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A REVIEW : THE EXISTENCE OF PLANKTON AS A BIOINDICATOR OF FRESH AND SEAWATER

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ABSTRACT

This review is a summary of several studies on plankton as a bioindicator in various countries. The research in this review includes those conducted in freshwater and sea waters. The purpose of writing this review is to summarize some of the previous research on plankton as a bioindicator in both fresh and marine waters from various countries not only in Indonesia but also in other countries. Bioindicators are living organisms such as plants, plankton, animals, and microbes, which are used to filter the health of natural ecosystems in the environment. Biological indicators can monitor on an ongoing basis and are easy indicators to monitor the occurrence of contamination. Plankton is aquatic organisms that live in passive movements and cannot fight against currents. Plankton which is always in motion can also be used as an indicator of water pollution. The use of plankton as a bioindicator in the water sector has been widely used both in fresh and sea waters. The use of plankton as an indicator in freshwater includes phytoplankton which is mostly used as an ecological indicator or water quality indicator while Zooplankton is widely used as an indicator of pollution. The use of plankton as a bioindicator in sea waters includes indicators of environmental quality, indicators of pollution, indicators of oceanographic complexity, as well as potential indicators of water mass. Plankton can be used as a bioindicator because plankton is a biota that is very responsive to water pollution and has a fast growth rate so that it can show indicators of significant ecological changes and can be measured on a short time scale.\

INTRODUCTION

Sea water is a component that interacts with the land environment, where the waste disposal from the land will empties into the sea. Besides, seawater is a place for receiving pollutants (polluted materials) that fall from the atmosphere (Imran 2016). The river is one of the places where water collects from an area. Surface water or runoff water flows gravity to a lower place (Asdak, C 1995 dalam Yogafanny 2015). The river is one of the lotic ecosystems (flowing waters), which functions as a place for organisms to live (Maryono 2005).

Monitoring the quality of the environment on the waters needs to be done to see if an impact occurs by looking at the impact's type and magnitude as an evaluation material for decision-makers to prevent and overcome negative impacts (Fachrul 2007). One aspect that can be used to monitor the quality of the aquatic environment is bioindicators. Bioindicators are very important to show the relationship between biotic and abiotic factors in an environment. Bioindicators or ecological indicators are a group of organisms that live and are vulnerable to environmental changes as a result of human activities and natural damage (Sumenge 2008). The purpose of writing this review is to summarize some of the previous research on plankton as a bioindicator in both fresh and marine waters from various countries not only in Indonesia but also in other countries.

DEFINITION OF PLANKTON

Plankton is an organism that is sensitive to environmental changes. The abundance, diversity, and dominance of plankton in the waters can be used as indicators of whether these waters are still in good condition or have experienced disturbances (Romimohtarto & Juwana 2001 dalam Anggara *et al.* 2017). he high and low levels of plankton diversity in the waters are influenced by abiotic factors, including DO, BOD, pH, temperature, and current velocity (Oktavia *et al.* 2015). Plankton consists of two groups, namely phytoplankton and zooplankton.

Phytoplankton is a natural food for various types of fish and shrimp which occupy the first producer level in the energy flow system. Phytoplankton as primary producers in waters is a source of life for all animal organisms. Besides, phytoplankton is a producer of dissolved O2 in waters. In the food chain, phytoplankton will be eaten by herbivorous animals in the form of zooplankton(Veronica *et al.* 2010). The existence of phytoplankton greatly affects aquatic life because it plays an important role as food for various marine organisms. Changes in water function are often caused by changes in the structure and quantitative values of phytoplankton. These changes can be caused by factors originating from nature or human activities such as sporadic increases in nutrient concentrations so that it can cause an increase in the quantitative value of phytoplankton beyond the normal limit that can be tolerated by other living organisms (Djokosetiyanto & Rahardjo 2006).

Zooplankton is very small aquatic animals and are non-motile or very weak swimmers and drift in the ocean, sea, or freshwater water column to move as far as possible. It usually moves in the sunlit zone where it is the most abundant source of food and is sometimes found in the deep sea. Zooplankton is heterotrophic (sometimes detritivores) and provides food for many marine animals. Zooplankton has an important role in the food web by connecting major producers (by consuming phytoplankton, especially various bacterioplankton and sometimes zooplankton) and higher trophic levels. Freshwater zooplankton that is most often found and become bioindicators include Protozoa, Rotifera, Cladocera, Copepoda and Ostracoda (Ferdous & Muktadir 2009).

DEFINITION OF BIOINDICATORS

Bioindicators come from two words, namely bio and indicator, bio means living things such as animals, plants, and microbes. Meanwhile, indicators mean variables that can be used for a state or status situation and change into changes that occur from time to time. so bioindicators are biotic components (living things) that are used as indicators. Naturally occurring bioindicators are used to assess environmental health and are also important tools for examining environmental changes, whether positive or negative and subsequently in human society. Certain factors discover the presence of Bioindicators in the environment such as light transmission, air, temperature, and suspended solids. Through the application of Bioindicators the natural condition of an area or the level/degree of pollution can be predicted (Khatri & Tyagi 2015).

Bioindicators measure changes in biological or non-biological factors in ecosystems with a focus on living things in several circumstances. Bioindicators show the life of an object or group of living things. It is used as a proxy for understanding and estimating general ecosystem status. But specifically or in general, it means the impact of environmental changes on habitats, communities, or ecosystems as species or groups of species that represent the status of living or non-living things in their environment. Can also show living things or groups of living things that show the diversity of taxonomic groups in an area or part of the diversity of diversity (Gerhardt 2002 dalam Han *et al.* 2015).

The advantages associated with using Bioindicators are as follows (Han *et al.* 2015):

a) Biological impacts can be determined.
b) For the synergistic and antagonistic impact of various pollutants on a creature.
c) Early-stage diagnosis as well as the harmful effects of the poison on plants, as well as humans, could be monitored.
d) Can be calculated easily, because of its prevalence.
e) An economically viable alternative when compared to other specialized measurement systems.

PLANKTON IN FRESHWATER

To monitor aquatic ecosystems and water integrity, plankton has been used for more than ten years as a bioindicator. Plankton has a very important function in the food chain and plays an important role in the natural purification of water. The relative abundance of chlorophyll is an indication of productive water, where chlorophyll is mostly found in phytoplankton. Plankton has a fast growth rate, so it can show indicators of significant ecological changes and can be measured on a short time scale. Zooplankton in freshwater is dominated by rotifers, cladocerans, and copepods. The relative abundance of plankton communities is influenced by prevailing abiotic and biotic parameters and this determines seasonal abundance, occurrence and variation (Rothhaupt 2000 dalam Arimoro *et al.* 2018). Plankton is very important in freshwater ecosystems as the main source of energy and has a very high nutritional value (Mishra & Joshi 2003 dalam Arimoro *et al.* 2018). Plankton responds quickly to environmental changes because it has a short life cycle, therefore, the species composition of plankton is more likely to indicate the quality of the water it inhabits.

Previous research on plankton diversity was carried out by Anggara *et al.* (2017) conducted in the waters of Tlogo Dringo, Dieng Plateau, Central Java. In this study, 24 types of plankton were found, consisting of 17 types of phytoplankton and 7 types of zooplankton with a total plankton abundance of 69,096 ind / L which is included in waters with moderate fertility. The physical and chemical parameters of the waters indicate that these waters are very good for supporting plankton life. However, the water temperature is lower than the requirements for plankton life in general so that it can limit the types of plankton that can live in these waters. In addition, research by Zhang *et al.* (2020) which is located on the Hanjiang River with a multilevel reservoir using the Planktonic Biotic Integrity Index (P-IBI) shows that diatom species occupy the largest proportion (40% in the dry season, 38.34% in the rainy season), followed by chlorophyte (33.08 % in the dry season, 37.15% in the rainy season), and Chrysophyta (14.62% in the dry season, 13.83% in the rainy season). A total of 291 phytoplankton species belonging to 118 genera and seven phyla were identified with abundances ranging from 3.2 × 104 to 8.48 × 107 cells / L, and Shannon-Wiener diversity index values ranging from 0.07 to

2.95. Meanwhile, the zooplankton community is represented by four groups: protozoa, rotifers, cladocerans, and copepods. Rotifers have the largest proportion (42.61% in the dry season, 53.24% in the rainy season) and the following protozoa (28.7% in the dry season, 23.74% in the rainy season). A total of 170 zooplankton species belonging to 100 genera have been identified with an abundance ranging from 20.3 to 1.63 × 104 cells / L and a ShannonWiener diversity index value ranging from 0.39 to 2.75. These results indicate the quality of aquatic ecosystems with the status of 'medium', oligotrophic, and class II (rainy season) -class III (dry season) evaluated by P-IBI, Saprobic Index (SI), and Comprehensive Water Quality Identification Index (CWQII). In this study, P-IBI effectively reflects the environmental conditions of current regulation in the mid-bottom of the Hanjiang River in China and can be used in future studies to measure the long-term status of river ecosystems affected by the multilevel dams.

PHYTOPLANKTON AS WATER QUALITY INDICATORS

The abundance of phytoplankton in waters is influenced by several environmental parameters and physiological characteristics. Abundance will change at various levels in response to changes in physical, chemical, and biological environmental conditions (Reynolds *et al.* 1984 dalam Veronica *et al.* 2010). Factors supporting phytoplankton growth are very complex and interact with each other between physical and chemical factors such as dissolved oxygen, temperature, brightness, and availability of nitrogen and phosphorus nutrients (Goldman dan Horne 1983 dalam Veronica *et al.* 2010). Water fertility is an indicator that can predict the capture of fisheries resources (Kasma *et al.* 2007 dalam Ratnapuri *et al.* 2013). Water fertility is highly dependent on the presence of phytoplankton and the Physico-chemical parameters of the waters. According to Yuliana *et al.* (2012), stated that the role of phytoplankton is very important in waters, apart from being the basis of the food chain (primary producer) it also acts as a parameter of fertility levels. Phytoplankton is dominated by the chlorophyll-a pigment, where the distribution of chlorophyll-a is closely related to the Physico-chemical parameters of the water (Ratnapuri *et al.* 2013).

Studies on water fertility based on phytoplankton indicators have been carried out in various regions in Indonesia, including Rasyid *et al.* (2018) in the waters of the Black River Estuary, Bengkulu; Fatmayanti *et al.* (2019) in Sei Pulai Reservoir, Bintan Island, Riau Islands; Sofarini (2012) in Riam Kanan Reservoir; Mukharomah *et al.* (2018) at the Jakabaring Palembang Sky Air Lake; Sidaningrat *et al.* (2018) at Lake Batur, Bali; dan Ridhawani *et al.* (2017) Rokan River Estuary, Rokan Hilir Regency. The results obtained in research conducted in Sei Reservoir, Bintan Island, show that the phytoplankton found in the waters of the littoral zone of the Sei Pulai Reservoir consists of three divisions with 18 genera. The most abundant phytoplankton was found at the inlet and the lowest at the outlet. Navicula sp. which is included in the Bacillariophyta division is the most common species found in all research areas. According to Kasrina *et al.* (2012), Navicula sp. is a diatom group that is cosmopolitan with a distinctive cell structure. The ecological index of phytoplankton in each part of the reservoir shows the same results, namely low diversity, moderate uniformity, and low dominance. The low diversity index indicates that the number of types and abundance of phytoplankton in the Sei Pulai Reservoir is relatively small. This can be due to the influence of environmental factors, one of which is a relatively low pH. Based on the saprobic index, the waters of the littoral zone in the Sei Pulai Reservoir are classified as moderate organic matter pollution or β / α-mesosaprobic with a saprobic coefficient range of 0 - 0.5. The mesosaprobic phase describes a moderately polluted environmental condition with the concentration of DO (dissolved oxygen) starting to increase from an anoxic state, no H_2S, and if there is a certain amount of ammonia, it will oxidize quickly (Fatmayanti *et al.* 2019).

ZOOPLANKTON AS WATER QUALITY INDICATORS

Bioindicators and biotic indices have been used by Europeans to assess the water quality of waters for the last 100 years. Zooplankton's potential as a bioindicator is very high because its growth and distribution depend on several abiotic components (such as temperature, salinity, stratification, pollutants) and biotic components (such as food limitation, predation, competition). Another study on the Ramjan river from Bihar, India (Pandey & Verma 2004) stated that abiotic parameters (eg; pH, transparency, temperature, dissolved oxygen, and some micronutrients) in relation to seasonal fluctuations affect zooplankton abundance. In this study, the size of the Rotifer community was the largest and showed a negative correlation with pH, dissolved oxygen, and transparency. Cladocera abundance was ranked second among total collections and showed a negative correlation with pH, transparency, and phosphate. Copepods, the third dense community, show a negative correlation with water temperature, nitrates, and phosphates.

One of the most common types of zooplankton is rotifer. Rotifers are small but important zooplankton in freshwater ecosystems, sensitive to environmental changes, acting as an effective indicator of trophic conditions. Rotifers are selected organisms with relatively short generation times, they respond to environmental changes and occupy open gaps immediately. Thus, they are widespread in the world and live in all kinds of waters. In addition, rotifer species are more useful as indicators of "bottom-up" processes than large zooplankton because they are less affected by fish predation, and rotifer abundance is largely related to food type and quantity, which in turn varies with changes in nutrient levels along the trophic gradient. In a study conducted by Liang *et al.* (2020) regarding the responsiveness of rotifers to environmental factors in typical urban river-lake ecosystems, showing results A total of 95 rotifer species were identified at 15 sampling locations during one survey year. The abundance of rotifers ranges from 1 (River Yuan) to 2628 ind. • L - 1 (Liuye Lake). Temperature, water depth, and trophic status are major factors for the spatial-temporal variation of rotifer communities in urban river-lake ecosystems. Individual rotifer indicators, biodiversity index, Brachionus: Trichocerca ratio, and Keratella index were less effective in evaluating trophic status in this study. However, the rotifer trophic state index (TSIROT) and the total rotifer abundance were strongly associated with the comprehensive trophic level index (TLIc) values. Furthermore, the TSIROT value shows stability and resistance to change when the time horizon increases. The results showed that the TSIROT index was a reliable indicator of water quality in river-lake ecosystems with high variations in water depth. The TLIc Index shows that the Chuanzi River and Liuye Lake are mesotrophic almost eutrophic, while the Yuan River is oligotrophic to mesotrophic.

PLANKTON IN SEA WATER

Seawater pollution can lead to reduced diversity or extinction of populations of aquatic organisms such as benthos, periphyton, and plankton. The aquatic ecological system has the ability to purify the environment that has been polluted as long as the pollution load is still within the carrying capacity of the environment concerned (Nugroho 2006 dalam Sulistiowati *et al.* 2016). Not only in freshwater, but plankton also has a role as bioindicators in marine waters. The role of plankton as a bioindicator in marine waters can be an indicator of environmental quality, an indicator of pollution, an indicator of oceanographic complexity (Wilson & Hayek 2019), and also a potential indicator of water mass (Yang *et al.* 2020). Sulistiowati *et al.* (2016) has submitted the results of their study on plankton as a bioindicator of environmental quality in Jayapura coastal waters. Where in the study, the results showed that in Youtefa Bay, Jayapura, 67 species of plankton were found, while in Yos Sudarso Bay there were 106 species. The total abundance of individual plankton in Youtefa Bay waters during the dry and rainy season ranges from 27.29 ind / L-205.29 ind / L. Meanwhile, the total abundance of individual plankton in the waters of Yos Sudarso Bay during the dry and rainy season ranges from 20.50 ind / L-181.90 ind / L. In the dry and rainy seasons in the waters of Youtefa Bay, the diversity index value (H ') ranges from 2.28-2.51, the uniformity index value (E) ranges from 0.66 to 0.71 and the dominance index value (C) ranges between 0.12-0.18. Meanwhile, in the waters of Yos Sudarso Bay during the dry and rainy seasons, it shows that the diversity index value (H ') ranges from 0.86 to 1.90, the uniformity value (E) ranges from 0.26-0.55, and the dominance index value (C) ranged from 0.31 to 0.68. From these results, it can be concluded that in general the quality of the marine environment in the waters of Youtefa Bay and Yos Sudarso Bay is not in accordance with seawater quality standards for marine biota. Based on the results of the diversity index analysis, the waters in Youtefa Bay and Yos Sudarso Bay are categorized as semi-heavily polluted. The abundance of plankton in the waters of Youtefa Bay and Yos Sudarso Bay during the dry and rainy season is categorized as low.

Research on plankton as an ecological indicator was also carried out by Aboul *et al.* (2014) in the El-Mex Bay, Southeast Mediterranean, and Ferrera *et al.* (2020) on the northwest Mediterranean Coast. In the results obtained in the El-Mex Bay, 38 species of rotifers were identified from 16 genera in 12 families and 3 species. The maximum density was observed in summer 2012 with an average of 1445 specimens / m3. During the fall of 2011, the rotifers appeared in low density. The abundance of rotifers is mainly controlled by fluctuations in environmental physical factors, particularly depth and temperature. Due to pollution and eutrophication, the number of Synchaeta and Brachionus is the greatest. This is because this type of rotifer has the ability to live in polluted waters so that it shows that the waters in the area can be classified as eutrophic and polluted waters.

Studies on plankton as an indicator of pollution in marine waters have been carried out, among others, by Labupili *et al.* (2018) and Imran (2016). Based on research conducted at the ports of Pengambengan, Benoa, and Amed, which are located in Bali. From the three ports with the same station characteristics, there were 3 classes with 16 genera, where the Bacillariophyceae class consisted of 11 genera, the Cyanophyceae class consisted of 3 genera, and Dinophyceaea consisted of 2 genera. The composition of zooplankton found during the observation at the three ports was obtained 4 classes with 6 genera, where the class Crustacea (2 genera), Cilliata (2 genera), Annelida (1 genus), and Monogonanta (1 genus). Based on the plankton diversity criteria, it can be seen that the average phytoplankton diversity index in 3 ports is moderate (1.60). Meanwhile, the average zooplankton diversity index is low (0.84). If the diversity of plankton (phytoplankton and zooplankton) is related to the level of pollution, the pollution level of the fishing port in Bali is indicated as moderate to severe or α-Mesosaprobik (1,22). This can occur due to activities at the port which can cause the water quality to be bad.

Apart from rotifers, foraminifera can also be used as planktonic bio-indicators from aquatic ecology. The study conducted by Zarkogiannis *et al.* (2020) stated that the smaller size and abundance of planktonic foraminifera shells than previous studies or different sizes at other stations is related to the presence of nutrients in the places where this foraminifera was found. Then the research conducted by Wilson & Hayek (2019) regarding foraminifera as an indicator of oceanographic complexity in the continental shelf of the southern Caribbean Sea. In this study, it is said that the planktonic foraminifera present in the surface sediment samples reflects the complexity of oceanography on the continental shelf and upper continental slopes, either associated with river plumes or upwelling foci. Furthermore, sedimentary assemblages from planktonic foraminifera may be useful in the study of evolution and palaeo-dispersion of upwelling water from upwelling foci.

CONCLUSION

The use of plankton as a bioindicator in the water sector has been widely used both in fresh and sea waters. The use of plankton as an indicator in freshwater includes phytoplankton which is mostly used as an ecological indicator or water quality indicator while Zooplankton is widely used as an indicator of pollution. The use of plankton as a bioindicator in sea waters includes indicators of environmental quality, indicators of pollution, indicators of oceanographic complexity, as well as potential indicators of water mass. Plankton can be used as a bioindicator because plankton is a biota that is very responsive to water pollution and has a fast growth rate so that it can show indicators of significant ecological changes and can be measured on a short time scale.

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