semak Daun Islands; meanwhile, a temporal comparison was performed for day and night time in Panggang Island only. All statistical analyses were performed using SPSS v. 15.0. To describe the relationship between zooplankton abundance and environmental conditions, we used canonical correspondence analysis (CCA) [18].

2.3. Sea grass observation
Sea grass observation was performed using the line transect method with 1 m² of transect size. Three lines transect along 50 meters of sea grass vegetation from coastal toward the sea. This method is used to determine the percentage of sea grass cover. Sea grass species were identified to species level in accordance Azkab [19].

2.4. Environmental parameters
Environmental conditions consist of physical-chemical and biological parameters. Physical-chemical parameters composed of temperature, salinity, turbidity, depth, dissolved oxygen (DO), and acidity (pH). Biological parameters such as chlorophyll-a concentration and sea grass coverage were obtained from satellite imaging and line transects method, respectively. The chlorophyll-a concentrations were derived from https://oceancolor.gsfc.nasa.gov/. The mapping image data was then analyzed using software Ocean Data View version 5.1.7. The results of the mapping were then adjusted to the zooplankton abundance obtained from the analysis.

3. Results and discussion

3.1. Zooplankton abundance
The total abundance of zooplankton in the coastal waters of the sea grass ecosystem of Panggang Island and Semak Daun Island both spatially and temporally are presented in Figure 2. In general, the abundance of zooplankton increases during the transition of rainy season to dry season (March to May), then decreases in the transition of dry season to the rainy season (August to November). The abundance of zooplankton in Semak Daun Island was higher than Panggang Island in February, March, April, July (Figure 2A), while density of zooplankton in Panggang Island was higher in May, August, and December. Overall, there was no significant difference in zooplankton abundance between sea grass ecosystem in Panggang Island and Semak Daun Island (p > 0.05).
In order to compare density of zooplankton between day and night, zooplankton abundance was calculated from day and night sampling in Panggang Island. Due to the bad weather condition, sampling was not conducted in night time of December 2018. The abundance of zooplankton on sea grass ecosystem of Panggang Island was quite more abundant during day time in February, March, and May. However, the density of zooplankton at night time in other months of the research period was higher than daytime. Overall, we found relatively few significant differences between day and night time catches of zooplankton in the sea grass ecosystem (p-value<0.05). The similar findings in coastal areas of Britsh Columbia, Canada [20] and along Karachi coast of North Arabian Sea, Pakistan [21].

3.2. Composition of zooplankton

A total of 52 genera belonging to 38 families of zooplankton were collected during one year of the study period. Copepods and protozoans were dominating in the zooplankton communities on both sea grass ecosystems of Panggang and Semak Daun Islands. The most abundant genus that always collected in each sampling location in each month of research period were Acartia, Calanus, Eutintinnus, Leprotintinnus, Macrostella, Microstella, Nauplius, Oithona, Paracalanus, and Tintinnopsis. The lists of zooplankton that were occurred in the study sites are shown in Table 1.

The composition of zooplankton species in the coastal waters of the sea grass ecosystem of Panggang Island and Semak Daun Island are shown in Figure 3. There was no difference between the composition of zooplankton species that exists both spatially and temporally. Calanoida, Choreotichida, Cyclopoida, and Harpacticoida were more abundant than other orders. Copepods such as Calanioda, Cyclopoida, and Harpacticoida, have a wide distribution throughout coastal and marine waters [22]. This group has optimum abundance in tropical waters [23] and become the main food items for many fish juveniles in Semak Daun Island [24] and Panggang Island [25]. Since early stage of fishes feeds directly on the zooplankton assemblage, our findings support that sea grass ecosystem plays an important role as a nursery ground for marine fishes.
Table 1. List of zooplankton that found during one year of sampling period in Semak Daun and Panggang Islands, Kepulauan Seribu National Park.

| Group       | Phylum          | Subphylum | Class         | Order             | Family              | Genus            |
|-------------|-----------------|-----------|---------------|-------------------|---------------------|------------------|
| Holoplankton| Arthropoda      | Crustacea | Branchiopoda  | Onychopoda        | Podonida            | Evadne           |
|             |                 |           | Hexanauplia   | Cyclopoida        | Corycaeidae         | Corycaeus        |
|             |                 |           |               |                   | Sapphirinidae       | Copilia          |
|             |                 |           |               |                   | Oithonida           | Sapphirina       |
|             |                 |           |               |                   | Oncaeaia            | Oithona          |
|             |                 |           |               |                   | Oncaeida            | Oncaea           |
|             |                 |           | Calanoida     | Acartiida         | Calanida            | Calanus          |
|             |                 |           |               |                   |                     | Centropages      |
|             |                 |           |               |                   |                     | Eucalanus        |
|             |                 |           |               |                   |                     | Paracalanus      |
|             |                 |           |               |                   |                     | Pseudocalanus    |
|             |                 |           |               |                   |                     | Metridia         |
|             |                 |           |               |                   |                     | Earytemora       |
|             |                 |           | Herpacticoida |                   |                     | Macrosetella     |
|             |                 |           |               |                   |                     | Microsetella     |
|             |                 |           |               |                   |                     | Clytemnestra     |
|             |                 |           |               |                   |                     | Eusterpina       |
|             |                 |           |               |                   |                     | Conchoecia       |
|             |                 |           |               |                   |                     | Euphausia        |
|             |                 |           |               |                   |                     | Mysis            |
|             |                 |           |               |                   |                     | Neomyys          |
|             |                 |           | Ostracoda     | Halocyprida       | Metridinida         | Sagitta          |
|             |                 |           |               |                   | Temorida            | Oikopleura       |
|             |                 |           |               |                   | Miraciida           | Salpa            |
|             |                 |           |               |                   |                     | Thalia           |
|             |                 |           | Malacostraca  | Euphausiacea      | Pelphidiida         | Mesodinium       |
|             |                 |           |               |                   | Euphausiida         | Orthodonta       |
|             |                 |           |               |                   | Mysisia             | Eutintinnas      |
|             |                 |           |               |                   |                     | Leprotintinnas   |
|             |                 |           |               |                   |                     | Tintinnopsis     |
|             |                 |           |               |                   |                     | Cyttarocylida    |
|             |                 |           |               |                   |                     | Codonellopoda    |
|             |                 |           |               |                   |                     | Pychocylida      |
|             |                 |           |               |                   |                     | Rhabdonella      |
|             |                 |           |               |                   |                     | Steinstrupiella   |
|             |                 |           |               |                   |                     | Bolivina         |
|             |                 |           |               |                   |                     | Globigerina      |
|             |                 |           |               |                   |                     | Orbulina         |
| Chaetognatha| Chaetognatha    | Tunicata  | Appendicularia| Copelata           | Sagittida           | Sagitta          |
| Chordata    |                 |           | Thaliacea     | Salpida           | Oikopleurida        | Oikopleura       |
|             |                 |           |               |                   | Salpida             | Salpa            |
|             |                 |           |               |                   |                     | Thalia           |
| Ciliophora  | Intramacronucleata | Litostomatea | Gymnostomatida | Mesodinida        | Cth ballotida       | Mesodinium       |
|             |                 |           |               |                   | Mysidida            | Orthodonta       |
|             |                 |           |               |                   |                     | Eutintinnas      |
|             |                 |           |               |                   |                     | Leprotintinnas   |
|             |                 |           |               |                   |                     | Tintinnopsis     |
|             |                 |           |               |                   |                     | Cyttarocylida    |
|             |                 |           |               |                   |                     | Codonellopoda    |
|             |                 |           |               |                   |                     | Pychocylida      |
|             |                 |           |               |                   |                     | Rhabdonella      |
|             |                 |           |               |                   |                     | Steinstrupiella   |
|             |                 |           |               |                   |                     | Bolivina         |
|             |                 |           |               |                   |                     | Globigerina      |
|             |                 |           |               |                   |                     | Orbulina         |
| Foraminifera| Foraminifera    | Globobalamea| Rotaliida      | Bolmimitida       | Lopadorrhynchidac   | Lopadorrhynchus  |
|             |                 |           |               |                   | Globobergeridac     | Pelagobia        |
|             |                 |           |               |                   |                     | Polydora         |
| Meroplankton| Annelida        | Annelida  | Polychaeta    | Phylodocida       | Lopadorrhynchidac   | Lopadorrhynchus  |
|             |                 |           |               |                   | Globobergeridac     | Pelagobia        |
|             |                 |           |               |                   |                     | Polydora         |
|             | Arthropoda      | Crustacea | Hexanauplia  | Cyclopoida        | Spionida            | Spionida         |
|             |                 |           |               | Sessilia          | Cyclopoida          | Cyclopoida       |
|             |                 |           | Malacostraca  | Decapoda          | Spionida            | Nauplius         |
|             |                 |           |               |                   | Balanida            | Balanus          |
|             |                 |           | Cnidaria      | Hydrozoa          | Gnatohpausidac      | Zoa              |
|             |                 |           |               |                   | Campunariadac       | Obelia           |
|             |                 |           |               |                   | Eirenidac           | Eutima           |
|             |                 |           |               |                   |                     | Diphyidae        |
|             |                 |           |               |                   |                     | Diphyidae        |
|             |                 |           |               |                   |                     | Diphyidae        |
|             | Echinodermata   | Asterozoa | Ophiuroidea   | Amphipodida       | Ophiuropleus        | Echinopluteus    |
|             |                 |           |               |                   | Ophiuropleus        | Echinopluteus    |
| Mollusca    | Mollusca        | Gastropoda| Pteropoda     | Limacinida        | Limacina            | Limacina         |
Figure 3. The composition of the zooplankton order on Panggang Island at day and night time, and Semak Daun Island.

Zooplankton composition is also different based on its life cycle, which consists of holoplankton and meroplankton. Holoplankton is plankton that a whole life cycle as a planktonic organism. Meanwhile, meroplankton is a group of plankton that one phase of its life cycle as a planktonic organism [26]. The composition and abundance of holoplankton and meroplankton were distinguished by season and presented in Figure 4. Holoplankton has a higher abundance compared to meroplankton in both islands. The abundance of holoplankton and meroplankton were highest in the transition Season 1 (March to May) and the lowest in the transition Season 2 (August to November).

3.3. Community structure of zooplankton
Community structure is a concept that studies the composition and abundance of species as a community unit. Community structure can be studied through the approach of biological index, the interaction between species, and functional interactions. The biology index is a measure estimation of environmental health conditions using biological indicators [27]. Commonly, the biological index used consists of diversity, uniformity, and dominance index which is derived through the Shannon-Wiener formula. Zooplankton community structure spatially and temporally is presented in Figure 5. There was no descriptive difference between all indexes value both spatially and temporally. Overall, the diversity index and uniformity (evenness index) were almost in the same range of values. Meanwhile, the dominance index value showed that there were no zooplankton species that dominates on sea grass ecosystem of Panggang and Semak Daun Islands.
Figure 4. Composition and abundance of holoplankton and meroplankton on Panggang and Semak Daun Islands.
Figure 5. Zooplankton community structure.

3.4. Percentage of sea grass cover
The percentage of sea grass cover describes the mean coverage of seabed areas by sea grass vegetation in percent units [28]. The results of observations of the percentage of sea grass cover on Panggang Island and Semak Daun Island are presented in Table 2.

| Station   | Panggang Island | Semak Daun Island |
|-----------|-----------------|-------------------|
| North     | 30              | 43                |
| East      | -               | 40                |
| South     | 27              | 27                |
The percentage of sea grass cover on Semak Daun Island was higher than Panggang Island (Table 2). The extent of sea grass coverage determines the health level of sea grass ecosystems [29]. Sea grass ecosystems with high sea grass cover areas generally have a higher abundance of zooplankton rather than sea grass ecosystems with low sea grass cover areas [5].

3.5. Composition of sea grass
The results of sea grass identification are presented to determine the composition of sea grass species that are most commonly found at each research station on each island and presented in Figure 6. The results of the measurement percentage of sea grass species in the quadrant transect showed that the sea grass ecosystem on Panggang Island was dominated by *Thalassia hemprichii*, followed by *Halodule uninervis* and *Enhalus acoroides*. At the same time, sea grass species on Semak Daun Island consist of *Thalassia hemprichii*, *Halodule uninervis*, and *Syringodium isoetifolium*.

![Figure 6. Composition of sea grass species on Semak Daun Island (A) and Panggang Island (B). EA (Enhallus acoroides), HU (Halodule uninervis), SI (Syringodium isoetifolium), TH (Thalassia hemprichii).](image)

Sea grass ecosystems with different compositions of sea grass species and the same expanse area may have different aquatic nutrient content. Aquatic nutrient content is generally higher in sea grass ecosystems which are dominated by sea grass species with smaller morphological structures. Binding ability of nutrients is influenced by surface area of sea grass. Sea grass species with smaller morphological structures have a greater surface area to binding nutrients from the waters [7].

3.6. The relationship of zooplankton abundance and water environmental conditions
Zooplankton has a high response to the influence of physical and chemical aquatic environments [30]. Therefore, the abundance and distribution of zooplankton are affected by physical–chemical conditions [31]. CCA was carried out for 12 genera of zooplankton that have the highest abundance and always found in every month. This analysis was conducted to determine the relationship zooplankton assemblages with the existing of environmental parameters (Figure 7).

Figure 7 shows three zooplankton groups that are strongly associated with certain environmental parameters. The first group in the second quadrant, consists of *Acartia*, *Calanus*, and *Paracalanus* which positively correlated by salinity, dissolved oxygen and sea grass cover. The second group is in the third quadrant, consists of *Eutintinnus*, *Leprotintinnus*, *Ophiopluteus*, and *Tintinnopsis*, which are negatively correlated with salinity, dissolved oxygen, and sea grass cover. The third group is in the fourth quadrant, consists of *Macrostella*, *Microstella*, and *Oithona* which are positively correlated with turbidity.
3.7 The relationship of zooplankton abundance and chlorophyll-a concentration

The mapping between chlorophyll-a concentration with zooplankton abundance is presented in Figure 8. The highest chlorophyll-a concentration was found in February 2018 and March 2019 with values ranged between 2.8-3.8 mg/m³; while the lowest was found in September and November 2018 with the concentration values ranging from 1.3-2.1 mg/m³. The mapping results show a linear relationship between chlorophyll-a concentration (X) and zooplankton abundance (Y), namely $Y = 1414.54 + 322.27X$, with determination coefficient ($R^2$) of 57.26%. Even though the determination coefficient was not too strong, but there was a tendency that the abundance and zooplankton assemblages in line with chlorophyll-a concentrations. The relationship between zooplankton abundance with chlorophyll-a concentration is not too strong [32]. Sometimes the chlorophyll-a concentration cannot directly describe the abundance of zooplankton.

4. Conclusion

There is no significant difference was observed in abundance of zooplankton between two sea grass areas of both islands (p > 0.05), however there was a significant difference between night and day sampling (p < 0.05). Daytime zooplankton was less abundant than night time. Canonical correspondence analysis underlines that zooplankton assemblages were significantly affected by environmental parameters such as salinity, dissolved oxygen, turbidity, and the percentage of sea grass cover. There is a tendency that zooplankton assemblages are in line with chlorophyll-a concentrations. Copepods such as Calanioda, Cyclopoida, and Harpacticoida are a dominant group of zooplankton in sea grass areas of both islands and play an important role as the main food items for many fish juveniles. Since early stage of fishes feeds directly on the zooplankton assemblage, our findings support that sea grass ecosystem in Kepulauan Seribu National Park has an indispensable role as nursery habitat for marine fishes.
Figure 8. Chlorophyll-a concentration [mg/m³].
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