E-ISSN 2549-8703 I P-ISSN 2302-7282

BIOTROPIKA *Journal of Tropical Biology*

https://biotropika.ub.ac.id/

Vol. 12 | No. 1 | 2024 | DOI: 10.21776/ub.biotropika.2024.012.01.06

WATER QUALITY EVALUATION OF CENTRAL LOMBOK AWANG BAY USING ZOOPLANKTON DIVERSITY AS A BIOINDICATOR

Reza Sagista[1)*], Amin Setyo Leksono[2)], Catur Retnaningdyah[2)]

Submitted : October, 21 2023
Accepted : May, 28 2024

Authors affiliation:
[1)] Master Program of Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya, Malang, Indonesia.
[2)]Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya, Malang, Indonesia.

Correspondence email:
*rezasagista@student.ub.ac.id

How to cite:
Sagista, R, Leksono AS, Retnaningdyah C. 2024. Water quality evaluation Of Central Lombok Awang Bay using zooplankton diversity as a bioindicator. *Journal of Tropical Biology* 12 (1): 49-56.

ABSTRACT

The water quality in Awang Bay, West Nusa Tenggara, Indonesia, is considered to be polluted due to human activities. This research aims to evaluate the water quality in Teluk Awang based on the physicochemical properties of water and zooplankton as bioindicators. Sampling was conducted at three beach locations: Awang, Ujung Kelor, and Ekas. The physicochemical water quality parameters measured included water temperature, pH, dissolved oxygen (DO), salinity, and transparency. Additionally, environmental factors were observed based on the naturalness and hemeroby index. The result of the identification and counting of the abundance of each zooplankton can then be used to analyze including taxa richness, total density, the diversity index of Shannon-Wiener (HSW), Margalef diversity index, Simpson diversity index, evenness index (E), and dominance index (C). The resulting research indicated that the physicochemical water qualities have met government quality standards for marine biota needs, except for the level of transparency at Ekas Station 3. Ekas Beach has the highest level of transparency, diversity, taxa richness, and total abundance of zooplankton, indicating the best water quality. Ujung Kelor Beach, which has the highest level of naturalness and the highest DO concentration, has moderate zooplankton diversity, indicating that the water quality is in the medium category. Meanwhile, Awang Beach, which had the highest human activity and the worst water quality, was characterized by low levels of transparency and DO, low diversity, taxa richness, and an abundance of zooplankton. Therefore, diversity, taxa richness, and abundance of zooplankton can be used as a bioindicator for changes in water quality.

Keywords: *Awang Bay, bioindicator, water quality, zooplankton*

INTRODUCTION

Awang Bay is a bay covering an area of approximately 247.15 km^2, surrounded by several beaches in two different regencies. In East Lombok Regency, there is Ekas Beach, where a significant portion of the local population is engaged in fisheries, tourism, seaweed farming, and trade. In Central Lombok Regency, there are Ujung Kelor Beach, located in Pemongkong Village, and Awang Beach, situated in Awang Hamlet, Mertak Village, Pujut District. Most residents in these areas have been traditionally fishermen, which led the local government to designate Teluk Awang, specifically in Awang Hamlet, Mertak Village, as the Nusantara Fishing Port in 1999. In 2017, it was further developed into an Oceanic Fishing Port to improve the fishermen's economic well-being. This expansion required a land area of 20 hectares, and land reclamation and development efforts continued until 2019, with only 9 hectares having been reclaimed thus far.

With the establishment of the oceanic fishing port, the unloading and loading of fish catches are expected to increase, ranging from small to large vessels. Furthermore, Teluk Awang is one of the areas where lobster seedlings are captured in the waters of Lombok. Other locations for lobster seedling capture include Gerupuk Bay, Telong-Elong, and Ekas Beach. This lobster seedling capture activity has been developing since the early 2000 [1]. While allowing this activity has positive effects on the local fishermen's economy, as selling lobster seedlings is more promising than selling regular fish, there is concern about the potential negative impact of this activity on the water quality of Teluk Awang itself.

The overall activities, particularly in the waters of Teluk Awang, are a cause for concern as they have the potential to damage the ecosystem within Teluk Awang. These activities contribute various types of waste runoff (including nutrients and toxic substances) into the water, which can result in a decrease in the water quality and even damage to the coastal ecosystem (such as abrasion, sedimentation, and intrusion) in the vicinity [2]. The diversity of marine life can be disrupted by human activities, and conversely, the presence of marine life can affect the physical and chemical conditions of the water [3]. Therefore, there is a need to evaluate the conditions of the coastal area for control and management.

Marine life, such as plankton, is often used as a bioindicator of water quality. Plankton plays a crucial role in biogeochemical cycles and the food web. Plankton consists of phytoplankton, which serves as a producer for higher trophic level animals like zooplankton [4]. Zooplankton is a good indicator of environmental changes. Zooplankton are heterotrophic organisms that have very weak motility in the water columns. Zooplankton only moves in the sunlight zone where food resources are most abundant. They play an important role in higher trophic levels of the food web by consuming phytoplankton, various bacterioplankton, and sometimes other zooplankton [5]. Some species of zooplankton are known to have different tolerances for changing environmental conditions. Therefore, zooplankton is considered a good natural bioindicator because of its rapid response to fluctuating environmental conditions [6, 7, 8].

Based on the background provided, this research aims to evaluate the physical, chemical, and biological profiles of the waters in Awang Bay, utilizing zooplankton organisms as bioindicators of water quality. The goal is to obtain information about the current condition of the waters in Awang Bay, which can serve as a foundation for the next steps in environmental management to be undertaken by the relevant ministry or authorities.

METHODS

Study area. This research was conducted in Teluk Awang Central Lombok Regency, West Nusa Tenggara Province, Indonesia, which covers an area of approximately 247.15 km^2. We chose three locations for the research sampling site, including Awang, Ujung Kelor, and Ekas Beach, which have different human activities (Figure 1 and Table 1). Teluk Awang is located at approximately 8.7500° S latitude and 116.2833° E longitude. Teluk Awang is an area with a tropical climate characterized by an annual rainfall of around 1,500 mm (with the rainy season typically spanning from June to December) and an average annual temperature of approximately 28°C. The research was carried out from March to August 2023.

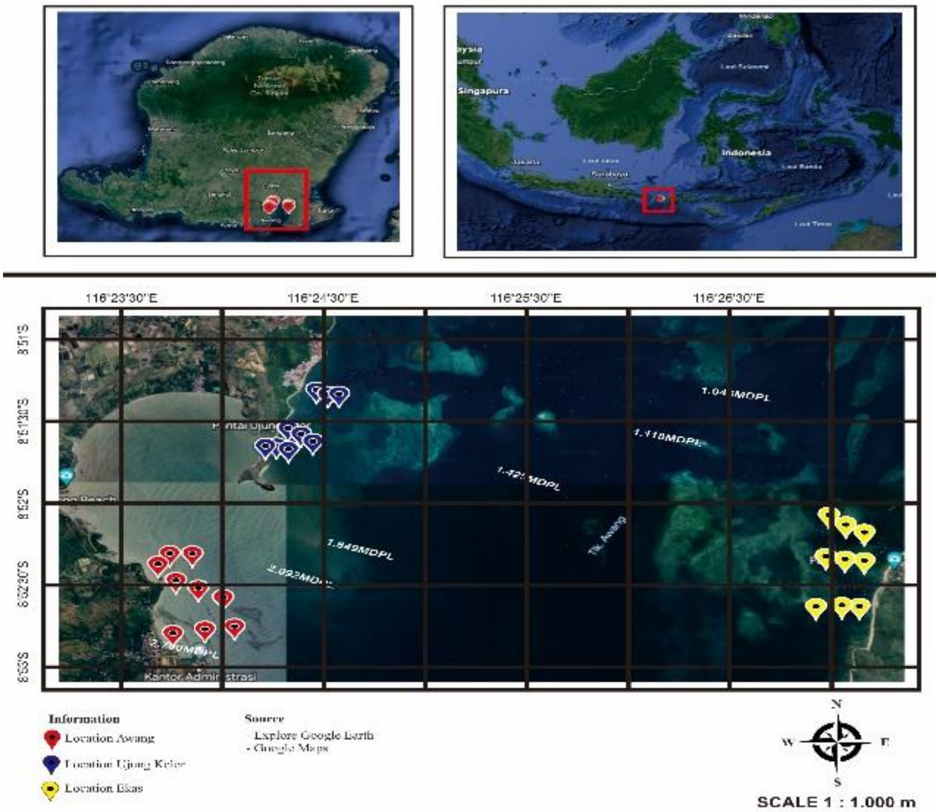

Figure 1. Sampling locations of zooplankton, water quality parameters, and land use

Table 1. Detailed information on human activities in sampling locations

Sampling Locations	Surrounding Human Activities
Awang Beach	Fishermen, fishing, netting, loading and unloading of large vessels, lobster cultivation, floating lobster seedling cages, infrastructure (residential areas, roads, public health centers, oceanic fishing port, embankment).
Ujung Kelor Beach	Fishing, netting, tourism, traditional fishing using "madak" (a type of traditional fishing gear), and gathering crabs during low tide.
Ekas Beach	Lobster seedling capture, lobster farming, seaweed farming, and grouper fish farming. Fishing, floating restaurant tourism, infrastructure (residential areas, floating restaurants).

Data collection. Sampling was conducted at three locations: Awang Beach, Ujung Kelor Beach, and Ekas Beach. At each location, samples were taken at three stations, with three replicates at each station (Figure 1). The sampling locations were selected based on the differences in anthropogenic activities in the surroundings (Table 1). A plankton net with a mesh of 30 µm was used for zooplankton sample collection. The physicochemical water quality was measured at each sampling location, including water temperature, pH, dissolved oxygen (DO), salinity, and transparency. DO was measured in the laboratory by handling water samples in a cool box so that the quality did not change, while other physicochemical water parameters were measured in situ. Water temperature was measured by a digital thermometer. Salinity was measured by a refractometer, and transparency was measured using a Secchi disc, whereas pH and DO were measured by a portable pH and DOmeter. Besides that, we also observed the Environmental factors, including land use conditions around the mangrove ecosystem and human activities, using the naturalness index [9] and the hemeroby index [10].

Data analysis. The results of the monitoring of physicochemical water quality were subjected to an Analysis of Variance (ANOVA), followed by the application of Tukey's Honestly Significance Difference (HSD) or Games-Howell post hoc tests using SPSS version 8.0. The identification and calculation of zooplankton abundance were then used to calculate various indices, including the Importance Value Index (IVI), Shannon-Wiener Diversity Index (HSW), Margalef Diversity Index (H Margalef), Simpson Diversity Index (H Simpson), Evenness Index (E), and Dominance Index (C). Identification and counting of zooplankton were performed using a Zeiss microscope with a magnification ranging from 20-40 x by comparing the morphological form of the organisms with the identification key book [11]. The data of physicochemical water parameters, zooplankton, and environmental factors were then used to determine the biplot analysis using Principal Component Analysis (PCA) using the PAST 4.05 software.

RESULTS AND DISCUSSION

Physical and chemical water quality profile in Awang Bay. The physical and chemical water quality condition during the observation is shown in Table 2. Water transparency is determined based on the depth of the Secchi disk. The highest water transparency is found in Ekas, ranging from 1.68 to 4 meters, while the lowest water transparency is observed in Awang, ranging from 0.8 to 1.13 meters. Transparency at all research locations (except Ekas station 3) does not meet the quality standards for seawater biota based on PP No. 22 of 2021, which requires more than 3 m. This showed that based on the transparency value, all research locations are generally included in the eutrophic category with high trophic levels and water transparency depths of less than 2 meters. However, Ekas station 3 is categorized as mesotrophic waters, which have a moderate trophic level with water transparency depths ranging between 2 and 4 meters [12]. The high transparency in Ekas is due to the absence of active river flows near the coast that would contaminate the water with waste or sediment from the mainland. In contrast, Awang's low transparency results from two active river flows contributing waste from the mainland and human settlement activities along the shoreline.

The highest temperature was found in Ujung Kelor, from 28.66 to 29°C, while the lowest was in Ekas, from 27.43 to 27.73°C. This water temperature is normal and still meets the Indonesian government's quality standards which require a temperature of between 28-30ºC. Temperatures lower than this range are caused by measurements taken in the morning. Water temperatures between 25°C and 30°C indicate the typical conditions of tropical waters and support phytoplankton growth [13].

The highest pH value was found in Ekas, reaching a value of 8.03, while the lowest pH was observed in Awang, with a value of 7.21. The pH value of all research locations has met government standards for marine biota, which require a range between 7-8.5 The pH range in tropical coastal waters typically ranges between 7.5 and 8.5 [14]. The decrease in pH values in Ekas is due to high human activity.

The highest salinity was found in Ujung Kelor, with a value of 5.16%, while the lowest salinity was in Awang at 4.10%. The Indonesian government, based on regulation No. 22/2021, standardizes water salinity for marine biota to range between 3.3-3.4%. Based on this, it can be concluded that the value obtained in this research has exceeded the government's quality standards. The highest dissolved oxygen (DO) concentration was observed in Ujung Kelor, with a value of 9.58 $mg.L^{-1}$, while the lowest DO concentration was found in Awang at 7.21 $mg.L^{-1}$. The DO concentration of all research locations is high and has met the quality standards set by the government which requires a DO value of more than 5 mg/L. The high DO in Ujung Kelor results from low human activity, whereas the high activity in Awang leads to low DO levels, such as the presence of a harbor and residential areas, which can produce

Table 2. Physicochemical parameters of water at three sampling locations

Parameters	Awang			Ujung Kelor			Ekas			Stand.
	St. 1	St. 2	St. 3	St. 1	St. 2	St. 3	St. 1	St. 2	St. 3	
Temperature (°C)	26.50 ± 0.00 bc	26.03 ± 0.06 a	26.00 ± 0.00 ab	28.66 ± 0.57 abcde	29.00 ± 0.00 e	29.00 ± 0.00 e	27.43 ± 0.57 d	27.66 ± 0.23 d	27.77 ± 0.11 d	28-30
DO (mg.L^{-1})	7.21 ± 1.50a	7.41 ± 0.22a	7.63 ± 0.41 a	9.58 ± 0.45 b	8.26 ± 0.23ab	8.10 ± 0.35a	8.62 ± 0.80ab	7.88 ± 0.37a	7.94 ± 0.82b	>5
pH	7.42 ± 0.08a	7.36 ± 0.04a	7.58 ± 0.27 ab	8.33 ± 0.30 ab	7.95 ± 0.04 b	7.98 ± 0.00 b	7.95 ± 0.04 b	8.00 ± 0.04b	8.03 ± 0.04b	7-8.5
Salinity (%)	4.33 ± 0.57abc	4.30 ± 0.17ab	4.10 ± 0,17a	5.16 ± 0.28 abc	5.00 ± 0.10 bc	5.00 ± 0.00 abc	5.00 ± 0.00 abc	4.96 ± 0.57 bc	4.83 ± 0.11 bc	3.3-3.4
Transparency (m)	1.13 ± 0.11	0.88 ± 0.07	0.80 ± 0.34	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	1.68 ± 0.35	2.45 ± 0.30	4.00 ± 0.00	>3

Note: Stand. (Standard) is based on Indonesian government regulation No 22/2021 appendix VIII for marine biota. The same notation of each parameter indicated no significant difference between the stations based on the Brown-Forsythe test followed by Games-Howell (except for DO, based on ANOVA followed by Tukey HSD with α 0.05).

organic pollution, which in turn will result in low DO. Human activities, including settlements and infrastructure development, can reduce dissolved oxygen concentration in water [15].

Profile of zooplankton community structure in Awang Bay. The highest total abundance of zooplankton was found at station 3 in Ekas, which is 203 individuals.L^{-1}, while the lowest value was at station 1 in Ujung Kelor, which was 23 individuals.L^{-1} (Figure 2). The highest species richness was observed at station 3 in Ekas, with 37 individuals.L^{-1}, while the lowest species richness value was at station 1 in Awang, which is 6 individuals.L^{-1}. The low species richness in Awang might be caused by the high level of activity in that location, from observation during the research, it was seen that there was the presence of a harbor, numerous fishing activities, and a densely populated area.

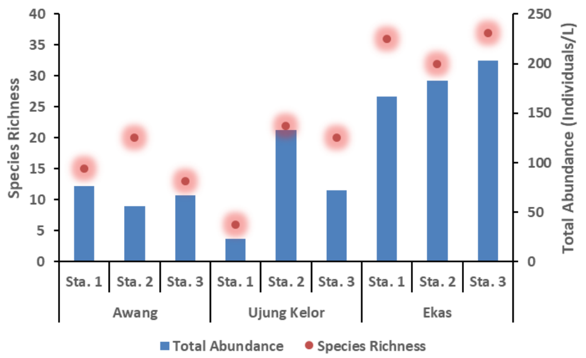

Figure 2. Total abundance and taxa richness of zooplankton (Note: Sta. is a station or sampling location).

Based on the Evenness index (E) calculation, the highest evenness was found at station 1 in Ujung Kelor, with an index value of 0.89 (Figure 3). Station 3 in Awang has the lowest index value, which was 0.75. The zooplankton diversity index varies based on station locations. These values indicate moderate to high evenness in zooplankton communities, with a value of almost 1. The high evenness at station 1 in Ujung Kelor suggests that the distribution of zooplankton communities is equally in the waters [16]. The highest Simpson dominance index (C) value is found at station 3 in Awang (0.2), while the lowest C index value is at station 1 in Ekas (0.07) (Figure 3). The dominance index is low at all research locations. A low dominance index indicates that zooplankton in the waters are not dominated by a single species in a community [17].

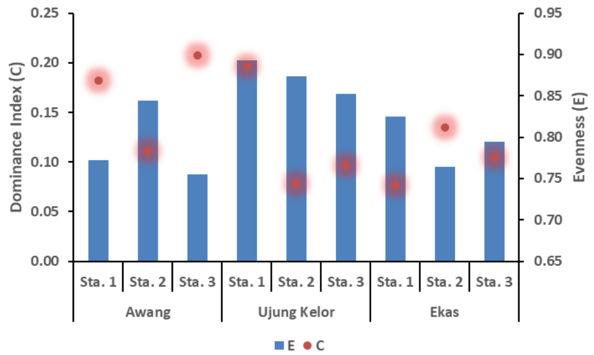

Figure 3. Dominance (C) and evenness (E) index of zooplankton (Note: Sta. is a station or sampling location).

Based on the Importance Value Index, the Awang location has two codominance species, namely *Calanus finmarchicus* and *Tigriopus japonicus Mori*, with Importance Value Index (IVI) values of 48.1% and 31.5% at station 1, 25.4% and 39% at station 2, and 55% and 33% at station 3 (Figure 4). In Ujung Kelor, different codominant zooplankton species were found. At station 1, the codominant species include *Balanus balanoides* (68.6%), *Oithona brevicornis* (34.6%), and (39.9%). At station 2, the codominant species are *Calanus finmarchicus* (24.3%) and *Oithona aruensis* (25.2%). Station 3 has codominant species, including *Calanus finmarchicus* (31.5%) and *Acartia Clausi* (29.62%).

In Ekas, there are varying codominant species. At station 1, the codominance species include

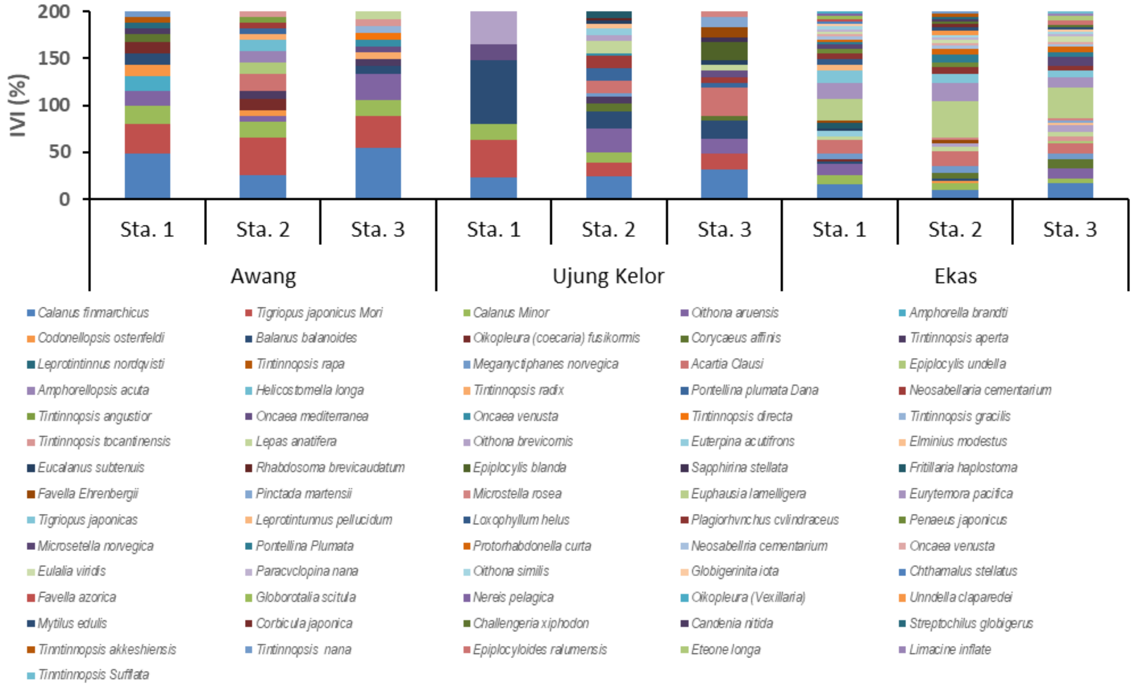

Figure 4. Importance Value Index (IVI) of zooplankton (Note: Sta. is a station or sampling location).

Euphausia lamelligera (22.2%), *Eurytemora pacifica* (17.8%), and *Calanus finmarchicus* (16.2%). At station 2, the codominance species are *Euphausia lamelligera* (38.2%) and *Eurytemora pacifica* (19.3%). Station 3 has codominance species, including *Euphausia lamelligera* (32.7%) and *Calanus finmarchicus* (16.9%).

The zooplankton species *Euphausia lamelligera* is classified as herbivorous and feeds on phytoplankton [18]. Meanwhile, *Eurytemora pacifica* can be classified as herbivorous or omnivorous [19]. *Calanus finmarchicus* has a significant number of individuals or biomass in the zooplankton community across all locations. This could be attributed to several factors, such as a broad food preference and tolerance to specific environmental parameters. *Calanus finmarchicus* is a species capable of adapting to changes in water physicochemical quality, such as transparency [20].

The Simpson diversity index in Figure 5 showed that the highest value was found at station 1 in Ekas, which is 0.92, while the lowest value was found at station 3 in Awang, with a value of 0.79 (Figure 5). Then, the Margalef diversity index shows the highest value at station 1 in Ekas, which is 15.75, while the lowest is at station 1 in Ujung Kelor, with 3.69. The Shannon-Wiener index (HSW) indicates the highest value at station 1 in Ekas, which is 4.266, while the lowest value is at station 3 in Awang, with 2.303. The average index values at all stations indicate HSW > 3, signifying high diversity, except at station 3 in Awang and station 1 in Ujung Kelor, which showed moderate diversity with values ranging from 2.307-2.794. The low values of the zooplankton diversity index at station 3 in Awang and station 1 in Ujung Kelor are influenced by environmental factors. Zooplankton is a water organism highly sensitive to environmental changes, making it vulnerable to alterations in physical and biological factors [21, 22]. In these locations, there are river inflows contributing pollutants from the land. Excessive human activities are a concern and are feared to impact zooplankton abundance [23, 24]. By monitoring the community structure and abundance of zooplankton, valuable information can be gained regarding environmental changes, as zooplankton serves as an indicator of environmental health [25].

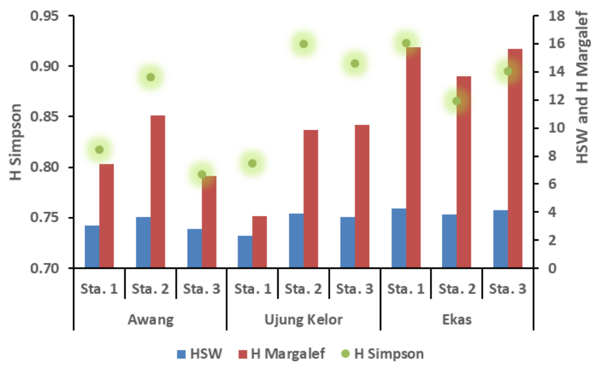

Figure 5. Diversity index of Shannon-Wiener (HSW), Margalef diversity index (H Margalef), and Simpson diversity index (H Simpson) of zooplankton (Note: Sta. is station or sampling location).

The highest naturalness index was found at station 1 in Ujung Kelor, with a value of 5, categorized as a low-intervention system (Figure 6). This location is a shallow coastal area with minimal human activities. On the other hand, the station with the lowest naturalness index is station 1 in Awang, with a value of 0, categorized as an artificial system. The low naturalness index at this station is due to extensive development, including settlements, docks, and other infrastructure.

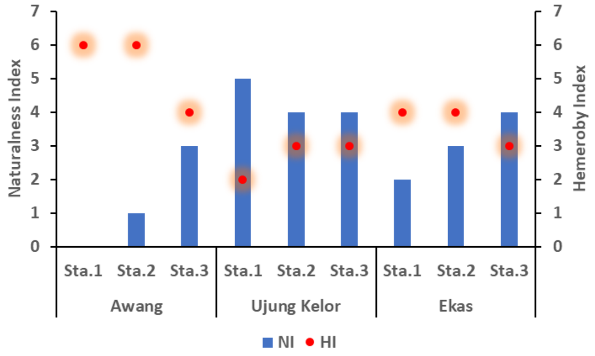

Figure 6. Naturalness index (NI) and hemeroby index (HI) of zooplankton (Note: Sta. is station or sampling location).

The highest hemeroby index is observed at station 1 in Awang (Figure 6), with a value of 6, classified as metahemerobic. This is due to fairly intense activities, including loading and unloading at the port, local fishermen's activities, lobster farming, and the capture of lobster fry using floating cage nets. However, the lowest hemeroby index is found at station 1 in Ujung Kelor, with a value of 2, categorized as mesohemerobic, indicating fewer human activities at this location.

The results of the biplot analysis using PCA indicate a shift in water quality at each research location (Figure 7). Based on the PCA analysis, Awang Beach is determined by the highest Hemeroby index parameter. This indicates that anthropogenic intervention at Awang Beach is the highest Compared to Ujung Kelor Beach and Ekas Beach. A high hemeroby index will reduce the physicochemical water quality, thus reducing the diversity of zooplankton.

The environmental factor observations showed that Ekas Beach and Ujung Kelor Beach have lower hemeroby index compared to Awang Beach, indicating better diversity and water quality in these two beaches. Ekas Beach was characterized by a high Margalef diversity index, high Taxa Richness, high Shannon-Wiener diversity index, and high Simpson diversity index. Ujung Kelor Beach was characterized by high salinity, temperature, pH, naturalness Index, and DO. Ujung Kelor Beach has the highest Naturalness Index with minimal anthropogenic intervention. A high Naturalness Index also indicates high physicochemical water quality [26].

Therefore, it can be concluded that Awang Beach has the worst water quality, characterized by a high hemeroby index (HI) with low transparency, salinity, temperature, pH, naturalness index (NI), dissolved oxygen (DO), low diversities value (Shannon-Wiener, Margalef and Simpson) and also taxa richness and abundance of zooplankton. On the other hand, Ekas Beach has the best water quality, with the highest level of transparency and also the highest diversity and taxa richness of zooplankton. The existence of fish and lobster farming in this area is assumed to increase the nutrient levels from leftover fish feed that is subsequently decomposed by microbes, becoming a nutrient source for phytoplankton, thus leading to increased zooplankton diversity. Meanwhile, Ujung Kelor Beach, with the highest level of Naturalness index, has better water quality with the highest levels of DO, temperature, salinity, and pH with moderate zooplankton diversity, indicating that the water quality is in the medium category. Therefore, diversity, taxa richness, and abundance of zooplankton can be used as a bioindicator for changes in water quality.

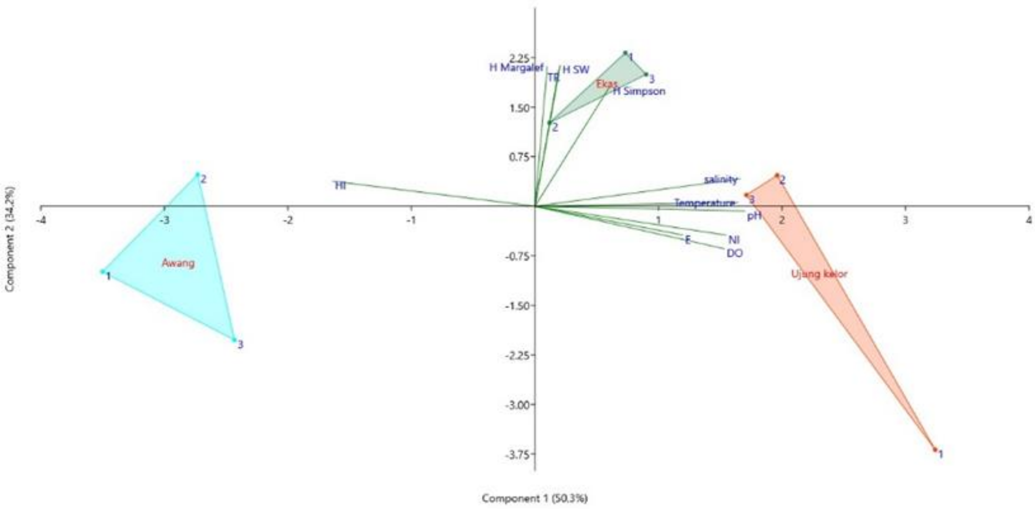

Figure 7. Water quality in Awang Bay based on biplot analysis using PCA. Note: HI (hemeroby index), NI (naturalness index), HSW (Shannon-Wiener diversity index), DO (dissolved oxygen), pH, TR (total richness).

CONCLUSION

Some of the physicochemical water qualities such as pH, DO, and temperature at the three beaches of Awang Bay have met government quality standards for marine biota needs. However, the level of transparency is very low and does not meet these standards, except at Ekas Station 3. Ekas Beach has the highest level of water transparency, zooplankton diversity, taxa richness, and total density of zooplankton, indicating the best water quality. Ujung Kelor Beach, with the highest level of naturalness, has the highest levels of DO, temperature, salinity, and pH with moderate zooplankton diversity, indicating that the water quality is in the medium category. Meanwhile, Awang Beach, which has the highest human activity (hemeroby index), has the worst water quality, characterized by low levels of transparency and DO, as well as low diversity, taxa richness, and abundance of zooplankton.

ACKNOWLEDGMENT

The authors would like to appreciate the Laboratory of Ecology and Tropical Ecosystem Restoration, Biology Department, Universitas Brawijaya, for the research equipment, Mr. Rizaldi Saputra, Mr. Sopian Hadi, and others who have helped with the survey and sampling of the research site, and Mr. Zainul Muttaqin Sany who has helped in preliminary article concept.

REFERENCES

[1] Erlania, Radiarta IN, Sugama K (2014) Dinamika kelimpahan benih lobster (*Panulirus* spp.) di Perairan Teluk Gerupuk, Nusa Tenggar Barat. Tantangan Pengembangan Teknologi Budidaya Lobster, J. Ris. Akuakultur 9(3): 475-486.

[2] Shahabudin MM, Musa S (2018) Occurrence of surface water contaminations: an overview. In IOP Conference Series: Earth and Environmental Science 140(012058).

[3] Zhang L, Shen T, Cheng Y, Zhao T, Li L, Qi P (2020) Temporal and spatial variations in the bacterial community composition in Lake Bosten, A Large, Brackish Lake in China. Scientific Reports 10(304):1-10.

[4] AbdAllah AT, Ghazwani AA, Alfifi MH (2018) Biodiversity of zooplankton at some mangrove habitats at Jazan coastal areas. Life Science Journal 15(10): 61-65.

[5] Zannatul F, Z, Muktadir AKM (2009) A review: potentiality of zooplankton as bioindicator. American Journal of Applied Sciences 6 (10): 1815-1819.

[6] Kamlesh M, Prahlad D (2018) A critical review of zooplankton studies of lentic water bodies of India. International Journal of Environmental Sciences 7(3): 79-83.

[7] Hemraj DA, Hossain MA, Ye Q, Qin JG, Leterme SC (2017) Plankton bioindicators of environmental conditions in coastal lagoons. Estuarine, Coastal and Shelf Science 184: 102-114.

[8] Rashid H, Prakash MM (2022) Zooplanktons as bioindicators of water pollution from Vikram Tearth Sarovar Ujjain (M.P). Journal of Pharmaceutical Negative Results 13(Special Issue 5): 888-895.

[9] Machado A (2004) An index of naturalness. Journal for Nature Conservation 12(2): 95-110.

[10] Kim YM, Zerbe S, Kowarik I (2002) Human impact on flora and habitats in Korean rural settlements. Preslia 74: 409–419.

[11] Hickman CP, Roberts LS, Keen SL, Larson A, l'Anson H, Eisenhour DJ (2011) Integrated Principles of Zoology.15th edition. Mc-Graw Hills Higher Education Publishers. Boston, Madrid

[12] Kalipci E, Varol S, Hüseyin Cüce (2020) Evaluation of water quality and trophic condition of Yuvacik (Kocaeli-Turkey) drinking water dam reservoir. Mugla Journal of Science and Technology 6(2): 128-139.

[13] Mesquita MC, Prestes ACC, Gomes AM, Marinho MM (2020) Direct effects of temperature on growth of different tropical phytoplankton species. Microbial Ecology 79: 1-11.

[14] Dalpadado R, Amarasinghe D, Gunathilaka N (2022) Water quality characteristics of breeding habitats in relation to the density of *Aedes aegypti* and *Aedes albopictus* in domestic settings in Gampaha district of Sri Lanka. Acta Tropica 229:106339.

[15] Cahyaningsih AP, Deanova, AK, Pristiawati CM, Ulumuddin YI, Kusumaningrum L, Setyawan AD (2022) Causes and impacts of anthropogenic activities on mangrove deforestation and degradation in Indonesia. International Journal of Bonorowo Wetlands, 12(1): 12-22

[16] Nurfadillah N, Desrita D, Dewiyanti I, Rahayu RS, Maulidawati S, Sari S, Karina I (2022) Community structure of plankton in Aneuk Laot Lake Sabang Pulau Weh. E3S Web of Conferences 339: 03008.

[17] Xiang C, Ke Z, Li K, Liu J, Zhou L, Lian X, Tan Y (2021) Effects of terrestrial inputs and seawater intrusion on zooplankton community

structure in Daya Bay, South China Sea. Marine Pollution Bulletin 167: 112331.

[18] Israel AA, Gordo FC, Gutierrez GJ, Kozak ER (2015) Reproductive biology, embryo and early larval morphology, and development rates of krill (*Euphausia lamelligera* and *Euphausia distinguenda*), endemic to the Eastern Tropical Pacific. Sex Early Dev Aquat Org 1: 143–161.

[19] Moon SY, Choi JH, Kim JN, Ki SK, Maran BA (2016) New extension range and complementary description of *Eurytemora americana* (Calanoida: Temoridae) in northern Korea. Marine Biodiversity Records 9: 76.

[20] Sorensen L, Rogers E, Altin D, Salaberria I, Booth AM (2020) Sorption of PAHs to microplastic and their bioavailability and toxicity to marine copepods under co-exposure conditions. Environmental Pollution 258: 113844.

[21] Zhang K, Jiang F, Chen H, Dibar DT, Wu Q, Zhou Z (2019) Temporal and spatial variations in zooplankton communities in relation to environmental factors in four floodplain lakes located in the middle reach of the Yangtze River, China. Environ. Pollut. 251: 277–284.

[22] Pang Y, Tian Y, Fu C, Wang B, Li J, Ren Y, Wan R (2018) Variability of coastal cephalopods in overexploited China Seas under climate change with implications on fisheries management. Fish. Res. 208: 22–33.

[23] Halpern BS, Walbridge S, Selkoe KA, Kappel CV, Micheli F, Bruno JF, Casey KS, Ebert C, Fox HE, Fujita R, Heinemann D, Lenihan HS, Madin EMP, Perry MT, Selig ER, Spalding M, Steneck R, Watson R (2008) A global map of human impact on marine ecosystems. Science 319(5865): 948–952.

[24] Borgwardt F, Robinson L, Trauner D, Teixeira H, Nogueira AJ, Lillebø AI, Piet G, Kuemmerlen M, O'Higgins T, McDonald H, Arevalo-Torres J, Barbosa AL, Iglesias-Campos A, Hein T, Culhane F (2019) Exploring variability in environmental impact risk from human activities across aquatic ecosystems. Sci. Total Environ. 652: 1396–1408.

[25] Jakhar P (2013) Role of phytoplankton and zooplankton as health indicators of aquatic ecosystem: A review. Int. J. Innov. Res. Stud, 2: 489–500.

[26] Jahan R, Bodratti AM, Tsianou M, Alexandridis P (2020) Biosurfactants, natural alternatives to synthetic surfactants: Physicochemical properties and applications. Advances in colloid and interface science 275:102061.