

# Plankton diversity in Raja Ampat: foundation of the coral reef trophic structure

Inna Puspa Ayu<sup>1\*</sup>, Niken T.M. Pratiwi<sup>1</sup>, Majariana Krisanti<sup>1</sup>, Mufti Aprizan<sup>1</sup>, Dondy Arafat<sup>1</sup>, Aldiano Rahmadya<sup>2</sup>, Beginer Subhan<sup>1,3</sup> and Davin H. E. Setiamarga<sup>1,3,4,5,6</sup>

<sup>1</sup>Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Indonesia

<sup>2</sup>Research Center for Limnology, The Indonesian Institute of Science

<sup>3</sup>Department of Applied Chemistry and Biochemistry, National Institute of Technology (KOSEN), Wakayama College, Gobo, Wakayama 644-0023, Japan

<sup>4</sup>Advance School for Ecosystem Engineering, National Institute of Technology (KOSEN), Wakayama College, Gobo, Wakayama 644-0023, Japan

<sup>5</sup>Institute for Community Innovation in Collaboration with KOSEN (MILLA), Toyohashi University of Technology, Toyohashi, Aichi 441-8580, Japan

<sup>6</sup>Wakayama Prefectural Museum of Natural History, Kainan, Wakayama 642-0001, Japan

**Abstract.** Raja Ampat, located within the Coral Triangle, features multiple management zones, including core, open access, and tourism areas. Planktons, as the base of the marine food web, play a vital role in sustaining coral reef ecosystems. Understanding their diversity is essential for evaluating ecosystem health and informing conservation efforts. This study aimed to assess plankton biodiversity in the coral reef ecosystem of Raja Ampat. Sampling was conducted in January 2018 across multiple sites from surface waters using a 23  $\mu\text{m}$  mesh net. The samples were preserved in Lugol's solution, quantified microscopically, and morphologically identified. Biodiversity indices were analyzed using the Shannon-Wiener index ( $H'$ ), evenness (E), and dominance (C), whereas spatial patterns were examined using Bray-Curtis cluster analysis. In total, 11–21 phytoplankton taxa were recorded, including *Cyanophyceae*, *Bacillariophyceae*, *Dinophyceae*, and *Chlorophyceae*. Zooplankton consisted of 2–6 taxa from Protozoa, Crustacea, and Chaetognatha. Phytoplankton diversity was the highest in Arefi ( $H' = 2.21$ ) and the lowest in Paniki Besar. Cluster analysis identified three phytoplankton groups and two zooplankton groups. These findings highlight the spatial variation in plankton communities and emphasize their value as indicators of coral reef ecosystem structure and health in the Raja Ampat.

**Keywords:** Community-structure, conservation, food-web, indicator, morphology

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\* Corresponding author: [inna@apps.ipb.ac.id](mailto:inna@apps.ipb.ac.id)

## 1 Introduction

Raja Ampat is located in the West Papua Province, Indonesia. Raja Ampat has more than 1500 small islands. Management zones called Marine Protecting Areas (MPAs) have been established to protect the area or called MPAs (Marine Protecting Areas). Management zones include core, open-access, and tourism zones [1]. As the most biodiverse coral triangle area in the world, it is rich in marine resources and has a globally significant biodiversity. The plankton assemblage in the Raja Ampat coral reef ecosystem was diverse.

Biodiversity, as a natural system attribute, can inform the base of the food web in ecosystems. In particular, plankton biodiversity represents the fundamentals of food sources in ecosystems [2]. Plankton, as the base of the aquatic food web and connected to the aquatic environment, could inform conservation strategies for higher trophic organisms, indicate water quality and protect human health, and support marine policy [3].

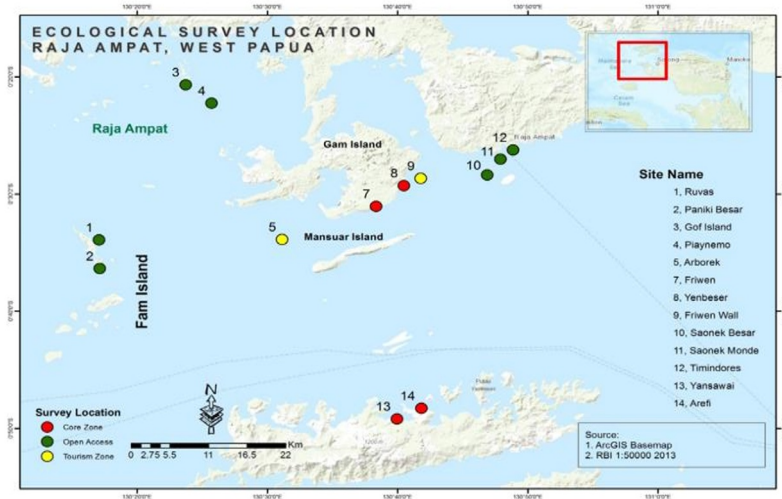
The basic components of biodiversity can be determined using taxonomic information. The plankton in the assemblage were characterized by determining the resulting taxonomic information. Taxonomic data contains present, absent, and abundant plankton species information [4, 5]. Detailed taxonomic data are needed to strengthen the analysis of sensitive species and community level indicators, which are important for recognizing sensitive changes in aquatic ecosystems in conservation and management terms [6].

Currently, plankton taxonomic information is recorded in several databases. The Convention on Biological Diversity (CBD) established the Global Taxonomy Initiative [4]. The development of the dataset created comprehensive resource plankton taxonomy, which is useful for ensuring the availability of plankton data for marine policy and conservation [7].

This study investigates plankton biodiversity in the Raja Ampat Islands, West Papua, Indonesia, to provide fundamental ecological data that contribute to understanding ecosystem functions and guiding future marine conservation strategies. Because plankton are sensitive to environmental changes, the 2018 dataset is valuable for ecological assessments. This allows comparisons between present and future studies to evaluate how plankton communities respond to environmental variability and management interventions. This study aimed to determine the biodiversity of plankton in Raja Ampat Island, West Papua, Indonesia. The findings will contribute to long-term monitoring efforts, support conservation and management strategies, and provide insights relevant to marine policy in the Coral Triangle.

## 2 Methods

Plankton sampling was conducted in January 2018 on the Raja Ampat Island, West Papua, Indonesia (**Fig. 1**). There were 13 stations: open access (Ruvas, Paniki Besar, Golf Island, Piaynemo, Saonek Besar, Saonek Monde, and Timindores), core zones (Friwen, Yenbeser, Yansawai, and Arefi), and tourism zones (Arborek and Friwen Wall).



**Fig. 1.** Sampling location of plankton in Raja Ampat, West Papua, Indonesia.

Water samples were collected using a plankton net with a 23 µm mesh size to filter 100 L of surface water. Plankton samples were preserved in situ with Lugol solution, identified morphologically, and counted under a microscope (Olympus with maximum 40x magnification) following the APHA [8] methods. The identification of plankton, both phytoplankton and zooplankton, followed the guidelines for marine plankton proposed by Yamaji and Thomas. Photographs of plankton were recorded using an Axio camera (Axio ErC5) at 100x magnification. Plankton abundance was observed using a Sedgewick Rafter Counting Chamber (SRC). The abundance of phytoplankton was expressed in cells per m<sup>3</sup> and zooplankton were expressed as individuals per m<sup>3</sup> using the following formula [8]:

$$N = n \times \frac{V_t}{V_{src}} \times \frac{A_{src}}{A_a} \times \frac{1}{V_d} \quad (1)$$

Description:

N= Abundance of phytoplankton (cell/m<sup>3</sup>) or zooplankton (ind/m<sup>3</sup>)

n = Organisms observed (cell)

Vd = Volume of filtered water (m<sup>3</sup>)

Vt = Volume of water filtered (ml)

Vsrc = Volume of the SRC (1 ml)

Asrc = Cross-sectional area of SRC

Aa = Area of observation

The Shannon-Wiener diversity index (H'), evenness index (E), and dominance index (C) were calculated to understand the community structure of plankton. Clustering analysis was performed using the Bray Curtis index to show clusters of plankton spatial distribution based on the species number. The equations for the ecological indices [9] are as follows:

$$H' = -\sum_{i=1}^S p_i \ln p_i \quad (2)$$

with:

H' : Diversity index

p<sub>i</sub> : n<sub>i</sub>/N

n : Total number of organisms of species

N : Total number of organisms of all species

$$E = \frac{H'}{H_{maks}} = \frac{H'}{\ln \ln (S)} \quad (3)$$

with:

E : Evenness index  
 H' : Diversity index  
 H<sub>max</sub> : ln S  
 S : Number of genus

$$C = \sum_{n=1}^n \left( \frac{n_i}{N} \right)^2 \quad (4)$$

with:

C : Simpson domination index  
 n<sub>i</sub> : Total number of organisms of species  
 N : Total number of organisms

Cluster analysis was conducted to assess the similarity among sampling stations based on phytoplankton and zooplankton communities using the Bray-Curtis similarity index. Biodiversity parameters included the Shannon-Wiener diversity index (H'), evenness (E), and dominance index (D), along with plankton composition of both phytoplankton and zooplankton from the abundance of plankton classes.

## 3 Results and discussion

### 3.1 Result

High values of Shannon's index (H') or diversity index of phytoplankton were recorded at the Arefi site compared to other sites (**Table 1**). Low Shannon index values were recorded for the Paniki Besar site. Arefi was located in the core zone, and Paniki Besar was located in the open access zone. The highest zooplankton Shannon's index (H') was recorded for Yansawai.

**Table 1.** Diversity indices of phytoplankton

Location	H' (Diversity Index)	E (Evenness Index)	C (Domination Index)
Ruvas	1.30	0.56	0.42
Paniki Besar	0.70	0.28	0.71
Gof Island	1.34	0.52	0.43
Piaynemo	1.64	0.55	0.37
Arborek	1.50	0.51	0.43
Friwen	1.68	0.56	0.31
Yenbeser	1.48	0.49	0.43
Freiwen Wall	1.91	0.63	0.24
Saonek Besar	1.62	0.54	0.34
Saonek Monde	1.92	0.68	0.22
Timindores	1.90	0.66	0.23
Yansawai	1.53	0.64	0.32
Arefi	2.21	0.73	0.17

The lowest value of the zooplankton Shannon's index (H') was recorded in Yenbeser and Saonek Monde (**Table 2**). The Simpson index varies between 0.17 (Arefi-core zone) and 0.71

(Paniki Besar-open access) for phytoplankton and 0.39 (Yansawai-core zone) and 0.96 (Friwen tourism zone) for zooplankton.

The low dominance index values indicate that there were no predominant species in the plankton community. The evenness index varied from 0.28-0.73 for phytoplankton and 0.14-0.73 for zooplankton.

The highest evenness index of phytoplankton in Raja Ampat was recorded at the Arefi site and the lowest at the Paniki Besar site. The highest evenness index of zooplankton was recorded at the Ruvas site and the lowest at the Friwen site.

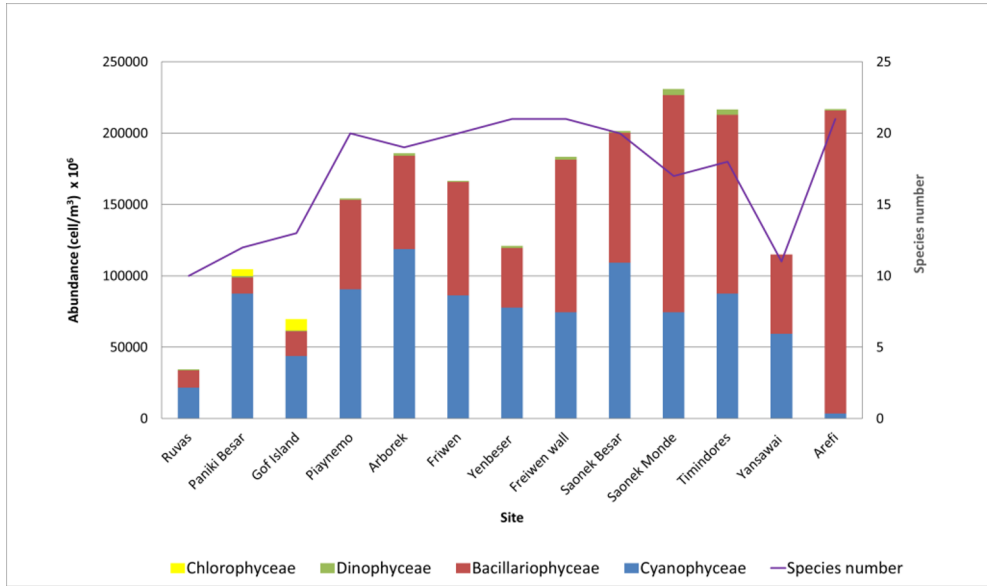
Low species richness for phytoplankton was recorded in Ruvas (Figure 4), and zooplankton were recorded in Saonek Monde and Timindores (Figure 5). Despite high species richness, the overall diversity was lower in several entities due to the strong dominance of a limited number of species (Fig. 5 and 6).

**Table 2.** Diversity indices of zooplankton

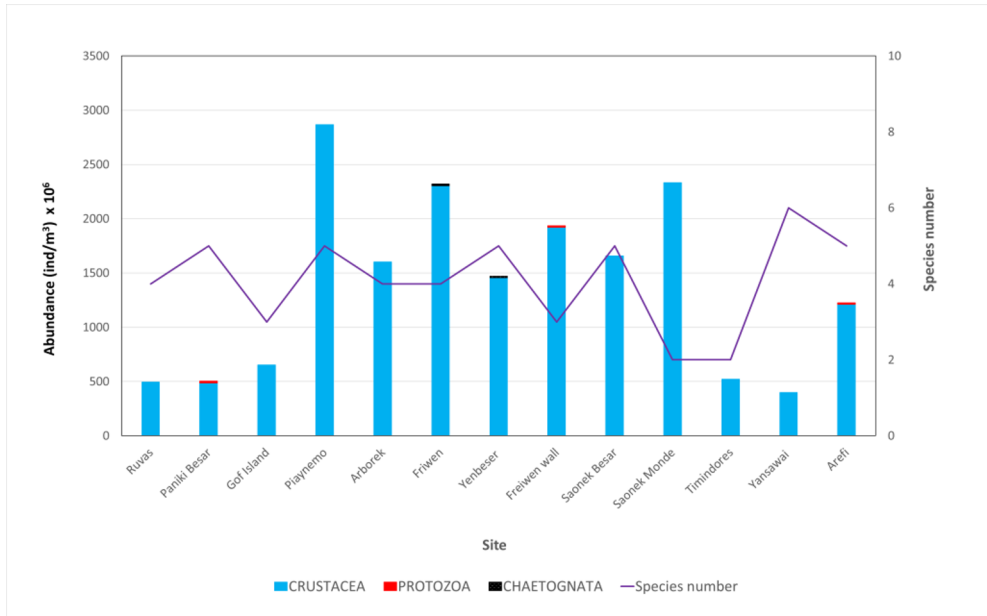
Location	H' (Diversity Index)	E (Evenness Index)	C (Domination Index)
Ruvas	1.00	0.91	0.40
Paniki Besar	1.00	0.62	0.46
Gof Island	0.35	0.32	0.84
Piaynemo	0.25	0.16	0.91
Arborek	0.46	0.33	0.79
Friwen	0.12	0.09	0.96
Yenbeser	0.24	0.15	0.92
Freiwen wall	0.22	0.16	0.91
Saonek Besar	0.19	0.14	0.93
Saonek Monde	0.12	0.17	0.95
Timindores	0.24	0.35	0.88
Yansawai	1.18	0.73	0.39
Arefi	0.53	0.30	0.77

Arefi (core zone), which belongs to the core zone, has the most abundant *bacillariophyceae* ( $212256 \times 10^6$  cell/m<sup>3</sup> or approximately 97.8%) (Fig. 2). Saonek Monde (open access zone) had the second highest *bacillariophyceae* abundance ( $152214 \times 10^6$  cell/m<sup>3</sup> or about 65.89%), and Paniki Besar (open access zone) had the lowest *bacillariophyceae* abundance ( $11502 \times 10^6$  or ~ 10.99%). *Bacillariophyceae* is the most common plankton found in seawater. *Bacillariophyceae* was the dominant phytoplankton group across the study area. In addition to *Bacillariophyceae*, *Cyanophyceae* and *Chlorophyceae* were also present at all sites; however, *Chlorophyceae* was found only at Paniki Besar and Golf Island (open-access zone).

The zooplankton phylum consists of crustaceans, protozoa (unicellular protists), and chaetognatha. Crustacea was found at all sites; protozoa were found in Friwen Wall (tourism zone) and Arefi (open access zone), whereas chaetognatha was only present in Friwen (core zone) and Yenbeser (core zone) (Fig. 3). Piaynemo (open access) had the highest abundance of crustaceans, whereas the lowest was found in Yansawai (core zone).

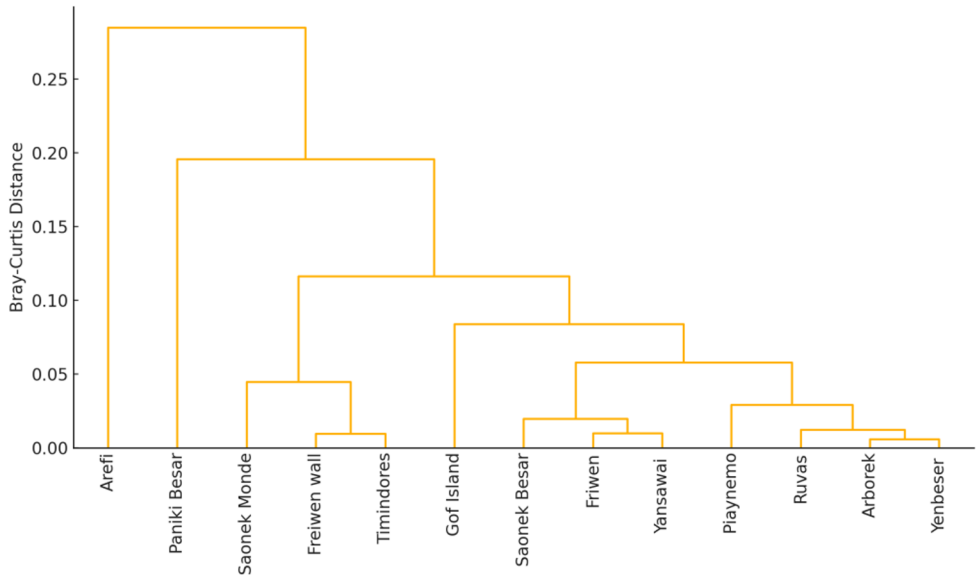


**Fig. 2.** Phytoplankton abundance and species richness in Raja Ampat.



**Fig. 3.** Zooplankton abundance and species richness in Raja Ampat.

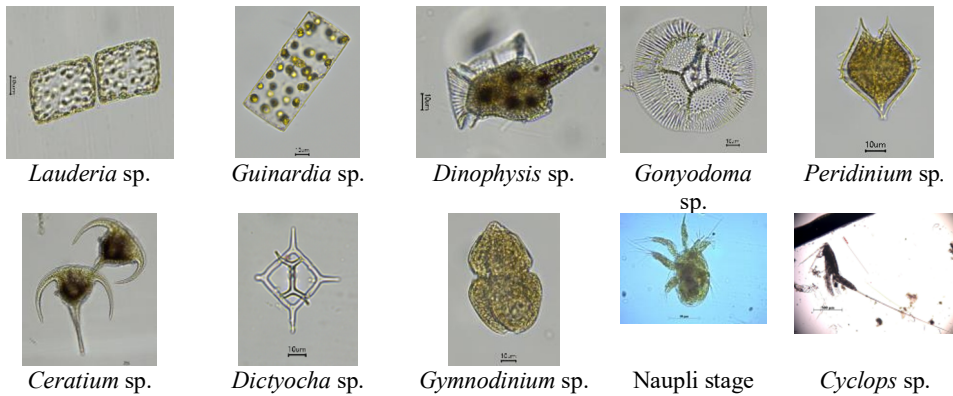
Cluster analysis revealed patterns of similarity among sampling sites based on evenness, diversity, dominance indices, and plankton abundance by class. Four distinct site groups were identified at the 90% similarity threshold. Group one only consisted of Arefi (core zone), whereas Group 2 included only Paniki Besar (open access). Group 3 was comprised of Saonek Monde (open access), Timindores (open access), and Friwen Wall (tourism zone). Group 4 included the following remaining stations: Gof Island (open access), Saonek Besar (open access), Friwen (core zone), Yansawai (core zone), Piaynemo (open access), Ruvas (open access), Arborek (tourism zone), and Yenbeser (core zone) (**Fig. 4**).



**Fig. 4.** Cluster of stations based on biodiversity indices and plankton composition in Raja Ampat.

Diversity indices were obtained by identifying plankton at the genus level. Representative photographs of plankton species observed in Raja Ampat, West Papua, Indonesia, are presented in **Fig. 5**.





**Fig. 5.** Photographs of phytoplankton and zooplankton species in Raja Ampat, West Papua, Indonesia.

### 3.2 Discussion

A high value of Shannon's index ( $H'$ ) indicates planktonic diversity [10]. The diversity index ( $H'$ ) of phytoplankton and zooplankton was below 3 for all stations in this study. The diversity index varies among the ecosystems. In phytoplankton diversity research in Riau Island, Pari Lagoons Island, and Kepulauan Seribu [11, 12, 13], values above 2 of the diversity index indicate a high specific structure of these groups. Indeed, low diversity characterizes young species settlements in principle. While high diversity indicates mature settlements, the low diversity index shows a weak internal population structure [14]. However, in Raja Ampat, the highest value of  $H'$  (2.21) of phytoplankton could indicate a highly specific structure of these groups and characterize mature settlements of species.

The wide range of species evenness values in Raja Ampat reflects the population heterogeneity. The high evenness index showed high similarity in proportion among the species that compose the community. Plankton diversity varied between sites and could have been influenced by environmental factors.

Clustering analysis based on phytoplankton and zooplankton diversity indices revealed distinct spatial patterns across sampling stations. Arefi, located on Batanta Island and designated as a core zone, exhibited the highest relative abundance of *Bacillariophyceae* compared to other sites. In contrast, Yansawai, also located in Batanta and designated as a core zone, was grouped separately in the cluster analysis, indicating notable differences in community structure despite its geographic proximity and similar management status. Paniki Besar, an open-access site on Fam Island, also formed its own cluster, distinct from nearby stations, such as Ruvas, despite sharing similar zoning. Paniki Besar was characterized by the highest relative abundance of *Cyanophyceae*, suggesting that localized environmental or anthropogenic factors influence phytoplankton composition. Saonek Monde and Timindores, both located near Waisai and categorized as open-access areas, exhibited similar phytoplankton diversity indices as Friwen, a tourism zone on Gam Island. These stations formed a separate cluster, reflecting the shared ecological conditions across different management zones. The remaining stations, Saonek Besar, Piaynemo, and Ruvas (open access), Arborek (tourism zone), and Yansawai and Yenbeser (core zones), were grouped into a final cluster. This group had a broader range of phytoplankton diversity indices, suggesting more heterogeneous ecological conditions.

Of particular interest, the zooplankton class Chaetognatha (arrow worms), often considered a bioindicator of healthy marine ecosystems, was uniquely observed at Friwen and Yenbeser. Their presence supports the ecological significance of these sites and may

reflect favorable environmental conditions for higher trophic-level dynamics. The phylum Chaetognatha is a unique group of planktonic organisms that play an important role in the marine food web. Arrowworms are active predators that feed on copepods and other small organisms. Chaetognaths are ecologically sensitive and can serve as bioindicators of ecological–oceanographic pollution changes [14, 15].

*Bacillariophyceae*, *Cyanophyceae*, *Dinophyceae*, *Chlorophyceae* are the phytoplankton classes found at the Raja Ampat site. Their existence was influenced by nutrients; moreover, their distribution was also influenced by current, wave, etc. Therefore, a dataset of chemical and physical parameters is important to justify the presence or absence of phytoplankton in an ecosystem.

Phytoplankton and zooplankton in the food web were linked by predator-prey relationships. The zooplankton dataset, both by time series and distribution, describes the principal relationship between primary producers and the highest consumers at the trophic level. The Zooplankton abundance in group one was lower than in group two. The range of abundance in group one (Ruvas, Paniki Besar, and Yansawai) is  $503 \times 10^2$  ind/m<sup>3</sup>. The abundance in group two is  $2867 \times 10^2$  ind/m<sup>3</sup>. Nauplius was found at all sampling sites, with the highest abundance found in Piaynemo, followed by Saonek Monde, Friwen Wall, and Yenbeser. Piaynemo and Saonek Monde belong to the open-access area, the Friwen wall belongs to the tourism zone, and Yenbeser belongs to the core zone. The limitation of morphological identification in this study is the inability to distinguish Nauplius stadia from copepods or macrocrustacea. The ability to identify each trophic level, such as microcrustacea and macrocrustacea, clearly illustrates the construction of a food web. Furthermore, the presence of meroplankton, such as Nauplius stadia, could provide information for MPAs development.

The results of this research present a biodiversity dataset and interpret plankton community composition. Community data were provided by plankton identification at the species level and were then used in the diversity index calculations [4]. This dataset provides information on the community structure and captures the taxonomic diversity of plankton assemblages.

## 4 Conclusion

There were found 11-21 taxa of phytoplankton belonging to the *Cyanophyceae*, *Bacillariophyceae*, *Dinophyceae*, and *Chlorophyceae*, and 2-6 taxa of zooplankton belonging to the Protozoa, Crustacea, and Chaetognatha groups in Raja Ampat, Papua, Indonesia. The value of the biodiversity index varied between sites in Raja Ampat. The diversity index at all sites, for both phytoplankton and zooplankton, was below 3. The Evenness index varied from 0.28-0.73 for phytoplankton and 0.14-0.73 for zooplankton. Domination index in all site are 0.22 and 0.71 for phytoplankton and 0.39-0.96 for zooplankton.

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