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Distribution of Plankton Communities in the Waters of the Riau Archipelago: A Literature Review

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ABSTRACT

Plankton plays an essential role in aquatic ecosystems as the primary producer, energy transfer component, and biological indicator of environmental quality. This study aimed to synthesize information regarding community structure and plankton distribution in the waters of the Riau Archipelago Province through a literature review approach. Scientific articles published between 2007 and 2026 were collected and evaluated to identify patterns of plankton composition, diversity, and environmental drivers influencing their occurrence. The synthesis showed that phytoplankton communities were predominantly composed of Bacillariophyta, followed by Dinoflagellata, Cyanophyta, and Chlorophyta, whereas zooplankton communities were mainly represented by Crustacea, especially Copepoda. Phytoplankton diversity ranged from low to moderate levels (H' = 0.57–2.77), indicating varying ecological conditions among study locations. Most studies were concentrated in marine ecosystems (75%), while estuarine and freshwater environments remained underrepresented. Variations in community structure were strongly associated with nutrient availability, salinity, hydrodynamics, and anthropogenic pressures. The review also revealed limited long-term monitoring and insufficient zooplankton investigations. Future studies should integrate broader ecosystem coverage and advanced approaches to support sustainable aquatic ecosystem management in the Riau Archipelago.

Keywords: *aquatic ecology, biology, phytoplankton, Riau Archipelago, zooplankton*

1. INTRODUCTION

Plankton are microscopic organisms that live in the waters and play an important role in maintaining the balance of aquatic ecosystems. In general, plankton are divided into two main groups, namely phytoplankton as primary producers and zooplankton as primary consumers in the food chain (Prakasa et al., 2021; Nasaruddin et al., 2023). The presence of plankton greatly determines aquatic productivity because it serves as an initial energy provider for higher trophic level organisms, including fish and other aquatic biota (Yousif et al., 2017; Yusuf et al., 2021).

In aquatic ecosystems, the structure of plankton communities is one of the important indicators in describing the ecological conditions of a water. The structure of the community includes the species composition, diversity, dominance, and abundance of plankton organisms (Octavina et al., 2021; Rifahyanti et al., 2022). in the structure of plankton communities often reflect changes in the environment, both caused by natural factors and

human activities (Hidayat et al., 2019; Sulawesty et al., 2021). The distribution of plankton in a body of water is influenced by various physical, chemical, and biological factors. These factors include temperature, salinity, light intensity, current, and the availability of nutrients such as nitrates and phosphates. In addition, anthropogenic activities such as sewage disposal, industrial activities, and urbanization also affect the distribution patterns and structure of plankton communities (Damayanti et al., 2017).

Tropical waters are known to have relatively high productivity due to the high intensity of sunlight throughout the year. However, high productivity does not always go hand in hand with high plankton diversity. In many cases, nutrient-rich (eutrophic) aquatic conditions tend to be dominated by certain species, thus lowering the overall level of diversity of plankton communities (Kamilia et al., 2021; Samidjan et al., 2020).

The Riau Archipelago is one of the maritime areas in Indonesia that have complex water characteristics. This area includes various types of ecosystems, such as coastal marine waters, estuaries, and freshwater ecosystems. In addition, the Riau Archipelago is also an area with high anthropogenic activity, including industries, ports, and settlements, which has the potential to put pressure on the aquatic environment (Akbar et al., 2021). Previous studies in the Riau Archipelago have shown that plankton communities are dominated by diatoms (Bacillariophyceae) and zooplankton from the Copepod group. However, the level of diversity found is generally in the low to medium category. In addition, the distribution of plankton also shows variations influenced by environmental factors such as nutrients and salinity (Ayatillah et al., 2022; Ginting et al., 2023; Puspita, 2018; Yanti et al., 2024).

Based on this background, this review aims to compile a literature review on community structure and plankton distribution in the waters of the Riau Archipelago. Through the literature review approach, it is hoped that a comprehensive picture can be obtained of the ecological pattern of plankton and the factors that influence it. The results of this study are expected to be the basis for the management of aquatic resources as well as the development of further research in the field of aquatic ecology.

2. MATERIALS AND METHODS

This study used a literature review approach with the aim of synthesizing various research results related to community structure and plankton distribution in the waters of the Riau Archipelago. The literature review method was chosen because it is able to integrate various findings of previous research so that it can provide a comprehensive picture of the

ecological patterns of plankton in an area (Fitra & Zakaria, 2022; Snyder, 2019). The study includes articles published between 2016 and 2026 accessed through the Google Scholar database. This type of research is a descriptive qualitative review by collecting, evaluating, and synthesizing relevant research results without conducting meta-analytical statistical analysis. This approach is used to identify common patterns, relationships between variables, as well as research gaps (Creswell, 2014). This method is commonly used in the study of aquatic ecology, especially when the available data come from different locations with different characteristics.

Literature searches were conducted systematically through several scientific databases by utilizing Google Scholar as the primary source to obtain relevant publications. The article search process uses a combination of different keywords to expand the scope of references and improve the accuracy of search results. The keywords used include Riau Archipelago plankton, phytoplankton, zooplankton, coastal waters, plankton diversity, plankton community structure, distribution of aquatic plankton, as well as the names of regions such as Batam, Tanjungpinang, Anambas, Natuna, Karimun, and Bintan.

3. RESULTS AND DISCUSSION

Based on the results of the synthesis of various studies summarized in **Table 1**, plankton communities in the waters of the Riau Archipelago show significant variations in composition and abundance between locations and observation times. The number of phytoplankton found ranges from 11 to 35 species, while zooplankton tends to be lower, between 2 to 17 species. The dominant phytoplankton groups are Bacillariophyta (diatoms), Dinoflagellata, Cyanophyta, and Chlorophyta, while zooplankton is dominated by Crustaceans especially Copepods as well as some groups of Protozoa.

The dominance of Bacillariophyta in almost all observation sites shows that this group of phytoplankton has a high ecological adaptation capacity to variations in aquatic environmental conditions, especially in coastal ecosystems which are generally characterized by nutrient input dynamics, salinity fluctuations, and changes in aquatic physical-chemical conditions. The high abundance of Bacillariophyta indicates that the environmental conditions at the research site are still able to support the growth and reproduction process of diatoms optimally. This group is known to have a relatively fast growth rate, high light utilization efficiency, and the ability to absorb and convert inorganic

nutrients, especially nitrogen and phosphorus into biomass effectively, so they often dominate phytoplankton communities in productive waters.

Table 1. Distribution of plankton obtained from a literature review study in the Riau Archipelago Province

No	References	Research area	Phytoplankton	Zooplankton	Groups
1	(Riyadi & Santos, 2016)	Sekupang, Batam City	25	-	Bacillariophyta Cyanophyta Dinoflagellata
2	(Puspita, 2018)	Enam River, East Bintan	11	2	Bacillariophyta Dinoflagellata
3	(Fatmayanti et al., 2019)	Waduk Sungai Pulai, Bintan	18	-	Bacillariophyta Chlorophyta Cyanophyta
4	(Ayu et al., 2017)	Small Islands, Riau Archipelago	31	17	Bacillariophyta Chlorophyta Chrycophyta Crustacea Cyanophyta Dinoflagellata Protozoa
5	(Ayatillah et al., 2022)	South Bintan	35	-	Bacillariophyta Chlorophyta Cyanophyta Dinoflagellata
6	(Ginting et al., 2023)	Tanjungpinang City Coast, Bintan	-	6	Crustacea Hexanauplia
7	(Yanti et al., 2024)	Senggarang Besar Waters, Tanjungpinang	21	-	Bacillariphyta Chlorophyta Dinoflagellata
8	(Muzammil et al., 2026)	Senggarang Waters, Tanjungpinang	33	9	Bacillariophyta Branchipoda Chlorophyta Copepoda Cyanophyta Dinoflagellata Sarcodina Tintinnidae

The phenomenon is in line with the findings of B-Béres et al. (2023) and Marella et al. (2021) which states that diatoms are the main primary producers in marine and coastal waters because they have high photosynthesis efficiency and good tolerance to changes in nutrient availability. In addition, the competitive success of Bacillariophyta is also related to the silica cell wall structure (frustule) which provides protection against environmental pressure and supports the physiological stability of organisms in fluctuating aquatic conditions. In environments with sufficient nutrient supply and good water mass mixing conditions, diatoms tend to be superior to other phytoplankton groups because they are able to maintain primary productivity in a relatively short period of time.

Variations in the number of plankton between locations indicate the influence of environmental factors such as nutrients (nitrates and phosphates), salinity, anthropogenic

activities (sewage, ports, industry). For example, the high number of plankton in the study of Ayu et al. (2017) 31 phytoplankton and 17 zooplankton) showed relatively productive aquatic conditions, while low abundance in some locations indicated environmental stress or nutrient limitations. According to Sulastri et al. (2022) and Hidayat et al. (2019), eutrophic conditions can increase plankton abundance but often decrease diversity due to the dominance of certain species.

The distribution of plankton research in the Riau Archipelago by water type showed a very strong dominance in marine ecosystems (75%), followed by estuarine ecosystems (12.5%) and freshwater (12.5%). This pattern reflects the tendency of research directions to be more focused on coastal areas and open seas, in line with the geographical characteristics of the Riau Archipelago as an archipelagic province whose territory is mostly dominated by marine waters. This condition causes marine ecosystems to become objects of study that are more accessible and at the same time considered to have high strategic value, both from ecological and economic aspects, especially related to primary productivity, fishery resources, coastal conservation, and environmental dynamics due to shipping, industrial, and coastal area development activities.

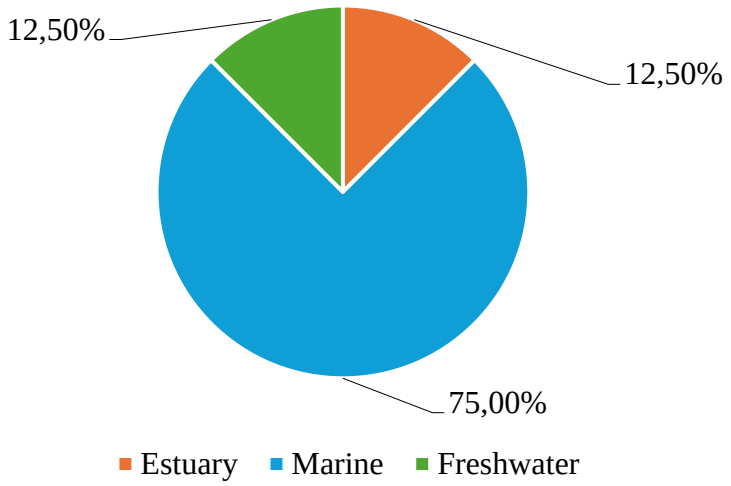

Figure 1. Percentage of plankton research by water type in the Riau Archipelago

Therefore, the uneven distribution of research shows the need to strengthen the research agenda on estuarine and freshwater ecosystems in the Riau Archipelago in order to gain a more comprehensive understanding of diversity, distribution patterns, and responses of plankton communities to environmental changes in various types of waters. The

percentage of plankton research based on the type of waters in the Riau Archipelago is presented in **Figure 1**.

Estuarine ecosystems are transitional areas between land and sea waters that are known to have high biological productivity and complex ecological dynamics. These characteristics are formed due to the continuous interaction between freshwater flows, seawater intrusion, tidal processes, and the input of organic matter and nutrients from the catchment area. According to Bilbao & Seoane (2024), estuaries are among the most productive ecosystems in the world due to the mixing process that increases the availability of nutrients and supports the high rate of primary production. These conditions make estuaries important habitats for various groups of aquatic organisms, including plankton, which serve as the basis of food webs and indicators of sensitivity to environmental changes. Variations in salinity, nutrient availability, light intensity, and high hydrodynamic processes cause plankton communities in estuaries to have more dynamic distribution patterns and community structures than other aquatic ecosystems. The plankton community structure shown in **Figure 2** shows that the phytoplankton diversity index (H') value is in the range of 0.57 to 2.77, indicating a low to moderate level of diversity. The highest diversity value was recorded in 2021 (H' = 2.77), which indicates relatively stable ecosystem conditions with a more even distribution of species. Conversely, low diversity values in some locations indicate environmental pressures or the dominance of certain species.

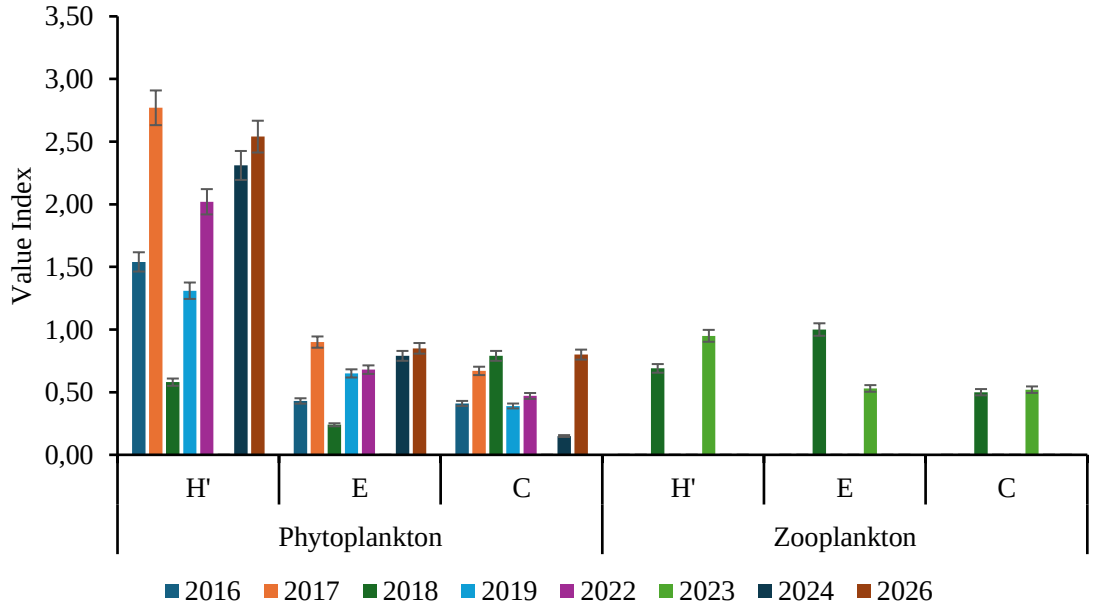

Figure 2. Plankton community structure based on a literature review synthesis in the Riau Archipelago

A relatively high uniformity index value (E) (0.68–0.90) indicates that the distribution of individuals between species is fairly even in some locations, while the varying dominance value (C) reflects the presence of a particular species that dominates the community. For zooplankton, the diversity value tends to be lower, ranging from 0.69 to 0.95, which indicates that zooplankton communities are simpler than phytoplankton. is in accordance with the opinion (Sabo et al., 2008) that zooplankton is greatly influenced by the availability of phytoplankton as the main source of energy in the food chain, so that phytoplankton fluctuations will have a direct effect on the structure of zooplankton communities.

Based on **Figure 3**, the composition of plankton groups found in the Riau Archipelago shows a fairly clear pattern of dominance, with Bacillariophyta being the most frequently reported group (7 occurrences), followed by Dinoflagellates (6 occurances), and Chlorophyta and Cyanophyta which were recorded 5 occurrences each. This pattern illustrates that aquatic ecosystems in the Riau Archipelago have a relatively high level of productivity and are supported by environmental conditions that are able to maintain the sustainability of diverse phytoplankton communities. Ecologically, the structure of plankton communities is the result of an interaction between oceanographic conditions, nutrient dynamics, habitat characteristics, and environmental pressures that work simultaneously. The high frequency of the emergence of several phytoplankton groups suggests that the waters in this region not only provide suitable conditions for the growth of a particular group, but also support the formation of communities that reflect the heterogeneity of the aquatic environment, both on a spatial and temporal scale.

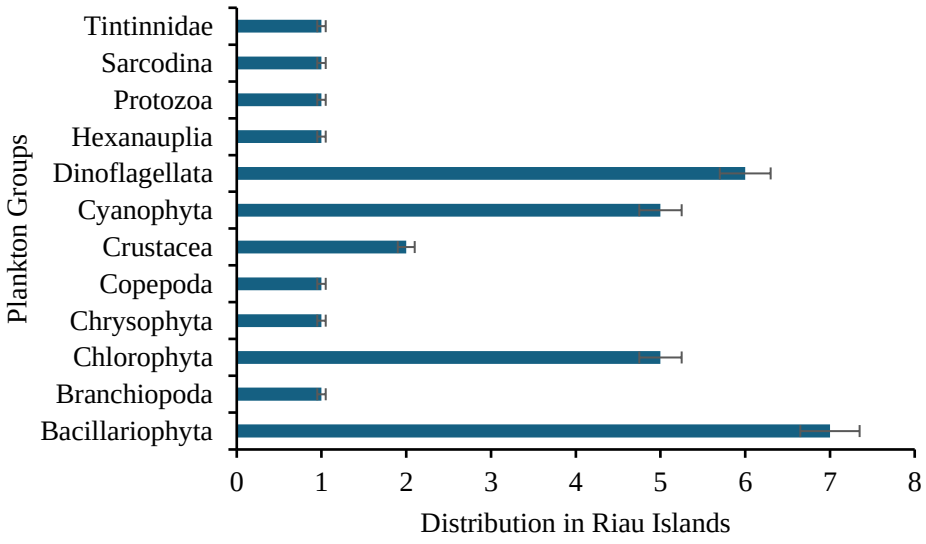

Figure 3. Frequency of occurrence of plankton groups in the Riau Archipelago

The dominance of Bacillariophyta in **Figure 3** indicates that most of the water conditions in the Riau Archipelago tend to favor the growth of diatoms as the main primary producers. Diatoms are known as a group of phytoplankton that have high photosynthesis efficiency, fast reproduction rates, and the ability to utilize nutrients effectively so that they often dominate productive waters. According to Kesaulya et al. (2023), Mawarni et al. (2020) and Seygita et al. (2021), Diatom dominance generally occurs in waters with high levels of turbulence and abundant nutrient availability. Turbulent conditions play a role in increasing the mixing process of the water column so that nutrients such as nitrates, phosphates, and silicates remain available in the euphotic layer where photosynthesis takes place. In addition, the existence of silica cell walls (frustule) provides adaptive advantages for diatoms in the face of changing environmental conditions. The geographical characteristics of the Riau Archipelago, which are dominated by coastal areas, open sea waters, and areas with strong tidal influence, are likely to be factors that support the high frequency of occurrence of this group. The dominance of Bacillariophyta may also indicate that most of the waters studied are still in conditions that support primary productivity and active nutrient circulation.

On the other hand, the high occurrence of Dinoflagellates, as well as the presence of Chlorophyta and Cyanophyta, show that the environmental conditions in the Riau Archipelago are not homogeneous, but have quite complex ecological variations. Dinoflagellates generally thrive better in stable water conditions and undergo water column stratification because this group has the ability to move vertically using flagella to optimize light and nutrient acquisition. The presence of this group indicates that some of the research sites may have quieter hydrodynamic characteristics than areas dominated by diatoms.

Meanwhile, Chlorophyta is often associated with waters that have high light penetration and nutrient input from land, while Cyanophyta is known to have a wide tolerance to environmental changes as well as the ability to survive certain nutrient conditions. The combination of the emergence of various plankton groups reflects that the community structure in the Riau Archipelago is formed by the simultaneous interaction of various environmental factors, including physical factors (temperature, current, brightness, turbulence), chemical factors (salinity, pH, nitrate, phosphate, silicate, dissolved oxygen), and biological factors (competition, predation, and community succession dynamics). Therefore, the composition of plankton in Figure 3 not only represents the condition of

aquatic productivity, but can also be used as a biological indicator to understand the dynamics and quality of aquatic ecosystems in the Riau Archipelago more comprehensively.

Overall, the results of this review show that the structure of plankton communities in the Riau Archipelago is in the category of low to moderate diversity with the dominance of phytoplankton from the diatom group, as well as distribution influenced by environmental factors and human activities. Nevertheless, there are some significant research gaps. First, research is still dominated by marine ecosystems, while estuary and freshwater ecosystems are still minimally studied. Second, zooplankton data are still limited compared to phytoplankton, even though their role is important in trophic energy transfer. Third, most of the research is still short-term, so it has not been able to comprehensively describe the temporal dynamics of plankton. Fourth, studies linking plankton community structure to the impact of anthropogenic activities such as pollution, eutrophication, and climate change are still very limited.

In addition, the approach used is still dominated by conventional methods based on morphology, so it is necessary to develop modern methods such as DNA metabarcoding to improve the accuracy of identification. Therefore, future research needs to be directed at strengthening the study of estuary and freshwater ecosystems, increasing zooplankton studies, developing long-term research, and integrating molecular and ecological approaches to support sustainable water management in the Riau Archipelago

4. CONCLUSION

Based on the literature review, the plankton community structure in the waters of the Riau Archipelago is predominantly composed of phytoplankton, particularly members of the Bacillariophyta group. This dominance indicates relatively stable primary productivity, although diversity levels are generally categorized as low to moderate. Spatial and temporal distribution patterns are strongly influenced by environmental variables such as nutrient availability, salinity, hydrodynamics, and anthropogenic pressures. However, existing studies remain concentrated on marine environments and provide limited insights into estuarine and freshwater systems, zooplankton community dynamics, and long-term ecological trends. Therefore, comprehensive research integrating multi-ecosystem perspectives, advanced analytical approaches, and continuous monitoring is essential to improve ecological understanding and to support evidence-based and sustainable

management of aquatic resources in the Riau Archipelago region. Future studies should also emphasize climate variability impacts significantly.

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