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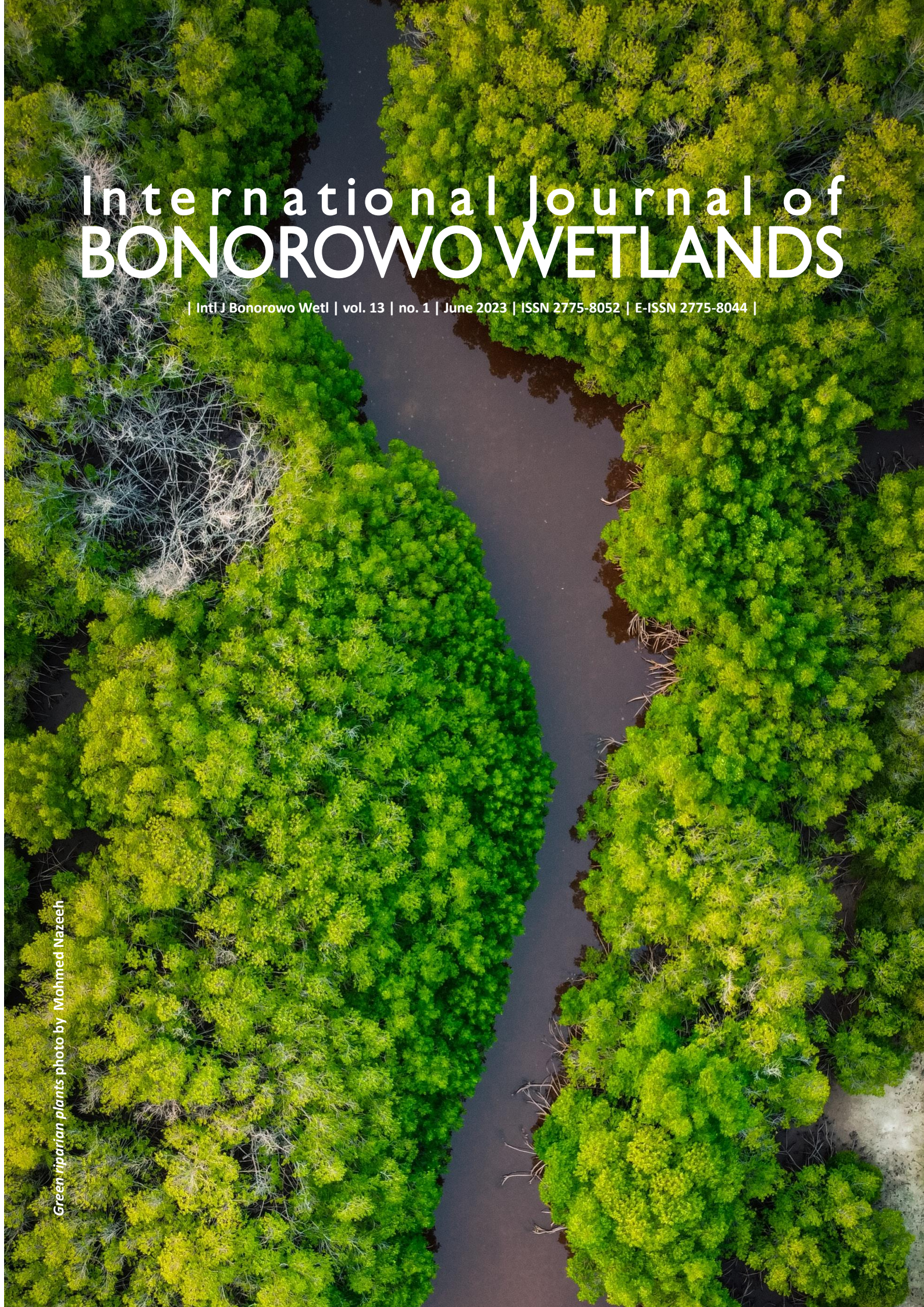

Green riparian plants photo by Mohmed Nazeeh

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Abstract A concise abstract is required (about 200 words). The abstract should be informative and state briefly the aim of the research, the principal results and major conclusions. An abstract is often presented separately from the article, thus it must be able to stand alone (completely self-explanatory). References should not be cited, but if essential, then cite the author(s) and year(s). Abbreviations should be avoided, but if essential, they must be defined at their first mention. **Keywords** are about five words, covering scientific and local name (if any), research themes, and special methods used; and sorted from A to Z. **Abbreviations** (if any): All important abbreviations must be defined at their first mention there. **Running title** is about five words.

Introduction is about 600 words, covering the aims of the research and provide an adequate background, avoiding a detailed literature survey or a summary of the results. **Materials and Methods** should emphasize on the procedures and data analysis. **Results and Discussion** should be written as a series of connecting sentences, however, for a manuscript with long discussion should be divided into subtitles. Thorough discussion represents the causal effect mainly explains why and how the results of the research were taken place, and do not only re-express the mentioned results in the form of sentences. **Concluding** sentence should be given at the end of the discussion. **Acknowledgements** are expressed in a brief; all sources of institutional, private and corporate financial support for the work must be fully acknowledged, and any potential conflicts of interest are noted.

Figures and Tables of a maximum of three pages should be clearly presented. The title of a picture is written down below the picture, while the title of a table is written above the table. Colored figures can only be accepted if the information in the manuscript can lose without those images; the chart is preferred to use black and white images. The author could consign any picture or photo for the front cover, although it does not print in the manuscript. All images property of others should be mentioned the source. Author is suggested referring to Wikipedia for international boundaries and Google Earth for satellite imagery. If not specifically mentioned, it is assumed to refer to these sources. **There is no appendix**, all data or data analysis is incorporated into Results and Discussions. For broad data, it can be displayed on the website as a supplement.

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Journal:

Saharjo BH, Nurhayati AD. 2006. Domination and composition structure change at hemic peat natural regeneration following burning; a case study in Pelalawan, Riau Province. Biodiversitas 7: 154-158. DOI: 10.13057/biodiv/d070213.

The usage of "et al." in long author lists will also be accepted:

Smith J, Jones M Jr, Houghton L et al. 1999. Future of health insurance. N Engl J Med 965: 325-329. DOI: 10.10007/s002149800025.

Book:

Rai MK, Carpinella C. 2006. Naturally Occurring Bioactive Compounds. Elsevier, Amsterdam.

Chapter in the book:

Webb CO, Cannon CH, Davies SJ. 2008. Ecological organization, biogeography, and the phylogenetic structure of rainforest tree communities. In: Carson W, Schnitzer S (eds.). Tropical Forest Community Ecology. Wiley-Blackwell, New York.

Abstract:

Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta*. 50th annual symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.). Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:

Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

Information from the internet:

Balagadde FK, Song H, Ozaki J, Collins CH, Barnet M, Arnold FH, Quake SR, You L. 2008. A synthetic *Escherichia coli* predator-prey ecosystem. Mol Syst Biol 4: 187. DOI: 10.1038/msb.2008.24. www.molecularsystembiology.com.

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Population density and distribution patterns of *Austruca annulipes* (Ring-legged fiddler crab) in the mangrove of Bogowonto Estuary, Kulon Progo, Yogyakarta, Indonesia

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Abstract. *Fadilah RN, Yulia IT, Alfitra ZS, Armadhan WS, Widyaningtyas R, Rahmayani D, Permatasari DP, Igustita, Kusuma D, Prambudi SA, Berlin GE, Triyanto A, Sutarno, Indrawan M, Dadiono MS, Rahim KABA, Setyawan AD. 2023. Population density and distribution patterns of* Austruca annulipes *(Ring-legged fiddler crab) in the mangrove of Bogowonto Estuary, Kulon Progo, Yogyakarta, Indonesia. Intl J Bonorowo Wetlands 13: 1-8.* The mangrove forest ecosystem is a forest with coastal plant characteristics that are influenced by tides and tolerate high salt levels. Mangrove forests in Indonesia contain about 89 species of flora, and around 18% of their fauna are keystone species. Keystone species are species that play an important role in maintaining the balance of the ecosystem. *Austruca annulipes* (H. Milne-Edwards, 1837), or Ring-legged fiddler crab is one of the fauna species in the mangrove ecosystem, which has an important role in maintaining the balance of the food chain and nitrogen cycle, so the study of this species is very important for the sustainability of the ecosystem in mangrove area. This study aimed to determine the population density and distribution patterns of *A. annulipes* in the Mangrove Bogowonto Estuary Area, Kulon Progo, Yogyakarta, Indonesia. The research method was purposive random sampling using a 10m x 10m square plot. Furthermore, the identification of morphology and documentation of the activities of *A. annulipes* was carried out, and data were examined using calculations of crab density. Based on the research finding, the population density of *A. annulipes* is 0.9975 individuals/m^2. Calculating the Morisita Index of *A. annulipes* obtained a value of 1.38 with the category of clumped distribution patterns. Various factors influence this distribution, including abiotic factors such as soil moisture, temperature, air, salinity, and pH. In addition, the presence of vegetation has also affected the density of *A. annulipes* because it is used as a shelter and foraging among its roots.

Keywords: Behavior, coastal ecosystem, Crustacea, Morisita Index, morphology

INTRODUCTION

Indonesia is one of the countries with the highest levels of biodiversity in the world and ranks second after Brazil (Dahlia and Mukti 2021). However, biodiversity in Indonesia continues to experience declining significantly. The increase in population will be linear with increasing anthropogenic activities, which also increase human needs leading to the emergence of exploitation of various species, which could cause decreased biodiversity (Mujiono et al. 2021). The loss of biodiversity is a crucial problem because it has implications for the survival of other living things (Suryana and Antara 2021). Therefore efforts to protect and preserve biodiversity are important things to do in the future.

The mangrove forest ecosystem is one type of forest in the tidal area. Mangrove forests are a meeting place for two groups of fauna: terrestrial and aquatic (Hasan et al. 2020). Mangroves are described as the characteristics of plants that live in river mouths or on the coast, which are influenced by sea tides and tolerating on high salt levels (Ramadhan et al. 2022). Mangroves play an important role in absorbing carbon in the atmosphere, which positively impacts global climate stability. Meanwhile, mangroves have important value in terms of ecological aspects as habitats for various fauna, breeding grounds for various marine biota, shelters, nutritional sources for various living things, and preventing coastal abrasion (Zeng et al. 2021).

The existence of mangroves in Indonesia is recorded at the remaining 1.2 million hectares (Irma et al. 2020). Mangroves can be found between land and sea as well as

along tropical and subtropical coasts. Therefore, the health condition of mangrove forests is the most important factor in ensuring the sustainability of forest functions and benefits. That can be observed by assessing indicators of forest health forest, namely the biodiversity of fauna and flora in mangrove forests (Sari et al. 2019). In Indonesia's mangrove forests, flora species reach about 89 species of plants consisting of 35 trees, 5 species of herbs, 9 species of shrubs, 29 species of epiphytes, and 2 species of parasites (Rahim and Baderan 2017). Meanwhile, mangrove fauna consists of vertebrates and invertebrates such as Crustaceans, Carideas, Mollusks, Echinoderms, Polychaeta, aves, reptiles, amphibians, mammals and primates, as well as fish vertebrates (Driptufany et al. 2021).

Approximately 18% of the total individual fauna are categorized as keystone species (Yudha et al. 2021). Keystone species are species that have an important role in the structure, function or productivity of a habitat or ecosystem (habitat, soil and seed disperser). The loss of this species will result in changes to other types of populations or ecosystems (Roberge and Angelstam 2004). For example, one keystone species in the mangrove forest is the *Austruca annulipes* (H. Milne-Edwards, 1837) or violin/fiddler crab, which males crab will grow larger. That is intended as a means of defense from enemies and to attract the females' attention. Meanwhile, the two claws of female crabs are small and function to eat and dig burrows or holes. The hole is the home of *A. annulipes* which can protect it from predators, salinity, temperature, and other crabs' attacks (Aprilyanto et al. 2017).

The mangrove ecosystem of Bogowonto Estuary is located in Pasir Mendit Hamlet, Jangkaran Village, Temon Sub-district, Kulon Progo District, Yogyakarta, Indonesia is operated as an ecotourism area with the trade names of Jembatan Api-Api Mangrove and Pasir Kadilangu Beach. This area was originally known as dunes, and mangrove lagoon ecosystems mostly converted to pond areas. That can be observed from the preference for the livelihoods of the local residents, who are dominated as fish farmers. The riverside area is heavily planted with mangrove forests, whereas the construction of bridges facilitates access through the mangrove areas. *Casuarina equisetifolia (cemara laut)* is one of the most dominant associated mangrove species. It can withstand the crashing of sea waves to preserve the environment and protect coastal areas to preserve the surrounding (Musrifah and Munir 2020). In addition to the various types of mangroves plant, some fauna, such as benthic fauna species, exist. Moreover, compared to other fauna, the benthic species is dominant while examining the composition of fauna in the mangrove ecosystem. The benthic fauna commonly found in the Mangrove Bogowonto Estuary area are crustaceans, mollusks, and mudskippers (Sari et al. 2019). This research examined *A. annulipes* because it dominates the Bogowonto Estuary Mangrove area. The existence and domination of this crab make the soil of the mangrove ecosystem fertile (Putriningtias et al. 2019). Mangrove forests are used to cultivate crabs and have a close relationship with environmental development, preserving mangroves and other habitats (Harini et al. 2019). Crabs in the mangrove ecosystem can be a bioindicator of whether the mangrove forest is functioning correctly. According to Kalor et al. (2018), crabs are keystone species in mangrove forests that can convert nutrients, increase mineralization, increase oxygen distribution in the soil, help the carbon cycle, and act as natural food providers for various types of biota in the waters. Therefore, this study aims to determine the condition of the mangrove ecosystem, which can be determined by research in the form of population density and distribution patterns of *A. annulipes* in the Bogowonto Estuary Mangrove area, Kulon Progo, Yogyakarta, Indonesia.

MATERIALS AND METHODS

Study area

This research was conducted in November 2022 in the Mangrove of Bogowonto Estuary area (Jembatan Api - Api and Pasir Kadilangu), located in Jangkaran Village, Temon Sub-district, Kulon Progo District, Yogyakarta Province, Indonesia (Figure 1), with geographical coordinates 7.89476, 110.02536. The reason for choosing this location was based on the initial survey showing that in this location, there were *A. annulipes* species crabs with populations that were quite dominating compared to other crabs. In addition, no research examines the research topic that we did.

Procedures

Sampling techniques

Observations for sampling *A. annulipes* crab species were made by making 32 plots measuring 10 m x 10 m at the sampling location. Plot selection is based on the substrate and tidal conditions that differ in each location. After that, the total number of *A. annulipes* crab species in each plot caught was counted and recorded. In addition, to support the completeness of the field data, supporting data was also taken on abiotic environmental factors such as water, water and soil temperature, water and soil pH, humidity, and water salinity. This sampling was carried out by 7 people at 8.00 a.m. to 2.00 p.m. In addition, this sampling was also carried out at low tide conditions so that the habitat of the *A. annulipes* crab could be seen on the surface. The collection of crabs is conducted by hand-picking techniques and a shovel to dig into the ground the crabs are hiding. Some of the caught crabs are then put into bottles and treated with alcohol (70%) to be preserved before being identified.

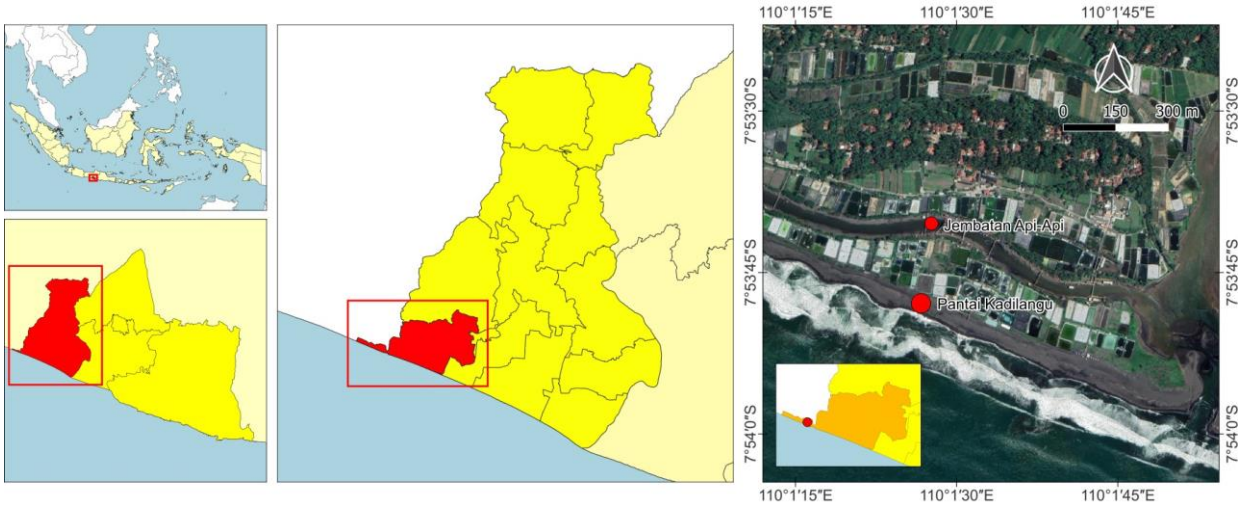

Figure 1. Research location of *Austruca annulipes* crab ecosystem in Mangrove Bogowonto Estuary, Kulon Progo District, Yogyakarta, Indonesia

Identification and behavioral activity

The *A. annulipes* crab type was identified based on its morphological characteristics, such as the color and size of the carapace surface; shape and color of pincers; body color; orbital area (the area around the eye); and body size. According to Michael et al. (2020), in the early stages of the crab species identification process, an introduction was made to the body parts of the crab used in the diagnosis process. Therefore, observations can be compared and described with the identification carried out by Michael et al. (2020) and strengthened by the identification book of violin crabs by Murniati and Pratiwi (2015).

The behavioral activity of the *A. annulipes* was directly observed and documented at each sampling location. The crab activities are obtained, such as entering the walking hole on the substrate, looking for food, eating bacteria deposited in the mud, competing with other species, and attention seeking (Table 1). Crab activity was observed for approximately 2 hours, with an average behavior observation of roughly 4-5 minutes for each plot.

Data analysis

Population density is defined as the number of individuals in a certain area in a community. The density of crab species is calculated relatively using the method below (Krebs 1998), namely :

$$N = \frac{\Sigma ni}{A}$$

Where:

N : Density of crabs (ind/m^2)

∑ni : Total number of individuals for species i (individuals)

A : The total area of the sampled area

$$id = n\frac{\Sigma X^2 - N}{N(N-1)}$$

Where:

id : Morisita spread index

n : Number of sampling plots

N : Total number of individuals in n plots

$\sum x^2$: Square of the number of individuals per n plots

After being analyzed, the Morisita index (Id) obtained values are interpreted as follows: (i) Id = 1, as a random distribution pattern, (ii) Id < 1, as a uniform distribution pattern, (iii) Id > 1, as a clumped distribution pattern.

RESULTS AND DISCUSSION

***Austruca annulipes* density**

The Mangrove Bogowonto Estuary (Jembatan Api - Api and Pasir Kadilangu) is a mangrove ecosystem with great potential to become a habitat for living organisms, like *A. annulipes*. Extensive mangrove ecosystem areas will also have high biodiversity. That is because the location of the mangrove ecosystem at this research location is between land and sea and is in tropical areas rather than sub-tropical. The divergence of biodiversity found in this location is also influenced by several factors, such as aquatic ecosystems that are regularly inundated by seawater due to tides, basic substrates in the form of soil compositions such as stagnant mud, and salinity values that are suitable for the needs of aquatic organisms. However, in this study, one of the biodiversity studied was a species originating from the crustacean community, namely the crab population. In the mangrove ecosystem, crabs are a group of animals that play a significant role in ecology, especially in the structure and function of mangroves (Fauzan et al. 2020). Crabs play an important role as the main linkage in the food chain. Crabs act as detritus eaters (related to the mineralization of organic matter) and control the number of residues in the mangrove ecosystem. Several groups of crabs that occupy mangrove habitats in tidal

areas can generally be found in abundant quantities. The density of crabs has closely related to the substrate's organic matter content and the density of mangrove plants. The higher the value of organic matter content and the density of mangrove plants will result in a higher total density of crabs in the region (Septiani et al. 2019). One type of crab identified that live densely in the Mangrove Bogowonto Estuary is *A. annulipes*.

The *A. annulipes*, also called fiddler or violin crabs, are a species that play a role in maintaining order between the food chain and the nitrogen cycle in mangrove ecosystems (Actuti et al. 2019). The *A. annulipes* live in nests in the form of holes in the ground, which are useful during high tide to serve as a place to hide. These holes can provide safe protection from temperature differences, predators, extreme salinity, and incursion from fellow crabs. The substrate content in this study site has a type of muddy sand and sand with an average soil moisture value of 10, a neutral soil pH, and a temperature of 32°C. According to Natania et al. (2017), this type of sandy soil makes it easy for *A. annulipes* to make holes because sandy soil has a high organic matter content. Based on this phenomenon, the substrate is an important environmental factor for the life of *A. annulipes*. Therefore, substrate suitability in the Mangrove Bogowonto Estuary affects the amount of density of the *A. annulipes* habitat. The population density of *A. annulipes* in the Mangrove Bogowonto Estuary (Jembatan Api - Api and Pasir Kadilangu), with a total of 32 plots of 10x10m^2 is 0.99 ind/m^2.

Out of a total of 97 *Austruca* crabs species in the world, there are around 19 species found in Indonesia (Krisnawati et al. 2018). The *A. annulipes* is a species of the genus *Austruca* (Naderloo et al. 2016). The diversity and density of *A. annulipes* are strongly influenced by environmental factors, such as salinity levels, tides, and the substrate where it lives. Therefore, *A. annulipes* will live well in suitable areas and could still live within their tolerance limits. However, changes in the salinity of the waters will affect the density of the crab population so that the population growth rate becomes higher in the higher salinity (Mumbah et al. 2018).

The density of *A. annulipes* is related to the organic matter content in a substrate, where the higher the organic matter content in the substrate, the higher the density (Krisnawati et al. 2018). Substrate plays an important role in the life of *Austruca* spp. (another type of fiddler crab), because the substrate is important for suitable spawning, foraging, and rearing children. Several studies reported that *Austruca* spp. found in mangrove areas in West Sumatra (Lauren and Sumarmin 2020), South Kalimantan (Fauzan et al. 2020), Central Java (Irwansyah et al. 2021), North Sulawesi (Rianta et al. 2018), Manado (Michael et al. 2020), and South Papua (Masiyah et al. 2021). In the mangrove ecotourism area of Pagatan Besar, Tanah Laut District, *A. annulipes* in the three observation plots with species density values in each plot sequentially, namely 0.42 ind/m^2, 1.08 ind/m^2, and 8.50 ind/m^2 (Fauzan et al. 2020). The increase in the density of *A. annulipes* was influenced by the type of substrate and direct exposure to sunlight. In Kema, North Sulawesi, the density of *A. annulipes* was 24.89 ind/m^2 throughout the forest (Rianta et al. 2018).

According to Michael et al. (2020), *A. annulipes* were found in two observation plots in Bahowo Waters, Manado, with density values of 1.6 ind/m^2 and 0.2 ind/m^2, where the Bahowo waters is a mangrove conservation area. On the mangrove area in Pacitan, East Java, to be precise in Teleng Ria, Grindulu, and Siwil Beaches, the average density of *A. annulipes* is 0.2 ind/m^2 (Irwansyah et al. 2021). Compared to the two previous studies, the density of *A. annulipes* in the Mangrove Bogowonto Estuary (Jembatan Api - Api and Pasir Kadilangu), Kulon Progo, Yogyakarta is quite high with a density value of 0.9975 ind/m^2. That is due to the environmental conditions in the Mangrove Bogowonto Estuary, which are suitable for the breeding habitat of *A. annulipes*.

Distribution pattern

Population distribution is the movement of individuals into and out of a population. The occurrence of distribution in a population, including *A. annulipes*, is due to the need to find food, avoid predators, climatic influences carried by water or wind, the desire to reproduce, and other physical factors. Populations of natural organisms generally have a clumped distribution pattern and are rarely found in a uniform pattern (Putra et al. 2018). Therefore, natural populations distribution is divided into uniform, random, and clumped distributions (Raunsay et al. 2020). Based on data from the calculation of the species *A. annulipes* in the Mangrove Bogowonto Estuary, the calculation results were obtained using the Morishita index formula of 1.38. Therefore, it can be concluded that the distribution pattern of *A. annulipes* in the Mangrove Bogowonto Estuary is clumped.

The distribution pattern of these crabs can be diverse in each place. For example, the distribution of crabs in a study conducted by Riswandi and Febriyani (2022) in the Curahsawo mangrove area, Probolinggo, Central Java, found 6 types of fiddler crabs, namely *Austruca rosea*, *Austruca lactea*, *Austruca vocans*, *Austruca perplexa*, *Austruca dussumieri*, and *Austruca demani*. The distribution patterns of the six types of fiddler crabs are divided into uniform and clumped distribution patterns, besides those three patterns described above. Types of fiddler crabs with a uniform distribution, namely *Austruca lactea*, *Austruca vocans*, *Austruca dussumieri*, and *Austruca demani*. In comparison, the types of fiddler crabs with a clumped distribution pattern are *Austruca rosea* and *Austruca perplexa*.

Abiotic factors and their relation to *Austruca annulipes* density

Environmental conditions are suitable for crabs, given the carrying capacity for *A. annulipes* to survive. However, *A. annulipes* have a vulnerable adaptability when drastic changes and conditions occur in the environment. The life of *A. annulipes* during the larval phase depends on salinity, temperature, and patterns of ocean currents. Meanwhile, when they are adults, they tend to live in holes around mangroves with sandy or muddy soil conditions and have a high dependence on substrate conditions. The mangrove

zone showed high levels of nutrients (N, P, TOC), silt, clay, soil moisture, high pore-water salinity, and low levels of porosity, sand, pH, temperature, and light mudflats compared to open mudflats (Min and Kathiresan 2021).

Environmental parameter values measured included soil moisture, air temperature, water temperature, soil temperature, water pH, soil pH, and soil salinity. Soil moisture obtained at 3 different sampling points in the Mangrove Bogowonto Estuary area (Jembatan Api-Api and Pasir Kadilangu) is 10 RH. According to Hanafi et al. (2020), soil moisture is affected by the water level in the soil. High groundwater causes the percentage of soil moisture to be high, this also affects the life of fiddler crabs. Fiddler crabs use a breathing apparatus in the form of gills, when at low tide the gills of fiddler crabs are modified to become like lungs. Modified breathing lasts only a short time, so it requires groundwater to breathe.

The *A. annulipes*, those living in mangrove ecosystems, have a tolerance to the temperature range between 23-33°C, and the optimum temperature for survival is not less than 20°C (Saparinto 2010). Based on temperature measurements in the field at three sampling points and three categories (water temperature, air temperature, and soil temperature), a water temperature value of 28.2-38.0°C was obtained; air temperature at the location is 27.4-37.5°C; and soil temperature at the location of 27-35°C. That shows that *A. annulipes* in the Mangrove Bogowonto Estuary live within their tolerance threshold.

The water pH, soil pH, and salinity have no differences significantly at each data location. The pH of the water at the data collection point is in the range of 7.5-8.2, and the soil pH based on three points has a value of 7. According to Saputri and Muammar (2018), under normal conditions, *A. annulipes* have a pH tolerance value of 6.5-9, which means crab *A. annulipes* or mud crabs can live in acidic to alkaline waters.

According to the identification results at three points in the field, a salinity value of 5-10 ppt was obtained. The range of salinity that can support crab life is oligohaline values (0.5-5 ppt) to mesohaline (5-18 ppt) and can still provide a suitable life for crustaceans (Rahayu et al. 2018). The highest salinity is at point 3 because this point is measured across the bridge, which is the closest point to the coast, so seawater has a more significant effect than fresh water. Salt levels in river waters in mangrove areas have fluctuating values and are influenced by freshwater runoff from the mainland and seawater inflow from river mouths (Kulkarni et al. 2010).

Furthermore, abiotic factors on environmental parameters influence the life of *A. annulipes*, which consist of the substrate, temperature, pH, humidity, and water salinity. For example, the fiddle crab, *A. annulipes*, is a crab type that can live in holes and only be found in mangrove forests, so the substrate and the availability of nutrients are the environmental factors that affect the life of *A. annulipes*. In addition, the density and size of mangrove trees will affect the area of canopy cover and the organic matter produced (Irwansyah et al. 2021).

Mangrove vegetation in the Mangrove Bogowonto Estuary area in the tree, sapling, and seedling phases all supported the life of the *A. annulipes* crab. That is because *A. annulipes* can grow, develop and forage among its roots. Therefore, the abiotic environmental conditions at the location of the plots and the sampling points can be categorized as good for mangrove ecosystems and the *A. annulipes*. Temperature values range from 28.5-38°C of water; 27.4-37°C of air; and 27-35°C of soil. In addition, pH values range from 7.0-8.2; humidity value 10 RH; salinity values of 5-10 ppt and sandy mud substrates are related to the density of *A. annulipes* in the Mangrove Bogowonto Estuary, Kulon Progo, Yogyakarta.

Austruca annulipes morphology

The *A. annulipes* population is the most observable part of this crab, so it has a significant impact on other observable parts except for populations, which are also important to examine, for example, 'reproduction', 'sex ratio', and 'fecundity.' Mangrove ecosystems are claimed to be habitats with critical status for animals, for example, the function of breeding places for fishery resources, where *A. annulipes* were becoming a threat (Chen et al. 2022). Specific features that can differentiate *A. annulipes* are the presence of sexual dimorphism and unbalanced or asymmetrical conditions on the claws (Figures 2 and 3), which are only shared by a few types of crabs. The asymmetrical condition of the male *A. annulipes* crab claws can be observed from the juvenile phase. In adult female crabs, the pair of claws is symmetrical and small compared to the claws of male crabs with large right pincers. Recent research has found that large and small claws' shape functions differ according to their objectives. The large claws of the *A. annulipes* crab do not change position even though they have undergone autotomy (Murniati and Pratiwi 2015).

The carapace shape of the *A. annulipes* crab is generally rectangular, which extends transversely with a size of 20-60 mm (Rahayu et al. 2018). The carapace color of this crab cannot be used as an identifying characteristic because the habitat can affect the color characteristic of the carapace, especially for *A. annulipes*. The *A. annulipes* that live in open space areas will directly be exposed to the sun and will have a lighter color, and vice versa. In addition, crab claws are formed by pollex and dactyl. Dactyls in *A. annulipes* located at the tips of the fingers, and the claws are shaped like spoons and function as a tool to take sand and mud substrates into the mouth. The large claws of male crabs do not have grooves on the outer surface of the dactilus and the outer surface of the pollex. Besides that, the manus is also not equipped with nodules. When examined by the morphology of male crabs, the larger claws of adult male crabs compared to female crabs are the main character trait of *A. annulipes* crabs.

Moreover, identification can be carried out on other body characters to distinguish the type. However, the difference in color types in male and female *A. annulipes* is a weak differentiator. Morphological characteristics that can be used to determine the species of *A. annulipes* can be observed on the carapace, the obit area around the eyes, the gonopod as the male genitalia, the gonopod as the female genitalia, the large claws on the male crab, the small claws, and the steae on the second maxilliped (Murniati and Pratiwi 2015).

Table 1. Ethogram behavior of *Austruca annulipes* crabs

Classification behavior	Behavior	Description
Territorial behavior	Take cover	Have an instinct or reflex to the presence of vibrations around its habitat so that when feeling the vibrations this crab will hide in its hole.
	Ingestif	Moving the claws repeatedly from the substrate to the mouth and back again to the substrate, this is similar to the movement of a violinist when moving the bow to the violin.
	Fighting or compete	Moving his large claws into the air to defend himself in the event of a fight between other species.
	Exploration	Walking touches the substrate using chelipeds and locomotion appendages (pereopods) while it moves.
Affiliative behavior	Attention-seeking	Male individuals will move their large claws up and down. This behavior indicates dominance to attract the attention of female individuals.

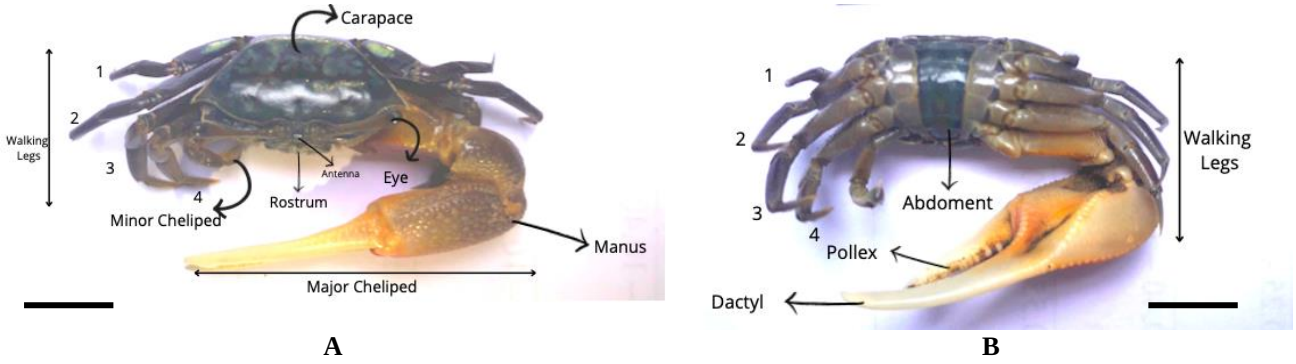

Figure 2. A. Upper and B. lower *Austruca annulipes* morphology. Bar = 1 cm

Figure 3. Difference between male and female *Austruca annulipes* crabs

The behavior of *Austruca annulipes* and its habitat

The behavior of *A. annulipes* in the observed habitat, namely in the Mangrove Bogowonto Estuary (Jembatan Api-Api and Pasir Kadilangu), Kulon Progo, Yogyakarta, observed as was walking on the substrate, going in and out of their hiding holes, eating, and interacting with other crabs. Crabs carry out the above activities at low tide because, at high tide, the crabs will crawl into the hole and then cover it with mud. While the *A. annulipes* crab is seen on the substrate, it quickly ducks into its hiding hole when it senses movement. That is because the *A. annulipes* prefer a quiet place, so when it feels vibrations, the *A. annulipes* will hide in its hole. Besides that, this action was also carried out as a form of self-protection for the *A. annulipes* crab from predators. When it feels safe, this crab will return and continue its activities, such as looking for food. In addition, *A. annulipes* also guard its territory against other crabs. If any animal invades their territory, *A. annulipes* will try to defend that area. Larger claws on crabs are used to defend themselves during a fight, as *A. annulipes* will try to defend the territory. In the observations that have been made, observed behavior such as ingestive movements can be carried out 20-40 times per minute, then fighting or competing behavior can be carried out as many as 20-35 moves per minute, draw attention behavior can be carried out as 15-30 times per minute. The take cover behavior is only carried out when *A. annulipes* feels a sudden vibration/movement from a predator or a foreign object. The exploration behavior was observed when *A. annulipes* was looking for food (more details can be seen in Table 1).

Figure 4. Habitats of *Austruca annulipes*

The holes made by crabs serve as a survival place and shelter from predators, a breeding ground, help crabs find food, and play a role in communication between vegetation (Figure 4) (Shofi 2021). When eating, the male *A. annulipes* crab often moves its large claws into the air while the other claws take food from the substrate. This movement is repeated and makes the claws of the *A. annulipes* crab look like a violin, so this crab is known as the violin crab. First, crab claws pick up the substrate and place it in the gap between a pair of maxillipeds. After that, there is a separation of organic matter from non-organic matter. This organic material will then slip into the crab's mouth, while non-organic material will be dropped or moved in the form of small grains. According to Lim et al. (2022), *A. annulipes* crabs prioritize activities to satisfy their hunger over other activities. This is related to the research of Xiang et al. (2020) which states that crabs spend 42.3% of their time eating, 27.0% eating while walking and 10.6% stationery respectively.

The density of *A. annulipes* in the ecosystem of Mangrove Bogowonto Estuary (Jembatan Api-Api and Pasir Kadilangu) based on the sampling results at 32 observation plots with a total density value of 0.9975 individuals/m². As for its distribution, *A.annulipes* can be found in areas with characteristics that can support life and are still within tolerance limits. Many factors, including abiotic factors such as soil moisture, temperature, air, salinity, and pH, influence this distribution pattern. Based on the calculation of the Morisita Index for the species *A.annulipe*s in the Mangrove Bogowonto Estuary, a value of 1.38 was obtained. This value means that the distribution pattern of *A. annulipes* is spread out in clumped distribution pattern. Besides that, existing vegetation in the study area affects the density of *A. annulipes* which can be used to shelter, grow, develop, and find food under the roots.

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REFERENCES

Actuti N, Apriansyah, Nurdiansyah SI. 2019. Keanekaragaman kepiting biola (*Uca* spp.) di Ekosistem Mangrove Desa Pasir, Kabupaten Mempawah Kalimantan Barat. Jurnal Laut Khatulistiwa 2: 25-31. DOI: 10.26418/lkuntan.v2i1.30162. [Indonesian]

Aprilyanto D, Fahri, Annawati. 2017. Identification of mud crab species of the Ocypodidae Family in Kabonga Kecil, Donggala, Central Sulawesi. Indones Zoo 26: 91-106.

Chen G, Mo Y, Gu X, Wang W, Cui B. 2022. Mapping the spatio-temporal dynamics of global mangrove crabs to reveal its status and challenges: A bibliometric evaluation of research output during 1980-2016. Watershed Ecol Environ 4: 100-111. DOI: 10.1016/j.wsee.2022.09.002.

Dahlia, Mukti BH. 2021. Keanekaragaman jenis kupu-kupu di perkebunan jeruk (*Citrus sinensis*) Desa Pisangan, Kecamatan Kandangan Barat, Kabupaten Hulu Sungai Selatan. Jurnal Pendidikan Hayati 7 (4): 217-225. [Indonesian]

Driptufany DW, Fajrin, Yulius H, Hidayat M, Kamal E, Razak A, Putra A. 2021. Karakteristik spesies fauna ekosistem mangrove dengan metode survey di Kawasan Teluk Bungsu-Padang. Jurnal Kependudukan dan Pembangunan Lingkungan 2 (1): 60-67. [Indonesian]

Fauzan N, Soendjoto MA, Zaini M. 2020. Kepadatan dan keragaman kepiting di Kawasan Ekowisata Mangrove Pagatan Besar, Kabupaten Tanah Laut, Indonesia. EnviroSci 16: 287-295. DOI: 10.20527/es.v16i2.9660. [Indonesian]

Hanafi H, Anwari MS, Yani A. 2020. Keanekaragaman kepiting biola pada Kawasan Hutan Mangrove Desa Karimunting Kecamatan Sungai Raya Kepulauan Kabupaten Bengkayang. Jurnal Hutan Lestari 8 (2): 350-364. DOI: 10.26418/jhl.v8i2.40332. [Indonesian]

Harini R, Ariani RD, Fistiningrum W, Ariestantya D. 2019. Economic valuation of mangrove management in Kulon Progo Regency. IOP Conf Ser: Earth Environ Sci 256: 1-1. DOI: 10.1088/1755-1315/256/1/012036.

Hasan S, Serosero RH, Abubakar S. 2020. Distribusi vertikal dan komposisi Moluska pada Ekosistem Hutan Mangrove di Gugusan Pulau-Pulau Sidangoli Kabupaten Halmahera Barat Provinsi Maluku Utara. Agrikan 13 (1): 29-37. DOI: 10.29239/j.agrikan.13.1.29-37. [Indonesian]

Irma W, Atmaja AT, Marfa'i MA. 2020. Biodiversitas vegetasi mangrove di Kecamatan Concong Kabupaten Indragiri Hilir Provinsi Riau. Majalah Ilmiah Biologi Biosfera 37 (2): 85-90. [Indonesian]

Irwansyah RM, Azzahra SIN, Darmastuti SA, Ramadhandi AR, Firdaus O, Daeni F, Safitri N, Fajri, Nugroho GD, Naim DMD, Setyawan AD. 2021. Crab diversity and crab potential as support for ecotourism in Teleng Ria, Grindulu and Siwil Beach, Pacitan, East Java, Indonesia. Intl J Bonorowo Wetlands 11: 75-83. DOI: 10.13057/bonorowo/w110204.

Kalor JD, Dimara L, Ottouw G, Piaki K. 2018. Status kesehatan dan uji spesies indikator biologi Ekosistem Mangrove Teluk Yotefa Jayapura. Journal Biosfera 35 (1): 1-9. DOI: 10.20884/1.mib.2018.35.1.495. [Indonesian]

Krebs CJ. 1998. Ecological Methodology (Second Edition). Addison-Welsey Educational Publishers, New York.

Krisnawati Y, Arthana IW, Dewi APWK. 2018. Variasi morfologi dan kelimpahan kepiting *Uca* spp. di Kawasan Mangrove, Tuban-Bali. J Mar Aquat Sci 4: 236-243. DOI: 10.24843/jmas.2018.v4.i02.236-243. [Indonesian]

Kulkarni VA, Jagta TG, Mhalsekar NM, Naik AN. 2010. Biological and environmental characteristics of mangrove habitats from Manori Creek, West Coast, India. Environ Monit Assess 168: 587-597. DOI: 10.1007/s10661-009-1136-x.

Lauren, Sumarmin R. 2020. Inventarisasi Decapoda di Hutan Mangrove Laguna Mangguang, Kota Pariaman, Sumatera Barat. Serambi Biologi 5: 79-85. [Indonesian]

Lim SSL, Mazlan D, Toh CKW. 2022. Larder hoarding versus immediate in situ food consumption in two fiddler crab species: Is it an evolutionarily stable strategy? Zool Stud 61: 1-19. DOI: 10.6620/ZS.2022.61-72.

Masiyah S, Nisaa K, Melmambessy EHP, Lutfi MA. 2021. Keanekaragaman kepiting biola (*Uca* spp.) dan respon tekstur tanah di Pantai Payunb Kabupaten Merauke. AGRIKAN - Jurnal Agribisnis Perikanan 14 : 734-756. [Indonesian]

Michael SC, Kaligis EY, Rimper JRTSL. 2020. Deskripsi, keanekaragaman jenis, dan kelimpahan kepiting (Brachyura Decapoda) di Perairan Bahowo Kelurahan Tongkeina Kecamatan Bunaken Kota Manado. Jurnal Pesisir dan Laut Tropis 8: 91-97. DOI: 10.35800/jplt.8.1.2020.27495. [Indonesian]

Min WM, Kathiresan K. 2021. Burrow morphologies crab characteristics and soil properties in different seasons across intertidal areas of a restored mangrove forest. J Sea Res 177: 102-111. DOI: 10.1016/j.seares.2021.102111.

Mujiono, Astuti W, Soehartono. 2021. Identifikasi flora dan fauna dalam pengelolaan keanekaragaman hayati di Kawasan Konservasi PT Indonesia Power Semarang. Neo Teknika 7: 42-46. [Indonesian]

Mumbah SK, Manyala JO, Njiru J. 2018. Influence of salt works' hyper-saline waste-brine on distribution of mangrove crabs (Decapoda) within the Gongoni-Kurawa Intertidal Area, Kenya. Kenya Aquat J 4: 38-47. DOI: 10.2022/ajest.v4i3.102.

Murniati DC, Pratiwi R. 2015. Kepiting *Uca* di Hutan Mangrove Indonesia: Tinjauan Aspek Biologi dan Ekologi Untuk Eksplorasi. Lipi Press, Jakarta. [Indonesian]

Musrifah S, Munir M. 2020. Membangun perisai pesisir dengan penanaman mangrove di Kawasan Pantai Desa Margosuko Kecamatan Bancar Kabupaten Tuban. J Abdi Mas TPB. 2: 54-59. DOI: 10.29303/amtpb.v2i1.43. [Indonesian]

Naderloo R, Schubart CB, Shihc HT. 2016. Genetic and morphological separation of *Uca occidentalis*, a new East African fiddler crab species, from *Uca annulipes* (H. Milne Edward, 1837) (Crustacea: Decapoda: Brachyura: Ocypodidae). Zoologischer Anzeiger 262: 10-19. DOI : 10.1016/j.jcz.2016.03.010.

Natania T, Herliany NE, Kusuma AB. 2017. Struktur komunitas kepiting biola (*Uca* spp.) di Ekosistem Mangrove Desa Kahyapu Pulau Enggano. Enggano Journal 2: 11-24. DOI: 10.31186/jenggano.2.1.11-24. [Indonesian]

Putra S, Ali MS, Huda I. 2018. Pola persebaran Gastropoda di Ekosistem Mangrove Sungai Reuleung Leupung Kabupaten Aceh. Jurnal Biotik 6: 59-62. DOI : 10.22373/biotik.v6i1.4044. [Indonesian]

Putriningtias A, Faisal TM, Komariyah S, Bahri S, Akbar H. 2019. Diversity of crab types in the Kuala Langsa Mangrove Forest Ecosystem, Langsa City, Aceh. J Trop Biol 19: 101-107. DOI: 10.29303/jbt.v19i1.1074.

Rahayu SM, Wiryanto, Sunarto. 2018. Biola crab diversity in mangrove areas, Purworejo Regency, Central Java. J Bioexp 4: 53-63. DOI: 10.23917/bioeksperimen.v4i1.5933.

Rahim S, Baderan DWK. 2017. Hutan Mangrove dan Pemanfaatannya. Depublish, Yogyakarta. [Indonesian]

Ramadhan DA, Hasibuan FU, Damayanti D, Amalia T. 2022. Persepsi masyarakat terhadap Ekowisata Hutan Mangrove Kuala Langsa. Jurnal Pengabdian Masyarakat Biologi dan Sains 1 (2) : 7-14. [Indonesian]

Raunsay EK, Akobiarek M, Ruamba MY. 2020. Distribusi vertikal *Asplenium nidus* L. di Kawasan Hutan Imbowiari, Kepulauan Yapen Papua. Jurnal Sylva Lestari 8: 390-399. DOI: 10.23960/jsl38390-399. [Indonesian]

Rianta P, Ernawati W, Chen G, Chen S. 2018. Diversity and abundance of mangrove fiddler crabs, genus *Uca* (Decapoda, Ocypodidae) at a Mangrove in Kema, North Sulawesi, Indonesia. Acta Oceanologica Sinica 37: 92-96. DOI : 10.1007/s13131-018-1336-8.

Riswandi A, Febriyanti U. 2022. Pola persebaran kepiting biola (*Uca* sp.) di Kawasan Mangrove Curahsawo Probolinggo, Jawa Timur. Jurnal Ilmu Perikanan Air Tawar (CLARIAS) 3 (13): 11-17. DOI: 10.56869/clarias.v3i1.345. [Indonesian]

Roberge JM, Angelstam P. 2004. Usefulness of the umbrella species concept as a conservation tool. Conserv Biol 18 (1): 76-85. DOI : 10.1111/j.1523-1739.2004.00450.x.

Saparinto C. 2010. Consumption Fish Business in 100 m^2 Land. Independent Spreader, Jakarta.

Saputri M, Muammar. 2018. Habitat characteristics of mangrove crab (*Scylla sp*.) in the Silang Cadek Mangrove Ecosystem, Baitussalam District, Aceh Besar District, Aceh Province. J Botik 6: 75-80. DOI: 10.22373/biotik.v6i1.4436.

Sari RN, Safe R, Iswandaru D. 2019. Biodiversitas fauna sebagai salah satu indikator kesehatan hutan mangrove. Jurnal Parennial 15 : 62-66. DOI: 10.24259/perennial.v15i2.6061. [Indonesian]

Septiani M, Sunarto, Mulyani Y, Riyantini I, Prihadi DJ. 2019. Pengaruh kondisi mangrove terhadap kelimpahan kepiting biola (*Uca* spp.) di Karangsong Kabupaten Indramayu. Jurnal Perikanan dan Kelautan 10: 84-91. [Indonesian]

Shofi S. 2021. Community Structure of *Uca* spp. (Crustacea: Decapoda: Ocypodidae) in the Mangrove Forest Area of Banyuurip Village, Gresik Regency. [Thesis]. Maulana Malik Ibrahim State Islamic University, Malang. [English]

Suryana IGPE, Antara IGMY. 2021. Pengembangan teknologi informasi geografi sebagai media eksplorasi keanekaragaman hayati (biodiversitas) di Indonesia. J Appl Comput Inform Syst 3: 46-55. DOI: 10.33173/jsikti.117. [Indonesian]

Xiang H, Li K, Cao l, Zhang Z, Yang H. 2020. Impacts of pollution, sex, and tide on the time allocations to behaviors of *Uca arcuata* in Mangroves. Sci Total Environ 742: 1-13. DOI : 10.1016/j.scitotenv.2020.140609.

Yudha RP, Sugito YS, Sillanpaa M, Nurvianto S. 2021. Impact of logging on the biodiversity and composition of flora and fauna in the mangrove forests of Bintuni Bay, West Papua, Indonesia. For Ecol Manag 488: 1-12. DOI: 10.1016/j.foreco.2021.119038.

Zeng Y, Friess DA, Sarira TV, Siman K, Koh LP. 2021. Global potential and limits of mangrove blue carbon for climate change mitigation. Curr Biol 31: 1737-1743. DOI: 10.1016/j.cub.2021.01.070.

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Assessment of water quality with comparative study of soil organic carbon stock in Nagdaha Lake and its adjacent agricultural land of Lalitpur, Nepal

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Abstract. *Bhatta M, Joshi R. 2023. Assessment of water quality with comparative study of soil organic carbon stock in Nagdaha Lake and its adjacent agricultural land of Lalitpur, Nepal. Intl J Bonorowo Wetlands 13: 9-16.* The lakes are an important component of the terrestrial Carbon (C) cycle. Estimates of global C burial by lakes suggest burial rates ranging from 0.03-0.07 Pg C yr^{-1}. In the present study, the water quality of Nagdaha Lake and comparative analysis of Soil Organic Carbon (SOC) in Nagdaha Lake and its adjoining agricultural area has been studied. Water quality was determined following APHA (1998); SOC was determined by the Walkey and Black (1934) Titration Method. The present study results show that the mean N-nitrate and P-phosphate concentration in the waters of Nagdaha Lake is 0.135 mg/L and 0.123 mg/L, respectively, and the mean SOC concentration of Nagdaha Lake (71.39±42.58g kg^{-1}) is higher than the adjacent agricultural land (14.36±8.38g kg^{-1}). The t-test result also shows that there is a significant difference in SOC concentration in lakes (t = 9.18) and agricultural (t = 7.66) for agricultural land ($p < 0.0001$). Nagdaha Lake's area decreased from 52 ropani to 42 ropani between 1964 and 2022. Despite the decrease in area, Nagdaha Lake has more carbon per unit area than agricultural land. Since the conversion of lake land to agricultural land can release a large amount of carbon into the atmosphere, it is imperative to preserve the lakes to mitigate increasing atmospheric CO_2 concentration.

Keywords: Agricultural land, Nagdaha Lake, organic carbon, water quality

INTRODUCTION

The Great Lakes play a greater role in global carbon (C) cycling than their area would otherwise predict (Toming et al. 2020). While the lakes make up less than 2% of the earth's surface area, they bury over three times more carbon in their sediments than the world's oceans combined (Dean and Gorham 1998; Bonnema et al. 2022). Small lakes with a lot of algae bury the most carbon, so small drainage, and farm ponds, as well as recreational lakes all over the world, are important sites for C cycling and a source of information about global climate change (Downing et al. 2008; Heino et al. 2021). The potential relevance of lakes to the global C budget has received attention recently, with the realization that lakes form an important component of the terrestrial carbon cycle (Algesten et al. 2004; Cole et al. 2007; Downing et al. 2008). It is estimated that the rate of global C burial by lakes ranges from 0.03 to 0.07 Pg C yr^{-1} (Cole et al. 2007). Globally, the burial of organic carbon (OC) in the sediments of natural lakes has been estimated in the range of 30 to 70 Tg C a^{-1} (Mulholland and Elwood 1982; Dean and Gorham 1998). Degradation of lakes due to eutrophication, excess evaporation due to rising temperatures, and irrigated water directly entering the wetland may be the primary causes of lake disappearance (Schindler 2001). Agriculture runoff is a serious pollutant of lakes (Higgins et al. 2020). Besides its role in enteric epidemics, it contains high amounts of nitrogen, phosphorous, pesticides, etc. (Chowdhary et al. 2020). Agriculture runoff adds excess nitrogen and phosphorous from synthetic fertilizers, bringing about eutrophication (Domagalski et al. 2007). Carbon dioxide originates mainly from the bacterial degradation of organic matter, and oxygen is mainly produced by green plants (Nebbioso and Piccolo 2013). Globally, this burial of OC in the sediments of natural lakes has been estimated to be 30 to 70 Tg Ca^{-1} (Mulholland and Elwood 1982; Dean and Gorham 1998). Even though lakes bury huge amounts of carbon, they also tend to release more carbon dioxide into the atmosphere than they absorb, making them net sources of greenhouse gases (Mendonça et al. 2012). Generally, lakes drain large landscapes, and the carbon from forests, fields, and lawns becomes concentrated in lakes, where it can be buried or released into the atmosphere (Pilla et al. 2022).

Lakes and ponds have always been important water sources in Nepal because they are major water sources for different sectors like irrigation, drinking water, industrial uses, etc. (Gurung et al. 2019; Sunar et al. 2022), which cover 5% of the total land area in Nepal (Sharma 2008). They are distributed with geological and altitudinal variations in the form of springs, rivers and flood plains, ponds, and swamps (Maltby et al. 2011). The shrinking of lakes in many parts of the country has identified the importance of conserving and managing wetlands (Mitra et al. 2005). However, limited research and a lack of management have made the lakes vulnerable, especially

concerning carbon sequestration. Particularly, studies on carbon stock estimation in lakes are still hard to find in Nepal, especially in the upland. Because of the above matter, the present study has been conducted in Nagdaha Lake and its surrounding agricultural area. The study's main objectives are to assess the water quality and the differences in SOC concentration in Nagdaha Lake and its adjacent agricultural land.

MATERIALS AND METHODS

Study area

The research was carried out at Nagdaha Lake, located in Dhapakhel, Lalitpur; 5 kilometers away from Kathmandu, Nepal. The water flows out of the lake and forms two small wetlands covering an area of 3.07 ha with a zigzag shape. It is located at latitude $27^0$37'53" N latitude and $85^0$19'97" E longitude with 0.3 to 3.6 m depth (Thapa and Shrestha 2010; Parajuli 2017). The major water source is yellow water and has 2 eye-type outlets called "Ankhi Daha." Water is mainly used for irrigation, household purposes, washing clothes, bathing, subsistence, and commercial activity. About 300-400 ropani of agricultural land is irrigated by this lake water (DNPWC 2006) annually. Closed circles in Figure 1 denote sample locations for water quality determination, and "numbers" denote the samples of soil taken for carbon determination.

Sampling method

The required samples were determined using a formula developed by APHA (1998).

$$N = \left(\frac{t \cdot s}{D \cdot \bar{x}}\right)^2$$

Where: N= number of samples, t= t-test value, s= standard deviation, D= depth of soil sample in the core, and ẍ= mean value. Soil samples were collected from the lake and agricultural land (present in the south and west), as shown in the schematic diagram (Figure 1), which were collected by systematic random sampling. For organic carbon determination, 20 samples were taken from agricultural land. Soil cores were taken using a 5.5 cm diameter and an 18 cm high cylindrical column. Soil cores were limited up to the depth of the topmost soil horizon of the agricultural land. In the case of the lake, 30 core samples were taken from Nagdaha lake from surface sediment with the help of a Grab-Sampler (Wagtwch, Cambria, UK; Duncan and Associated Ltd.) without disturbing the upper natural layer. Samples were taken along an imaginary transverse line across the lake. Thus, obtained soil samples were placed in sealed plastic bags and used for soil analysis in the laboratory.

Soil analysis

The Walkey and Black Titration method determined Soil Organic Carbon determination. First, 0.5 g of soil was weighed and transferred to the well-labeled, dried 500 mL conical flask. Then, 10 mL of 1 N potassium dichromate solution and 20 mL of concentrated sulfuric acid were added and mixed by gentle swirling. The flask was kept for about 30 minutes to react with the mixture. After the reaction, the mixture was diluted with 200 mL of distilled water and 10 mL of phosphoric acid added, followed by 1 ml of diphenylamine indicator. Finally, the sample was titrated with 0.4 N ferrous ammonium sulfate, and the endpoint was changed to brilliant green. Then, the blank was run again, followed by the above procedure without the soil sample.

The percentage of Soil Organic Carbon (SOC) was calculated by using the following equation:

% of SOC=3.951/g × (1-T/S)

Where: g= weight of soil sample taken
S=ml (ferrous) solution with blank titration
T=ml (ferrous) solution with sample titration

The total Soil Organic Carbon (SOC) was calculated by using the method (Batjes 1996) as follows:

SOC (kg/m^2) = %SOC × bulk density(g/m^3) ×thickness of the soil horizon (m).

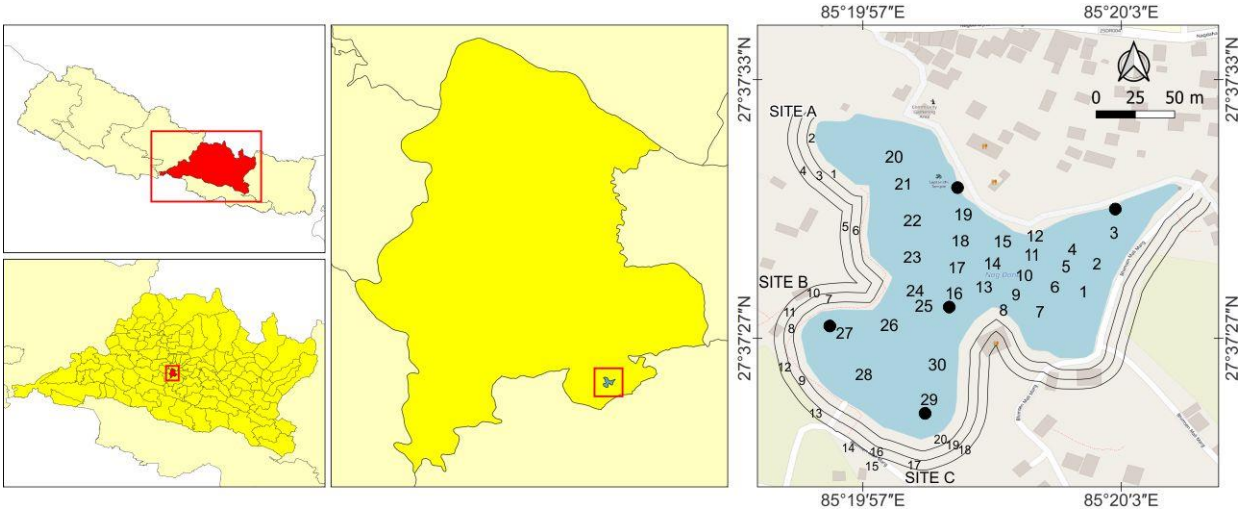

Figure 1. Schematic diagram of the study area

Bulk density

Soil bulk density was determined using a core sampling method of known volume. The soil samples were collected using core samplers without disturbing the natural structure. The collected soil samples were oven dried in a hot air oven at 105ºC for 24 hours. Soil bulk density was calculated by using the following relationship:

Bulk Density (D_b) = W_{os}/ V_{os}

W_{os} = weight of oven-dried soil)

V_{os} = volume of the core sampler

Organic matter

Organic Matter (OM) present in the soil was determined by:

OM = %OC × 1.724

Water quality determination

For the determination of different water quality parameters, 5 water samples were taken from Nagdaha lake. These five samples were taken from the lake's five sites (Figure 1). All the samples (water and soil) were tested in the Central Department of Environmental Science laboratory, Tribhuvan University, Kirtipur. In addition, water samples were immediately tested soon after they arrived from the field. As a result, the water quality of the lake was determined following APHA (1998) and Trivedi and Goel (1984) as follows:

Temperature

The water temperature was measured by using a mercury-filled Celsius thermometer. The surface water was collected in a beaker, and the reading was noted.

pH

Next, to measure the pH (Potentia Hydroegnii), a water sample was taken in a clean beaker, and the electrode (rinsed with water and blot dried) of the pH meter was dipped into the water sample until the constant displayed the score. Finally, equilibrium between the electrode and the water sample was established by stirring the water sample to ensure homogeneity.

Electrical conductivity

It was measured by a conductivity meter. The conductivity meter was dipped into a beaker containing the sample water, and the constant reading was noted.

Dissolved oxygen

It was determined by the Wrinkler or iodometric method. A BOD bottle of 300 ml was filled with sample water with the utmost care and immediate use of the stopper to avoid bubbling and trapping the air bubble in the bottle. Then, brown precipitation occurred after adding 2 ml of Manganese Sulphate ($MnSO_4$) and an alkaline Potassium Iodide (KI) solution. The solution was shaken well in an "8" shape repeatedly. Precipitation was allowed to settle the water completely, leaving a clear supernatant layer. Next, 2 mL of Hydrogen Sulphuric acid (H_2SO_4) concentration was added and shaken well to dissolve the precipitate. Then the 50 mL solution was taken in a conical flask and added with 2-3 drops of starch solution as an indicator (turns blue). This solution was titrated against Sodium Thiosulfate until the solution changed color from blue to colorless. Dissolved oxygen was calculated as (if the fraction of the content is used for titration):

Dissolved oxygen (mg/L) = (Volume × Normality) of titrant × 8 × 1000

V_2 (V_1- V) / V_1

Where,

V_1 = volume of the sample bottle

V_2 = volume of the part of content titrated

V= Volume of $MnSO_4$ and KI added

Calorimetric method

Phosporus-Phosphate in the water was determined by the Calorimetric Method in the laboratory.

Phenol di-sulphuric acid method

Notrogen-Nitrate was determined by the Phenol Di-sulphuric acid Method in the laboratory.

Data analysis

Data were analyzed with the SAS software, Ms-word, and Ms-Excel and statistically tested by student's t-test for comparisons of carbon content.

RESULTS AND DISCUSSION

Water quality determination

The water quality (temperature, pH, conductivity, DO, phosphate, and nitrate) and carbon content of the lake and its adjoining agricultural land were assessed. Water quality was determined from five sites in the lake based on allogenic sources in the lake. Because the lake is used for different purposes, water qualities were determined from different sites in the lake.

The water was slightly alkaline, and the pH was almost constant at around 8 .070±0.070. Electrical conductivity was found to be 191.200±3.631 µS/cm. Phosphorus-phosphate was 0.123±0.0004 mg L^{-1}, and nitrogen-nitrate was found at 0.135±0.067 mg L^{-1}. The Dissolvable Oxygen (DO) was found to be 3.636±0.416 mg L^{-1}. Thapa and Shrestha (2010) in his study found the lake hypereutrophic based on PO_4-P while DO was slightly higher than in this study, i.e., 4.32 mg L^{-1} and NO_3-N was 0.123 mg L^{-1} in three water samples. Similarly, Thapa and Shrestha (2010), in the wetland of Terai (Ghodaghodi Lake), have considered the lake with a mean DO of around 5 mg L^{-1} as eutrophic. The water samples from sites one to five were taken from the cloth washing outlet part, Nag temple, the middle part, the southern hotel side area, and the agricultural side, respectively (Table 1). Water quality also varied with the source of the sample taken.

Soil Organic Carbon stock in Nagdaha Lake

Carbon was estimated from 30 core samples taken from the lake (Figure 2). SOC in Nagdaha lake was found to be 2.032 kgm^{-2}. The mean OM (%) in the lake was 12.31±

7.31. Mean OC and SOC were 71.39±42.582g kg^{-1} and 20.530±8.948 k gm^{-3} in Nagdaha Lake, respectively.

Carbon stock in agricultural land

The carbon stock was estimated from agricultural land (Figure 3). Altogether, 20 samples were taken from agricultural land, which covered more than half the boundary area around the lake. The mean carbon stock in agricultural land was 1.680 kg m^{-2}. The mean bulk density was 1.169 g mL^{-1} in agricultural land higher than the lake, i.e., 0.349±0.154 g mL^{-1}. The mean OC and SOC were 14.36±8.383 g kg^{-1} and 16.8±10.082 kg m^{-3}, respectively.

Comparison of carbon in Nagdaha Lake and agricultural land

There is a significant difference in mean organic carbon between the two sources (t = 9.18 and $p < 0.0001$) (Nagdaha Lake and agricultural land). Similarly, mean organic carbon is lower in agricultural land. The conversion of the lake into agricultural land shows a difference of 57.024 gk g^{-1} organic carbon between Nagdaha lake and agricultural land. There is a significant decrease in organic carbon in agricultural land (t = 7.66 and $p < 0.0001$) (Table 2).

Carbon accumulation in a lake is influenced by various factors, including initial primary productivity in the lake, external input, dilution by minerals, and post-depositional minerals in the lake (Last and Ginn 2005; Amezcua et al. 2021). On the other hand, the lake's age also affects the lake's carbon stock (Hinkel et al. 2003). Among the dissolved gases, carbon dioxide (CO_2) and oxygen (O_2) are biologically the most important ones (Bajracharya et al. 2016). CO_2 originates mainly from the bacterial degradation of OM, and O_2 is mainly produced by green plants (Miltner et al. 2005). Research shows that the CO_2 released from lakes comes from organism respiration and the breathing of bacteria, algae, zooplankton, fish, and other species (Hessen 1992; Cole et al. 2006; Brett et al. 2017). In the study area, nitrogen and phosphorus used on the agricultural land during the monsoon leach out and could enter the lake water, which might accelerate the vegetation growth in the lake that might be seasonal or all year around. Agricultural residues decompose into simpler forms of carbon sequestered in the agricultural soil.

Table 1. Water quality determination of Nagdaha Lake, Lalitpur, Nepal

Sample	pH	Temp.	Electrical conductivity (µS/cm)	P-phosphate (mg L^{-1})	N-nitrate (mg L^{-1})	DO (mg L^{-1})
1.	8.010	28.70	196.000	0.124	0.160	3.300
2.	8.010	24.10	194.000	0.123	0.106	4.109
3.	8.060	24.30	188.000	0.123	0.099	4.030
4.	8.080	24.90	190.000	0.123	0.111	3.536
5.	8.190	25.40	188.000	0.123	0.103	3.201
SD	0.070	1.870	3.631	0.0004	0.067	0.416
mean	8.070	25.480	191.200	0.123	0.135	3.635

Table 2. Statistical parameters

Sampled Area	Mean OC (gkg^{-1})	Standard deviation	Maximum value	Minimum value	t value	df	*p*
Lake	71.387	42.582	179.000	24.690	9.180	29	<0.0001
Agricultural land	14.363	8.383	32.930	3.290	7.660	19	<0.0001

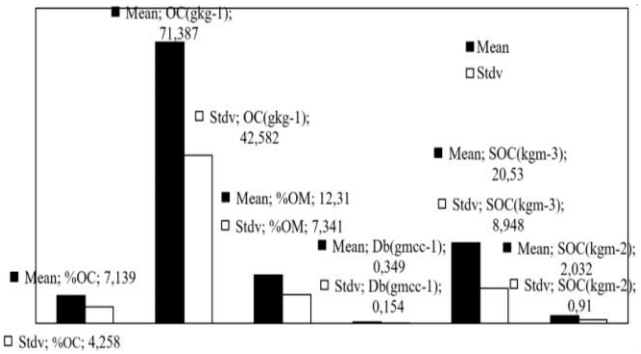

Figure 2. The carbon content of Nagdaha Lake, Lalitpur, Nepal

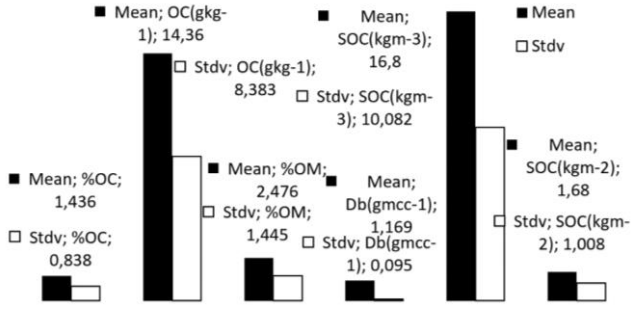

Figure 3. The carbon content of agricultural land adjacent to Nagdaha Lake, Lalitpur, Nepal

Similarly, human activities like bathing, washing, cleaning boats, etc., also contribute to the nutrient load of the lake and affect water quality. Cardille et al. (2007) estimated that the total regional carbon flux from the lake surface was 31% higher in the wet scenario and 46% lower in the dry scenario in highland lakes. The mean carbon stock in the lake was higher than on the agricultural land. SOC (kgm^{-3}) was found at 20.530±8.948 in Nagdaha lake and 16.8±10.082 in agricultural land. According to the Nagdaha Conservation and Improvement Committee (2011), the lake area was 2.65 hectares (52 ropani) in 1964, and in 2022, it was reduced to 2.14 hectares (42 ropani). That indicates that the lake area has decreased by 0.51 ha. Thapa and Shrestha (2010) found the lake area in 2008 decreased by 0.4. The lake is slowly changing into the land through the transformation from a lake to a swamp, grassland, and finally, agricultural land. Due to the high carbon load in lakes, the conversion of a lake into agricultural land could emit a large amount of carbon into the atmosphere. Lakes emit more carbon into the atmosphere than agricultural land because they bury more carbon. Agricultural land tends to have carbon-rich soil that, when tilled for cropping, is very susceptible to rapid erosion (Downing et al. 2008) and drains to lakes. Fertilizers used on agricultural land are major contributors to nutrients like phosphorus and nitrogen in the water. Shah et al. (2011) classified this Nagdaha lake in the fair water quality class using the macroinvertebrates-based Nepal Lake Biotic Index (NLBI) with a score of 4.55. According to Thapa and Shrestha (2010), OC was found at 111.49±75.16 g kg^{-1} in Ghodaghodi lake and 89.86±28.25 g kg^{-1} in Nakhrodi lake. Comparatively, OC was found lower in Nagdaha than in Ghodaghodi Lake and the associated Nakhrodi lake. These lakes are mainly covered by forest and grassland and are located in the lower Terai belt.

In conclusion, the water quality of the lake indicates that the lake is eutrophic. Agricultural land is a major contributor of nitrogen and phosphorus to the lake, increasing aquatic plants' growth rate. OC was found at 71.39±42.58 g kg^{-1} in Nagdaha Lake, and 14.36±8.38g kg^{-1} in agricultural land and is significantly higher in the lake than in the agricultural land. Therefore, the conversion of lake land to agricultural land has the potential to release a large amount of carbon into the atmosphere.

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REFERENCES

Algesten G, Sobek S, Bergström AK, Ågren A, Tranvik LJ, Jansson M. 2004. Role of lakes for organic carbon cycling in the boreal zone. Glob Change Biol 10 (1): 141-147. DOI: 10.1111/j.1365-2486.2003.00721.x.

Amezcua N, Gawthorpe RL, Marshall J. 2021. Lacustrine carbonate lithofacies characterization, paleontological content and depositional processes in the Mayrán Basin System. J South Am Earth Sci 111: 103451.

APHA [American Public Health Association]. 1998. Standard Methods for the Examination of Water and Wastewater, 20th ed. In: Clesceri LS, Greenberg AE, Eaton AD (eds.). American Public Health Association, Washington D.C., USA.

Bajracharya S, Vanbroekhoven K, Buisman CJ, Pant D, Strik DP. 2016. Application of gas diffusion biocathode in microbial electrosynthesis from carbon dioxide. Environ Sci Pollut Res 23 (22): 22292-22308. DOI: 10.1007/s11356-016-7196-x.

Batjes N. 1996. Total carbon and nitrogen in the soils of the world. Eur J Soc Sci 47: 151-163. DOI: 10.1111/j.1365-2389.1996.tb01386.x.

Bonnema M, David CH, Frasson RPDM, Oaida C, Yun SH. 2022. The global surface area variations of lakes and reservoirs as seen from satellite remote sensing. Geophys Res Lett 49 (15): e2022GL098987. DOI: 10.1029/2022GL098987.

Brett MT, Bunn SE, Chandra S, Galloway AW, Guo F, Kainz MJ, Kankaala P, Lau DCP, Moulton TP, Power ME, Rasmussen JB, Taipale SJ, Thorp JH, Wehr JD. 2017. How important are terrestrial organic carbon inputs for secondary production in freshwater ecosystems? Freshwater Biol 62 (5): 833-853. DOI: 10.1111/fwb.12909.

Cardille JA, Carpenter SR, Coe MT, Foley JA, Hanson PC, Turner MG, Vano JA. 2007. Carbon and water cycling in lake-rich landscapes: Landscape connections, lake hydrology, and biogeochemistry. J Geophys Res: Biogeosci 112 (G2): G02031. DOI: 10.1029/2006JG000200.

Chowdhary P, Bharagava RN, Mishra S, Khan N. 2020. Role of industries in water scarcity and its adverse effects on environment and human health. In: Shukla V, Kumar N (eds). Environmental Concerns and Sustainable Development. Springer, Singapore. DOI: 10.1007/978-981-13-5889-0_12.

Cole JJ, Carpenter SR, Pace ML, Van de Bogert MC, Kitchell JL, Hodgson JR. 2006. Differential support of lake food webs by three types of terrestrial organic carbon. Ecol Lett 9 (5): 558-568. DOI: 10.1111/j.1461-0248.2006.00898.x.

Cole JJ, Prairie YT, Caraco NF, McDowell WH, Tranvik LJ, Striegl RG, Duarte CM, Kortelainen P, Downing JA, Melack JM. 2007. Plumbing the carbon cycle: Integrating inland waters into the terrestrial carbon budget. Ecosystems 10: 171-184. DOI: 10.1007/s10021-006-9013-8.

Dean WE, Gorham E. 1998. Magnitude and significance of carbon burial in lakes, reservoirs, and peatlands. Geology 26 (6): 535-538. DOI: 10.1130/0091-7613(1998)026<0535:MASOCB>2.3.CO;2.

DNPWC. 2006. Sagarmatha National Park: Management and Tourism Plan 2006-2011. Department of National Park and Wildlife Conservation, Kathmandu, Nepal.

Domagalski J, Lin C, Luo Y, Kang J, Wang S, Brown LR, Munn MD. 2007. Eutrophication study at the Panjiakou-Daheiting Reservoir system, northern Hebei Province, People's Republic of China: Chlorophyll-a model and sources of phosphorus and nitrogen. Agric Water Manag 94 (1-3): 43-53. DOI: 10.1016/j.agwat.2007.08.002.

Downing JA, Cole JJ, Middelburg JJ, Striegl RG, Duarte CM, Kortelainen P, Laube KA. 2008. Sediment organic carbon burial in agriculturally eutrophic impoundments over the last century. Glob Biogeochem Cycles 22 (1): GB1018. DOI: 10.1029/2006GB002854.

Gurung A, Adhikari S, Chauhan R, Thakuri S, Nakarmi S, Ghale S, Rijal D. 2019. Water crises in a water-rich country: Case studies from rural watersheds of Nepal's mid-hills. Water Policy 21 (4): 826-847. DOI: 10.2166/wp.2019.245.

Heino J, Alahuhta J, Bini LM, Cai Y, Heiskanen AS, Hellsten S, Angeler DG. 2021. Lakes in the era of global change: Moving beyond single-lake thinking in maintaining biodiversity and ecosystem services. Biol Rev 96 (1): 89-106. DOI: 10.1111/brv.12647.

Hessen DO. 1992. Dissolved organic carbon in a humic lake: Effects on bacterial production and respiration. Hydrobiologia 229 (1): 115-123. DOI: 10.1007/BF00006995.

Higgins MJ, Rock CA, Bouchard R, Wengrezynek B. 2020. Controlling agricultural runoff by use of constructed wetlands. In: Higgins MJ, Rock CA, Bouchard R, Wengrezynek B (eds.). Constructed Wetlands for Water Quality Improvement. CRC Press, Boca Raton, Florida. DOI: 10.1201/9781003069997-43.

Hinkel KM, Eisner WR, Bockheim JG, Nelson FE, Peterson KM, Dai X. 2003. Spatial extent, age, and carbon stocks in drained thaw lake basins on the Barrow Peninsula, Alaska. Arctic Antarctic Alpine Res 35 (3): 291-300. DOI: 10.1657/1523-0430(2003)035[0291:SEAACS]2.0.CO;2.

Last WM, Ginn FM. 2005. Saline systems of the great plains of Western Canada: An overview of the limnogeology and paleolimnology. Saline Syst 1 (1): 1-38. DOI: 10.1186/1746-1448-1-10.

Maltby E, Ormerod S, Acreman M, Dunbar M, Jenkins A, Maberly S, Ward R. 2011. Freshwaters: Openwaters, Wetlands and Floodplains. Chapter 9. UK National Ecosystem Assessment: Technical Report.

Mendonça R, Barros N, Vidal LO, Pacheco F, Kosten S, Roland F. 2012. Greenhouse gas emissions from hydroelectric reservoirs: What knowledge do we have and what is lacking. In: Liu DG (eds.). Greenhouse Gases–Emission, Measurement and Management. DOI: 10.5772/32752.

Miltner A, Kopinke FD, Kindler R, Selesi D, Hartmann A, Kästner M. 2005. Non-phototrophic CO_2 fixation by soil microorganisms. Plant Soil 269 (1): 193-203. DOI: 10.1007/s11104-004-0483-1.

Mitra S, Wassmann R, Vlek PL. 2005. An appraisal of global wetland area and its organic carbon stock. Curr Sci 88 (1): 25-35.

Mulholland PJ, Elwood JW. 1982. The role of lake and reservoir sediments as sinks in the perturbed global carbon cycle. Tellus 34 (5): 490-499. DOI: 10.3402/tellusa.v34i5.10834.

Nebbioso A, Piccolo A. 2013. Molecular characterization of dissolved organic matter (DOM): A critical review. Anal Bioanal Chem 405 (1): 109-124. DOI: 10.1007/s00216-012-6363-2.

Parajuli BP. 2017. Algal flora of Nagdaha Lake, Lalitpur, Nepal. Himal Biodivers 5 (1): 92-95. DOI: 10.3126/hebids.v5i1.36159.

Pilla RM, Griffiths NA, Gu L, Kao SC, McManamay R, Ricciuto DM, Shi X. 2022. Anthropogenically driven climate and landscape change effects on inland water carbon dynamics: What have we learned and where are we going? Glob Change Biol 28 (19): 5601-5629. DOI: 10.1111/gcb.16324.

Schindler DW. 2001. The cumulative effects of climate warming and other human stresses on Canadian freshwaters in the new millennium. In: Bendell-Young L et al. (eds.). Waters in Peril. Springer, Boston, MA. DOI: 10.1007/978-1-4615-1493-0_11.

Shah RDT, Shah DN, Nesemann H. 2011. Development of a macroinvertebrate-based Nepal Lake Biotic Index (NLBI): An applied method for assessing the ecological quality of lakes and reservoirs in Nepal. Intl J Hydrol Sci Tech 1 (2): 125-146. DOI: 10.1504/IJHST.2011.040744.

Sharma CM. 2008. Freshwater fishes, fisheries, and habitat prospects of Nepal. Aquat Ecosyst Health Manag 11 (3): 289-297. DOI: 10.1080/14634980802317329.

Sunar CB, Pandey N, Chand B, Upadhyaya LP, Thapa B, Pant RR, Khanal L. 2022. Effect of water physicochemistry on amphibian abundance in Sub-tropical Kupinde Lake of the Nepal Himalaya. Intl J Bonorowo Wetlands 12: 89-95. DOI: 10.13057/bonorowo/w120205.

Thapa S, Shrestha GKC. 2010. Study on water quality and encroachment status of Nagdaha, Lalitpur. Enviro-Zing Sustain Dev Environ Conserv 1: 36-38.

Toming K, Kotta J, Uuemaa E, Sobek S, Kutser T, Tranvik LJ. 2020. Predicting lake dissolved organic carbon at a global scale. Sci Rep 10 (1): 1-8. DOI: 10.1038/s41598-020-65010-3.

Trivedi RK, Goel PK. 1984. Chemical and biological methods for water pollution studies. Karad Environmental Publication, Kathmandu.

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Contribution and challenges of mangrove conservation to community's wellbeing in eastern Tanzania

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Abstract. *Ngowi N, Zakayo G. 2023. Contribution and challenges of mangrove conservation to community's wellbeing in eastern Tanzania. Intl J Bonorowo Wetlands 13: 15-21.* There have been several mangrove conservation programs implemented in Tanzania to reverse degradation of mangrove ecosystem in the country. However, after their introduction in 1990s, many small-scale farmers relying on the mangrove ecosystems lost their livelihoods. To ensure that the people's well-being and ecological integrity of the mangrove ecosystem is sustained, this study investigated the impact of nature conservation practices on financial sustainability, and food security of local communities as well as ecological integrity of the mangrove ecosystem. The study employed mixed - method approach where a survey was used to collect quantitative data from 90 household respondents selected randomly for a questionnaire survey. This was supplemented by data collected through personal observations and interviews administered to 30 local people (mainly key informants and focus group discussion). Quantitative data were analyzed through crosstab IBM SPSS version 20. Qualitative data were analyzed using content method. The results indicated that the conservation practices introduced brought a significant difference in financial stability ($p<0.05$) by increasing incomes of the implementing households to US $80.29 compared to US $69.20 for the non-implementing households. However, 83% of the implementing households still faced food insecurity by having meal only twice per day, although it was slightly higher compared to 80% for the non-implementing households. The 85% of the implementing and 65% of non-implementing households perceived that the conservation practices had improved the ecological integrity of the mangrove ecosystem by increasing the vegetation cover. The results of this study suggest that conservation practices in the mangrove ecosystem have increased financial sustainability and ecological integrity but failed in enhancing food security. This study recommends the integration of rights of local communities on usage of land for paddy and fish farming to achieve sustainable economic growth in the estuary.

Keywords: Ecosystem, estuary, integrity, mangrove, nature

INTRODUCTION

Tanzania, like many other countries, faces the problem of loss of wetland ecosystem services (Dalu et al. 2022; Ngowi 2018). Being part of the wetland's ecosystem, mangroves are vegetation found in tropical regions that are salt-resistant and thus can survive on the coastal saline habitats (Duke and Schmitt 2015). Globally, there are estimated 16 million hectares of mangroves (Monga et al. 2018) and home of a diverse ecosystems (Machava-António et al. 2022). Asian Continent has the largest extent of mangrove ecosystem, accounting for 40% of total global mangrove areas, while Africa accounts for 19% or 3.2 million ha (Friess et al. 2019). In East Africa, mangrove ecosystem is a unique type of forest cover, covering about 37% of the entire mangrove on the continent (Ajonina et al. 2013) with Tanzania contribute to 14% of all the mangrove ecosystem of East Africa (Nyangoko et al. 2020; Japhet et al. 2019).

Mangrove ecosystem offers various ecosystem services, from providing various fisheries, timber and non-timber products, regulating climate via sequestration of carbon, protecting coastal areas from abrasion, strong waves, storm and tsunami, serving as habitat of various marine and terrestrial organisms and providing socio-cultural benefits for coastal communities (Cahyaningsih et al. 2022). In many regions, mangrove ecosystem is one of the major providers of livelihoods of coastal communities through fishing activities (Hlaing et al. 2017). Despite its global importance, the deforestation and degradation of mangroves is increasing worldwide due to ecological and economical drivers (Monga et al. 2018). The socioeconomic drivers caused by increasing human activities through unsustainable uses of the mangrove ecosystems (e.g. cutting mangroves for burning lime or smoking fish, mangroves conversion for paddy or rice farming, aquaculture, and dynamite fishing) have intensified particularly among the world poor whose wellbeing directly depends on mangrove ecosystem. For instance, Mungai et al. (2019), Mshale et al. (2017), and Ajonina et al. (2008) show that in the past 25 years, about 8% of mangrove ecosystem in Eastern Africa covering Kenya, Mozambique, and Tanzania has been lost at an average of 3,000 hectares in a year. The major drivers for mangrove degradation among others in the region are associated with humans as well as natural factors, such as climate change and siltation (Nyangoko et al. 2022). Due to this, different practices have been introduced in many mangrove ecosystems worldwide to address the problem of degradation.

Mshale et al. (2017) notes that in the Rufiji estuarine ecosystem of eastern coastal Tanzania, three key nature conservation practices were implemented in the three districts of Rufiji-Mafia-Kilwa area between 2006 and 2012. These are: Rufiji Environmental Management Project (REMP), and Marine and Coastal Management practises between 2005 and 2011. According to UNDP (2012), the long-term goals of these conservation activities included the wise use of lower wetlands ecosystem, biodiversity conservation, maintenance of ecosystem functions, restoration of natural resources, and enhancement of the rural communities' wellbeing.

Inspite of the fact that some of the conservation practices introduced have contributed immensely to the restoration of mangrove ecosystem in Tanzania (Duvail et al. 2006), less attention is given to improving households' wellbeing (Mshale et al. 2017). In order to nature conservation practices and achieving their intended purpose, there should be a good balance between the wellbeing of implementers involved in the conservation practices and the requirements of ecosystem services. Chinangwa et al. (2016) show that the livelihood assets include resource base of the community available in the form of - human, natural, financial, physical, and social capital which help to understand people's resilience and provide the direction of changing wellbeing from bad to good (Chinangwa 2016). Chinangwa et al. (2016) provided the description of the five livelihood capital assets as follows: (i) Natural: The natural resources or ecological services that form the basis for human survival and economic activities (e.g., forests). (ii) Financial: Bases that enable a household to pursue particular livelihoods strategy (e.g., income). (iii) Physical: Basic infrastructure (e.g., housing). (iv) Social: Aspects of the society or community upon which households depend, when pursuing livelihood strategies that require coordinated actions (e.g., networks, social relations, and associations). (v) Human: Skills, knowledge, labour, good health, and physical capability that enable one to pursue livelihood strategies. Ngowi (2018) on the other hand described livelihoods as capabilities and activities required for a means of a living including coping with and recover from stress and shocks and maintain or enhance its capabilities now and in future without destroying the natural resource base.

Therefore this research examines the contribution and challenges of conservation actions and or interventions on the major components of human livelihoods affecting the wellbeing of households in ecologically vulnerable mangrove area of Kibiti area in eastern Tanzania. The results of this research will be used as baseline information for developing the policies of estuary resources conservation practices for inclusive sustainable economic growth in the area.

MATERIALS AND METHODS

Conceptual framework

We employed Sustainable Livelihood Analytical Framework (Figure 1) developed by the Department for International Development (DFID) (1999) with modification to uncover the impact of conservation activities on three variables namely; financial sustainability, food security, and ecological integrity.

From Figure 1, three domains (A, B, and C) are interrelated. This study investigated on how these three domains influence the domain D - variables in terms of the wellbeing of those involved in the conservation actions: (i) Financial sustainability – maintenance of sufficient income to cover local community expenses beyond the conservation action period; (ii) Food security – physical and economic access of sufficient food to all people all the times; and (iii) Ecological integrity – the expected processes occurring within the frequency and intensity of any environment which is both influenced by human actions such as land use cover land use change and changing climate. The implementation of conservation practices namely Rufiji Environmental Management Project, and Marine and Coastal Management (Domain A) using relevant public policies (Domain B) helped to avoid degradation of estuary resources, thus improving the natural and ecosystem function of estuary resources (Domain C). Ecological degradation intensifies the conflict between human and the environment (Lin et al. 2022). The decline in pressure and degradation influenced the wellbeing of implementers through financial sustainability, food security, and ecological integrity (Domain D).

Study area

The study was conducted in Kibiti estuary located in Eastern Tanzania (Figure 2; Japhet et al. 2019). The district has a total area of 109,555 km^2 and is mainly bordered by the Indian Ocean to the East, North and South East. The study area forms an estuarine environment with the highest concentration of mangrove ecosystem in Eastern Africa (Monga et al. 2018). For instance, a study by Dai et al. (2022) shows that Kibiti District where the studied area is located is covered by the largest mangrove area in Tanzania. More than half of the mangrove species are found in the villages located on the northern parts of the studied area followed by villages on the south having about a quarter, and the remaining species are in the villages located at the centre. Table 1 is the list of mangrove species found in the studied area. There is limited information on the occurrence of *Xylocarpus moluccensis* (Lam.) M.Roem and *Pemphis acidula* J.R. Forst. & G. Forst species in this area.

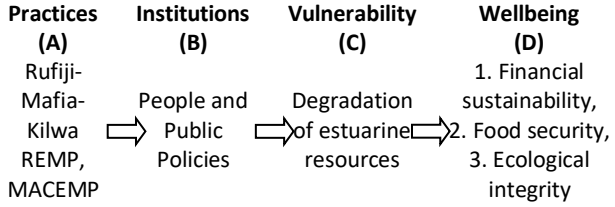

Figure 1. Peoples' well-being analytical framework modified from DFID (1999)

The human population in the studied area is about 49,000 people with the growth rate of 1.9% per year. There are three major ethnic groups namely Wandengereko, Wamatumbi and Wamakonde living in the area (Nyangoko et al. 2020).

Methodological framework

This research adopted an explanatory sequential design Ngowi (2018) to collect quantitative data first followed by qualitative data (Figure 3). The use of the explanatory sequential approach to data collection as the first step helped to inform the qualitative step, and the later was used to explain the results of the first step. More emphasis was given to the quantitative methods than the qualitative methods where explorative approaches were used to provide a better understanding of the problem being investigated than using either stories or the trend line data alone.

Table 1. A list of mangrove species in the studied area

Family name	Species name	Common name	Local name
Avicenniaceae	*Avicennia marina* (Forssk.) Vierh	White mangrove	Mchu
Lythraceae	*Sonneratia alba* J. Smith	Apple mangrove	Mpira
Rhizophoraceae	*Ceriops tagal* (Perr.) C.B.Rob	Indian mangrove	Mkandaa
Combretaceae	*Lumnitzera racemosa* Willd	White-flowered mangrove	Mkandaa dume
Rhizophoraceae	*Bruguiera gymnorrhiza* (L.) Lam	Black mangrove	Msinzi
Rhizophoraceae	*Rhizophora mucronata* Lam	Red mangrove	Mkoko
Meliaceae	*Xylocarpus granatum* J.Koenig	Cannonball mangrove	Mkomafi
Malvaceae	*Heritiera littoralis* Aiton	Glass-looking/tulip mangrove	Msikundazi

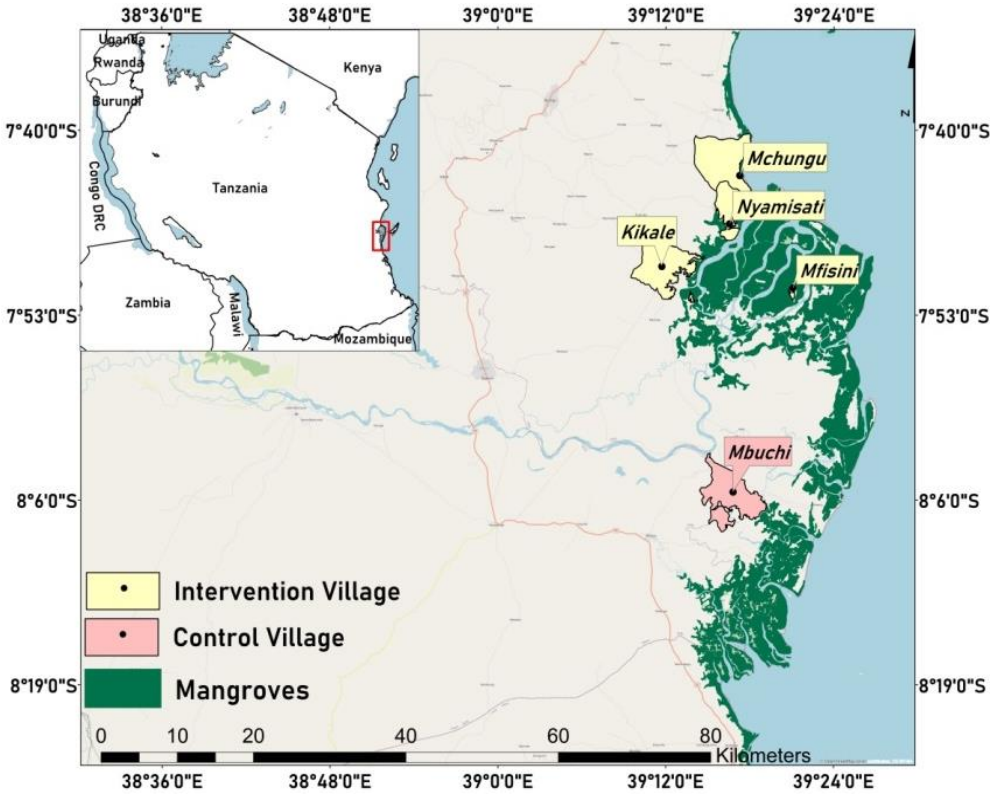

Figure 2. The map of Kibiti estuary in eastern Tanzania showing the sampled villages

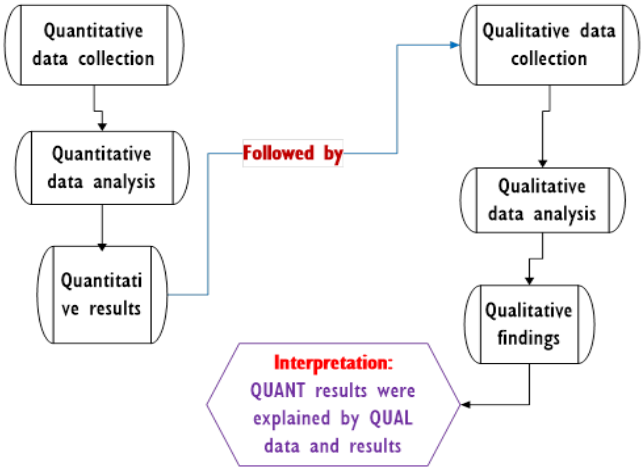

Figure 3. Methodological framework in data collection and analysis following Ngowi (2018)

Data collection procedure

Initially, identification of the specific study villages and prioritization of conservation actions introduced in the estuary ecosystem of the studied area was made through discussions with different actors (administrations, development agents, and individuals) with specific knowledge of the subject being investigated and who could share non documented information such as project activities or able to summarize issues pertaining to mangrove history, and trends in the availability of resources during the implementation of conservation efforts. The discussions aimed to provide a clear picture on the benefits of the efforts to the different groups of people. Following the discussion, four villages: (i) Kikale, (ii) Nyamisati, (iii) Mchungu, and (iv) Mfisini were selected from the intervention site and the fifth village (v) Mbuchi was taken as a control one. The non-random sampling method was employed to identify conservation actions and key informants involved in this study. The probability formula by Israel (1992):

$$\mathbf{n} = \frac{\mathbf{N}}{\mathbf{1} + \mathbf{N} \cdot (\mathbf{e})^{\mathbf{2}}}$$

It was used to obtain a sample of 90 heads of households (respondents) who implemented the conservation actions/interventions from a total of 8,460 households (Namangaya and Mushi 2019). From the formula, **n** are respondents, **N** is the Number of households, and **e** is the sampling error at 5%. In addition, 30 respondents were drawn from the control group for comparison purposes. The control group approach was used to select respondents not affected by the intervention actions. Different studies, for instance Ngowi (2018), used the control group method to investigate changes in livelihoods resulting from Wetland Friendly Investment Approach (WFI) program in Iringa District, Tanzania. A ten-section questionnaire developed to cover socio-economic and demographic characteristics of respondents collected information on mangrove conservation actions and well-being of people of the area.

Primary data

Primary qualitative information was collected through a checklist of interview questions involving 10 key informants, and 20 members who participated in the Focus Group Discussions (FGD) representing elders, youth group, male-headed and female-headed families each having 4 - 5 members. The selection was based on their long period of living in the study area, good experience with the conservation practices introduced in the area, ability to identify mangrove plants and narrate the history and functions of the mangrove ecosystem of the area. The direct observation method was used to obtain information from the mangrove sites. This method involved making observation as researchers walk along the set transects in the field where conservation actions were implemented. A timeline on the historical changes of the mangrove cover and or use and drivers for the change was drawn with assistance of the elderly villagers. Photographs were taken to corroborate this information as appropriate. The qualitative information was used to supplement themes not considered in the quantitative data. For example, existing threats and drivers for the mangrove change. The perception-based approach Nyangoko et al (2022) was used to listen, learn, and understand the experiences of the local people of the studied area on their environment.

Secondary data

Secondary data involved the review of literature mainly published works (journal articles, books and book chapters, reports), and information from websites.

Data processing and analysis

Statistical analysis using IBM SPSS version 20 statistical software for quantitative categorical data, and test for independent sample analysis (mainly for data collected using the questionnaires) in which p=0.05 was used as cut off point for statistical significance between people who were involved in the conservation actions and those who did not. Qualitative data were analyzed through content analysis method which also assisted the analysis and interpretation of the quantitative information.

RESULTS AND DISCUSSION

Connecting nature conservation to financial sustainability

The results in Figure 4 show that about 50% of the income of the households through various nature-based activities ranges between 201,000/= and 300,000/= Tanzanian Shillings (TShs) (equivalent to US $87.99 and US $130.43). Majority of these being those who are involved in the conservation actions.

The results in Table 2 show that the mean income of the households in the intervention area, i.e. those who were involved in the conservation actions was about Tanzanian Shillings 184,667/= (equivalent to US $80.29 with a standard deviation of TSh. 59,816/= (US $26.00) as opposed to the control site (those who were not involved in the conservation actions) which had a mean of TSh. 159,167/= (US $69.20) and standard deviation of TSh.

47,162/= (US $20.50). This equivalence is calculated at an exchange rate of 1.00 US $ = 2300/=Tanzanian Shillings). This implies that the income per month for the households who engaged in the conservation is categorized as moderate or average compared to those who did not.

The results in Table 3 show that there is a difference in the mean income between the implementing and non-implementing households ($p=0.036<0.05$). This research found that households of the control site had lower income (159166.67 ± 47162.29) than the income of intervention households (184666.67 ± 59816.19). A study of Nyangoko et al. (2022) show that in Rufiji delta, income dynamics are also determined by a number of activities including change in fishing season, cutting and/or selling of mangrove poles and rice farming in the mangrove ecosystem. For instance, the study shows that about 60% of income in the study area was from mangrove-based farming, fishing, and non-mangrove-based crop farming. Increased households income through licensing of timber harvesting by the local community enhanced reinvesting of funds into construction of community residential buildings and support of Village Environment and Natural Resources Committees (VEC and or VNRCs) activities for sustainability of the income and the mangrove ecosystem.

Food security

The results in Figure 5 show that majority of households (83%) in the intervention area ate twice in a day, 10% ate once, while very few (5%) ate three times and 2% had four meals in a day. On the control site (non-implementing households), results show that 80% ate twice, 15% ate once, and 5% ate three times while none ate four meals per day. These results show that 83% of the respondents involved in the conservation actions had more meal frequency compared to non-implementers, implying that local community in the mangrove ecosystem are living in the state of food insecurity despite introduction of the conservation actions in their areas. These results are supported by Mangora (2011) on poverty and institutions, which shows that poverty is the driver of mangrove ecosystem degradation. Furthermore, William et al. (2005) show among developing countries mangrove conservation practices and improvement of the wellbeing cannot go simultaneously.

From MACEMP's point of view, the Coastal Village Funds (CVF) run by the local community was found to have not significantly increased food security, and opportunities for a long-term positive effect on food security in the area. There is a need for observing land rights in relation to the usage of land by local communities. Land use for paddy/rice farming, inter-planting with maize and beans was proved to increase households' food security.

Ecological integrity of mangrove resources

With respect to the perceptions of the local community on the significance of conservation practices to ecological integrity of mangrove ecosystem, 85% of the implementers and 65% of non-implementers said that conservation practices had increased the vegetation cover of the mangrove ecosystem (Figure 6). These results are supported by Monga et al. (2018) which shows that from 2010 to 2015 afforestation and natural regeneration practices had increased the coverage of mangrove ecosystem. Furthermore, they are also consistent with a study by Ntibona et al. (2022) which shows that paddy farming and illegal cutting of mangrove poles had significantly reduced post 1990s after introduction of conservation practices. This was made possible through the campaign of replanting mangroves while at the same time strengthening the management capacity of local institutions such as district councils and village forest committees.

This research shows that there were positive impacts associated with the conservation practices in the mangrove ecosystem. According to participants of group 2 involved in the focus group discussion, conservation practices introduced in the Rufiji delta had increased recovery of mangrove ecosystem as well as wildlife. In their own words, Mchungu villagers said, "*The mangrove forest ecosystem has been increasing since conservation practices started in 1990s and these trees are well protected through government, non-government organisations and other stakeholders*". This quotation reflects that people know that conservation practices had improved mangrove ecosystem of the area but failed in addressing the conflicts, which arise on the replanting of mangroves versus agriculture land in the mangrove habitat.

Table 2. The monthly income of the households between the intervention vs control site

Location site	Respondents (n)	Mean	Std. deviation	Std. error mean
Control	30	159166.6667	47162.29012	8610.61672
Intervention	90	184666.6667	59816.19787	6305.18088

Table 3. Test for independent samples

T-test for equality of means						
T value	DF	Sig.	Difference in means	Std. error	95% Confidence Interval	
					Lower	Upper
-2.123	118	.036	-25500.00000	12009.79146	-49282.65676	-1717.34324
-2.389	62.575	.020	-25500.00000	10672.30182	-46829.72756	-4170.27244

Note: Sig.= 2 tailed

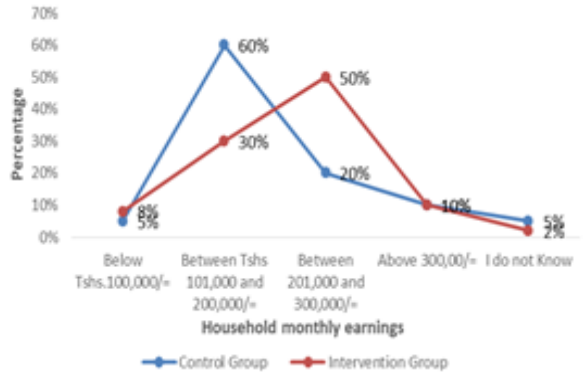

Figure 4. Distribution of household monthly earnings between the intervention vs control site

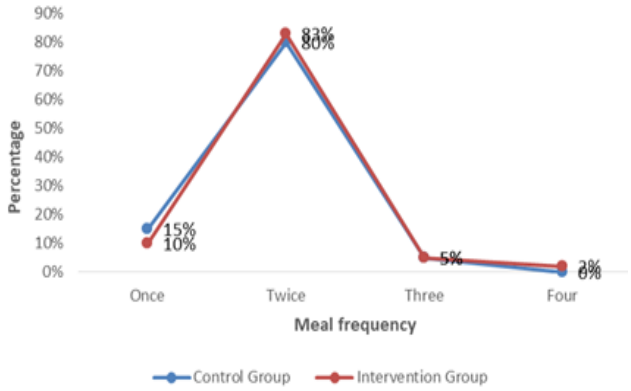

Figure 5. Distribution of meal frequency between the intervention vs control sites

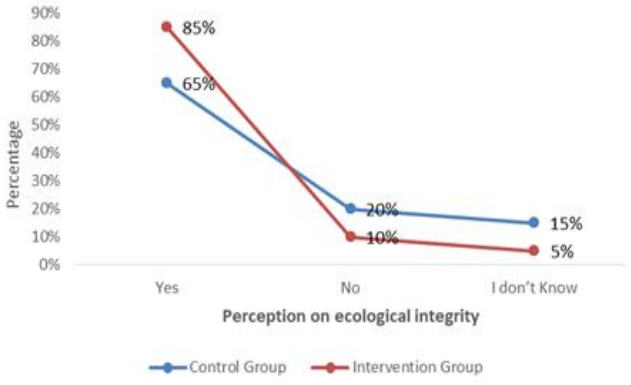

Figure 6. Community perceptions on ecological integrity between the intervention vs control locations

This research investigated financial sustainability, food security, and ecological integrity of the conservation of mangrove ecosystem in eastern Tanzania. The results show that established farming groups failed to progress well due to a lack of knowledge about running cooperative groups. On the income aspects, it was found that the implementing households had higher mean income compared with the non-implementers and that the difference between the two is significant (p<0.05). These results reveal that conservation practices in mangrove ecosystem have made significant contributions in increasing the income and network of cooperation among women farming group members, which in return were found to have: (i) Equally increased financial stability in the mangrove ecosystem; (ii) Increased ecological integrity by reducing degradation of mangrove ecosystem, thus managed to mobilized resources for enforcing policies/by-laws; (iii) Failed to increase food security through the frequency of meals household members consumed in a day.

Based on the findings from this study, in order to improve the local community wellbeing and security of natural resources for sustainable economic growth, three paths are recommended to be followed: (i) Reviewing strategies adopted in the conservation practices; (ii) Observing the rights of the local communities' use of land for paddy farming; and (iii) Integrating fish farming and ecotourism in mangrove ecosystem of the area. These are useful for the planning and decision making of the programs implemented in the studied area.

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REFERENCES

Ajonina G, Diamé A, Kairo J. 2008. Current status and conservation of mangroves in Africa: An overview. World Rainforest Movement Bulletin 133: 1-6.

Cahyaningsih AP, Deonova AK, Pristiawati CM, Ulumuddin YI, Kusumawati L, Setyawan AD. 2022. Causes and impacts of anthropogenic activities on mangrove deforestation and degradation in Indonesia. Intl J Bonorowo Wetl 12 (1). DOI: 10.13057/bonorowo/w120102.

Ajonina G, Diamé A, Kairo J. 2013. Current Status and Conservation of Mangroves in Africa: An overview. J Chem Inf Model 53 (9): 1689-1699.

Chinangwa L, Pullin AS, Hockley N. 2016. Livelihoods and Welfare Impacts of Forest Co-Management. Int J. For. Res 2016: 1-12. DOI: 10.1155/2016/5847068

Dai Z, Trettin CC, Mangora MM, Tang W. 2022. Soil carbon within the mangrove landscape in Rufiji River Delta, Tanzania. Wetlands 42 (7): 1-17. DOI: 10.1007/s13157-022-01608-9.

Dalu MT, Mukhuwana O, Cuthbert RN, Marambanyika T, Gunter AW, Murungweni FM, Dalu T. 2022. Understanding communities' perceptions, demographics and uses of wetlands in Vhembe Biosphere Reserve, South Africa. Wetl. Ecol. Manag 30: 1231–1244. DOI: 10.1007/s11273-022-09892-2.

DFID. 1999. Sustainable Livelihoods Guidance Sheets. https://www.ennonline.net/attachments/871/dfid-sustainable-livelihoods-guidance-sheet-section1.pdf.

Duke NC, Schmitt K. 2015. Mangroves: Unusual Forests at the Seas Edge. In: Köhl, M., Pancel, L. (eds) Tropical Forestry Handbook. Springer, Berlin.

Duvail S, Hamerlynck O, Nandi RX, Mwambeso P, Elibariki R. 2006. Participatory Mapping for Local Management of Natural Resources in Villages of the Rufiji District, Tanzania. Electron J. Inf. Syst. Dev. Ctries 25 (1): 1–6. DOI: 10.1002/j.1681-4835.2006.tb00167.x.

Friess DA, Rogers K, Lovelock CE, Krauss KW, Hamilton SE, Lee SY, Lucas R, Primavera J, Rajkaran A, Shi S. 2019. The State of the

World's Mangrove Forests: Past, Present, and Future. Annu. Rev. Environ. Resour 44 (1): 89–115. DOI: 10.1146/annurev-environ-101718-033302.

Hlaing ZC, Kamiyama C, Saito O. 2017. Interaction between Rural People's Basic Needs and Forest Products: A Case Study of the Katha District of Myanmar. Intl. J. For. Res 2017: 1–18. DOI: 10.1155/2017/2105012.

Israel GD. 1992. Sampling the evidence of extension program impact. Institute of Food and Agriculture Sciences EDIS, University of Florida Cooperative Extension Service, Gainesville, FL. DOI: 10.1.1.564.9215.

Japhet E, Mangora MM, Trettin CC, Okello JA. 2019. Natural Recovery of Mangroves in Abandoned Rice Farming Areas of the Rufiji Delta, Tanzania. West. Indian Ocean J. Mar. Sci. 18 (2): 25–36. DOI: 10.4314/wiojms.v18i2.3.

Lin Z, Zengrang XU, Wuxue C. 2022. Ecological Protection and Livelihood Improvement in Ecologically Vulnerable Regions. J Resour Ecol 13 (5): 759-762.

Machava-António V, Fernando A, Cravo M, Massingue M, Lima H, Macamo C, Bandeira S, Paula J. 2022. A Comparison of Mangrove Forest Structure and Ecosystem Services in Maputo Bay (Eastern Africa) and Príncipe Island (Western Africa). Forests 13 (9): 1466-1487. DOI: 10.3390/f13091466.

Mangora MM. 2011. Poverty and Institutional Management Stand-off: A Restoration and Conservation Dilemma for Mangrove Forests of Tanzania. Wetl. Ecol. Manag 19 (6): 533–543. 10.1007/s11273-011-9234-2.

Monga E, Mangora MM, Mayunga JS. 2018. Mangrove Cover Change Detection in the Rufiji Delta in Tanzania. West. Indian Ocean J. Mar. Sci. 17 (2): 1-10. DOI: 10.4314/wiojms.v17i2.1.

Mshale B, Senga M, Mwangi E. 2017. Governing mangroves: Unique challenges for managing Tanzania's coastal forests. Bogor, Indonesia and Washington, DC: CIFOR and USAID Tenure and Global Climate Change Program. https://hdl.handle.net/10568/94401.

Mungai F, Kairo JG, Mironga JM, Kirui BY, Mangora MM, Koedam N. 2019. Mangrove cover and cover change analysis in the transboundary area of Kenya and Tanzania during 1986–2016. J. Indian Ocean Reg 15: 157 - 176.

Namangaya AH, Mushi DM. 2019. Actors' Influences on Land Use Planning Decisions in Small Towns: The Case of Geita, Gairo and Kibiti Towns in Tanzania. Open J. Soc. Sci 7 (7): 172–190. DOI: 10.4236/jss.2019.77016.

Ngowi NJ. 2018. Contribution of wetland friendly investment approach on livelihoods and ecosystem services: the case of Ndembera River Valley in Iringa, Tanzania. [Dissertation]. University of Dar es Salaam, Dar es Salaam.

Ntibona LN, Shalli MS, Mangora MM. 2022. Incentives and Disincentives of Mangrove Conservation on Local Livelihoods in the Rufiji Delta, Tanzania. Trees, Forests and People 10: 100326. 10: 100326. DOI: 10.1016/j.tfp.2022.100326.

Nyangoko BP, Berg H, Mangora MM, Gullström M, Shalli MS. 2020. Community Perceptions of Mangrove Ecosystem Services and Their Determinants in the Rufiji Delta, Tanzania. DOI: 10.3390/su1301.

Nyangoko BP, Berg H, Mangora MM, Shalli MS, Gullström M. 2022. Local perceptions of changes in mangrove ecosystem services and their implications for livelihoods and management in the Rufiji Delta, Tanzania. Ocean Coast Manag 219: 106065.

UNDP [United Nations Development Programme]. 2012. Rufiji Environment Management Project Tanzania. Equator Initiative Case Study Series, New York.

William DS, Arild A, Brian B, Paul B, Robert N, Levania S, Sven W. 2005. Livelihoods, forests, and conservation in developing countries. World Dev 33 (9): 1383-1402. DOI: 10.1016/j.worlddev.2004.10.004.

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Analysis of drinking water quality based on biological, physical and chemical parameters in Lekobalo Village, Gorontalo City, Indonesia

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Abstract. *Katili L, Baderan DWK, Kumaji SS. 2023. Analysis of drinking water quality based on biological, physical and chemical parameters in Lekobalo Village, Gorontalo City, Indonesia. Intl J Bonorowo Wetlands 13: 22-29.* Lekobalo Village is a part of the Gorontalo City, Indonesia area, which has not yet received full clean water coverage. Therefore, the community in Lekobalo used the wellsprings as the source of drinking water. An open water tank around the wellspring has been the source of drinking water for people in the surrounding. It becomes a place for household chores such as bathing, doing laundry, and serving as a lavatory. That makes the place look messy due to the household waste around the wellspring, which decreases the drinking water quality there. Hence, a test of the drinking water in Lekobalo is crucially needed. This study is descriptive-qualitative research that was conducted by a direct survey. Sample collection was conducted using sterilized bottles from the laboratory, and the data obtained were analyzed descriptively. This study aims to determine drinking water quality based on biological, physical, and chemical parameters. The research revealed that the quality of drinking water in Lekobali based on the biological parameter was considered polluted by *Escherichia coli* and coliform bacteria. The findings revealed that the average score of *E. coli* was 10.3 MPN/100 ml and coliform 200.5 MPN/100 mL. In physical parameters, the drinking water quality is relatively good with an average temperature of 20°C, turbidity NTU, scentless, tasteless, and colorless. The drinking water criterion that did not meet the physical parameters is the TDS (Total Dissolved Solid), which is 1,525 mg/L. According to the chemical parameter, the quality of the drinking water is considered relatively good with some average score of arsenic (As) 0 mg/L, fluoride (F) 1 mg/L, nitrite (NO_2) 0.02 mg/L, nitrate (NO_3) 3.6 mg/L, iron (Fe) 0.12 mg/L, Power of Hydrogen (pH) 6.6 mg/L and manganese (Mn) 0 mg/L. The chemical parameters that did not meet the standard qualification of drinking water based on the chemical parameters are chromium (Cr), and cadmium (Cd), as the average scores are 0.34 mg/L and 0.047 mg/L. This study can be used as one of the government's databases as an input in developing programs and activities to improve drinking water quality and control water pollution.

Keywords: Drinking water, Gorontalo, Indonesia, Lekobalo

INTRODUCTION

Water is one of the primary needs for living creatures and the human environment. Humans need water, especially for drinking and daily human activities such as bathing, cooking, washing clothes, and washing kitchen utensils (Daud et al. 2021). The standard categorized as the source of clean water is the water that meets the standard qualification based on the physical, chemical, and microbiological parameters. The normal water that can be used as a source of clean water is surface water, rainwater, and groundwater. The groundwater that naturally emerges from the land surface is called a wellspring. Wellspring is the flow of groundwater that emerges to the land surface naturally. The cut groundwater flow causes that due to the topographical shape of the area and its emergence from rocks (Sudipa and Nurjani 2022).

Gorontalo City is considered an average city in Indonesia which is always connected to the problems of clean water and drinking water service. That can be observed through the data of the Regional Drinking Water Company (PDAM) of Gorontalo City by the end of 2013 revealed that the pipeline service in distributing drinking water only reached 85.9% out of 180,994 residents. On the other hand, the Lekobalo Village is part of Gorontalo City, which is not involved in the coverage area receiving the thoroughly clean water supply. Therefore, some public places do not receive clean water from PDAM. That causes many people to use the wellspring. The local people use its existence to fill their daily needs for clean water. The wellspring comes from the ground, which most people believe is the grace given to them to be used as the source of drinking water.

The need for drinking water among the people of Lekobalo, if the condition of the environment is good (no flood), can be fulfilled by the wellspring that flows through the pipe hole. However, if there is flooding, the people get the water from the wellspring loaded in an open water tank and use it to complete their daily needs such as showering, laundry, and lavatory. That makes the location around the tanks full of household waste which may lower the quality of the drinking water from the wellspring. People's activities would also be likely to get the water contaminated because the water in the tank is connected to the pipe hole, and it is at a close distance. This contamination may be a chemical substance, and dangerous soap and feces bacteria can cause environmental and water pollution. According to Wiryono (2013), using water as a

place for waste disposal, lavatory, showering, and washing dishes would trigger the existence and spread of disease.

water pollution is the occurrence of compounds from human activities penetrating the water environment so that it worsens the physical, chemical, and biological peculiarities and esthetic. Thus, if the wellspring is not well conserved, it will reduce its quality. The water's good or poor quality can be examined by testing the water sample (Suryani 2016). The quality testing was conducted using physical, chemical, and biological parameters (Sahabuddin et al. 2014). The examination referred to the quality standards based on its function as drinking water regulated in the Regulation of Health Ministry of the Republic of Indonesia Number 492 the Year 2010 concerning the drinking water consumed after or without the processing that follows the health requirement and can be directly consumed. Gaining good quality water needs an initial process before being consumed. Therefore, an examination to elicit drinking water quality based on biological, physical, and chemical parameters in Lekobalo Village, Gorontalo City, Indonesia, is needed.

MATERIALS AND METHODS

Research location

This study was conducted in Lekobalo Village, Kota Barat Sub-district, Gorontalo City, Gorontalo Province, Indonesia. There is a wellspring that becomes the source of drinking water. Around the wellspring, a water tank becomes a place for the community to do house chores such as laundry, showering, and lavatory. That makes the environment around wellspring polluted due to the waste, triggering a water quality decrease from the wellspring. Geographically, Lekobalo has located in the City of Gorontalo; the eastern part borders on Pilolodaa Village, the western borders on Dembe I Village of Gorontalo City, southern borders on mountains, Iluta Village and northern borders on Tualango Village, Gorontalo District. This village is located in a coordinate of (0°32'53.03"N, 123°1'3.56"E) (Figure 1).

Procedures

Sampling stage

The test sample was collected using a sterilized carboy. Next, for chemical and physical tests, the water was poured into a bottle whose mouth was swabbed with alcohol. Finally, the sample was poured into a 100 mL bottle specifically used for bacteria for the microbiological test. Each sample bottle was given a name or code using labels and then transferred to the Laboratory of Public Health in the Regional Technical Implementation Unit (UPTD) of the Regional Health Laboratory Bureau of Gorontalo Province to be tested. The sampling was directly tested right after being received at the laboratory.

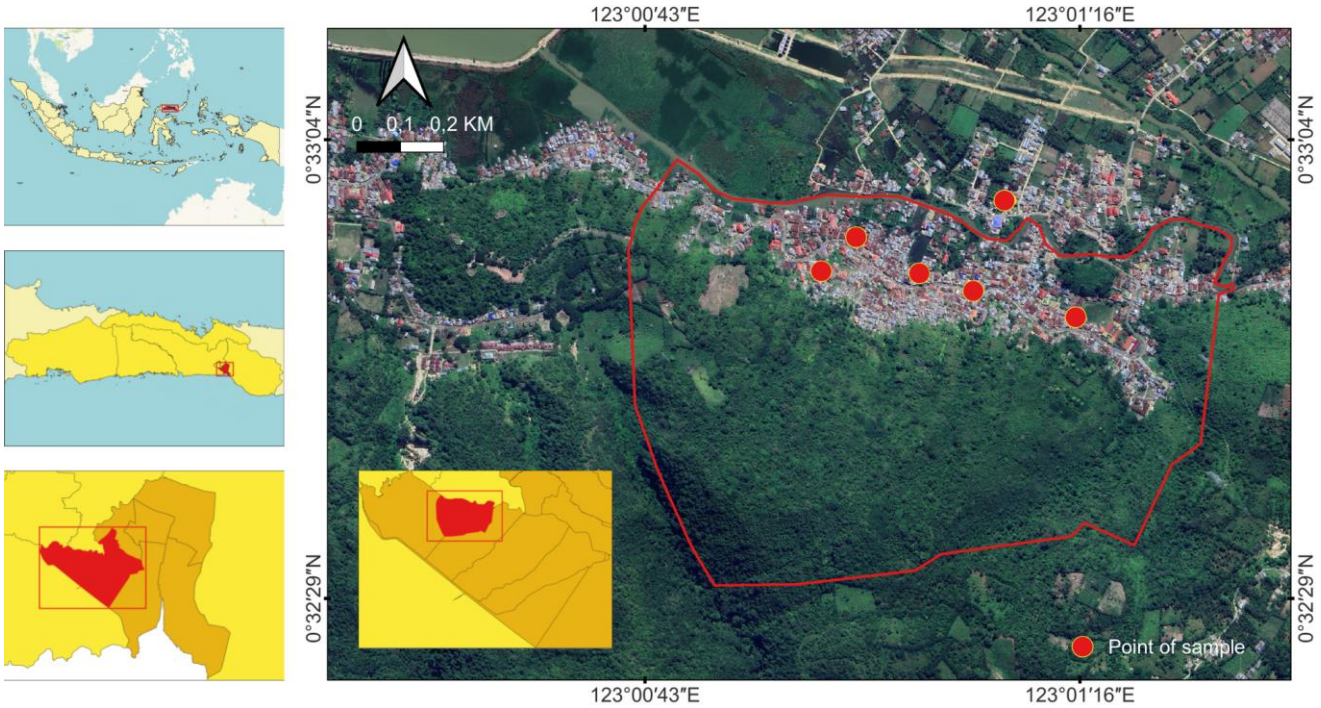

Figure 1. Map of research location in Lekobalo Village, Kota Barat Sub-district, Gorontalo City, Gorontalo Province, Indonesia

Stages of water quality test

The test must be conducted in-situ (where the sample is collected) and ex-situ (in the UPTD of the Regional Health Laboratory Bureau of Gorontalo Province). The test was conducted by referring to the standard drinking water qualification according to the Regulation of the Health Ministry of the Republic of Indonesia Number 49 the Year 2010. The test was repeated three times for each parameter. In addition, a physical parameter test was conducted in-situ (smell and taste) by five panelists. The smell parameter test was conducted directly in the location by taking the sample using a sterilized 100 mL beaker and smelling the aroma. Similarly, the taste parameter test was conducted in the field by pouring a small sample into a sterilized beaker and tasting and feeling the sample. The ex-situ test included the biological (*Escherichia coli* and coliform), physical (temperature, TDS, color, turbidity), and chemical (Arsenic (As), Fluoride (F), Nitrite (NO_2), Nitrate (NO_3), Iron (Fe), power of hydrogen (pH) and Manganese (Mn)) parameter tests.

Biological parameter test

The biological parameter test was conducted to detect the existence of *E. coli* and coliform by using the Quanti-Tray method. There are three steps in this testing. It started with preparing three sterilized bottles and giving them the label of repetition, such as 1, 2, and 3. Then, the sample was poured into each sterilized 100 mL bottle. Each was added colilert powder. After that, it was homogenized and ensured that all colilert reactors were perfectly dissolved. Next, the sample homogenized with colilert powder was poured into a Quanty-Tray; 1 bottle of sample is for 1 Quanty-Tray. The same things were done until it reached six samples in total, and each Quanty-Tray was given similar labels to those on the bottles. Then input the Quanty-Trays one by one in the tray sealer so that the samples were smoothly filled in the mold and the mold was tightly closed. Finally, the six molds were incubated under 30°C for 18 hours, then the color change was observed. The first thing to observe is the existence of coliform bacteria that makes the sample's color change from crystal clear to yellow. The square that changed was marked using a permanent marker. After observing the existence of coliform bacteria, the next step was to observe whether *E. coli* bacteria were in the sample. The sample was then observed using a long Wav UV lamp with a 365 nm wavelength. If flourentia happens, it was marked using a black permanent marker to make the *E. coli* bacteria test score easy to recapitulate. After completing the observation, the boxes on the molds that positively contained the coliform and *E. coli*. The total boxes found positive were adjusted to the score in a table determining the score of the coliform and *E. coli*.

Physical parameter test

The physical parameter test was conducted to determine the drinking water's physical quality based on several tests, i.e., water temperature, total dissolved solids, color, and turbidity. The color test was carried out using a turbidity meter. First, the repetition 1 test was conducted by pouring the sample into a beaker as big as 50 mL. After that, the turbidity meter was immersed in the glass, then waited until the device could read the temperature score. Then, the same thing was repeated until it reached 2 to 3 repetitions.

Similar to the temperature test, TDS was conducted using a turbidity meter by the Turbidimetry method. The first step was similar, the repetition 1 test; then, the sample was poured into a beaker amounting to 15 mL, based on the volume capacity of the Turbidity tube. After the tube was filled with the sample, it was covered and ensured that there was no sample left on the outer surface of the tube. Then it was stored in a measuring instrument of turbidity TB200 and anticipated for some time until the device detected the TDS score. After that, a similar thing was repeated until it reached 2 to 3 repetitions.

The first step that should be done on watercolor testing was preparing three 100 mL beakers. Then, the beakers were labeled as repetition 1, 2, and 3. After that, the samples were poured into each beaker as much as 100 mL. Then, the watercolor and other probable anomalies were observed by using a white background.

The turbidity test was begun by testing repetition 1. The initial step was pouring the sample into a turbidity tube amounting to 15 mL according to the volume capacity of the Turbidity tube. After the sample had filled the tube, the tube was covered and ensured that there was no sample left on the outer surface of the tube. The tube was then put in the Turbidity TB200 instrument and anticipated until the device read the turbidity score. Similar steps were carried out until repetitions 2 and 3.

Chemical parameter test

The chemical parameter test was conducted entirely ex-situ in the laboratory. The step of testing the fluoride, chromium, cadmium, nitrite, nitrate, zinc, and manganese is similar. It started with preparing 1 rack of test tubs containing 3 test tubes. Each test tube on the rack was labeled as repetition 1, 2, and 3. Other elements which are not aforementioned have a different initial step. The testing procedures are described in the following paragraphs.

Arsenic (As) testing was started by preparing three arsenic bottles. Each bottle was labeled as repetition 1, 2, and 3. After that, each bottle was given a sample of as much as 60 mL and added two drops of As1 reagent, one spoonful of As2 reagent, and one spoonful of As3 reagent. Next, the sample was homogenized, and an arsenic stick was inserted through a hole in the arsenic cover and then left for 20 minutes. After 20 minutes passed, the stick was pulled out and matched with the color indicator on the stick tube. Each color indicator has numbers that indicate the score result of As.

The next step was fluoride (F) testing. Initially, 2 mL F1 reagent was poured into each test tub then 5 mL of sample was added. Next, one spoonful of F2 reagent was given, homogenized, and left for 5 minutes. While waiting, the Autoselector instrument was inserted in the spectrophotometer (Spectroquant Pharo 300) so that the tool could automatically measure the parameter being tested. Next, the homogenized sample was poured into a cuvette amounting to 2.5 mL which is suitable for the

cuvette volume. Then it was put into a spectrophotometer testing tool and tested for the amount of its concentration. The score of the testing result will appear on the monitor of the testing tool.

The following step was chromium (Cr) testing. It was started by pouring one spoonful of Cr1 reagent into each test tube; six drops of Cr2 reagent and a 5 mL sample were added. Then it was homogenized and left for 1 minute. While waiting, insert the Autoselector into the spectrophotometer (Spectroquant Pharo 300) tool so that it can be measured automatically based on the tested parameter. After that, the homogenized sample was poured into a cuvette amounting to 2.5 mL based on the cuvette volume. Then it was put in a spectrophotometer testing tool and tested on how much the concentration was. The score result of the test will appear on the monitor of the testing tool.

The next step is cadmium (Cd) testing. Initially, 1 mL Cd1 reagent was poured into each test tube, then added with a 10 mL sample, with 0.2 mL Cd2 reagent and one spoonful of Cd3 reagent. It was then homogenized and left for 2 minutes. While waiting, insert the Autoselector into the spectrophotometer (Spectroquant Pharo 300) tool so that it can be measured automatically based on the tested parameter. Next, the homogenized sample was poured into a cuvette amounting to 2.5 mL based on the cuvette volume. Then it was put in a spectrophotometer testing tool and tested on how much the concentration was. The score result of the test will appear on the monitor of the testing tool.

The following step was nitrite (NO_2) testing. It was started by pouring a 5 mL sample into each test tube, one spoonful of NO_2 reagent, and homogenized and left for 10 minutes. While waiting, insert the Autoselector into the spectrophotometer (Spectroquant Pharo 300) tool so that it can be measured automatically based on the tested parameter. After that, the homogenized sample was poured into a cuvette amounting to 2.5 mL based on the cuvette volume used. Then it was put in a spectrophotometer testing tool and tested on how much the concentration was. The score result of the test will appear on the monitor of the testing tool.

The next step is nitrate (NO_3) testing. Initially, 4 mL $NO_3$1 reagent was poured into each test tube, then added with 0.50 mL sample and 0.50 ml NO_3 reagent. It was then homogenized and left for 10 minutes. While waiting, insert the Autoselector into the spectrophotometer (Spectroquant Pharo 300) tool so that it can be measured automatically based on the tested parameter. After that, the homogenized sample was poured into a cuvette amounting to 2.5 mL based on the cuvette volume used. Then it was put in a spectrophotometer testing tool and tested on how much the concentration was. The score result of the test will appear on the monitor of the testing tool.

The following step was Zinc (Fe) testing. It was started by pouring a 5 mL sample into each test tube and three drops of Fe reagent. It was then homogenized and left for 3 minutes. While waiting, insert the Autoselector into the spectrophotometer (Spectroquant Pharo 300) tool so that it can be measured automatically based on the tested parameter. Afterward, the homogenized sample was poured into a cuvette amounting to 2.5 mL based on the volume of the cuvette used. Then it was put in a spectrophotometer testing tool and tested on how much the concentration was. The score result of the test will appear on the monitor of the testing tool.

For pH testing, a particular test tube to test pH was prepared in the laboratory, where there were only two pH tubes. Thus, 2 test tubes were prepared. The first test was conducted for repetitions 1 and 2 of the clean water sample. After that, the test for repetition 3 of the clean water sample and repetition 2 for the drinking water sample, and the last test was repetition 2 and 3 of the drinking water sample. First, a 10 mL sample was poured into the test tube. Then it was added with four drops of pH reagent and homogenized, ensuring that the outer surface of the bottle was dry. Then it was put in a spectrophotometer (Spectroquant Pharo 300) testing tool and tested on how much the concentration was. The score result of the test will appear on the monitor of the testing tool.

The following test was Manganese (Mn). The initial step was pouring a 5 mL sample into a test tube. Then four drops of Mn1 reagent and two drops of Mn2 were added. It was then homogenized and left for 2 minutes. While waiting, insert the Autoselector into the spectrophotometer (Spectroquant Pharo 300) tool so that it can be measured automatically based on the tested parameter. Afterward, the homogenized sample was poured into a cuvette amounting to 2.5 mL based on the cuvette volume. Then it was put in a spectrophotometer testing tool and tested on how much the concentration was. The score result of the test will appear on the monitor of the testing tool.

Data analysis

After collecting the data, data analysis was conducted using the descriptive method. A conclusion was drawn by considering the standard quality of drinking water regulated by the Health Ministry of the Republic of Indonesia Number 492 in the Year 2010 concerning the drinking water. If the result were not relevant to the regulated standard quality of drinking water in Lekobalo Village, Gorontalo City, Indonesia, it would not be used as described.

RESULTS AND DISCUSSION

The quality test result of drinking water

The finding result of the quality test of drinking water by referring to the standard quality of drinking water regulated by the Health Ministry of the Republic of Indonesia Number 492 in the year 2010 was delivered in the table below. In addition, the result of the biological parameter test was exposed in Table 1, the physical parameter in Table 2, and the chemical parameter in Table 3.

Table 1. The result of the quality test on drinking water based on biological parameter

Parameter	Testing method	Average	Quality standard
E. coli	Quanti tray	10.3 MPN/100 mL	0 MPN/100 mL
Total coliform	Quanti tray	200.5 MPN/100 mL	0 MPN/100 mL

Table 2. The result of the quality test on drinking water based on the physical parameter

Parameter	Testing method	Average	Quality
Temperature	Turbidimetry	20°C	Air temp. ± 3°C
Total Dissolved Solid	Turbidimetry	1525 mg/L	1000 mg/L
Smell	Organoleptic	No smell	No smell
Color	Visual (Direct)	Colorless	Colorless
Taste	Organoleptic	Tasteless	Tasteless
Turbidity	Turbidimetry	0 NTU	25 NTU

Table 3. The result of the quality test on drinking water based on the chemical parameter

Parameter	Testing method	Average	Quality
Arsenic (As)	Spectrophotometry	0 mg/L	0.05 mg/L
Fluoride (F)	Spectrophotometry	1 mg/L	1,5 mg/L
Chromium (Cr)	Spectrophotometry	0.34 mg/L	0.05 mg/L
Cadmium (Cd)	Spectrophotometry	0.047 mg/L	0.005 mg/L
Nitrite (NO_2)	Spectrophotometry	0.02 mg/L	1 mg/L
Nitrate (NO_3)	Spectrophotometry	3.6 mg/L	10 mg/L
Zinc (Fe)	Spectrophotometry	0.12 mg/L	1 mg/L
Manganese (Mn)	Spectrophotometry	0 mg/L	0.4 mg/L
pH	Spectrophotometry	6.6 mg/L	6.5-8.5 mg/L

Discussion

Analysis of quality test on drinking water based on biological parameter

Water quality based on biological parameters seen through the content of *E. coli* bacteria showed that the drinking water from the wellspring located in the Lekobalo Village, Gorontalo City, did not fit the criteria of quality standard that is 0 MPN/100 mL. The high composition of *E. coli* in the water was caused by the condition of the surroundings, where a toilet nearby is frequently used for feces disposal. That triggers the high content of *E. coli* bacteria in the water. Another factor that causes the high content of *E. coli* bacteria in the water is the condition when taking the sample. The water tank was fully loaded due to the rainwater that drops daily, which may create the great possibility that E. coli contaminates the water, considering the toilet's location is close to the wellspring. Lipinwati et al. (2018) state that water containing pathogenic organisms such as *E. coli* has been polluted with human and animal excrement. As a result, the water cannot be used for drinking, laundry, or cooking food due to a disease-related gastrointestinal such as diarrhea. Therefore, drinking water quality standards required 0 *E. coli* in 100 mL water.

The content of coliform obtained from the test result in the laboratory revealed that the capacity of the drinking water from the Lekobalo Village is not eligible for drinking based on the qualification on quality standard, that is 0 MPN/100 mL. The cause of high-rate coliform in the water from the Lekobalo Village is similar to the high rate of *E. coli* related to the community's activity concerning lavatory usage. That is also supported by Kumala et al. (2019), who stated that the high amount of waste marks the potential of coliform bacteria to breed. Furthermore, the microorganism in water proves that the water was populated by human and warm-blooded animal excrement. That also implies a potential for various pathogenic organisms to live periodically in the gastrointestinal tract to transmigrate in the water.

Analysis of quality test on drinking water based on the physical parameter

Temperature is one of the parameters that have an important role in environmental factors (Baderan et al. 2019). The finding result drinking water temperature in the Lekobalo Village has been eligible for drinking based on the qualification of quality standard that is ± 3°C (the temperature score reaching 3°C above and below the temperature of the surrounding). When the research was carried out, the air temperature in the research location was around 22°C. Water temperature with an average score of 20°C was obtained during the sample collection in the afternoon and rain. According to Sofiana et al. (2022), a good temperature range for water is between 18-30°C.

The TDS score of the drinking water is not eligible for drinking based on the quality standard of drinking water. The water in the research location had been polluted by people's activity in the wellspring, such as doing laundry and showering. These activities caused more waste and leftovers of soap and detergent. That is also supported by Setiari et al. (2012), who stated that the main factor causing the existence of TDS in water is the leftovers of organic materials and molecular leftovers such as soap, detergent, and surfactant dissolved in the water.

The turbidity score of the test sample obtained had been eligible for drinking based on the quality standard of drinking water. The drinking water in Lekobalo Village does not contain particle and suspension materials that hinder sunlight to penetrates the water. Therefore, the water turbidity level is considered based on the drinking water quality standard threshold determined based on its function. Besides, the environment where the sample is located is considered clean as there was no mud and clay, so the turbidity score is low or comply the quality standard. Pramesti and Puspikawati (2020) stated that the increase in turbidity score was caused by suspended solid materials, clay, mud, and inorganic or highly organic substances.

The test samples that were being tested visually revealed colorless water. According to Kumala et al. (2019), the decrease in water can be indicated by the increase in color parameter rate, that is, the color transformation from brownish to blackish. Therefore, the colored water can be from the chemical substance and colored microorganisms. Thus, to avoid intoxication from

various chemical substances and colored microorganisms, the water should be colorless.

The responses of five panelists towards the test sample showed that the drinking water in the Lekobalo Village was not smelly and tasteless. This result is relevant to the quality standard of drinking water that should not be smelly and tasteless. Moreover, standardized drinking water must be physically colorless, odorless, plain, and clear (Permana et al. 2020).

Analysis of quality test on drinking water based on chemical parameter

Arsenic content obtained from the analysis results in the laboratory revealed that the drinking water from the wellspring in the Lekobalo Village, Gorontalo City, has low arsenic content and has been eligible for drinking based on the quality standard, which is 0.05 mg/L. The absence of stimulants for high levels of arsenic, such as in volcanoes, mining, and other industries, causes the low arsenic content. That is related to a notion by Sembel (2015), who stated that naturally, arsenic could penetrate an environment through volcanic ash produced by volcanic eruptions, rocks weathering, and minerals containing arsenic that penetrate the groundwater. In addition, nature, human activities, and household waste can cause arsenic to penetrate the environment.

The result obtained for fluoride content in the test sample has been eligible for drinking based on the quality standard of drinking water, which is 1.5 mg/L. The quality condition of drinking water in the Lekobalo Village is considered good. Therefore, it can be used as the quality drinking water standard that meets the regulations. According to Nuradi and Jangga (2020), fluoride content ranging from 1-1.5 mg/L will strengthen teeth' enamels. However, ranging from 1.5-4 mg/L, the fluoride may cause dental fluorosis, and if the content of fluoride ranges from 4-10 mg/L for a long time, it does cause not only dental fluorosis but also skeletal fluorosis that will cause the skeletons that support the body becomes weakened.

The chromium content obtained from the test did not become eligible for drinking based on the quality standard of drinking water, which is 0.05 mg/L. That indicates the drinking water in the Lekobalo Village was contaminated by chromium, a heavy metal. The high rate of chromium, the heavy metal containing the water, is caused by people's activities around the wellspring that creates household waste. That is relevant to the statement by Nuraini et al. (2017), who stated that chromium, the heavy metal in water, is from nature with a very small amount such as rock weathering process and the runoffs from lands. However, chromium heavy metal can increase in numbers due to human activities such as industry, household waste, and other activities through the wastes that penetrate the waters. According to Mauna et al. (2015), chromium (Cr) is a heavy metal essential for our body. Moreover, it is needed for the metabolism process of insulin hormone and regulating sugar blood level. However, it may be intoxicating if it is consumed in high numbers. Besides, the toxic nature of chromium is carcinogenic or can cause cancer. Therefore, considering the test result in this parameter, the drinking water in the Lekobalo Village is not recommended to be used for drinking as it has the potential to endanger our health.

The result of cadmium (Cd) testing revealed it was not eligible for drinking based on the quality standard of drinking water, which is 0.03 mg/L. That is affected by human activities around the wellspring that created domestic wastes so that the rate of Cd, the heavy metal content in the water, exceeds the limit of quality standard of drinking water which had been determined. These results are aligned with Irsan et al. (2013), who stated that the detected heavy metals mark the decreased quality of groundwater as pollutants which were cadmium (Cd), Lead (Pb), and Manganese (Mn) that are from industrial wastes, landfills leaching, excessive use of fertilizer and domestic wastes. Other sources that can cause Cd heavy metal pollution are agricultural and livestock activities, metal coatings, oil spills, plastic, coal, batteries or accumulators, and garbage deposits. According to Irsan et al. (2013), the pollution caused by cadmium (Cd) negatively impacted the ecosystem and human living.

Furthermore, cadmium heavy metal in the drinking water used for daily consumption, could harm the body's health if consumed beyond limitation. Therefore, considering the result analysis of this parameter, the drinking water from the wellspring is not eligible for the source of drinking water as it may harm our health. That is relevant to a notion by Ghifari et al. (2022), stating that Cd metal is categorized as a non-essential metal like Lead (Pb), Mercury (Hg), and Arsenic (Ar). Non-essential metals do not function in the human body unless becoming toxic and poisonous stated by Adhani and Husaini (2017).

Based on the quality standard determined, the Nitrite test result revealed that the drinking water from the wellspring could be used as the source of drinking water. The result obtained was eligible for consumption based on the quality standard of drinking water, 3 mg/L. The low nitrite content in this drinking water is caused by the absence of human activities that use organic fertilizer, which can trigger the high nitrite content in the water. Based on a notion by Indrayani et al. (2015), the natural source of nitrite and nitrate is the nitrogen cycle, while the source of human activities comes from the use of nitrogen fertilizer, industrial wastes, and human organic wastes.

The content of nitrate heavy metal in this study obtained was eligible for consumption based on the quality standard of drinking water, which is 50 mg/L. Furthermore, that indicated factors causing nitrate content in the water, such as the fertilizer runoff that contains nitrate, which does not pollute the water in the research location. Thus, the nitrate content in the wellspring drinking water was eligible for consumption based on the determined quality standard. However, according to Sitepu et al. (2021), nitrate can penetrate the water directly due to the runoff of the fertilizer that contains nitrate.

According to the result obtained for zinc (Fe) content in the drinking water, that is 0.3 mg/L, it was indicated that Fe heavy metal pollutants do not pollute the drinking water in the Lekobalo Village. Therefore, the result demonstrated the quality of the drinking water had been eligible for

drinking, and the water is categorized as good for consumption. According to Supriyantini and Endrawati (2015), zinc (Fe) is an essential metal that living creatures need present in a certain number. However, an excessive amount of it will cause toxic effects.

The pH content in the drinking water located in the Lekobalo Village is still considered eligible for drinking based on the quality standard of clean water and drinking water, which is 6.5-8.5 mg/L. The research showed that the water quality based on the pH parameter in a neutral category (or normal based on its function) had been regulated in the determined quality standard of water. According to Sahabuddin (2012), the pH of normal water ranges from 6.5-7.5. Budiyono and Sumardiono (2013) stated that pH (pouvoir Hydrogen) reflects the hydrogen ion concentration in the water. Therefore, the pH content can be used to determine the base or acid levels of water.

The quality test of drinking water concerning Manganese content yielded that the water does not contain manganese heavy metal. However, the test result is relevant to the physical parameter test such as smell, color, and turbidity that is considered eligible for consumption based on the determined quality standard of drinking water. It is because the methods to check the content of manganese in the water is by observing its color changes, whether it has a taste and whether the water is muddy or not. That echoes the notion by Febrina and Ayuna (2015), stating that water containing excessive manganese (Mn) will create a taste, color (brown/purple/black), and turbidity.

It can be concluded that the quality of drinking water in the Lekobalo Village, Gorontalo City, Indonesia, is polluted by *E. coli* and coliform bacteria. The findings revealed that the average score of *E. coli* was 10.3 MPN/100 mL and coliform 200.5 MPN/100 mL. Based on physical parameters, the quality of drinking water in the Lekobalo Village, Gorontalo City is relatively good concerning temperature, turbidity, smell, taste, and color measurements. In comparison, the parameter that did not fulfill the quality standard on physical is TDS (Total Dissolved Solid), which reached an average score of 1,525 mg/L. Moreover, according to chemical parameters, the quality of the drinking water is relatively good concerning the tests on Arsenic (As), Fluoride (F), Nitrite (NO_2), Nitrate (NO_3), Zinc (Fe), pH, and Manganese (Mn). On the other hand, Chromium (Cr) and Cadmium (Cd) did not fulfill the quality standard based on the chemical parameter. The average score of chromium is 0.34 mg/L and Cadmium 0.047 mg/L. Therefore, it is suggested to conduct further research to observe the impacts of the drinking water quality on the community in the Lekobalo Village, Gorontalo City, Indonesia.

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REFERENCES

Adhani R, Husaini. 2017. The Heavy Metals Around the Community. Pustaka Buana, Banjarmasin. [Indonesian]

Baderan DWK, Hamidun MS, Utina R, Sukirman R, Rifal D. 2019. The abundance and diversity of Mollusks in mangrove ecosystem at coastal area of North Sulawesi, Indonesia. Biodiversitas 20 (4): 987-993. DOI: 10.13057/biodiv/d200408.

Budiyono, Sumardiono S. 2013. Water Processing Technique. Graha Ilmu, Yogyakarta. [Indonesian]

Daud SUD, Kumaji, SS, Arpin. 2021. Identification of Escherichia coli bacteria in dug wells in Kota Timur District of Gorontalo City. Sci Dr Aloei Saboe J 8 (1): 1-6.

Febrina L, Ayuna A. 2015. Study on the reduction of Iron (Fe) and Manganese (Mn) contents in groundwater using ceramic filter. Tech J 7 (1): 35-44. [Indonesian]

Ghifari F, Santoso A, Suprijanto J. 2022. The potential risks of human health as the impacts of consuming *Perna viridis* containing Cadmium. J Mar Res 11 (1): 19-29. DOI: 10.14710/jmr.v11i1.32338. [Indonesian]

Indrayani E, Nitimulyo KH, Hadisusanto S, Rustadi R. 2015. Content analysis of nitrogen, phosphor, and organic carbon in Sentani Lake-Papua. J Hum Environ 22 (2): 217-225. DOI: 10.22146/jml.18745. [Indonesian]

Irsan PR, Hasan W, Chahaya I. 2013. Analysis on Cadmium (Cd) in a well water around the farming area in Mompang Village, Padangsidimpuan Angkola Julu District, Padangsidimpuan City in 2013. Jurnal Neliti 10 (2): 14665. [Indonesian].

Kumala IGAH, Astuti NPW, Sumadewi NLU. 2019. Quality Test of drinking water in a wellspring of Baturiti Village, Baturiti District, Tabanan Regency. J Environ Health 5 (2): 100-105. [Indonesian].

Lipinwati, Darmawan A, Kusdiyah E, Karolina ME. 2018. Quality Test of refill drinking water in Jambi City. Jambi Medical Journal 4 (2): 203-210. [Indonesian]

Mauna RB, Ma'rufi I, Ningrum PT. 2015. The content of chromium (cr) on liquid wastes and river water and health complaints from the community around the electro-planting industry (a study in x electro-planting industry Tegal Besar Sub-district, Kaliwates District, Jember Regency). Artikel Ilmiah Hasil Penelitian Mahasiswa 2015: 1-6. [Indonesian]

Nuradi, Jangga. 2020. Analysis of Fluoride content on several branded bottled water distributed in Rappocini District, Makassar City. Jurnal Media Analis Kesehatan 11 (1): 56-61. DOI: 10.32382/mak.v11i1.1509. [Indonesian]

Nuraini RAT, Endarwati H, Maulana IR. 2017. Analysis on the content of Chromium (Cr) the heavy metal in water, sediment and green shell (*Perna viridis*) in Trimulyo Waters, Semarang. Trop Mar J 20 (1): 48-55. DOI: 10.14710/jkt.v20i1.1104. [Indonesian]

Permana B, Syafei DI, Syafei H, Olifvia O, Fitri NC, Sundari NR, Saharai W, Vanesia D, Aini AN, Gamellia BO, Katipah K, Arif M, Anggraani A. 2020. Analysis on physical characteristics and acidity degree towards the quality of drinking water refill package from 20 houses in RW 01 Cilember Sub-Village, Jogjogan Village, Cisarua District, Bogor Regency. Risenologi 5 (1): 54-69. DOI: 10.47028/j.risenologi.2020.51.82. [Indonesian]

Pramesti DS, Puspikawati SI. 2020. Analysis on turbidity test of bottled drinking water distributed in Banyuwangi Regency. J Pub Health 11 (2): 75-85. [Indonesian]

Sahabuddin ES. 2012. Water pollution and the achievable sustainability of natural resources. Edu Pub J 11 (2): 102-111. DOI: 10.22487/preventif.v11i2.59. [Indonesian]

Sahabuddin H, Harisuseno D, Yuliani E. 2014. Analysis of water quality status and load capacity of Wanggu River pollution in Kendari City. J Waters Eng 5 (1): 19-28. [Indonesian]

Sembel DT. 2015. Environmental Toxicology. Andi Offset, Yogyakarta. [Indonesian]

Setiari NM, Mahendra MS, Wayan I. 2012. Identification of pollutant sources and analysis on water quality of Tukad Yeh River in Tabanan Regency by using pollution index method. Ecotrophic 7 (1): 383535. [Indonesian]

Sitepu DMB, Ima YP, Kartika IWD. 2021. Content of Nitrate and Phosphate in water of Telagawaja River, Karangasem Regency, Bali. Curr Trends Aquat Sci 4 (2): 212-218. [Indonesian]

Sofiana M, Kadarsah A, Sofarini D. 2022. Water quality impacted from wastes as the indicator of sustainability development in Sub Das

Martapura, Banjar Regency. Jurnal Teknik Lingkungan 8 (1): 18-31. DOI: 10.20527/jukung.v8i1.12966 . [Indonesian]

Sudipa N, Nurjani. 2022. The Potentials of pollutants and quality of wellspring of Penida and Guyangan as the standard source of drinking water in Nusa Penida. Ecotrophic 16 (1): 36-44. DOI: 10.24843/EJES.2022.v16.i01.p04. [Indonesian]

Supriyantini E, Endrawati H. 2015. The content of Iron (Fe) heavy metal in water,sediment, and green shell (*Perna viridis*) in the Tanjung Emas Waters, Semarang. Trop Mar J 18 (1): 38-45. DOI: 10.14710/jkt.v18i1.512. [Indonesian]

Suryani A. S. 2016. Community perception in using clean water (a case study on riverside community in palembang). Aspirasi 7 (1): 33-48. [Indonesian]

Wiryono 2013. Pengantar Ilmu Lingkungan. Pertelon Media, Bengkulu. [Indonesian]

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Short Communication: Diversity of small mammals (non-volant) in tropical peatland ecosystem of Orang Kayo Hitam Forest Park, Jambi, Indonesia

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Abstract. *Dara W, Iswandaru D, Wulandari C, Novriyanti, Prasetia H. 2023. Short Communication: Diversity of small mammals (non-volant) in tropical peatland ecosystem of Orang Kayo Hitam Forest Park, Jambi, Indonesia. Intl J Bonorowo Wetlands 13: 30-35.* Peatlands areas dominate Orang Kayo Hitam Forest Park (OKH Forest Park), Jambi, Indonesia. The largest forest fire in the OKH Forest Park area occurred in 2015, damaging more than 70% of the area. The event subsequently affected the existing biodiversity, especially the diversity of small mammals. Small mammals have an important role in the ecosystem as agents in regeneration and restoration, including in the OKH Forest Park. The method used is the cage trap method which is placed by systematic sampling. Traps were placed in two types of habitats, namely shrubs, and forests. The bait variation consisted of coconut, sweet potato, banana, and oil palm fruit. All baits were treated by burning to give off an aroma. The resulting data were analyzed quantitatively using the Shannon-Wiener Diversity Index. Types of small mammals found in shrubs and forest habitats are Malaysian field rats (*Rattus tiomanicus* (Miller, 1900)) and plantain squirrels (*Callosciurus notatus* (Boddaert, 1785)) The diversity index shows a low category with a value of (H' = 0.17884). That indicates the condition of the habitat in the post-burnt peat ecosystem is still relatively depressed.

Keywords: Diversity, peatland, small mammals

INTRODUCTION

Living things rely on peatlands to play a critical role in mitigating the impacts of global climate change (Sudrajat and Subekti 2019). However, the peatlands soil is not easily weathered, accumulates in an anaerobic state, and there is organic matter that is primarily undecomposed (Masganti et al. 2014). Peatlands are vulnerable ecosystems, and restoring them to their original condition is difficult in the event of damage. Peatland management must be carried out ecologically because peatlands are combustible ecosystems. The fire on peatlands is more dangerous as it can spread rapidly below the ground surface. The rehabilitation of burnt peatlands is a challenging and expensive task (Wibisono and Dohong 2017). In addition, the productivity of peatlands decreases due to the degradation of soil fertility, soil biology, and physical properties of the soil (Maftuah and Hayati 2019).

Orang Kayo Hitam Forest Park (OKH Forest Park) has a peat swamp ecosystem in Jambi Province, Indonesia (Wulandari et al. 2021). OKH Forest Park is located in two districts, Muaro Jambi District and Tanjung Jabung Timur District with an area of 18,363.79 ha. Based on the 2012 OKH Forest Park landscape map, there are five classes of land cover, namely primary swamps (18.7 ha), secondary swamps (10,710.35 ha), shrubs (7,394 ha), open land (1.35 ha), and swamps (109.92 ha). A major fire in 2015 resulted in more than 70% of the existing acreage being burned and becoming an open area. Moreover, the OKH Forest Park is a *Panthera tigris* subsp. *sumatrae* (Pocock, 1929), Sumatran elephants (*Elephas maximus* subsp. *sumatranus* Temminck, 1847), gibbons (*Hylobates syndactylus* (Raffles, 1821)), and asian tapirs (*Tapirus indicus* Desmarest, 1819) (Mulyani and Iqbal 2020). OKH Forest Park still has tree species typical of peat ecosystems, such as *jelutung rawa* (*Dyera polyphylla* (Miq.) Steenis), *pulai rawa (Alstonia pneumatophora* Backer ex Den Berger), and several other tree species living places for the animals in it (Tamin et al. 2019). Degraded peatlands caused by repeated fires dominate the OKH Forest Park area, worsening forest and land degradation (Tamin et al. 2021). That will affect biodiversity and small mammals.

As of 2019, Indonesia is recorded to have approximately 776 mammals out of 12,000 species worldwide and is a country that ranks first in mammal diversity (Derajat 2022). Mammals are a group of vertebrate animals that have mammary glands. Mammals are divided into two based on their body size, namely large and small mammals (Irsaf et al. 2018). According to Apriyani and Nasihin (2017), small mammals, such as mice and squirrels, weigh less than five kilograms on adults. Rats are small nocturnal mammals with hair-covered heads, bodies, and tails (Heriyanto and Ristiyanto 2017). Small mammals have a higher metabolic rate and shorter life span than large mammals. Small mammals have a vital role in ecosystems, such as seed scatterers, pollinators, insect

population control, and prey for carnivorous animals (Kartono 2016). They are essential in supporting forest regeneration (Mazerolle et al. 2001). Research on small mammals has been widely carried out in Indonesia, such as Husson et al. (2018) in the Sebangau Peat Swamp Forest of Central Kalimantan Province, Harrison dan Rieley (2018) in the peat swamp forests of Southeast Asia, Derajat (2022) in Ujung Kulon National Park, Banten Province, Putra et al. (2022) at the Batu Tegi Forest Management Unit (KPH) of Lampung Province, and Ramadhani et al. (2019) in Ijen Nature Reserve, East Java Province. However, based on research that has been carried out, there have yet to be studied on small mammals in the OKH Forest Park peat ecosystem. This study illustrates how the condition of small mammal diversity in the OKH Forest Park peat ecosystem can support the restoration of peatlands. Therefore, this study aims to analyze the diversity of small mammal species in the OKH Forest Park peat ecosystem of Jambi Province, Indonesia.

MATERIALS AND METHODS

Study area

This research was conducted in September 2022 at the peat ecosystem of the Orang Kayo Hitam Forest Park, Jambi Province, Indonesia, located in the Muaro Jambi and Tanjung Jabung Timur Districts. Observations were made in two types of habitat, namely scrub (Lat -1.355847◦, Long 104.055337◦) and Young Forest (Lat -1.354469◦, Long 104.057755◦). These two habitats were selected because they reflect the condition of the OKH Forest Park post-burning in 2015. Land cover characteristics in the scrub habitat are filled with shrubs 1-2 meters high, while the land cover in Young Forests is dominated by mahang (*Macaranga* sp.), rengas (*Gluta renghas* L.), and punak wood (*Tetramerista glabra* Miq.) with a height of 5-8 meters and an average diameter of 16.8 cm. OKH Forest Park has an area of 18,363.79 ha, and based on the landscape map of OKH Forest Park in 2012, there are five land cover classes, namely secondary swamp (10,710.35 ha), primary swamp (18.7 ha), shrubs (7,394 ha), open land (1.53 ha), and swamp (109.92). The OKH Forest Park is predominantly comprised of peatlands designated as conservation areas. Therefore, this area is highly susceptible to burning, especially during drought-dominated periods, by peatlands included in the conservation area. Therefore, it is vulnerable and easily burnt, especially during dry spells. The location map of this research can be seen in Figure 1.

Trapping procedures

This research followed the cage trap method (locally-made trap) performed by Rianisa et al. (2018). Traps were placed in two different habitat types: scrub and Young Forest. Traps are installed by systematic sampling at 20 meters and placed on both sides (right and left) of the inspection path. The distance between the trap and the inspection line is 5 meters each. The traps were made of wire 35 cm x 3cm x 12 cm. Then, these traps were filled with bait such as coconut, sweet potatoes, bananas, and oil palm fruit. Before being placed in the trap, the bait is burned to release its fragrance. Traps were checked twice daily, in the morning from 07.00-09.00 am and in the evening from 04.00-06.00 pm, for eight days, and the baits were replaced twice a day.

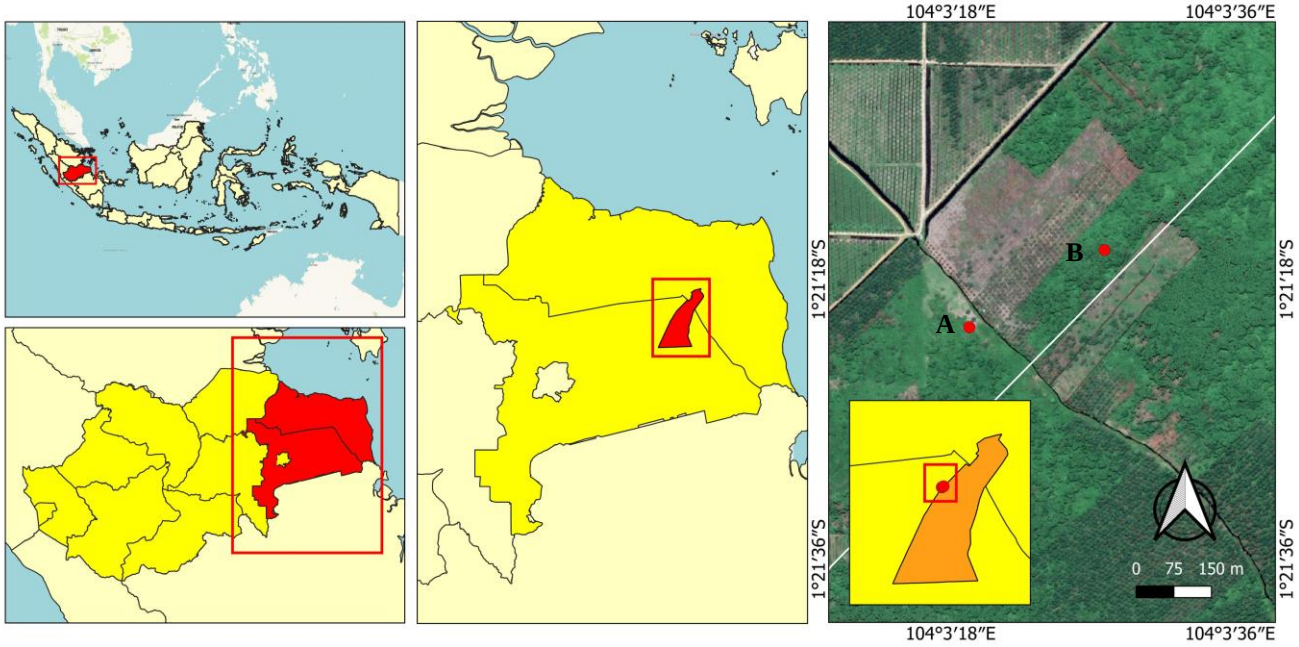

Figure 1. Map of research locations in the Orang Kayo Hitam Forest Park, Jambi Province, Indonesia. A. Scrub, B. Young Forest

Every small mammal caught was identified, following the key identification in the Mammals in Kalimantan, Sabah, Sarawak, and Brunei Darussalam Field Guide by Payne et al. (2000) and Guidebook for Identification of Protected Wildlife Species; Mammals by KLHK (2019). The small mammals caught were recorded for their physical characteristics, documented, marked with hair paint, and released.

Data analysis

The data obtained were analyzed using the Shannon Wiener Species Diversity Index (H') with excel and Spearman Correlation Analysis with SPSS. The level of species diversity is a mathematical measure of species diversity in a community. The determination of the species diversity index in this study used the Shannon-Wiener Index (Odum 1994), which is calculated by the following formula:

$$H' = -\sum_{i=1}^{S} (pi)\ lnpi$$

Where:
H' : Shannon Wiener diversity index
S : number of types
pi : proportion of the i-th individual count (ni/N)
ln : natural log

The Shannon Index has the following indicators:
H'<1.5 = low diversity level
1.5≤H'≥3.5 = moderate diversity level
H'>3.5 = high diversity level

Determining the relationship between bait and the diversity of small mammals in this study used Spearman correlation test analysis which was calculated using the following formula:

$$r_s = 1 - \frac{6\sum_{i=1}^{n}[R(x_i) - R(y_i)]^2}{n(n^2-1)} = 1 - \frac{6\sum_{i=1}^{n} d^2}{n(n^2-1)}$$

Where:
r_s : spearman correlation coefficient
$R(x_i)$ and $R(y_i)$: ranking score data variables X and Y
n : amount of data

The Spearman correlation test has the following indicators:
rs→±1 : there is a very close relationship between the variables X and Y, if the sign is minus (-), then the relationship between variables is not unidirectional, and if the sign if positive (+), then the relationship between variables is unidirectional
rs→±0 : there is no relationship between the variables x and y
±0.10< rs<±0.30 : very weak variable relationship
±0.30< rs<±0.50 : moderate variable relationship
±0.50< rs<±0.70 : close variable relationship
±0.70< rs<±1 : very close variable relationship

RESULTS AND DISCUSSION

Diversity of small mammals

Based on observations of small mammals caught during the study, only two species were found: the plantain Squirrel (*Callosciurus notatus* (Boddaert, 1785)) and the Malaysian Field Rat (*Rattus tiomanicus* (Miller, 1900)). This type of small mammal is found in scrub and Young Forest habitats. The results of calculating the number of individuals are presented in Table 1.

Two species were obtained, namely *C. notatus* and *R. tiomanicus*, with a total of 23 individuals. The *R. tiomanicus* species were found 22 individuals, with nine males and 13 females. In addition, the *C. notatus* species was found with a total of one individual only. However, the sex could not be identified due to its high mobility. The head and body length of the *R. tiomanicus* measured from the anus to the nose was 14-18.8 cm, the tail length measured from the tip of the tail was 12-18.1 cm, the total length measured was 26-36.9 cm, and the weight was 78-125 grams. The *R. tiomanicus*'s upper body is dark brown, the lower body is pale gray with white hair tips, and the tail is dark brown. The feet are relatively wide, with subtle bumps on the soles. The male *R. tiomanicus* has a pubic area far from the anus compared to the female *R. tiomanicus*. Some testicles hang down in male rats, while in female rats, there is a vaginal opening behind the bulge.

The *C. notatus* found had a head and body length of 17.5 cm, a tail length of 16 cm, a total length of the *C. notatus* measured was 33.5, and a weight of 210 grams. The upper body of the *C. notatus* has fine brownish spots with brown and black side stripes. The underside of *C. notatus* is dark and reddish. The male *C. notatus* has sex and anus, which are farther apart than the female *C. notatus*, and the male *C. notatus* has a penis length of 1 cm.

Feed and diversity correlation test

Based on the correlation test results, it is known that bait variations and small mammal diversity are not correlated, or there is no significant relationship. This can be seen from the Sig. (2-tailed) which shows a value of 0.301, meaning that the relationship between bait and the diversity of small mammals is very weak. According to Raharjo (2017), if Sig. (2-tailed)>0.05, the correlation between these variables is insignificant. The correlation coefficient value was obtained at -0.276, which showed a negative value meaning that the relationship between the two variables was not unidirectional (Table 2).

The results of the bait preferences showed that a higher number of small mammals were trapped using oil palm fruit and coconut baits compared to those caught with banana and sweet potato baits (Figure 2). Based on the data obtained in the two habitats, namely shrubs and Young Forest, seven were consumed for coconut bait, zero for sweet potato bait, two for bananas bait, and 10 for oil palm fruit bait. The total bait consumed was 19, and four traps contained two individuals.

Table 1. Types of small mammals found in Orang Kayo Hitam Forest Park, Jambi Province, Indonesia

Family	Local name	Scientific name	Individuals	Males (n)	Females (n)	H'
Muridae	Plantain Squirrel	*Callosciurus notatus*	1	-	-	0.17884
Sciuridae	Malaysian Field Rat	*Rattus tiomanicus*	22	9	13	
	Individuals Total		23			

Table 2. Results of Spearman correlation between bait variation and diversity of small mammals in Orang Kayo Hitam Forest Park, Jambi Province, Indonesia

		Correlations	Bait variation	Diversity of small mammals
Spearman's rho	Bait variation	Correlation coefficient	1.000	-0.276
		Sig. (2-tailed)	0.000	0.301
		N	16	16
	Diversity of small mammals	Correlation coefficient	-0.276	1.000
		Sig. (2-tailed)	0.301	0.000
		N	16	16

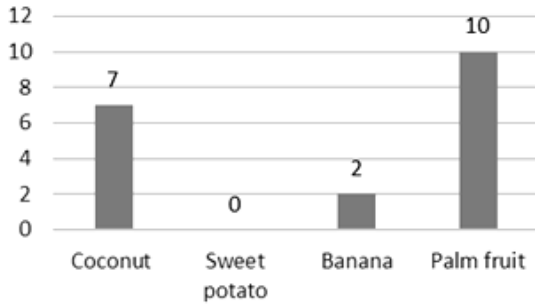

Figure 2. Types of feed used

Discussion

The most commonly found species is the *R. tiomanicus*. This is because *R. tiomanicus* have a wide distribution area and food range. The *R. tiomanicus* are small mammals that are nocturnal and primarily terrestrial. It is often found in short thickets, secondary forests, mountains, and shrubs. Peninsular Malaysia, Java, Sumatra, Borneo, and several adjacent islands are where *R. tiomanicus* is distributed (Payne et al. 2000).

Of the 22 individuals of the *R. tiomanicus* that entered the trap, it was observed that the female individuals were recorded more than the male ones. This suggests that female mammals are more actively foraging than male mammals. According to Nasir (2012a), female mammals have a chance of being caught during the lambing and lactation season because, at that time, females need a large amount of food. Good adaptability to environmental conditions damaged after the fire in 2015 is one of the success factors for *R. tiomanicus* and *C. notatus* to breed. This is also influenced by the omnivorous feed, the lack of competition with other kinds of mammals, and the relatively high reproductive ability, so the population continues to increase. The International Union for Conservation of Nature (IUCN) reported that the conservation status of *C. notatus* and *R. tiomanicus* shows the least concern (LC) category; currently, there is a tendency to increase the population of *C. notatus* and *R. tiomanicus* (Nasution and Fatah 2021). The species diversity index (H') indicates a low category with a H'=0.17884. That suggests the habitat conditions in post-burning peat ecosystems are still depressed, with minimal vegetation conditions producing fruit in both habitat types.

The *R. tiomanicus* belongs to the omnivore group but is likely to eat seeds (Priyambodo 2003), for example, the oil palm fruit. The results showed that *R. tiomanicus* preferred oil palm fruit bait over the other baits. This supported that, between the oil palm plantations and the research location, there is only a 2-meter wide canal. According to (Lim 2015), *R. tiomanicus* is found in oil palm plantations and takes refuge in piles of palm fronds and crowns. Besides that, *R. tiomanicus* also like roasted coconut as bait. This is because roasted coconut gives off a fragrant aroma which can invite small mammals to enter the trap (Nasir 2012b). Moreover, using oil palm fruit and roasted coconut as bait can last longer even though it is exposed to rain and not drying while exposed to heat (Nasir et al. 2017). The captured small mammals are shown in Figures 3A and 3B.

The OKH Forest Park area is dominated by peatlands that have experienced a decline in function or degradation. One of the causes is the repeated occurrence of fires which damage vegetation and exacerbate forest land degradation (Tamin et al. 2021). The vegetation types that dominated the Young Forests (Figure 4A) in OKH Forest Park after the fire were: mahang (*Macaranga* sp.), rengas (*G. renghas*), and punak wood (*T. glabra*). The average tree diameter in the Young Forest is 16.8 cm, with a trunk height of 5 to 8 meters. However, Young Forests can still be a habitat for small mammals because the Young Forest is a secondary forest where trees grow as a place to rest during the day and take shelter from predators (Lim 2015).

Figure 3. A**.** Malaysian field rat (*R. tiomanicus*), B. Plantain squirrel (*C. notatus*)

Figure 4. Habitat conditions of Young Forests (A), Shrubs (B)

Shrub habitat (Figure 4B) close to canals is one of the *R. tiomanicus* favorite areas. The *R. tiomanicus* can eat many types of feed available in nature, including those carried by flowing water (Nasir et al. 2017). In this area, *R. tiomanicus* can get food from water-drifting seeds, fruit, and leaves in the canals. Adequate food availability is thought to cause many *R. tiomanicus* to be caught. That follows the results of research by Nasir et al. (2017), which showed that food availability in scrub habitats comes from seeds produced by the constituent vegetation from the leftover food of other animals. In addition, the scrub habitat is filled with shrubs 1-2 meters high, making it suitable as a shelter for small mammals, including *R. tiomanicus*, from predators (Lim 2015).

In conclusion, 2 species of small mammals were found in the OKH Forest Park, namely *R. tiomanicus* and *C. notatus*. The total number of individuals found was 23. The diversity index shows a low category with a value of (H' = 0.17884). That indicates the condition of the habitat in the post-burnt peat ecosystem is still relatively depressed. Variation of feed is not significantly related to the diversity of small mammals due to the specialist factor of small mammals feed and their small population.

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REFERENCES

Apriyani P, Nasihin I. 2017. keanekaragaman jenis mamalia besar di kawasan Bukit Sarongge RPH Ciniru BKPH Garawangi KPH Kuningan. Jurnal Wanaraksa 11 (2): 1-7. DOI: 10.25134/wanaraksa.v11i2.4414. [Indonesian].

Derajat N. 2022. Diversity of small mammals in Ujung Kulon National Park. Jurnal Inovasi Pendidikan Dan Sains 3(1): 18-23. DOI: 10.51673/jips.v3i1.934. [Indonesian]

Harrison ME, Rieley JO. 2018. Tropical peatland biodiversity and conservation in Southeast Asia: Foreword. Mires Peat 22 (2018): 1-7. DOI: 10.19189/MaP.2018.OMB.382

Heriyanto B, Ristiyanto. 2017. Binatang Penular Penyakit Di Sekitar Lingkungan Rumah. Yayasan Pustaka Obor Indonesia, Jakarta. [Indonesian]

Husson SJ, Limin SH, Adul, Boyd NS, Brousseau JJ, Collier S, Cheyne SM, D'Arcy LJ, Dow RA, Dowds NW, Dragiewicz ML, Smith E, Iwan, DAE, Iwan, Hendri, Houlihan PR, Jeffers KA, Jarrett BJM, Kulu IP, Morrogh-Bernard HC, Page SE, Perlett ED, Purwanto A, Capilla BR, Slahuddin, Santiano, Scjrevene SJJ, Struebig MJ, Thornton SA, Tremlett C, Yeen Z, Harrison ME. 2018. Biodiversity of the Sebangau Tropical Peat Swamp Forest, Indonesian Borneo. Mires Peat 22 (2018): 1-50. DOI: 10.19189/MaP.2018.OMB.352.

Irsaf Z, Annawaty, Achmadi AS. 2018. Efektivitas perangkap yang digunakan dalam koleksi mamalia kecil rodensia dan eulipotyphla. Jurnal Biocelebes 12 (3): 79-86. [Indonesian]

Kartono AP. 2016. keragaman dan kelimpahan mamalia di perkebunan sawit PT Sukses Tani Nusasubur Kalimantan Timur. Media Konservasi 20 (2): 85-92. DOI: 10.29244/medkon.20.2.%p. [Indonesian]

KLHK (Kementrian Lingkungan Hidup dan Kehutanan). 2019. Panduan Identifikasi Jenis Satwa Liar dilindungi Mamalia. Kementrian Lingkungan Hidup dan Kehutanan. Jakarta. [Indonesian]

Lim BL. 2015. The field rats and field mouse in Malaysia and Southeast Asia. Utar Agric Sci J 1 (3): 35-42.

Maftuah E, Hayati A. 2019. Pengaruh persiapan lahan dan penataan lahan terhadap sifat tanah, pertumbuhan dan hasil cabai merah (*Capsicum annum*) di lahan gambut. Jurnal Hortikultura Indonesia 10 (2): 102-111. DOI: 10.29244/jhi.10.2.102-111. [Indonesian]

Masganti, Wahyunto, Dariah A, Nurhayati, Yusuf R 2014. Karakteristik dan potensi pemanfaatan lahan gambut terdegradasi di Provinsi Riau. Jurnal Sumberdaya Lahan 8 (1): 59-66. DOI: 10.21082/jsdl.v8n1.2014.%25p. [Indonesian]

Mazerolle MJ, Drolet B, Desrochers A. 2001. Small-mammal responses to peat mining of southeastern Canadian bogs. Can J Zool 79 (2): 296-302. DOI: 10.1139/cjz-79-2-296.

Mulyani YA, Iqbal M. 2020. Burung-Burung Di Kawasan Sembilang Dangku. In ZSL Indonesia, Sumatera Selatan. [Indonesian]

Nasir M, Amira Y, Mahmud AH. 2017. Keanekaragaman jenis mamalia kecil (Famili Muridae) pada tiga habitat yang berbeda di Lhokseumawe Provinsi Aceh. Jurnal Bioleuser 1 (1): 1-6. DOI: 10.22373/pbio.v6i1.4271. [Indonesian]

Nasir M. 2012a. Kondisi Cuaca terhadap peluang menangkap mamalia kecil pada kawasan perkebunan sawit di Kabupaten Nagan Raya Provinsi Aceh. Prosiding Seminar Nasional Biologi, Medan. [Indonesian]

Nasir M. 2012b. Distribusi mamalia kecil pada tiga lokasi di sekitar perkebunan sawit di Kabupaten Nagan Raya Provinsi Aceh. Prosiding Seminar & Rapat Tahunan BKS- PTN B MIPA, Medan. [Indonesian]

Nasution ED, Fatah H. 2021. Rapid survei keanekaragaman hayati status konservasi Permen LHK (P.106/2018) dan IUCN di areal nilai konservasi tinggi perkebunan kelapa sawit. Jurnal Agrifor XX (106): 161-174. DOI: 10.31293/agrifor.v20i1.521. [Indonesian]

Odum EP. 1994. Dasar-Dasar Ekologi. Edisi-3. Terjemahan Tjahjono Samingan. Universitas Gajah Mada Press, Yogyakarta. [Indonesian]

Payne J, Francis CM, Phillips K, Kartikasari SN. 2000. Panduan Lapangan Mamalia di Kalimantan, Sabah, Serawak, dan Brunei Darussalam. Wildlife Conservation Society Indonesia Program, Jakarta. [Indonesian]

Priyambodo S. 2003. Pengendalian Hama Tikus Terpadu. Penebar Swadaya, Jakarta. [Indonesian]

Putra AB, Darmawan A, Dewi BS, Fitriana YR. 2022. Diversity of small mammals in four types of land cover in the Batutegi Forest. Makila J 16: 5-7. DOI: 10.30598/makila.v16i2.6297.

Raharjo S. 2017. Uji Korelasi Rank Spearman dengan SPSS. SPSS Indonesia, X. https://www.spssindonesia.com/2017/04/analisis-korelasi-rankspearman.html. [Indonesian]

Ramadhani C, Rahayu SE, Achmadi AS. 2019. Keanekaragaman mamalia kecil terestrial di Cagar Alam Kawah Ijen, Kabupaten Banyuwangi, Jawa Timur. Jurnal Fauna Tropika 28 (2): 112-121. DOI: 10.52508/zi.v28i2.4100. [Indonesian]

Rianisa CD, Utamy I, Wassalwa M. 2018. Keanekaragaman jenis mamalia kecil (Muridae) Di Kawasan Deudap Pulo Aceh, Kabupaten Aceh Besar. Prosiding Seminar Nasional Biotik 2018: 362-366. DOI: 10.22373/pbio.v6i1.4271. [Indonesian]

Sudrajat ASE, Subekti S. 2019. Pengelolaan ekosistem gambut sebagai upaya mitigasi perubahan iklim di Provinsi Kalimantan Selatan. Jurnal Planologi 16 (2): 219-237. DOI: 10.30659/jpsa.v16i2.4459. [Indonesian]

Tamin RP, Ulfa M, Saleh Z. 2019. identifikasi potensi pohon induk pada tegakan tinggal Taman Hutan Raya Orang Kayo Hitam pasca kebakaran hutan. Jurnal Ilmiah Ilmu Terapan Universitas Jambi: 3: 10-17. DOI: 10.22437/jiituj.v3i1.7337. [Indonesian]

Tamin RP, Ulfa M, Saleh Z. 2021. Identifikasi potensi permudaan alam di hutan rawa gambut Taman Hutan Raya Orang Kayo Hitam Provinsi Jambi Pasca Kebakaran Hutan. Al-Kauniyah: Jurnal Biologi 14 (1): 42-51. DOI: 10.15408/kauniyah.v14i1.15136. [Indonesian]

Wibisono ITC, Dohong A. 2017. Panduan Teknis Revegetasi Lahan Gambut. Badan Restorasi Gambut Republik Indonesia, Jakarta. [Indonesian]

Wulandari C, Novriyanti N, Iswandaru D. 2021. Integrating ecological, social and policy aspects to develop peatland restoration strategies in Orang Kayo Hitam Forest Park, Jambi, Indonesia. Biodiversitas 22 (10): 4158-4168. DOI: 10.13057/biodiv/d221005.

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Lesser spiny eel (*Macrognathus aculeatus*) feeding preferences in the Progo River, Yogyakarta, Indonesia

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Abstract. *Djumanto. 2023. Lesser spiny eel (*Macrognathus aculeatus*) feeding preferences in the Progo River, Yogyakarta, Indonesia. Intl J Bonorowo Wetlands 13: 36-42.* Lesser spiny eel (*Macrognathus aculeatus* Bloch, 1786) is a highly valued fish species in the Progo River, Yogyakarta, due to its delectable taste, high nutritional value, and attractive aquarium filler. Therefore, this study aims to identify the dietary preferences of *M. aculeatus* collected between September 2020 and March 2021. Each fish was measured for individual length and weight, followed by an abdomen examination and digestive tract extraction. The intestinal length was also measured, and the digestive tract contents were classified based on the type and volume. Other parameters examined included relative gut length, the proportion of each kind of feed, the index of the largest portion, and the trophic level. The results showed that the ratio of gut length to total length ranged between 0.51 and 0.67, indicating that *M. aculeatus* were carnivorous. Their diet's six categories of organisms included crustaceans, annelids, insects, phytoplankton, zooplankton, and detritus. Female *M. aculeatus* was found to primarily consume shrimp (77.88%), followed by additional detritus feed (19.53%) and complementary feed (3%). Meanwhile, the males consumed 99.04% shrimp as their primary diet, and the remaining 0.9% were complementary. The feed niche area for female and male *M. aculeatus* was 0.137 and 0.005, respectively, indicating a minimal diet selection. Based on the results, the larger the fish, the more limited the feed options available. That indicates domestication and reintroduction should be made to preserve genetic diversity through food formulation and spawning from natural stocks.

Keywords: Food, fresh water, leather fish, river

INTRODUCTION

Lesser spiny eel (*Macrognathus aculeatus* Bloch, 1786) is a tropical Southeast Asian freshwater fish found in Cambodia, Vietnam, Laos, Thailand, Malaysia, and Indonesia (Serajuddin et al. 1998; Pethiyagoda et al. 2008; Gupta 2016). Furthermore, these fish are mostly found in Indonesia's western regions, including Sumatra, Kalimantan, and Java islands. They also inhabit fresh-flowing waters like streams, rivers, ditches, and channels with muddy sand or gravel-sand bottoms. For example, in Yogyakarta, Indonesia, *M. aculeatus* have been observed at depths of over one meter in the Opak-Oya and Progo Rivers. These fish are typically captured in the morning or evening using nets and fishing rods. They can also be caught year-round, although the best results are obtained after rains stop a few days when the water is clear. *M. aculeatus* are highly valued in the market for their ornamental appeal and as a food source (Herawati et al. 2021). Consequently, catching these fish is increasing to meet the demand of ornamental fish traders and protein needs.

Macrognathus aculeatus is essential to meet the community's nutritional needs in the Yogyakarta. In the Bantul District, *M. aculeatus* is in high demand and fetches a higher market price (US 4-5 $ per kg) than walking catfish (US 2-3 $ per kg), primarily sold alive. *M. aculeatus* has a living habit on the bottom of the waters and is generally caught with fishing rods and cast nets (Nurdawati and Yuliani 2009). Local gear such as net rods were used exclusively to catch bottom-dwelling fish, including *M. aculeatus* from the Progo River. The natural population of this species tends to decline rapidly in the Special Region of Yogyakarta, as observed by the reduced supply in the ornamental fish market, reduced consumption due to habitat changes, and increased exploitation (Ohee et al. 2018). Recently, natural or river water collection catches meet all demands for *M. aculeatus*. Unregulated exploitation of *M. aculeatus* can harm the populations in their natural habitat. There is almost no information on fisheries and *M. aculeatus* resources for management and conservation. *M. aculeatus* is included in the Low Risk or Near Threatened category (Froese and Pauly 2023). However, it is not yet included in the list of protected fish by the government of the Republic of Indonesia.

In Yogyakarta, *M. aculeatus* are crucial in increasing the fishing community's income while simultaneously addressing their protein demands. Despite the razor-sharp fins, the meat of these fish is surprisingly tender, making it a popular choice among locals. However, capturing them is difficult due to the species' limited population, with catches accounting for less than 1% of the total individual yield or weight (Djumanto et al. 2013). That highlights the alarming scarcity of *M. aculeatus* in their natural habitat, further exacerbated by excessive fishing and dwindling broodstock. Moreover, several studies showed that attempts to breed *M. aculeatus* have been unsuccessful, indicating that fishermen should continue to rely on river capturing; this problem can cause a reduction in their population,

thereby posing a threat of scarcity and even extinction. On the other hand, a previous study reported that the survival of this species should be maintained due to their important role in the river's ecosystem (Verma and Alim 2013). Therefore, several preservation methods have been developed, including domestication, spawning actions, and preventing juveniles from spawning.

Based on previous reports, there are only a few studies on *M. aculeatus*, particularly on the feeding habits of the fish in Yogyakarta's Progo River, which have a distinct ecosystem character. The feeding habits of *M. aculeatus* have been studied in the Musi River in South Sumatra Province, and the results showed that crustaceans, gastropods, pelecypods, pisces, insects, and litter were the main component of their diet (Nurdawati and Yuliani 2009). Furthermore, seasonal rainfall and drought have been reported to affect the number of prey species in the Progo River ecosystem. Therefore, this study aims to collect reliable data on feeding patterns and preferences as a first step in domesticating *M. aculeatus*.

MATERIALS AND METHODS

Study area

The Progo River originated from Temanggung District, Central Java, Indonesia and flowed approximately 140 km through the Magelang District and the western part of the Yogyakarta Special Region (DIY), Indonesia. Furthermore, it flowed across the Yogyakarta for roughly 56 km, with the Kaminjoro Dam positioned approximately 20 km from the estuary. The downstream river was 100 and 150 meters wide and one to four meters deep. The *M. aculeatus* fishing station was located 100 meters downstream of the Kaminjoro Dam in Yogyakarta (-7°52'43.7"S 110°15'58.4"E), as shown in Figure 1. During the six-month fishing season, sampling was conducted in the Progo River's lower regions between September 2020 and March 2021.

Procedures

The fishing spot was selected based on information from a local fisherman that a significant population of *M. aculeatus* inhabited the Kaminjoro Dam at a depth of 1-3 meters. Furthermore, the fishing location was around 100 meters downstream of the dam structure, with a little water flow, the substrate was muddy sand, and the riverbank was completely covered in plants. As a result, this station's water level rose during the rainy season, flooding the surrounding area.

The fishing rod with hook number 7 and commercial feed components ingredients was used to catch *M. aculeatus* in the morning. The samples were captured and preserved in plastic boxes with ice to keep them fresh. That method is done to inhibit the digestive process in the digestive system, followed by transportation to the laboratory for further examination.

Stomach contents analysis was performed on 99 specimens among the 120 collected samples. Each sampled specimen's total length (nearest 1 mm) and weight (nearest 0.1 g) were then measured. After mounting the fish on a wax plate, the abdomen was dissected, starting near the anus. The incision was continued vertically to the vertebrae bone using surgical scissors, then forward to the base of the pectoral fins and ended beneath the pectoral.

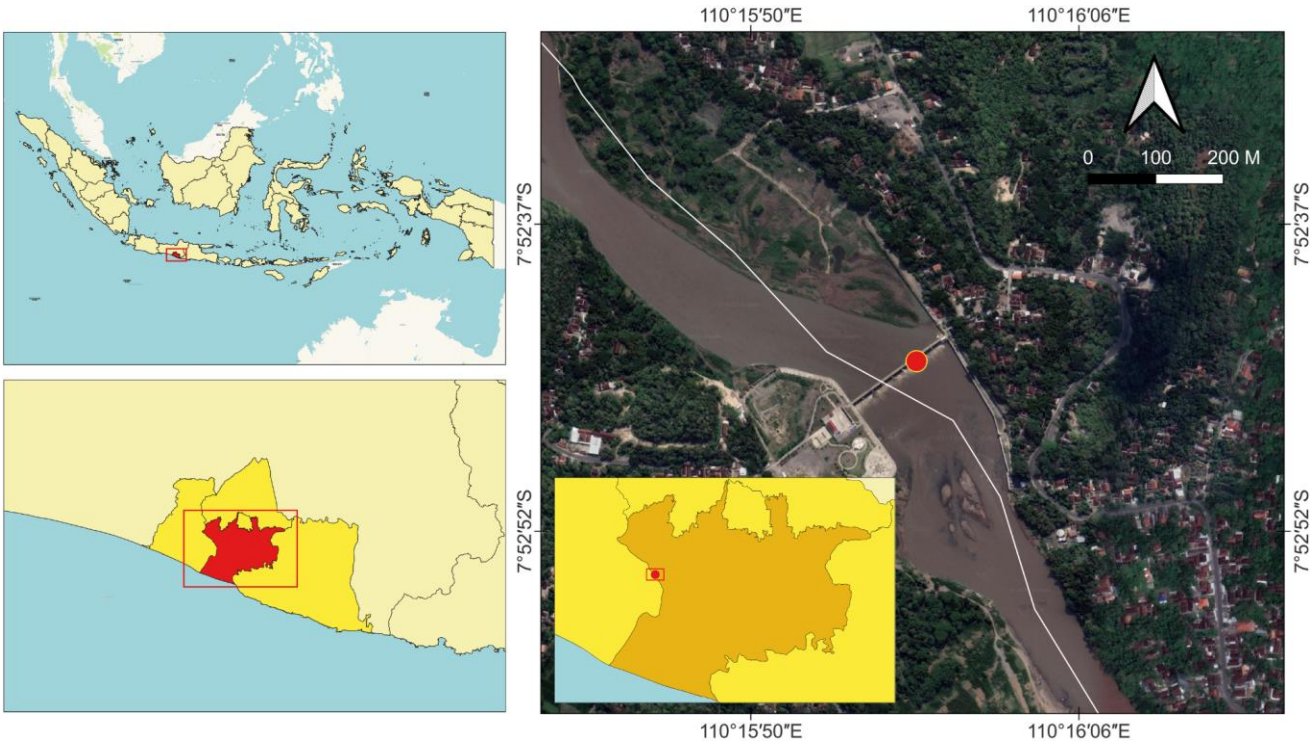

Figure 1. A map shows a *Macrognathus aculeatus* fishing ground in the lower reaches of the Progo River, about 100 meters from the Kaminjoro Dam, Yogyakarta, Indonesia

Next, the intestinal length was measured using a ruler from the base of the esophagus to the anus (nearest 0.1 cm). For further analysis, the contents of the digestive system were stored in plastic bottles and preserved in a 5% formaldehyde solution.

The digestive tract was dissected from the beginning of the stomach to the base of the anus. The contents were scraped off with a spatula and poured into a petri dish. On graph paper, food items in the petri dishes were positioned to determine their area, kind, and volume. Furthermore, standard light microscopes were used to identify small food items. Next, macro-sized food observations were carried out directly, followed by manual identification to make them more visible through a binocular microscope. Finally, a stereo microscope was used to determine the digestive sample kinds. Next, the digestive system's prey items were classified at the appropriate taxonomic level. Each prey item in the stomach was counted in quantity, volume, and frequency. In addition, the *M. aculeatus* sex was classified as male if the observed individual possessed testes and female with the observation of ovaries.

Data analysis

Macrognathus aculeatus can be classified as carnivores, herbivores, or omnivores using the morphological variable of gut length relative to the total length. In addition, the gut length ratio to total length can also be used to identify feed groups within each age group.

Relative Gut Length (RGL) was calculated with the formula (Biswas 1993):

$$RGL = \frac{\text{intestinal length}}{\text{total length}}$$

Where: RGL values < 1 denoted carnivores, 1-3 indicated omnivores, and > 3 referred to herbivores.

The preponderance index, also known as the significant proportion index, was a formula used to determine eating habits, namely the percentage of the most consumed feed types. Furthermore, the preponderance index was obtained by multiplying the frequency of occurrence by the volume of feed consumed by the prey with the following formula (Biswas 1993):

$$IP = \frac{V_i O_i}{\sum V_i O_i} \times 100$$

Where: IP denotes the preponderance index, while Vi and Oi indicate the volume and frequency of specific feeds (i) in the fish menu, respectively. Preferences for various types of feeding and species specialization were evaluated using the criteria, where IPs of > 40%, 4%-40%, and <4% were for the main, complementary, and supplementary feed, respectively.

The trophic level of a fish was determined based on the relationship between the trophic status of natural food and the eating patterns, which enabled classification within the ecosystem's food web. The following formula can determine the organism's trophic level (Biswas 1993).

$$TP = 1 + \sum \left(\frac{Ttp \times IP}{100} \right)$$

Where: TP denotes the trophic level of fish, Ttp denotes the trophic level of the p-th food group, and IP means the index preponderance. Values of <2.49, 2.5-2.99, and >3 indicated herbivores, omnivores, and carnivores, respectively. Fish species were classified into five trophic levels: (i) Herbivores (eat aquatic plants, algae, and other animals), (ii) Piscivores (eat fish), (iii) Carnivores (eat insects, arthropods, and other animals), (iv) Omnivores (eat a balanced diet of plants and animals), and (v) Detritivores (eaters of litter, detritus or sediment).

Feed niche breadth was used to determine the competition for food resources available to an organism within a species and across species or sizes. Furthermore, the food niche breadth value was standardized to be between 0 and 1, and it was calculated with the following formula (Biswas 1993):

$$Bi = \frac{1}{(n-1)} \left[\frac{1}{(\sum P_{ij}^2)} - 1 \right]$$

Where: Bi denotes the standardized niche breadth index, pij denotes the proportion of predatory food i on prey j, and n means the total number of items (resources). Bi ranged from 0 (species consumes only one item) to 1 (species exploits available items in equal proportion). Values of < 0.4, 0.4-0.6, and > 0.6 were considered low, moderate, and high, respectively.

RESULTS AND DISCUSSION

The morphometry of the *M. aculeatus* is presented in Figure 2. The number of *M. aculeatus* caught in this study was 99, consisting of 45 females and 54 males. Among the females, the average length and weight were 33.4 cm (range 24.0-41.8 cm) and 132.0 g (range 16.0-239.0 g), respectively. Meanwhile, males' average length and weight were 30.8 cm (range 21.8-51.0 cm) and 98.3 g (range 33.0-372.0 g), respectively. The digestive system examination revealed that 31 female and 32 male individuals contained food, while the remaining were empty (36.36% emptiness). Based on sex, 14 females (31.11%) and 22 males (40.74%) had empty intestines. The results showed that the males had nearly three-fourth of the females' empty intestine contents.

The relative gut length of the *M. aculeatus* (Table 1) can be used to determine the type of food consumed by the fish. Furthermore, the intestinal length in each group varied, ranging from 21.8 to 51.0 cm. For example, in the <30, 30-40 cm, and >40 cm total length group, the gut length was 0.51-0.62, 0.62-0.67 cm, and 0.66-0.67 cm, respectively.

Macrognathus aculeatus were generally carnivorous based on the relative gut length ranging from 0.51 to 0.67. The results showed the value of the relative gut length increased along with the total length of the fish.

Table 1. Number of individual samples, size class, intestine length, relative gut length, and *Macrognathus aculeatus* food category

Length group (cm)	n (individual)	Gut length (cm)	Average gut length (cm)	Relative gut length	Average relative gut length	Eater category
30<	23	21.8-29.8	26.54	0.51-0.62	0.58	Carnivore
30-40	35	30.0-37.8	33.77	0.62-0.67	0.61	Carnivore
> 40	5	40.5-51.0	43.52	0.66-0.67	0.66	Carnivore

Table 2. Preponderance index (%) by sex and length group

Food category	Food item	Sex		Feed group	Length group (cm)			Feed category
		Female	Male		<30	30-40	>40	
Shrimp	*Macrobrachium* sp.	77.884	99.041	*	89.59	90.25	100	*
Worm	*Tubifex* sp.	0.010	0.226	***	1.81	0.00	0	***
Insects	Dragonfly nymph	0	0.007	***	0.06	0.01	0	***
Phytoplankton	*Synedra* sp.	2.365	0.098	***	0.90	1.11	0	***
Phytoplankton	*Volvox* sp.	0.020	0.007	***	0.01	0.02	0	***
Phytoplankton	*Navicula* sp.	0.107	0.002	***	0.10	0.01	0	***
Phytoplankton	*Merismopedia* sp.	0.004	0.001	***	0.01	0.00	0	***
Phytoplankton	*Rhizosolenia* sp.	0.004	0	***	0.01	0.00	0	***
Phytoplankton	*Melosira* sp.	0.033	0	***	0.00	0.02	0	***
Zooplankton	*Cyclops* sp.	0.045	0	***	0.00	0.02	0	***
Digested organic matter	Detritus	19.527	0.618	*** (M), ** (F)	7.52	8.57	0	** <30 cm, **30-40 cm, ***>40 cm

Note: * main feed, ** complementary feed, *** supplementary feed

Table 3. Feed niche breadth in each sex group and length group

Counting	Sex		Length group (cm)		
	Female	Male	<30	30-40	>40
$\sum P_i^2$	0.645	0.981	0.809	0.822	1.000
Niche breadth	1.550	1.019	1.237	1.217	1.000
Standardization	0.137	0.005	0.059	0.110	0

Figure 2. Specimen photography of *Macrognathus aculeatus* (Bloch, 1786) caught in the lower reaches of the Opak River, Yogyakarta, Indonesia. Female, 20.5 cm TL

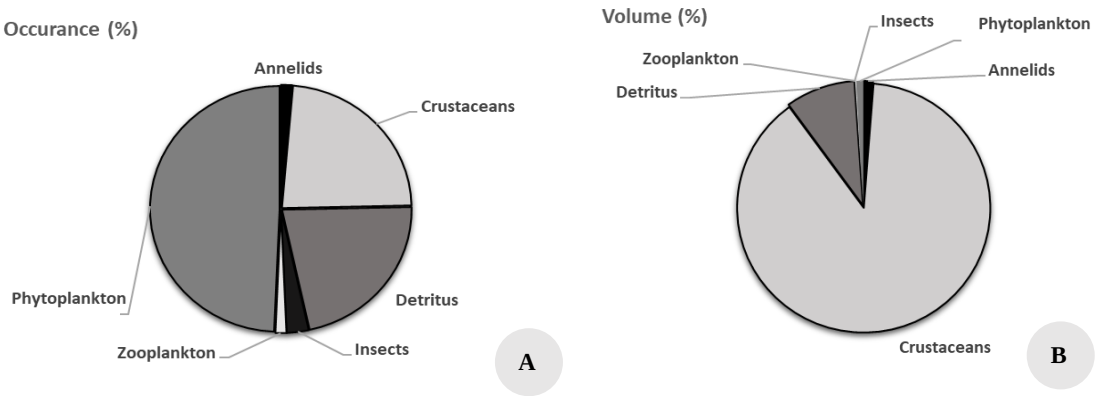

Figure 3. The composition of the feed types of *M. aculeatus* grouped based on the frequency of occurrence (A) and the volume of the feed (B)

The grouping of food composition, which includes annelids, crustaceans, detritus, insects, zooplankton, and phytoplankton, is presented in Figure 3. The frequency of occurrence shows that for each type of feed, phytoplankton has the highest frequency (49.32%), followed by crustaceans (23.29%) and detritus (21.92%), while annelids and zooplankton each are 1.37%. Based on the volume of feed in the fish stomach, the crustacean-type feed has the highest volume (88.76%), followed by detritus (8.92%) and annelids (1.23%). In contrast, insects, zooplankton, and phytoplankton have a total volume of 1.08%.

Based on the preponderance index, shrimp was the main feed for the male with an IP value of 99.04%, while other types of feed were complementary, as shown in Table 2. However, slightly different results were obtained among females with the same main feed with an IP value of 77.88%. Furthermore, detritus with an IP value of 19.53% and other types of feed were complementary.

The preponderance index value obtained for each size group showed that shrimp was the main feed with IP: 89.59%, 90.25%, and 100% for samples with sizes of <30 cm, 30-40 cm, and >40 cm, respectively. Furthermore, detritus served as supplementary feed for the <30 cm and 30-40 cm groups but as additional feed for the >40 cm. The results showed that the larger the length group, the higher the choice of shrimp. On the other hand, the worm was the highest additional feed for male fish and the <30 cm size group.

Niche breadth indicated whether an organism was a generalist or a specialist using available forage resources. The exclusive dependence of an organism on one of the available feed sources (specialist) indicates that it has a narrow niche. The analysis results (Table 3) showed that the male (Bi: 0.050) and female (Bi: 0.137) *M. aculeatus* had a very narrow feed niche. Similar results were also revealed in the length groups <30 cm, 30-40 cm, and >40 cm, with Bi of 0.059, 0.110, and 0, respectively. In the 30-40 cm long and the female groups, the range of the feed niche was more expansive compared to others.

Based on sex, female fish have a wider feed niche than males. According to the length, samples with a size <30 cm had the widest feed niche, which decreased along with increasing length. These results showed that female and young *M. aculeatus* could receive more diverse food types.

Discussion

The abundance of *M. aculeatus* in the Progo River was very low, causing a low catch in this study. That was due to the limited suitable habitats, which caused differences in the abundance of fish at each location (Nurdawati and Yuliani 2009). Furthermore, the feed was highly correlated with a particular water fish species. A previous study showed many factors influencing spatial distribution, including behavior in habitat selection and environmental factor interactions (Suresh et al. 2006). This election behavior was determined by fish activities, among others grouped in foraging and spawning activities (Craig and Crowder 2002). Fish tended to forage in areas rich in preferred food resources (Stenberg and Persson 2005), causing the *M. aculeatus* to occupy certain areas with a lot of feed (Abujam et al. 2013). *M. aculeatus* often remain in specific habitats throughout their lives and must adapt to prey on food available in these areas throughout the year (Gupta 2016). The same species occupying different habitats can eat different types of food (Nakazawa 2020), while the diet in several of the same regions still varies. Several studies showed that the feed consumed depended on age and level of growth. The timing and extent of diet and feeding habits changes varied between species, often followed by feeding style or habitat changes (Volkoff and Peter 2006).

Macrognathus aculeatus habitats included flowing waters, rivers, streams, or channels in the lowlands or adjacent to estuaries. Furthermore, the distribution of their habitats in Yogyakarta was relatively limited downstream of the river. This made the preferred fishing location very limited to the river flow, which was calm and fairly deep (Suresh et al. 2006; Djumanto et al. 2013); the low number of suitable habitats caused the *M. aculeatus* population density to be very low. The number of *M. aculeatus* caught in this study represented the population state in their habitat. In addition, catching fish was easier in the morning when the sun was shining with commercial pellet baits. Catches were also relatively high in the rainy season, especially after the rains in the upstream stop for a few days, so the water is fairly clear and calm, and the ratio of males to females was relatively balanced. The rainy season was believed to trigger the formation of spawning groups. During hunting for prey, fish mainly relied on the sight and smell of the bait. The study results were inconsistent with the fishing season for *M. aculeatus* in the Musi River, Sumatra, during the dry season (Nurdawati and Yuliani 2009). The maximum length of fish caught in this study was shorter than those from the Musi River. It was assumed that the limited availability of food and habitat caused *M. aculeatus* in the river to have difficulty finding suitable food to grow more freely and longer.

In this study, the total intestinal emptying rate was 30.25%, with higher values obtained in males. These findings are similar to a study on *Mastacembelus armatus* (Lacepède, 1800) in the Ganga River, India, where the rate at 39% (Alam et al. 2020). Furthermore, the rainy season preceding the breeding season was characterized by increased feeding activity for *M. armatus* (Uthayakumar et al. 2013). Furthermore, the percentage of empty stomachs was influenced by the amount of available prey and the relatively limited food choice (Khaing and Khaing 2020). The limited feed availability caused an empty stomach or minimized the feeding time in the morning when fish were collected, thereby leading to low intestinal content (Nurdawati and Yuliani 2009). Variations in empty or near-empty stomachs were related to the fish-to-prey ratio. However, *M. aculeatus* preferred to feed on shrimp, which is also the feed source for other species; hence, competition occurred. That limited prey availability condition, leading to several empty stomachs.

The relative gut length of *M. aculeatus* varied between 0.51 and 0.67 and increased compared to the total fish length or older fish size groups, which remained constant at <1. A low RGL value indicated that the *M. aculeatus* was a

carnivorous fish. The parameter also had a high correlation with the feed nature. Predatory fish have intestines that are typically short and straight. The feeding habits determined the intestinal length, with the meat-eating group having short intestines for easier meat digestion. Meanwhile, the intestines of herbivorous fish were longer and more circular than predatory fish because plant feed has an extended digestion period. *M. aculeatus* have relatively short and straight intestines, qualifying them as carnivores besides predatory. These findings are consistent with the intestinal length of *Mastacembelus aral*, which ranged from 0.54 to 0.68 mm (Abujam et al. 2013). RGL varied between young, adult, and elderly groups, but no statistically significant difference existed. Furthermore, the same RGL across all age groups and sizes indicated *M. aculeatus*, as carnivores do not constantly change their eating habits during growth.

The *M. aculeatus*'s intestines contained food classified into six broad categories: crustaceans, worms, phytoplankton, zooplankton, insect larvae, and detritus. Females consumed significant debris, including animal body parts, mud, and sand. Furthermore, shrimp was the primary food source for both sex, detritus was an additional source for females, while others served as a complementary feed. Due to the lack of large canine teeth capable of tearing the prey, *M. aculeatus* often swallow shrimp. Although they consume the same primary feed types, the sexes, and sizes vary slightly. These findings are consistent with the food consumed by *Mastacembelus pancalus* (Hamilton, 1822) in the Ganga River (Serajuddin and Ali 2005). The diet of *M. pancalus* was classified into seven major categories; all large fish groups were particularly fond of crustaceans (shrimp), while the young group preferred annelids (earthworms). Various foods' availability varies by month due to changes in the production or supply in the environment. The presence of sand and mud confirmed that fish, particularly females, hunt for prey immersed in sandy mud at the bottom of the water (Blaber 2001). Although the river riparian zone was densely vegetated with aquatic plants, no vegetation was in their intestines, which indicated aquatic vegetation was not a type of feed consumed by these fish.

Shrimp was the most preferred feed, and the preponderance index indicated this. It was also the most abundant food item in males, along with worms, while debris was dominant among females. That indicated *M. aculeatus* were carnivorous and forage on the bottom of the water. Furthermore, fish diets and feeding habits varied based on food availability and environmental ecology. For example, insect larvae comprised 63.1% of the feed on *M. aral* in the upstream district of Assam, India, followed by zooplankton (20.02%), others (10.59%), as well as crustaceans, annelids, and mud (6%) (Abujam et al. 2013). Similar findings were reported for *M. armatus* species, which exhibited nearly identical essential feeding habits. Diverse food intakes indicated that their habitats have varying levels of food availability (Serajuddin and Ali 2005). Therefore, the proportion of various feed preferences can be correlated with their availability and the fish's habitat at a certain time. Furthermore, food availability determined fish diets influenced by biotic and abiotic environmental factors. Based on the feed type consumed, fish were classified as detritivores, herbivores, carnivores, or omnivores. They can also be classified as euryphagous, which consumes a wide variety of food, stenophagous with a limited variety of food, and monophagous with only one feed (Pavlov and Kasumyan 2002). *M. aculeatus* ate shrimp exclusively, classifying them as euryphagous carnivores with a limited prey selection. In addition, food consumption patterns were affected by changes in the rainy season and the quality and quantity of available food organisms.

In the Progo River, *M. aculeatus* have a limited food niche due to their reliance on several unbalanced feed groups. These findings are consistent with the species in the Musi River, which preferred crab and shrimp in large quantities, while other types of feed were scarce and unbalanced (Nurdawati and Yuliani 2009). Fish with a sufficiently large feed niche area can adapt to changes in available food resources. The greater the value of the niche area, the more generalist and non-selective the food pattern of the organisms consumed. Meanwhile, the smaller the area, the more selective the fish were in their food selection. Although *M. aculeatus* had a small food niche, they can grow significantly larger in the Musi River due to their vast feed habitat, with abundant crabs and shrimp. The abundance of prey in the extensive habitat can provide sufficient prey and reduce competition with other fish types. Small fish can also occupy a limited niche and become more selective in their food selection (Volkoff and Peter 2006). Only a small part of the available feed resources in waters are favored by fish, which depends on the food size, the food availability in nature, and the appetite.

In conclusion, *M. aculeatus* eat various food items, including crustaceans, annelids, insects, phytoplankton, zooplankton, and detritus. Furthermore, shrimp was reported to be the preferred food, followed by detritus, worms, and others. The *M. aculeatus* was a critical economic fish in inland fisheries, which served as a source of food and ornamental fish, with conservation and domestication potential. This study determined the gut length to the total length to be <1. *M. aculeatus* were classified as carnivores and bottom feeders due to consuming shrimp and worms with a primary diet similar to other meat feeder groups. The results showed that feeding habits were similar between sexes and size groups. Due to the breadth of their feed niche and the diversity and adaptability of their diets, these fish were less capable of broadening the food spectrum in response to feed availability and habitat degradation.

Moreover, commercial *M. aculeatus* feed was recommended to be formulated following the nutrient necessities in their natural diet to ensure successful aquaculture. Meanwhile, in-situ research is needed to ascertain the nutritional requirements of fish from wild seed and brood collections to assess the potential for domestication. Furthermore, spawning technique and seed reintroduction is expected to help manage and conserve this species in public waters.

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REFERENCES

Abujam SS, Shah RK, Singh SJ, Biswas SP. 2013. Food and feeding habit of spiny eel *Mastacembelus aral* (Bloch and Schneider) from upper Assam. J FisheriesScience.com 7 (4): 360-373. DOI: 10.3153/jfscom.2013040.

Alam A, Gopinath V, Jha DN, Joshi KD, Kumar J, Das SCS, Thakur R, Gupta M, Das BK. 2020. Food and feeding biology of commercially important freshwater eel, *Mastacembelus armatus* (LACEPÈDE, 1800) from the Ganga River, India. J Oceanogr Fish 11 (4): 69-73. DOI: 10.19080/OFOAJ.2020.11.555819.

Biswas SP. 1993. Manual of Method in Fish Biology. South Asian Publishers Pvt Ltd, New Dehli.

Blaber SJM. 2001. Tropical estuarine fishes—Ecology, exploitation and conservation. Copeia 2001 (3): 880-883. DOI: 10.1643/0045-8511(2001)001[0880:]2.0.CO;2.

Craig JK, Crowder LB. 2002. Factors influencing habitat selection in fishes with a review of marsh ecosystems. In Weinstein MP, Kreeger DA (eds). Concepts and Controversies in Tidal Marsh Ecology. Springer, Dordrecht. DOI: 10.1007/0-306-47534-0_12.

Djumanto, Devi MIP, Setyobudi E. 2013. Ichthyofauna distribution in downstream region of Opak River, Yogyakarta. J Iktiologi Indonesia 13 (2): 97-108. DOI: 10.32491/jii.v13i2.97.

Froese R, Pauly D. 2023. Editors. FishBase. World Wide Web Electronic publication.www.fishbase.org.

Gupta S. 2016. Feeding and reproductive biology of *Mastacembelus pancalus* (Hamilton, 1822), an indigenous fish species of Indian subcontinent: A review. Intl J Res Fish Aquac 6 (1): 8-12.

Herawati T, Adiwiguna I, Yustiati A, Rostini I, Setyobudi RH, Juahir H, Sahidin A. 2021. Rainy season's fish diversity upstream and downstream Jatigede Reservoir of Cimanuk River, West Java, Indonesia. Sarhad J Agric 37: 25-34. DOI: 10.17582/journal.sja/2021/37.s1.25.34.

Khaing MM, Khaing KYM. 2020. Food and feeding habits of some freshwater fishes from Ayeyarwady River, Mandalay District, Myanmar. IOP Conf Ser: Earth Environ Sci 416: 1-18. DOI: 10.1088/1755-1315/416/1/012005.

Nakazawa T. 2020. Species interaction: Revisiting its terminology and concept. Ecol Res 35: 1106-1113. DOI: 10.1111/1440-1703.12164.

Nurdawati S, Yuliani W. 2009. Food habit of fire eel, *Mastacembelus erythrotaenia* Bleeker 1850 in Musi River. J Iktiologi Indonesia 9 (2): 129-138. DOI: 10.32491/jii.v9i2.185.

Ohee HL, Sujarta P, Surbakti SB, Barclay H. 2018. Rapid expansion and biodiversity impacts of the red devil cichlid (*Amphilophus labiatus*, Günther 1864) in Lake Sentani, Papua, Indonesia. Biodiversitas 19 (6): 2096-2103. DOI: 10.13057/biodiv/d190615.

Pavlov DS, Kasumyan AO. 2002. Feeding diversity in Fishes: Trophic Classification of Fish. J Ichthyol 42: S137-S159.

Pethiyagoda R, Silva A, Maduwage K, Kariyawasam L. 2008. The Sri Lanka spiny eel, *Mastacembelus pentophthalamos* (Teleostei: Mastacembelidae), and its enigmatic decline. Zootaxa 1931 (1): 37-48. DOI: 10.11646/zootaxa.1931.1.3.

Serajuddin M, Ali R. 2005. Food and feeding habits of striped spiny eel, *Mastacembelus pancalus* (Hamilton). Indian J Fish 52 (1): 81-86.

Serajuddin M, Khan AA, Mustafa S. 1998. Food and feeding habits of the spiny eel, *Mastacembelus armatus* (Hamilton). Asian Fish Sci 11 (1): 271-278. DOI: 10.33997/j.afs.1998.11.3-4.010.

Stenberg M, Persson A. 2005. The effects of spatial food distribution and group size on foraging behaviour in a benthic fish. Behav Process 70 (1): 41-50. DOI: 10.1016/j.beproc.2005.04.003.

Suresh VR, Biswas BK, Vinci GK, Mitra K, Mukherjee A. 2006. Biology and fishery of barred spiny eel, *Mastacembelus pancalus* Hamilton. Acta Ichthyol Et Piscatoria 36 (1): 31-37. DOI: 10.3750/AIP2006.36.1.05.

Uthayakumar V, Sreedevi PR, Senthilkumar D, Munirasu S, Kiruba K, Ramasubramanian V. 2013. Impact of seasonal variation and feeding on reproductive behavior of freshwater spiny eel *Mastacembelus armatus* from Cauvery River. Asian Pac J Reprod 2 (3): 189-195. DOI: 10.1016/S2305-0500(13)60145-1.

Verma ASK, Alim A. 2013. The role of corpuscles of stannius during ovarian cycle in female *Mastacembelus armatus*. J Indian Streams Res 3 (9): 1-6. DOI: 10.1371/journal.pone.0101439.

Volkoff H, Peter RE. 2006. Feeding behavior of fish and its control. Zebrafish 3 (2): 131-140. DOI: 10.1089/zeb.2006.3.131.