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The Ecological Status of the Bottom Waters of an Artificial Lake, East Rumbai District, Pekanbaru City, Riau Province, Uses the ABC Curve

Status Ekologis Dasar Perairan Danau Buatan Kecamatan Rumbai Timur Kota Pekanbaru Provinsi Riau Menggunakan Kurva ABC

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Abstract

Artificial Lake is one of the lakes located in Lembah Sari Village, Rumbai Pesisir District, which was expanded into East Rumbai District on December 30, 2020, with an area of 166.40 ha. The various activities in the artificial lake cause a decrease in water quality due to the input of waste dumped into the lake, thus impacting the ecological condition of the biota, one of which is macrozoobenthos. This research aims to determine the environmental status of bottom waters using macrozoobenthos. This research was carried out in July-August 2023 at three stations. The abundance of macrozoobenthos ranges from 115-465 ind/m^3, with the species consisting of 2 classes (Gastropoda and Oligochaeta) divided into four families. Generally, the macrozoobenthos found are the Oligochaeta, tolerant class, and the Gastropoda, facultative class. The diversity index for Stations I, II, and III ranges from 1.010 to 1.224, with a medium level of diversity. The ecological quality of the waters in the Artificial Lake based on the ABC Curve method for Stations I, II, and III showed that the seas were lightly polluted. In general, the water quality at Stations I, II, and III is not much different, where the parameters of temperature, brightness, depth, TSS, pH, and DO are still by class II quality standards PP No. 22 of 2021, but the BOD content is high. High BOD values indicate the amount of organic material at each station.

Keywords: ABC curve, Macrozoobenthos, Ecological status, Artificial Lake

Abstrak

Danau Buatan merupakan salah satu danau yang terletak di Kelurahan Lembah Sari Kecamatan Rumbai Pesisir dimekarkan menjadi Kecamatan Rumbai Timur pada tanggal 30 Desember 2020 dengan luas 166.40 ha. Beragamnya aktivitas di Danau Buatan yang menyebabkan penurunan kualitas air akibat masukan limbah yang dibuang kedalam danau, sehingga berdampak pada kondisi ekologis biota salah satunya makrozoobentos. Penelitian ini bertujuan untuk menentukan status ekologis dasar perairan menggunakan makrozoobentos. Penelitian ini dilaksanakan pada bulan Juli-Agustus 2023 di 3 stastiun. Kelimpahan makrozoobentos berkisar dengan jumlah 115-465 ind/m^3 dengan spesies yang ditemukan terdiri dari 2 kelas (Gastropoda, dan Oligochaeta) yang terbagi dalam 4 famili. Secara umum makrozoobentos yang ditemukan yaitu kelas Oligochaeta yang bersifat toleran, dan kelas Gastropoda yang bersifat fakultatif. Indeks keanekaragaman Stasiun I, II, dan III berkisar 1,010-1,224 dengan tingkat keanekaragaman sedang. Kualitas ekologis perairan di Danau Buatan berdasarkan metode Kurva ABC Stasiun I, II, dan III didapatkan kondisi perairan tercemar ringan. Secara umum kualitas air pada Stasiun I, II, dan III tidak jauh berbeda, dimana parameter suhu, kecerahan, kedalaman, TSS, pH, dan DO masih sesuai dengan baku mutu kelas II PP No. 22 tahun 2021, namun kandungan BOD tinggi. Nilai BOD tinggi menunjukkan banyaknya bahan organik pada masing-masing stasiun.

Kata kunci: Kurva ABC, Makrozoobentos, Status Ekologis, Danau Buatan

1. Introduction

Artificial Lake is one of the lakes located in Lembah Sari Village, Rumbai Pesisir District, which was expanded into East Rumbai District on Artificial Lake is one of the lakes situated in Lembah Sari Village, East Rumbai District with an area of 166.40 ha (1.07% of the area of Rumbai Pesisir District has been expanded into East Rumbai). The artificial lake was formed due to the damming of tributaries, namely the Ambang River and the Merbau River. Initially, this reservoir was used for agricultural irrigation and pond watering. However, since 1991, this reservoir has been developed as a tourist area and a floating net cage.

This existence is vital for nearby people because it has great potential, especially in tourism, economy, and fisheries (Wahyudi et al., 2019). The primary pollution that enters the lake's waters is caused by the habits of people who live around the lake, such as domestic waste from residential areas, nutritional waste from leftover feed that farmed fish do not consume, and waste from tourism in the form of rubbish from visitor activities. The surrounding community's activities can influence the quality of lake waters. Biotic and abiotic components in and around lake waters will interact to form a functional relationship. These components will then interact to create a flow of material and energy that will support ecosystem stability (Tulandi, 2022).

The variety of human activities causes a decrease in water quality due to the input of both tourism waste, household waste, and floating net cage waste, which results in pollution and damage to the biota and essential ecosystems of the waters. One of the biota affected by aquatic waste is macrozoobenthos. The minimal movement of macrozoobenthos causes macrozoobenthos not to migrate even though changes occur in the aquatic environment. Polluted waters will affect macrozoobenthos' lives because this organism is one of the biota easily affected by pollutants (Widhiandari et al., 2021).

Macrozoobenthos is an aquatic organism that settles at the bottom of the waters. It has relatively slow movements and a relatively long life cycle to continuously respond to water quality conditions (Fadillah et al., 2016). The size of macrozoobenthos ranges from 1.0 mm or more (Rahma et al., 2022). Macrozoobenthos is used as an indicator because it is capable of living sedentary (sessile) in water and can adapt to various environmental changes in water (Armita et al., 2021). The use of macrozoobenthos in evaluating the health of water bodies has the advantages of macrozoobenthos being widely distributed in waters, relatively low mobility, easy to collect, and having different sensitivities to pollution (Etemi et al., 2020; Aazami et al., 2015).

Changes in water quality and the substrate in which they live intensely influence the abundance and diversity of macrozoobenthos. Abundance and diversity are greatly influenced by tolerance and sensitivity to environmental changes (Sudia et al., 2020), so it is necessary to determine water quality based on the ecological status of the bottom of the waters using the abundance and biomass comparison curve method.

2. Material and Method

2.1. Time and Place

This research was conducted from August to October 2023. The research location was Artificial Lake, East Rumbai District, Pekanbaru City, Riau Province. Meanwhile, sample analysis was carried out at the Management Ecology and Aquatic Environment Laboratory and the Marine Chemistry Laboratory, Faculty of Fisheries and Marine, Universitas Riau.

Figure 1. Map of research locations

2.2. Methods

The survey method was used in this research. Determining research stations uses a purposive sampling method, namely a method where station determination is based on conditions and activities around the Artificial Lake, East Rumbai District, Pekanbaru City. The sampling station was divided into three stations with three sampling points for three repetitions with a time interval of fourteen days. The primary and secondary data used in this research are primary and secondary. Primary data is taken directly into the field, including temperature, brightness, depth, TSS, pH, dissolved oxygen, and BOD. Samples taken in the field include macrozoobenthos samples and sediment samples.

2.3. Procedures

2.3.1. Determining Station Locations

The pickup station locations are at three stations: Station 1 is an area located in an area where there are activities such as tourism and also as a fishing spot. The coordinates of this station are 0º35'08" N 101º28'34" E. Station 2: This area is close to residential areas. The coordinates of this station are 0º35'03" N 101º28'34" E. Station 3: This is an area in the floating net cage area, where leftover fish food and feces are thrown directly into the lake. The coordinates of this station are 0º35'05" N 101º28'53"E.

2.3.2. Sampling Method

Macrozoobenthos sampling was carried out at three sampling points at each specified station three times with an interval of fourteen days. Benthos samples were taken using a Van Veen Grab measuring 20×20 cm, which was lowered into the water to the bottom of the water. Then, the sample is removed, and the lifted substrate is filtered using a sieve or sieve with a mesh of 1.0×1.0 mm. Next, the macrozoobenthos samples obtained were composited and transferred into plastic clips, then labeled with the station code. Samples measuring 1-5 cm were given 4% formalin preservative in a cool box. The macrozoobenthos samples that have been obtained are then grouped based on the same shape and then identified in the laboratory. For this ABC curve analysis, biomass data (dry weight) is needed from macrozoobenthos samples, which are dried in an oven at 105℃ for around 1-2 hours and then weighed on an electric scale. After that, the samples were calculated for abundance, relative abundance, biomass, and relative biomass referring.

Sediment sampling in lake waters was carried out using a Van Veen Grab measuring 20×20 cm. 500 g of samples were taken to analyze sediment fractions and total organic matter content. Sediment samples were taken by dropping the Van Veen Grab into the bottom of the water. After the sediment sample is taken, it is lifted to the water's surface. Then, the sediment samples are put into plastic, labeled with a station code, and taken to the laboratory for analysis. Meanwhile, the method used in calculating total sediment organic matter is Loss on ignition or high-temperature burning (Alaerts & Santika, 1984).

Water quality measurements were carried out to determine the condition of the waters at the research location, including physical and chemical parameters. Water quality measurements are carried out at each observation station. The physical and chemical parameters of the waters measured are temperature, depth, brightness, TSS, degree of acidity (pH), dissolved oxygen, and BOD (Biochemical Oxygen Demand).

2.4. Data Analysis

2.4.1. The Diversity Index (H')

The diversity of macrozoobenthos types can be determined using the Shannon-Wiener diversity formula as follows:

$$H' = -\sum pi\ Log_2 pi$$
$$= -\sum_{n=1}^{n} pi\ In\ pi \qquad p_i = n_i/N$$

Description:

H' = Diversity index
p_i = Proportion of type I individuals from the entire population
n_i = Number of individuals of the ith species
N = Total number of individuals
In = Natural logarithm

2.4.2. Uniformity Index (E)

$$E = \frac{H'}{H_{max}} = \frac{H'}{In\ (S)}$$

Description:

E = uniformity index
H' = Shannon-Wiener diversity index
In = natural logarithm
H' max = maximum species diversity
S = number of species

2.4.3. Dominance Index (C)

$$C = \sum (pi)^2$$
$$C = \sum (ni/N)^2$$

Description:

C = Simpson's dominance index
p_i = Proportion of individuals of type 1 from the entire population (ni/N)
n_i = Number of individuals of the 1st species
N = Total number of individuals

2.4.4. Macrozoobenthos Abundance

Macrozoobenthos abundance is calculated based on the number of individuals per unit area (ind/m^2) divided by five van Veen grab uptake/drops, using the formula, namely:

$$K = \frac{number\ of\ individuals\ of\ a\ species}{sample\ unit\ area\ (20\times20\ cm)} \times 10000$$

$$\text{Relative Abundance} = \frac{K\ of\ a\ species}{K\ total} \times 100\%$$

$$\text{Biomass (B)} = \frac{Biomassa\ of\ an\ individual}{sample\ unit\ area\ (20\times20\ cm)}$$

$$\text{Relative Biomass (BR)} = \frac{B\ of\ a\ species}{B\ total} \times 100\%$$

The ABC (Abundance and Biomass Comparison) curve method is used to determine environmental conditions by analyzing the total number of individuals per unit area (density) and the weight per unit area of the macrozoobenthos community (Warwick, 1886). The stages of ABC curve analysis are as follows: Determine the list of relative percentages of the total number of individuals/m^2 and total weight per/m^2 of each type of macrozoobenthos; a) Each type is ranked based on the relative percentage of the total number of individuals/m^2 and total weight/m^2 of each type of macrozoobenthos, and determines the cumulative of the relative percentage of the total number of individuals per/m^2 and total weight/m^2, thus forming a cumulative percent dominant; and b) data on the ranking of the total number of individuals/m^2 and total weight per/m^2 are plotted on the x-axis in logarithmic form, while on the y-axis data is plotted on the dominant cumulative percentage of density and biomass.

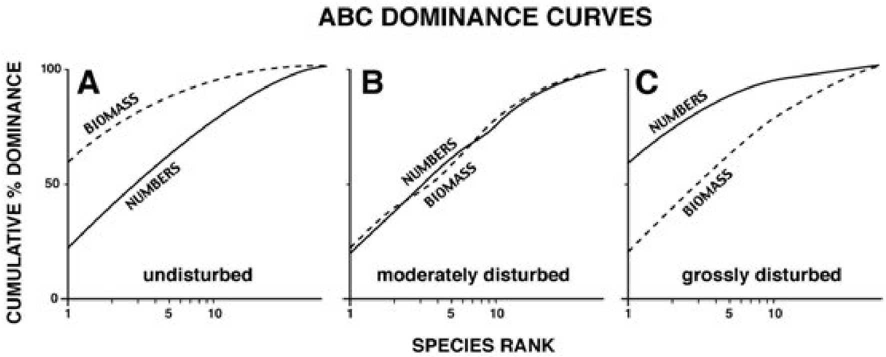

Figure 2. K-dominance curve hypothesis as an approximation to the ABC curve between species abundance (-) and biomass (------)
Description: (a) ecosystem conditions are not disturbed, (b) disturbed with moderate intensity (moderate), and (c) conditions where there is ecological disturbance and pressure.

3. Result and Discussion

3.1. Water Quality

The results of measuring water quality parameters; temperature values ranged from 28-29℃. According to PP no. 22 of 2021 class II, the temperature in the waters of the Artificial Lake still meets quality standards. According to Ruswahyuni (2010), a temperature of 25-30°C is suitable for macrozoobenthos. The brightness values measured ranged from 68-73 cm. The brightness of a body of water depends on its color and turbidity. According to Mustofa (2018), the brightness of water is influenced by suspended materials, whether in the form of mud, organic materials, plankton, and other microorganisms. The results of measuring the depth of the Artificial Lake range from 1.4 to 17 m. According to Odum (1993), several types of macrozoobenthos can generally be found at different depths, where various water depths will influence the type and abundance of macrozoobenthos. The TSS or Total Suspended Solid measurement results obtained ranged from 7.6-12.6 mg/L. Rahman et al. (2012) stated that the TSS value in waters is influenced by the amount of suspended solids, such as organic material originating from soil erosion, population waste, and rubbish that enters the waters. According to PP No.22 of 2021 class II, this value is still within the quality standards and is still classified as good.

Based on research results, the pH value ranges from 6.6-7. Water conditions with this pH value still support macrozoobenthos' life in artificial lakes. According to Azizah (2021), most aquatic biota is sensitive to changes in pH and usually have a pH of around 7-8.5. Some macrozoobenthos have sensitivity to optimum pH (Sulaeman et al., 2020). DO values range from 5.6-5.8 mg/L. Based on the quality standards according to PP No.22 of 2021 class II, the minimum threshold for dissolved oxygen is at least 4-6 mg/L, so it can be concluded that the dissolved oxygen in the Artificial Lake still meets the quality standard limit. This also follows research by Marpaung (2013), which states that the DO range of waters that support macrozoobenthic communities is between 4-6 mg/L. So, it can be said that the dissolved oxygen concentration in the waters of the Artificial Lake is good for macrozoobenthic biota. The BOD value ranges from 3.6-3.8 mg/L, showing that the three stations are classified as polluted. According to PP Number 22 of 2021 class II, the permitted BOD value is 3 mg/L, so the BOD at the three stations does not meet the quality standards. The high value of organic material is due to several community activities and floating net cage cultivation activities, so waste entering the waters causes a buildup of organic material. This follows Hatta's (2014) statement, which states that the BOD value will be higher with the increase in the amount of organic matter in the waters. For clarity, the results of measuring the water quality of the Artificial Lake are presented in Table 1.

Table 1. Water quality in artificial lakes in East Rumbai District

Parameters	Unit	Station I	Station II	Station III	Quality Standard
Temperature	°C	28	28	29	Dev*
Brightness	Cm	79	77	69	60-90**
Depth	M	1,2	1	1,4	
TSS	mg/L	7,6	10,3	12,6	50*
pH	-	7	6,6	7	6-9*
Dissolved Oxygen	mg/L	5,8	5,7	5,6	4-6*
BOD	mg/L	3,8	3,8	3,6	3*

Description (*): PP No.22 of 2021 (Class II); (**): Alaerts & Santika (1984)

3.2. Type Composition, Classification, and Morphology of Macrozoobenthos

Based on the research results, four types of macrozoobenthos are found in the waters of the Subdistrict Artificial Lake Eastern tassels (Table 2).

Table 2. Types of macrozoobenthos found at each research station

Class	Family	Genus	Species	Station		
				I	II	III
Gastropoda	Ampullaridae	Pomacea	*Pomacea canaliculata*	√	√	√
	Ampillariidae	Pila	*Pila ampullaceal*	√	√	√
	Viviparidae	Cipangopaludina	*Cipangopaludina c*	-	-	√
Oligochaeta			*Limnodrillus* sp.	√	√	√

The macrozoobenthos species found in the waters of Artificial Lake, East Rumbai Subdistrict, consist of the Mollusc phylum, which contains Gastropoda class 3 species, and the Annelida phylum, which contains Oligochaeta class 1 species. Most species found during the study were from the Gastropoda class. The high average density of these species is due to factors that directly affect the presence of these species. In addition, the ability of individuals of this species to tolerate environmental changes makes this species easily and widely found. This is because the gastropod class can live in all types of freshwater ecology (Purnama et al., 2019).

3.3. Sediment Fraction and Total Organic Matter

The results of measuring sediment fractions in the waters of the research location are presented in (Table 3).

Table 3. Artificial Lake sediment fraction results

Station	Sediment Fraction (%)			Sediment Type
	Gravel	Sand	Mud	
1	3,55	48,06	48,39	Sandy Mud
2	3,03	41,00	55,97	Sandy Mud
3	0,30	46,37	53,33	Sandy Mud

The Artificial Lake waters sediment fraction analysis results showed that the substrate texture values obtained at each station during three observations were sandy mud in stations I, II, and III. The results of sediment fraction analysis from the three stations were not much different. This also causes the macrozoobenthos found at each station to be almost identical. The high mud fraction at Station I is caused by activities at Station I, which, as a tourism area, produce domestic waste in the form of liquids and organic solids, which settle into black mud at the bottom of the sediment. Domestic waste is in the form of used washing water, waste from public toilets, and leftover food from tourists that is thrown away and enters the water. According to Ginting (2006), the nature of the substrate of a body of water dramatically determines the presence of macrozoobenthos in the water. The soft and ever-changing bottom usually limits the macrozoobenthos for shelter. The base in the form of rocks is dominated by macrozoobenthos, which can stick and adhere.

The average total organic matter value in each station's analysis results ranges from 3.25 to 13.41. The highest organic material analysis results were found at Station III. The high level of organic matter at Station III is due to floating net cage fish cultivation activities, which contribute much organic matter to the waters. If the input of aquaculture waste is large enough in the waters, it will either come from uneaten food residue that rots and floats in the waters or waste produced by fish in the form of excreted feces and urine. Station III's high organic material content is due to the large amount of organic material entering the waters. This is following the high abundance of macrozoobenthos at this research station. Apart from that, decay from plant and animal remains accumulating at the bottom of the waters also causes the high organic matter content at Station III. The amount of organic material in the waters also influences the existence of macrozoobenthos. The higher the organic material content in the waters, the higher the abundance of macrozoobenthos will be, even though the species diversity is low (Fajri & Kasry, 2013).

3.4. Diversity Index (H'), Uniformity Index (E), Dominance Index (C), and Macrozoobenthos Abundance

The macrozoobenthos that were obtained during the research were calculated, including indices of diversity, uniformity, dominance, abundance (K), relative abundance (KR), biomass (B), and relative biomass (BR), to determine the cumulative percentage of each species.

Table 4. Index of diversity, uniformity, and dominance of macrozoobenthos

Station	Type	Total	H'	E	C	K (ind/m^2)	KR (%)
1	*Limnodrilus* sp.	68	1,020	0,929	0,388	340	52,31
	Pomacea	34				170	26,15
	Pila	28				140	21,54
2	*Limnodrilus* sp.	59	1,010	0,919	0,396	295	53,63
	Pomacea	28				140	25,46
	Pila	23				115	20,91
3	*Limnodrilus* sp.	93	1,224	0,883	0,342	465	50,82
	Pomacea	38				190	20,77
	Pila	28				140	15,3
	Cipangopaludina	24				120	13,11

At the three stations, the water quality has the same level of pollution, namely, that of lightly polluted. This can also be seen from the relatively similar species diversity index values ranging from 1.010-1.224. However, the diversity index value obtained at Station III was higher due to the abundance and number of macrozoobenthos types found. The activities influence the number of macrozoobenthos found in the lake's waters. At Station III, there is a floating net cage fish cultivation activity. This causes high levels of organic matter at this station due to the remaining wasted feed settling at the bottom of the water. The high level of organic material will become a food source for macrozoobenthos, so the types of macrozoobenthos found are more diverse and abundant in quantity.

The diversity, uniformity, and dominance index values in the waters are classified as Artificial Lake waters, which are classified as good waters with a medium diversity index based on the Shannon Wiener diversity index, namely H' <3.00. Good environmental conditions will cause macrozoobenthos to be able to adapt and tolerate better, while poor environments will be a limiting factor for the life of macrozoobenthos (Safitri et al., 2021). According to Marnis (2019), the uniformity index shows a community's even or uneven pattern of species distribution and ecological balance. If the uniformity index value is high, it means that the distribution of each species is even in the ecosystem. The uniformity index value at the three research stations includes high uniformity, meaning that uniformity between species is relatively even or the ecosystem community is stable.

Based on the Simpson value criteria, if the dominance index is close to 1 ($C > 0.5$), it means that there is a species that dominates in that area. However, on the other hand, if the dominance index is close to 0 ($C < 0.5$), it is indicated that in that area, no species dominates, so it can be said that no species dominates other species to the extreme. This shows that the condition of the aquatic community is relatively stable.

3.5. Basic Ecological Status of Water Resources Using the ABC Curve Method

Biomass data (dry weight) from dried macrozoobenthos samples is required to analyze the ABC curve method. The ecological status obtained using the ABC curve method shows that the artificial lakes at stations I, II, and III have water quality in the lightly polluted range because each type can live in this water quality, resulting in the biomass development of each organism. According to Warwick (1986), in unpolluted conditions, the density of macrozoobenthos will be smaller than the biomass of macrozoobenthos because macrozoobenthos are considered capable of following the k-strategy pattern (slow growth, large size, and low adaptation). This can be seen at each station, showing that the cumulative percentage line for macrozoobenthic biomass is above and almost parallel to the line for the cumulative percentage of macrozoobenthic abundance. In contrast, if a body of water is polluted, the macrozoobenthic abundance will be greater than the macrozoobenthic biomass because the macrozoobenthic pattern follows the k-strategy. It will be hampered by macrozoobenthos, which can follow the r-strategy (fast growth, small size, and high adaptation).

Stations I and II are stations that have community activities, namely tourism and residential activities. The high value of organic matter at station III is due to floating net cage fish cultivation activities, which contribute much organic matter to the waters. According to Harianja et al. (2018), feeding fish will produce organic matter and feces, accumulating at the lake's bottom. This follows Setiawan et al. (2015), who state that the most preferred habitat for *Limnodrilus* sp. is mud deposits and enormous piles of organic material. Based on the results of research carried out in the Artificial Lake, East Rumbai District, it was concluded that the source of pollution in the Artificial Lake came from anthropogenic activities such as tourism, domestic waste from residential areas, and floating net cage cultivation activities.

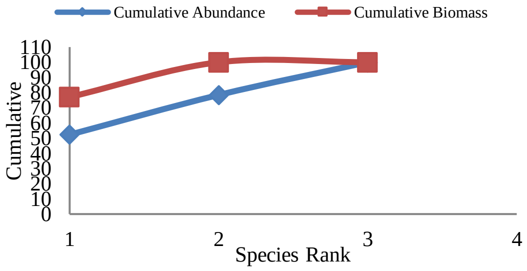

Figure 2. Station I ABC curve

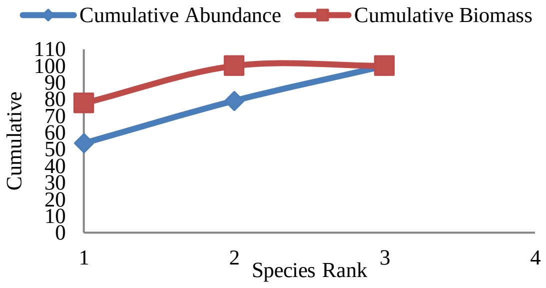

Figure 3. Station II ABC curve

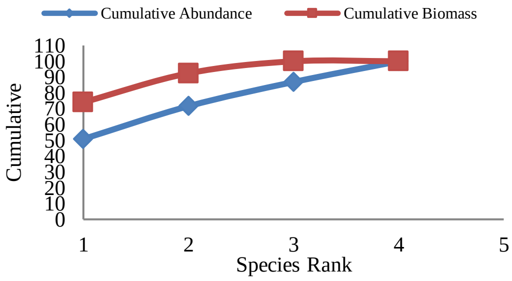

Figure 5. Station III ABC curve

4. Conclusions

Based on the research, it can be concluded that the macrozoobenthos found in artificial lakes consist of 2 classes: gastropods (3 species) and oligochaetes (1 species). The diversity of macrozoobenthos at the observation location is included in the medium category, which indicates lightly polluted waters. The macrozoobenthic uniformity index value is included in the high category, which suggests that there is no dominant type of macrozoobenthos and is also supported by the macrozoobenthic dominance index value, which is included in the low category at each station, with different pickup times. The basic ecological status of the waters of the Artificial Lake in East Rumbai District at Stations I, II, and III based on the ABC curve is included in the water category, which is classified as lightly polluted. Of all the water quality parameters observed, one parameter does not meet water quality standards, namely BOD.

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