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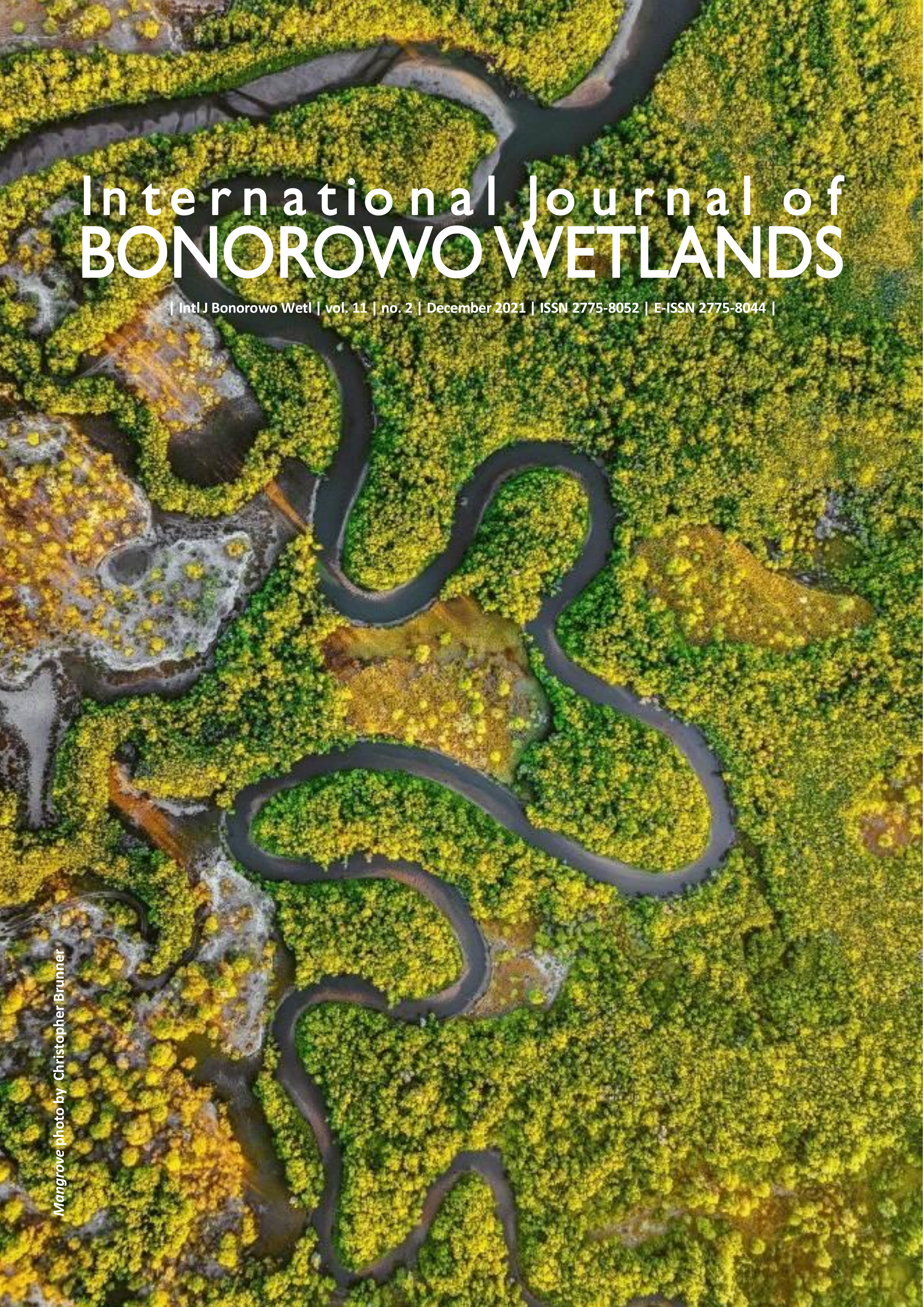

Mangrove photo by Christopher Brunner

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Chapter in book:

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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 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. www.molecularsystemsbiology.com. DOI:10.1038/msb.2008.24

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Community knowledge and utilization of mangroves in Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines

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Abstract. *Alimbon JA, Manseguiao MRS. 2021. Community knowledge and utilization of mangroves in Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines. Intl J Bonorowo Wetlands 11: 51-57.* Awareness of community knowledge and utilization patterns of mangrove ecosystems and their services is integral to conservation and management. However, this aspect remains less explored, especially in the Philippines. Hence, this study assessed the community knowledge and utilization of mangroves in Panabo Mangrove Park, Panabo City, Davao del Norte Philippines, using a survey research design. Through a simple random sampling procedure, 154 residents living near the area were surveyed using a questionnaire. Data were analyzed using frequency and percentages. Results revealed that the majority were knowledgeable of the existence and the services of mangroves except for their medicinal uses. It was also found out that many respondents have more minor to no knowledge of the different species of mangroves. Further, most respondents reported that they used the mangrove ecosystem as a food source on varying frequencies but never utilized it for other purposes such as fuelwood, medicine, dyeing agent, construction materials, fishing poles, household furniture, and other items.

Keywords: Community knowledge, utilization, ecosystem services, mangroves, Philippines

INTRODUCTION

Mangroves are a community of plants comprised of many species (see Tomlinson 1986; Primavera 2009; Spalding et al. 2010; Duke 2011; Lebata-Ramos 2013), which are known to be ecologically tolerant as they can survive in extreme conditions such as hypersalinity and high solar radiation (Adame et al. 2021). Worldwide, this ecosystem, which links the marine and terrestrial ecosystems, is considered one of the most productive (Sreelekshmi et al., 2021). The mangrove ecosystems are recognized for their roles in maintaining marine biodiversity in tropical and subtropical regions and their functions in the global biogeochemical processes and climate change mitigation (Wang and Gu 2021).

Moreover, mangroves are known to affect human well-being (Hsieh et al. 2015; Akanni et al. 2018) through their immense provisioning, regulating, supporting, and cultural ecosystem services (Primavera et al. 2018; Kadaverugu et al. 2021). These benefits include providing food and livelihood to residents (Sawairnathan and Halimoon 2017; Barua and Rahman 2019; Gevaňa et al. 2019; Quevedo et al. 2019). For example, the locals sell the fish, fuelwood, and logs in the market in exchange for cash to sustain their needs (Nfotabong-Athuell et al., 2009; Shah and Datta, 2010). The mangrove ecosystem also serves as a source of raw materials for charcoal making and construction (Nfotabong-Athuell et al. 2009; Sinfuego and Buot 2014; Gonzales et al. 2017). Other benefits include medicinal uses such as *Rhizophora* spp. as a treatment for external hemorrhage and tooth decay (Nfotabong-Athuell et al. 2011) and *Avicennia marina* for sunburn (Arbiastutie et al. 2021).

However, knowledge deficits of the mangrove ecosystem and its services exist (Dencer-Brown et al., 2018). As noted, local populations have limited knowledge of mangrove species and their ecological and economic benefits (Satyanarayana et al., 2012). Darkwa and Smardon (2010) even found out that fishers lack the scientific knowledge necessary to derive the benefits offered by mangroves ultimately. Another concern is that destruction is inevitable because of community dependence on its known consumptive uses like charcoal making (Kusmana and Sukwika 2018; Ritabulan et al. 2019). Anthropogenic threats to mangrove include firewood overharvesting, house construction, timber production, agriculture, and aquaculture activities (Nfotabong-Athuell et al. 2011; Warren-Rhodes et al. 2011; Jones et al. 2015; Gonzales et al. 2017; Marican et al. 2018) and, more recently, ecotourism (Ramli et al. 2018; Mahmood et al. 2021) and urban expansion (Moschetto et al. 2021).

These knowledge inadequacies and unsustainable human interventions primarily pose enormous challenges to mangrove conservation and restoration (Biswas et al., 2009). Though efforts were made, apparent gaps on how stakeholders (e.g., community members) can transform initiatives into actions for sustainable development are still evident (Garcia et al. 2014). Effective management and conservation of mangroves require knowledge of their ecosystem services (Friess et al. 2016). In the Philippines, very few studies (i.e., Quevedo et al. 2019; Tejada and Cauilan 2019; Ballad and Mangabat 2021) explored the local knowledge and perspectives on mangroves and their utilization. In Davao Gulf, which is found in the southeastern part of the Philippines, studies were primarily focused on the assessment of mangrove species diversity (Jumawan et al. 2015; Pototan et al. 2017, 2021; Cardillo and Novero 2018) and recently included aboveground biomass and carbon stock (Alimbon and Manseguiao 2021). Hence, this study aimed to assess mangroves' community knowledge and utilization in Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines. The results of this study are expected to provide baseline information on the sociodemographic profile, level of knowledge, and extent of utilization of the residents. Having this relevant data would help the authorities make informed decisions on the mangrove management and conservation efforts, especially those that involve the local populations.

MATERIALS AND METHODS

Study area

This study was conducted in Barangay J.P. Laurel, Panabo City, Davao del Norte, Philippines (Figure 1) last April 2019. It is located in the southeastern portion of the city facing Davao Gulf. This coastal village hosts the Panabo Mangrove Park (7°16’20.579” N, 125°40’50.984” E). This mangrove community houses several mangrove species, including *Aegeciras corniculatum, Avicennia marina*, *Rhizophora apiculata*, *Rhizophora mucronata*, and *Sonneratia alba* (Alimbon and Manseguiao 2021). Based on the 2015 Census of Population, Barangay J.P. Laurel had a population of 6,561 individuals (Philippine Statistics Authority, 2015).

Research design

This is a quantitative type of research employing a survey research design (Creswell 2012) to assess the community knowledge and utilization of mangroves in the area.

Research respondents

The respondents of this study were the residents inhabiting near or adjacent to the mangrove community. This study only included those living within the 500-m radius from the boundary of the mangrove park. A total of 154 respondents were selected using random sampling. This sample size was determined using Slovin’s formula: $n = N/(1+Ne^2)$, where n is the sample size, N is the population size, and e is the margin of error set at 0.05.

Figure 1. Location of Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines (Google Earth, 2021)

Research instrument

This study utilized a structured questionnaire designed to determine (1) the demographic profile of respondents, (2) the level of community knowledge, and (3) the extent of community utilization of mangroves. The questionnaire was translated into a local dialect of Panabo City, Philippines, to be easily understood. Indicators for community knowledge and utilization of mangroves were assessed using a 4-point Likert scale. To ensure validity, the instrument underwent content validation by experts. To ensure reliability, it was pilot tested to community members who are not included in the study yet, inhabit near a mangrove area. Inconsistencies noted during reliability checks were corrected before the actual data gathering.

Data analysis

Data on the demographic profile of residents, levels of community knowledge, and the extent of utilization were tabulated and analyzed using frequency and percentages.

RESULTS AND DISCUSSION

Profile of the respondents

Table 1 presents the demographic profile of the respondents. The majority of the respondents are aged 21-30 years old at 24.0%, males at 51.30%, and married at 66.2%. Most of them (55.8%) reached or finished secondary education, while few (2.60%) did not have formal education. In terms of occupation, only 5.8% of the respondents are into fishing which means that most are not into fishery-related or coastal-resource-utilization-related work. These include housewives (27.3%), skilled workers (26.6%), students (22.1%), businessmen (11.7%), private employees (3.3%), government employees (2.6%), and farmer (0.7%). Most of the respondents, at 31.2%, claimed to have resided in the area for five years or less, which means that they recently moved into the area. This influx of residents in the area should be monitored, for Chong (2006) mentioned that increasing coastal population could potentially cause mangrove degradation. In terms of income, 83.8% of the respondents earned Php 10,000.00 or less (≤ USD 200), which is lower than Php 10,756.00 (≈ USD 215), the average monthly poverty threshold for a family of five (PSA, 2020). This means that the monthly income of many families in the area is not sufficient to meet their minimum basic food and non-food needs.

Table 1. Demographic profile of the respondents

Demographic variables		n	%
Sex	Male	79	51.3
	Female	75	48.7
Marital Status	Single	44	28.6
	Married	102	66.2
	Widowed	5	3.3
	Others (e.g., live-in)	2	1.3
	Did not provide information	1	0.7
Age	20 and below	36	23.4
	21 to 30	37	24.0
	31 to 40	30	19.5
	41 to 50	23	14.9
	51 to 60	16	10.4
	61 and above	9	5.8
	Did not provide information	3	2.0
Education	No formal education	4	2.6
	Elementary	38	24.7
	Secondary	86	55.8
	College	18	11.7
	Graduate/Post-graduate	2	1.3
	Did not provide information	6	4.0
Number of years in the area	5 and below	48	31.2
	6 to 10	29	18.8
	11 to 15	27	17.5
	16 to 20	12	7.8
	21 or more	35	22.7
	Did not provide information	3	2.0
Occupation	Fisherman	9	5.8
	Farmer	1	0.7
	Housewife	42	27.3
	Student	34	22.1
	Businessman	18	11.7
	Government employee	4	2.6
	Private employee	5	3.3
	Others (i.e., skilled workers)	41	26.6
Monthly income	PhP 10,000.00 and below	129	83.8
	PhP 10,001.00 - PhP 20,000.00	23	14.9
	PhP 20,001.00 - PhP 30,000.00	2	1.3

Note: US$ 1.00 ≈ PhP 50.00

Level of community knowledge

This study assessed the community's knowledge of mangroves' existence and ecosystem services in the area (Table 2). The result showed that most of the respondents (81.1%) were very knowledgeable of the existence of mangroves in the area. Surprisingly, a few reported having less to nonknowledge of its presence, at 6.5% and 3.9%, respectively. This could be because they recently moved into the area since most respondents claimed to have lived there for only five years or less.

Despite the very high knowledge about mangrove existence demonstrated by most surveyed residents, results showed that many have more minor to non-knowledge of the different species of mangroves, both at 31.2%. Notably, during the survey, respondents could only provide generic local names of *Avicennia*, *Sonneratia*, and *Rhizophora* species. Only very few respondents could provide local terms specific for *R. apiculata* and *R. mucronata*. This observation is quite similar to the findings of Nfotabong-

Athuell et al. (2011), which revealed that residents near mangrove forests are only familiar with one to four species. Longépée et al. (2021) also found that their respondents have lower local ecological knowledge regarding the number of mangrove species and their names.

Community knowledge on provisioning services of mangroves was also asked. Many respondents reported that they were very knowledgeable on the following services: food source (59.7%), fuel resource (51.9%), and construction and fishing materials (44.8%). Awareness that mangroves provide one or all of these benefits was documented in several studies (e.g., Dencer-Brown et al. 2019; Quevedo et al. 2019; Setiyaningrum 2019; Wahyuni et al. 2021). Most locals recognize these benefits due to their perceived importance and direct value to human livelihood (Nyangoko et al., 2021). Interestingly, many surveyed residents were not knowledgeable of mangroves being a source of firewood and charcoal at 24.7% and construction and fishing materials at 27.9%. Further, the community seems to have limited knowledge of the medicinal use of mangroves since 76.0% of the respondents claimed not to know this benefit. Similar accounts were reported wherein respondents demonstrate a doubtful understanding of the medicinal benefits of mangroves (Sulaiman et al. 2019; Wahyuni et al. 2021). Nyangoko et al. (2021) even found that local inhabitants perceive this benefit as unimportant compared to other provisioning services.

Further, knowledge on supporting and regulating services of mangroves was assessed. Most surveyed respondents were knowledgeable about mangroves being a habitat and a nursery or spawning ground for other organisms, at 70.8% and 71.4%, respectively. In addition, 74.0% of the locals were very knowledgeable about the mangrove community as protection from coastal erosion and intense winds and waves during storms. In comparison, 38.3% were very knowledgeable on the role of mangroves in oxygen release and carbon sequestration. Residents' significant knowledge of the above benefits could be attributed to their educational attainment. Education is regarded as an essential factor that elevates ability and determines the understanding of residents about the mangrove ecosystem (Abd Rahman and Asmawi 2016; Sawairnathan and Halimoon 2017). As reflected in Table 1, 68.83% of the respondents reached secondary (high school) education. Secondary education allows residents to have minimum knowledge of the mangroves (Abd Rahman and Asmawi 2016). This record of local populations' sufficient knowledge affirmed the findings of several studies (Nfotabong-Athuell et al. 2011; Warren-Rhodes et al. 2011; Ferichani and Prasetya 2012; Da Silva 2015; Sawairnathan and Halimoon 2017; Tejada and Cauilan 2019), which mentioned that residents are aware of the goods and ecological services they benefit from the mangrove ecosystem.

The extent of community utilization

The extent of community utilization of mangroves was also assessed (Table 4). Many respondents (71.4%) reported that mangroves serve as their food source on varying frequencies from rare occasions to all the time. The food items usually collected from the area were fish and shellfish. However, 28.6% of the surveyed locals never accessed the site to obtain food.

Though several studies (e.g., Dahdouh-Guebas et al. 2000; Nfotabong-Athuell et al. 2011; Da Silva 2015; Gonzales et al. 2017; Numbere 2019) already documented that local inhabitants used mangroves as firewood, charcoal, fodder, construction materials, fishing apparatus such as poles, medicine, dyeing agent, household furniture, and other items, very few respondents claimed to have benefited these uses of mangroves in the study site. Even as a source of income, only 16.2% reported to benefit from it. These income-generating mangrove-related activities included selling caught fish and shellfish and participating in activities initiated by the local government unit.

Table 2. Level of community knowledge of mangroves in Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines

Community knowledge	Very knowledgeable		Moderately knowledgeable		Less knowledgeable		No knowledge at all	
	n	%	n	%	n	%	n	%
Mangroves exist near my area	125	81.1	13	8.4	10	6.5	6	3.9
Mangroves have different species	32	20.8	26	16.9	48	31.2	48	31.2
Mangroves serve as habitat for other organisms	109	70.8	12	7.8	15	9.7	18	11.7
Mangroves serve as a nursery ground for fish, mollusks, crabs, and shrimp	110	71.4	17	11.0	14	9.1	13	8.4
Mangroves offer protection from coastal erosion and intense wind and waves during storms	114	74.0	12	7.8	13	8.4	15	9.7
Mangroves serve as a food source	92	59.7	18	11.7	23	14.9	21	13.6
Mangroves provide fuel resources (e.g., firewood, charcoal)	80	51.9	18	11.7	18	11.7	38	24.7
Mangroves provide construction and fishing materials (e.g., timber, fishing stakes, and fishing boats)	69	44.8	25	16.2	17	11.0	43	27.9
Mangroves have medicinal use	16	10.4	8	5.2	13	8.4	117	76.0
Mangroves release oxygen and absorb carbon dioxide	59	38.3	26	16.9	26	16.9	43	27.9

Table 3. The extent of community utilization of mangroves in Panabo Mangrove Park, Panabo City, Davao del Norte, Philippines

Community utilization	Always		Sometimes		Rarely		Never	
	n	%	n	%	n	%	n	%
I use mangroves as a food source	26	16.9	29	18.8	55	35.7	44	28.6
I use mangroves as construction materials for houses	4	2.6	6	3.9	7	4.5	137	89.0
I use mangroves as fishing materials (e.g., poles for fish traps, rafts, boats)	6	3.9	5	3.2	10	6.5	133	86.4
I use mangroves as medicine	3	1.9	4	2.6	12	7.8	135	87.7
I use mangroves as firewood	7	4.5	6	3.9	7	4.5	134	87.0
I use mangroves as charcoal	5	3.2	2	1.3	5	3.2	142	92.2
I use mangroves as house furniture (e.g., chairs, tables) and household items (e.g., baskets, mortar, tool handles)	7	4.5	6	3.9	9	5.8	132	85.7
I use mangroves in agriculture (e.g., fence, fencing posts, fodder [feeds])	8	5.2	4	2.6	10	6.5	132	85.7
I use mangroves as a dyeing agent	4	2.6	1	0.6	5	3.2	144	93.5
I use mangroves as a source of income	4	2.6	5	3.2	16	10.4	129	83.8

This non-extensive utilization of mangroves can be attributed to the fact that most residents' occupations are not fisheries and other mangrove-related activities. Only nine (5.84%) respondents claimed to be fishermen. Further, this could be due to the considerable knowledge of residents about laws and policies regarding conservation, protection, utilization, and development of mangroves (Sulistyowati and Astuti 2018). In the Philippines, cutting off all mangrove species is banned (Revised Forestry Code of the Philippines). Also, conversion of mangroves to fishpond or any purpose is declared unlawful under Republic Act No. 10654. As observed in the study site, a poster was hung reminding the public not to cut trees or build a structure within the mangrove forest.

Moreover, the result of this study was on the contrary of the findings of studies in a few countries in Africa where a large percentage of households living near mangrove forests still depend on these resources for subsistence and other economic needs (Nfotabong-Athuell et al. 2009; Da Silva 2015; Warui et al. 2020). In addition, Gonzales et al. (2017) found out that in Rio Tuba, Palawan, Philippines, the community still harvests mangrove trees for house construction and charcoal production. However, it was noted by Satyanarayana et al. (2012) that the trend of utilizing mangrove resources has now decreased.

In conclusion, the community is knowledgeable of the existence of mangroves in the area, but a significant number of the surveyed respondents did not know that mangroves have different species. Also, the majority are knowledgeable of the mangrove ecosystem services except for medicinal uses. In terms of utilization, it can be considered as not extensive except being a food source since many respondents reported that they obtain food (e.g., fish, shellfish) from the area at varying frequencies. This non-utilization of mangroves, incredibly destructive uses (e.g., fuelwood, charcoal) by most residents, could be due to their line of occupation and their awareness of existing laws that prohibit such acts.

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Assessment of fish species richness and physicochemical parameters of Mt. Hamiguitan Range Wildlife Sanctuary river systems in Mindanao, Philippines

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Abstract. *Dapar MLG, Lagumbay AJD, Parcon J, Tubongbanua Jr. RM, Amoroso VB. 2021. Assessment of fish species richness and physicochemical parameters of Mt. Hamiguitan Range Wildlife Sanctuary river systems in Mindanao, Philippines. Intl J Bonorowo Wetlands 11: 58-68.* Being a UNESCO World Heritage Site, Mt. Hamiguitan Range Wildlife Sanctuary (MHRWS) is an exceptional area of diverse flora and fauna with conservation concerns. MHRWS river systems provide significant spawning and nursery grounds for freshwater fishes. However, anthropogenic activities may result in the degradation of fish habitats which calls for conservation. This study provides an updated assessment of the fish diversity of selected MHRWS river systems and recommends policies for the proper management of the rivers and riparian ecosystems. An inventory of fish species and an assessment of the physicochemical parameters were conducted in the three river systems of Mt. Hamiguitan Range Wildlife Sanctuary. A series of line transect of 100 m were established along the banks of the three rivers in three sampling stations (upstream, midstream, and downstream). Results showed that the Dumagooc River has the highest fish species than Maug and Banahaw River. Generally, the species richness increased from upstream to downstream. The high species richness observed upstream, and midstream is due to the presence of an intact forest with areas far from human disturbances. A total of 31 species in 11 families comprising 121 individuals were collected and identified. Of these, one endemic species, 29 native species, and two introduced species were identified, representing 4.16% of 48 species recorded in the country. As to the physicochemical characteristics of the three river systems, the results showed that the temperature, pH, NTU, and DO values of the sampling sites are within the minimum acceptable limit to be considered as within the standards for class AA, A, and B rivers.

Keywords: Endemic, introduced, inventory, native, policies, water quality

INTRODUCTION

The Philippines is one of the mega-diverse countries recognized by the United Nations Environment Programme (UNEP) World Conservation Monitoring Centre and, at the same time, a biodiversity hotspot (Heaney et al. 2004; Mallari et al. 2001). The Philippines hosts about 3,010 fish species with only 343 (10%) species occurring in freshwater, of which 83 species are endemic, 206 species are native, 44 species are introduced, and 42 species are of uncertain status (Froese and Pauly 2011). However, most fish studies conducted in the country were devoted to marine ecosystems, and little is known about the freshwater diversity (Ong et al., 2002). Marine and freshwater fishes are equally valuable as bioindicators of ecosystem health and an integral part of our country's natural heritage (Ng et al. 1998; Vallejo 1986). Many unique freshwater fishes, particularly gobies, pipefish, and halfbeaks, are restricted only to isolated lakes and rivers in major islands in the Philippines, but their current status in the surrounding freshwater habitats is unknown (Butler 2006; Herre 1953; Paller et al. 2011).

Rivers in the Philippines, as in other countries, support a rich but barely known biota (Allen 1991). However, most of these rivers have remained poorly understood and less studied despite their significant functions in human populations (Kottelat and Whitten 1993). Freshwater fishes are among the most endangered groups because of their high vulnerability to aquatic habitat modification (Kang et al., 2009; Laffaille et al., 2005; Sarkar et al., 2008). Among known hazards affecting rivers are habitat degradation, conversion to private use, impacts of climate change and pollution, overexploitation, and introduction of invasive species (Bagarinao 2001; Cagauan 2007).

Several studies on freshwater fish were conducted in the rivers and lakes of Mindanao. Manacop (1953) studied the life history and habits of gobies in the Cagayan River, while Myers (1960) examined the endemic fish fauna of Lake Lanao. Recent studies were conducted by Vedra et al. (2013) on the goby population in Mandulog River at Iligan City and its potential in the fishery resources (Vedra and Ocampo 2014). Uy et al. (2015) studied the productivity and biodiversity of Lake Mainit, including the fish inventory in the lake and its outlet. The most recent study on freshwater fish was conducted by Quimpang et al. (2015) in the five long-term ecological research (LTER) sites in Mindanao, including selected rivers of Mt. Hamiguitan Range Wildlife Sanctuary (MHRWS).

Mt. Hamiguitan Range Wildlife Sanctuary, located in Davao Oriental Province, Mindanao, is a protected area covering 6,834 ha between 6 °40 'N to 6 °47 'N and 126 °09 'E to 126 °13 'E with the highest elevation of 1,637 masl. (Karger et al., 2012). It was designated as a UNESCO World Heritage Site in June of 2014 and is known as the Mindanao Long Term Ecological Research Site (Amoroso and Aspiras 2011). Mt. Hamiguitan serves as headwater of several major rivers such as Bitaogan River, Tibanban, Maua River, Dumagooc, and numerous creeks with discharge points to the Davao Gulf on the river West and the Philippine Sea on the East. The three major rivers are the water source to irrigate the lowlands of the municipality of Governor Generoso. The river systems emanate from usually forested hinterlands and receive organic materials to be recycled, contribute to the river's energy, support its high biodiversity and productivity (Giller and Malmqvist 1998), and serve as food sources, primarily for fishes (Vannote et al. 1980). Thus, the freshwater fish assessment provides information about their community, structure, and composition. It will also update the new list of freshwater fish found in the area.

This study, therefore, aims to assess the species richness of the fish about physicochemical characteristics of the river systems and recommend policies for the conservation and proper management strategies.

MATERIALS AND METHODS

Study area

Freshwater fishes were inventoried in the three river systems of Mt. Hamiguitan Range Wildlife Sanctuary, as described in Table 1.

Maug River is a 10 km river located in Sitio Tumaliti (06°69.776'N, 126°05.517'E), San Isidro, Davao Oriental, Philippines. It has a primary and secondary forest upstream (Puting Bato), a secondary forest with an agroecosystem in the midstream. Small scale quarry, residential area, and high valued crops are present downstream (Table 1). Dumagooc river is in Barangay Osmena (06°41.903'N, 126°06.596'E), Governor Generoso, Davao Oriental. It has a thick primary forest upstream. Homes such as residential areas, schools, and bridges are observed near the midstream area with few trees such as fig trees (*Ficus* spp.), kalingag (Cinnamomum sp.), and coconuts. Some of the residents do their laundry in the river. The barangay center is located near the downstream area, where there are many houses, schools, and bridges. Banahaw river is in Barangay Surop, Governor Generoso, Davao Oriental. This location is an agroecosystem forest with a vast plantation of coconut. The downstream is also located at the center of the barangay, where some of the residents do their laundry.

The study was conducted from August 2019 to January 2021 at the Dumagooc river of Brgy. Osmeña, Governor Generoso, Maug of Sitio Tumaliti, San Isidro, Davao Oriental, and Banahaw River, Barangay Surop, Governor Generoso, Davao Oriental, Philippines (Figure 1). Three stations were assigned to collect fish and water quality parameters (Upstream, Midstream, and Downstream). Each station was sampled equally during the year's dry season to avoid possible floods and landslides in the area.

Entry protocol

Gratuitous Permit (GP) was obtained from the Department of Environment and Natural Resources-Protected Areas Management Board (DENR-PAMB). The study was accompanied by representatives from the DENR-PAMB and the Provincial Environment and Natural Resources (PENRO) of DENR XI.

Sampling design

Three stations were selected for each of the three sites (Figure 1). A 100-meter stream reach was chosen at each station (upstream, midstream, and downstream) using a measuring tape. Before fish collection, parameters like water temperature, pH, electrical conductivity (EC), turbidity, dissolved oxygen (DO), and total dissolved solids (TDS) were measured in situ using a Pro DSS multi-parameter probe. Nine sampling points were randomly selected in every river sampling station close to the right and left riverbanks and in the middle of the river with triplicates.

Table 1. Elevation, location, and land use of selected study sites

Site	Elevation (m. asl.)	Location		Surrounding land uses
		N	E	
Maug River				
MUS	240	06°69.776'	126°15.020'	Primary forest (Puting Bato)
MMS	131	06°43.735'	126°07.786'	Secondary forest
MDS	44	06°41.968'	126°05.517'	Small scale quarry, residential area, and high valued crops
Dumagooc River				
DUS	209	06°41.903'	126°09.029'	Primary forest thick
DMS	115	06°40.571'	126°07.715'	Few fig-trees, kalingag trees, coconut trees, residential area, laundry area
DDS	80	06°40.134'	126°06.596'	Bridge, residential area, barangay hall, laundry area
Banahaw River				
BUS	280	06°28.426'	126°11.641'	Secondary forest
BMS	132	06°27.696'	126°10.122'	Shrubs and coconut trees
BDS	17	06°26.841'	126°07.492'	Bridge, washing/laundry area, residential area near the estuarine

Note: US: Upstream, MS: Midstream, DS: Downstream

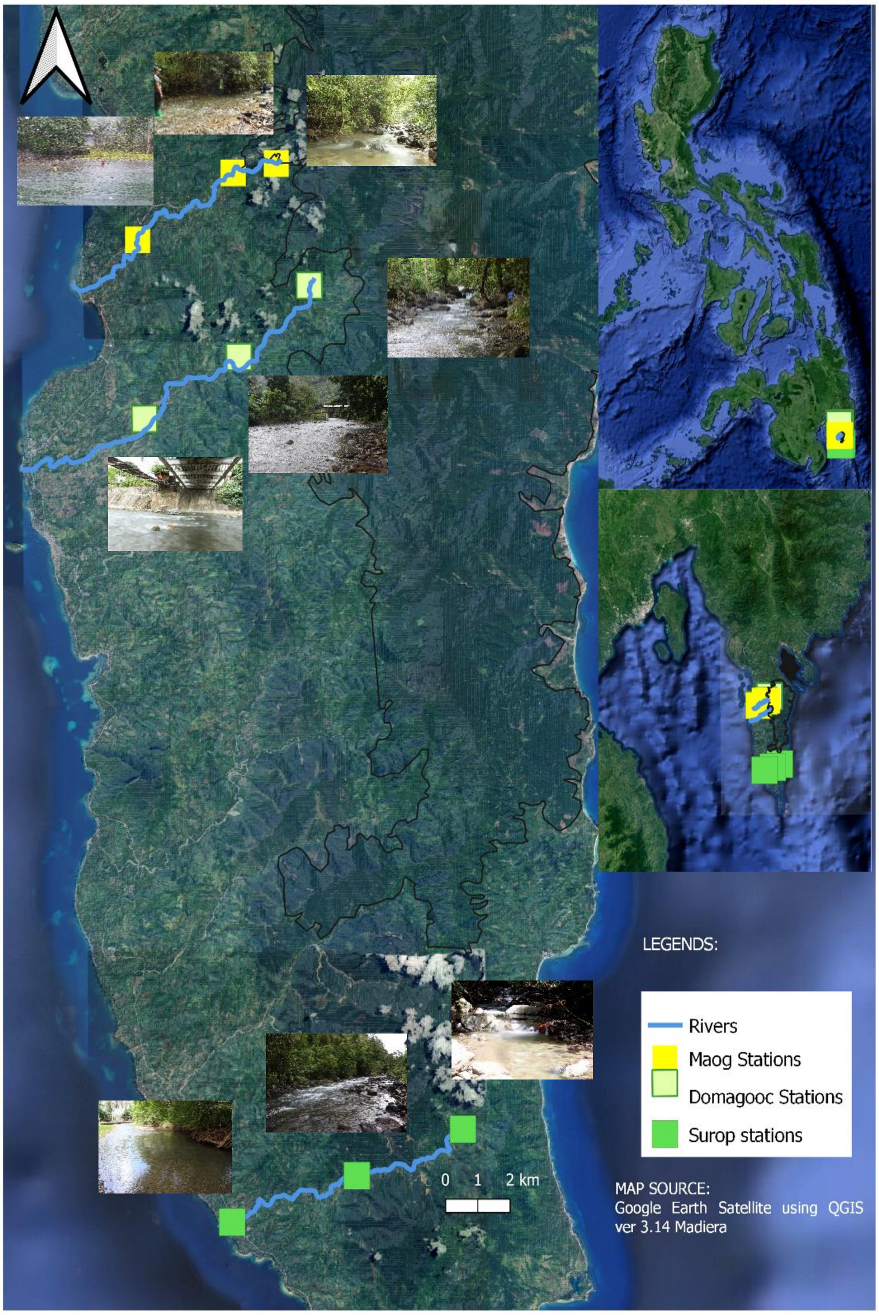

Figure 1. A. Philippine map. B. Location map of the study showing MHRWS. C. Location map of the study area showing Maog (*up*), Dumagooc (*middle*), and Banahaw (*down*) Rivers with the sampling stations of Mt. Hamiguitan Wildlife Sanctuary, Philippines

Fish collection, identification, and preservation

The collection of fish was done along with the three sampling stations within the river gradient using a low voltage (10V) improvised backpack electrofishing gear accompanied by a gill net with approximately 1.2mm x 1.2mm mesh size employed in the down part of the river's gradient (Figure 2. A). A line transect of 100m was established along the banks of the three rivers of each sampling station, upstream, midstream, and downstream. The electric fishing method was intentionally used to catch specific fish species of interest where seine netting is not applicable (Paller et al., 2011).

The stunned fishes caught by this method were immediately put in a bucket, documented, and initially identified in the field. Description of the live fish was done by noting their color, the number of fins and barbels if present, the shape of the tail and head, body structure, and mouth. Voucher specimens for each species were preserved in a 10% formalin solution, and other stunned fish were returned to the water after their recovery from the current shock.

A B C

Figure 2. A. Backpack electrofishing; B. Reading using multi-parameter probe; C. Preserving voucher specimen

Collected specimens were identified and classified up to species level using the Philippine freshwater fish taxonomic keys of Herre (1953), Hubilla (2007), Paller et al. (2011), and Froese and Pauly (2018). Other published articles on fish species in Mindanao Island by Quimpang et al. (2015) and Quimpang et al. (2016) were also used for identification. Consultation with experts was also done for the verification of species. The collected voucher specimens were deposited in the CMU museum for further taxonomic analysis and identification. Fish specimens were compared with the existing literature and Pisces collection of the CMU museum for proper identification.

Fish species indicators

Whether native, endemic, or introduced, the fish status was noted based on the listing and classification of Fishbase ver.10, 2015.

RESULTS AND DISCUSSION

A total of 122 individuals of freshwater fish comprising 25 species representing 11 families were sampled from three river systems of MHRWS. Family Gobiidae was the most represented family with nine species recorded from all sites, followed by Syngnathidae (pipefishes) with four species, then by Eleotridae (3 spp.), and then Cyprinidae (2 spp.). Other families such as Ambassidae, Anguillidae, Butidae, Kuhliidae, Muraenidae, Poecillidae, and Rhyacichthyidae were represented by a single species. Among all species observed, *Barbodes bantolanensis* was the most numerous (n=20) and constituted 23.7%. It was found abundant upstream of Dumagooc river, few in Maug river and not observed in Banahaw river. *Anguilla marmorata* (Mottled eel) was the second most abundant species (n=14), comprising 11.4%, observed in all sites, except in the midstream of Maug and Banahaw river. The third abundant species was *Stiphodon atropurpureus* (Blue neon goby/balolo), with a relative abundance of 10.6% (n=13). All species were identified as native in the Philippines except *Poecilia reticulata* (Guppy/Butitirot), which was introduced to the country.

This study presents an updated list of species identified in the free-flowing sections of the MHRWS river systems and information on the composition of fish species along a longitudinal gradient of the river. This fish species richness assessment provides a basis for long-term monitoring of the MHRWS headwaters and their tributaries which constitutes a reference status for similar future evaluations of other river systems in Mindanao, Philippines. Although current environmental monitoring of the MHRWS river systems primarily focuses on physicochemical parameters and fish species richness, the biological quality elements and surrounding land uses are also being monitored in the area (Table 1). The continuing biodiversity assessments of fish species and physicochemical parameters will provide valuable insights on the impact of currently implemented management and conservation strategies, as well as the potential effects of climate change.

This study exhibited lower species richness than Quimpang et al. (2016). However, several misidentified species in the study, such as *Schismatogobius marmoratus*, which was identified as *Gobioterus mindanaoensis*; *Lutjanus argentimaculatus* identified as *Waigieu seaperch*; and *Ryhacichthys aspro* identified as *Pterygoplichtys pardalis* (Table 3**). Moreover, some species identified in the previous study were not recorded in the list of freshwater fishes in the Philippines. Hence, species verification must be conducted to prove the occurrence of these species in the country. Interestingly, this study added 14 additional species to the diversity of freshwater fishes in MHRWS (Figure 3).

No reported indigenous or traditional management practices were practiced and implemented in the MHRWS river system to conserve its fish biodiversity. The locals have traditional and customized fishing gears for fishing and exploitation of the stocks. Anthropogenic activities and environmental disturbances identified in the surrounding area may affect the fish diversity and the physicochemical values in the three river systems.

Table 2. Diversity of freshwater fish in Dumagooc, Maug, and Banahaw River, Philippines

Family/species	DDS	DMS	DUS	MDS	MMS	BDS	BMS	BUS
Ambassidae								
Ambassis interrupta Bleeker, 1853						1		
Anguillidae								
Anguilla marmorata Quoy & Gaimard, 1824	2	3	4	2		1		2
Butidae								
Oxyleotris sp.						1		
Cyprinidae								
Barbodes bantolanensis Day, 1914	5	2	20	1	1			
Puntius sp.				1				
Eleotridae								
Eleotris acanthopoma Bleeker, 1853	3			1	1			1
Eleotris fusca Forster, 1801	1	1	1	2	1	3		1
Mogurnda mogurnda Richardson, 1844				1				
Gobiidae								
Glossogobius celebius Valenciennes 1837				1				
Lentipes mindanaoensis Chen, 2004	1	1	2	1				
Schismatogobius marmoratus Peters, 1868	1			2			1	
Sicyopterus lagocephalus Pallas, 1770			1	1	3			
Sicyopterus longifilis de Beaufort, 1912		1		1				
Sicyopterus micrurus Bleeker, 1853							1	
Sicyopus zosterophorus Bleeker, 1856							1	1
Stiphodon atropurpureus Herre, 1927		2	1	1	3	3	2	1
Stiphodon elegans Steindachner, 1879	1	1	3	1	1		1	
Kuhlidae								
Kuhlia marginata Cuvier, 1829				1		1		
Muraenidae								
Gymnothorax sp.	1					1		
Poeciliidae								
Poecilia reticulate Peters, 1859		3						
Rhyacichthidae								
Rhyacichthys aspro Valenciennes, 1837						1	1	1
Syngnathidae								
Doryichthys boaja Bleeker, 1850	1			1				
Hippichthys heptagonus Bleeker, 1849	2			1		1		
Hippithichthys sp.				1				
Microphis brachyurus Bleeker, 1854				1				
Grand total	18	14	32	21	10	13	7	7

Note: DDS: Dumagooc Downstream; DMS: Dumagooc Midstream; DUS: Dumagooc Upstream; MDS: Maug Downstream; MMS: Maug Midstream; MUS: Maug Upstream; BDS: Banahaw Downstream; BMS: Banahaw Midstream; BUP: Banahaw Upstream

The number of fishes collected in this study is lower than previous collections as 33 species were recorded by Quimpang et al. (2016) in the Maug and Dumagooc in Mt. Hamiguitan. However, the present collection is higher than the 16 species recorded by Paller et al. (2011) in Mt. Makiling Forest Reserve and five species reported by Hansel et al. (2004) in Lake Duminagat, Mt. Malindang Range Natural Park. The Maug, Dumagooc, and Banahaw rivers support one endemic species, 29 native species, and one introduced species which represents 4.16% of 48 species recorded in the country. The native species represents 14.02% of 221 native fish species here in the Philippines, while the endemic species *Puntius bantolanensis* represents 2.27% of 44 fish species. Mostly geographically isolated freshwater systems are home to many native and endemic fish species. Some species remain unknown and potentially face a significant threat from extinction (Herre 1953; Butler 2006). Members of the family Gobiidae, Oxudercidae, and Syngnathidae exhibited the highest species richness. Habitat loss, human interventions, pollution, and the introduction of alien species contribute to the major threats to the country's freshwater diversity (Guerrero 2002; Vidthayanon 2007).

Physicochemical properties of the river

The summary of the mean average values of physicochemical parameters of Dumagooc, Maug, and Banahaw River. This is shown in Table 2.

Temperature

An increasing level of temperature from upstream (21.18 ˚C and 23.8 ˚C, respectively) to a downstream station (25.3 ˚C, 26.6 ˚C, and 27.5 ˚C), respectively, was observed in Maug and Banahaw rivers (Figure 4. A).

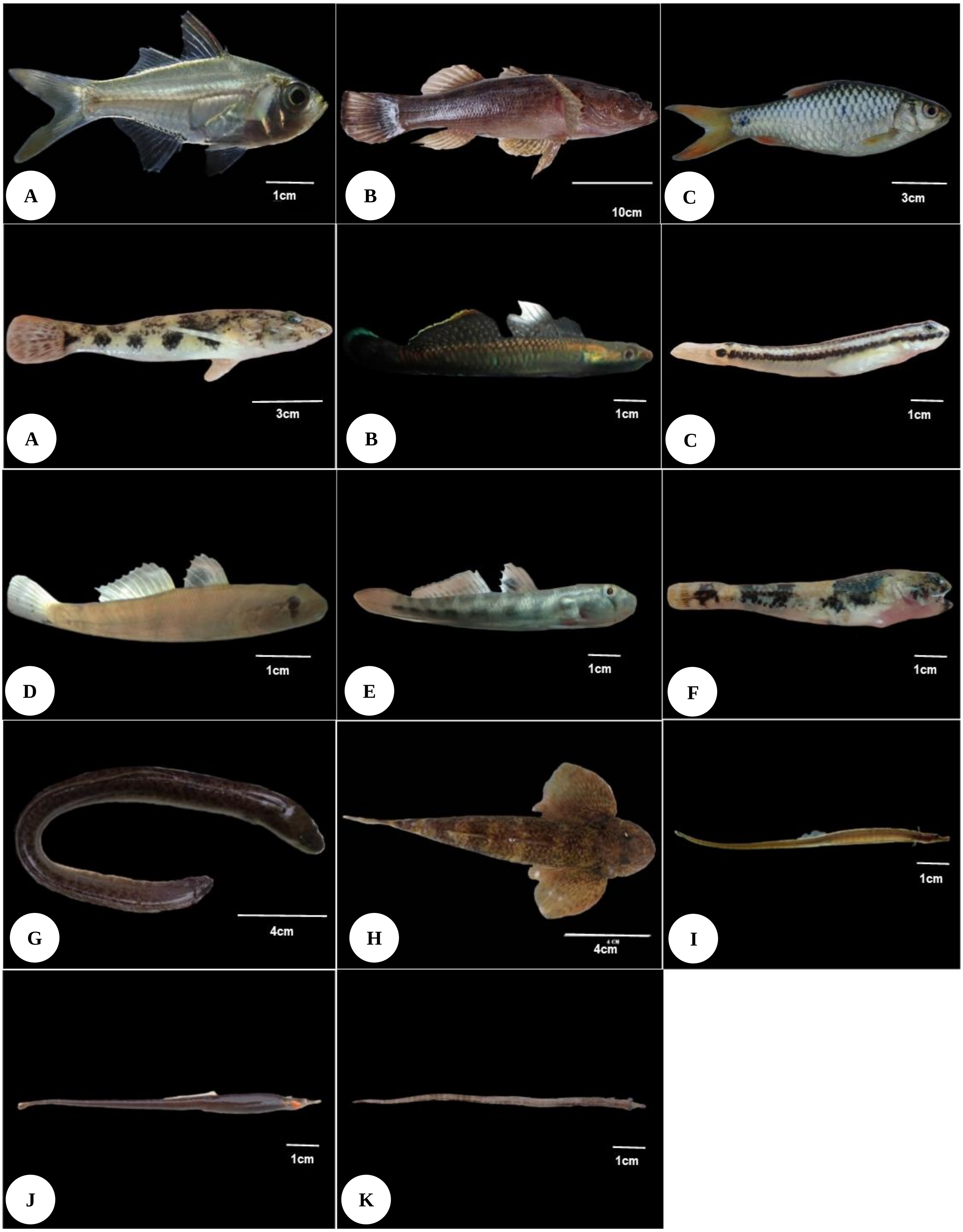

Figure 3. Additional fish species in Mt. Hamiguitan Range Wildlife Sanctuary, Philippines. A. *Ambassis interrupta* Bleeker, 1853, B. *Oxyeleotris* sp., C. *Puntius* sp., D. *Glossogobius celebius* (Valenciennes, 1837), E. *Lintipes mindanaoensis* Chen, 2004, F. *Sicyopterus longifinis* de Beaufort, 1921, G. *Sicyopus zosterophorus* Bleeker, 1856, H. *Schismatogobius marmoratus* (Peters, 1868, I. *Stiphodon elegans* (Steindachner, 1879), J. *Gymnothorax* sp., K. *Rhyacichthys aspro* (Valenciennes, 1837), L. *Hippichthys heptagonus* (Bleeker, 1849), M. *Hippichthys* sp., N. *Microphis brachyurus* (Valenciennes, 1842)

Table 3. Comparison of freshwater fish species in rivers of Mt. Hamiguitan Range Wildlife Sanctuary, Philippines

Family/Species	**Quimpang et al. 2016**		**In this present study**			**Assessment**
	Maug	**Dumagooc**	**Maug**	**Dumagooc**	**Banahaw**	
Ambassidae						
Ambassis dussumieri (Cuvier,1828)*		x				Native
Ambassis interrupta Bleeker, 1853					x	
Anguillidae						
Anguilla marmorata Quoy & Gaimard, 1824	x	x	x	x	x	Native
Butidae						
Oxyeleotris lineolata (Steindachner, 1867)*	x	x				Native
Oxyleotris sp.					x	
Butis amboinensis (Bleeker,1853)		x				Native
Ophiocara porocephala (Valenciennes, 1837)		x				Native
Cyprinidae						
Barbodes bantolanensis (Valenciennes, 1842)	x	x	x	x		Endemic
Puntius sp.			x			
Eleotridae						
Allomogurnda insularis (Allen, 2003)*	x	x				Native
Eleotris oxycephala (Temminck and Schligel, 1845)*	x	x				Native
Mogurnda mogurnda (Richardson, 1845)	x	x	x			Native
Eleotris acanthopoma (Bleeker, 1853)		x	x	x	x	Native
Eleotris fusca (Foster, 1801)		x	x	x	x	Native
Gobiidae						
Acentrogobius janthinopterus (Bleeker,1853)*		x				Native
*Awaous grammepomus (*Bleeker, 1849)	x	x				Native
Callogobius hastatus (McKinney and Lachner, 1978)*		x				Native
Callogobius maculipinnis (Fowler, 1978)	x	x				Native
Glossogobius celebius (Valenciennes, 1837)			x			Native
Gobioterus mindanensis (Herre,1944)**	x	x				Native
Lintipes mindanaoensis Chen, 2004			x	x		Native
Oligolepis acutippenis (Valenciennes, 1837)		x				Native
Sicryopterus micrurus (Bleeker, 1853)	x	x			x	Native
Sicryopterus lagocephalus (Pallas, 1770)	x	x	x	x	x	Native
Sicyopterus longifinis de Beaufort, 1921			x	x		Native
Sicyopus zosterophorus Bleeker, 1856					x	Native
Schismatogobius marmoratus (Peters, 1868			x	x	x	Native
Stiphodon atropurpureus (Herre, 1927)		x	x	x	x	Native
Stiphodon elegans (Steindachner, 1879)			x	x	x	Native
Hemiramphidae						
Hyporchampos affinis (Stephanidis,1971)		x				Native
Kuhlidae						
Kuhlia marginata (Cuvier,1829)	x	x	x		x	Native
Latidae						
Waigieu seaperch (Cuvier,1828)**		x				Native
Loricarridae						
*Pterygophicthys pardalis***	x					Introduced
Mugilidae						
Chelon subviridis (Valenciennes,1836)*		x				Native
Muraenidae						
Gymnothorax sp				x	x	Native
Ophicephalidae						
Ophicephalus striatus (Bloch, 1793)*		x				Introduced
Ophichthidae						
Ophichthus apicalis (Bennett, 1830)*	x	x				Native
Poeciliidae						
Gambusia affinis (Baird &Girard, 1853)	x	x				Introduced
Poecilia reticulata (Peters, 1859)	x	x		x		Introduced
Rhyacichthidae						
Rhyacichthys aspro (Valenciennes, 1837)					x	Native
Sillaginidae						
Sillago sihama (Forsskål,1775)		x				Native
Syngnathidae						
Doryichthys boaja (Bleeker, 1854)		x	x	x		Native
Hippichthys heptagonus (Bleeker, 1849)			x	x	x	Native
Hippichthys sp			x	x		Native
Microphis brachyurus (Valenciennes, 1842)			x			
Bhanotia fasciolata (Dumirel, 1870)*		x				Native
Terapontidae						
Terapon jarbua (Forsskål, 1775)		x				Native

Note: *Not Listed in the Philippines Freshwater Fishes (www.fishbase.com). **Corrected identification from Quimpang et al. (2016)

This could be because the upstream stations were dominated by trees, shrubs, ferns, and lycophytes and were in higher elevations. Open grassland with human settlements was observed in downstream stations, and the river flow led to the open ocean. These observations contradict the study of Quimpang et al. (2020) in the two rivers of Mt. Apo, where the temperature of the two rivers' upstream stations is much higher than their downstream stations.

The optimal temperature for tropical freshwater fish species ranges from 24-27°C, depending on the species. Most stations have suitable temperatures for fish except downstream of Banahaw river with slightly hot temperatures, possibly not suitable for some species (Table 4). Water temperatures higher than 32°C might cause fish to die.

Total Dissolved Solids (TDS)

A higher recorded level of Total Dissolved Solids (TDS) was observed downstream of Maug (229.67mg/L) and Banahaw (263.67 mg/L) rivers (Figure 4G.). The recorded temperature level in the Dumagooc river midstream station was 23.7 ˚C, much cooler than its upstream. This was due to the level of dissolved solids of around 169 mg/L in the area, where soil erosion happened during road construction. According to the study of Martinez et al. (2011), the increase in dissolved and suspended solids can increase temperature mainly because the dissolved solids absorb more heat.

Turbidity

The turbidity level in the midstream station of Maug River was around 3.26 NTU (Table 4). The high turbidity level indicates the presence of colloidal particles from discharges of sewage and industrial waste, from silt and clay during rainfall, or the presence of many microorganisms (Olatayo 2013). Hence, the landslides and soil erosion from the ongoing road widening may contribute to the turbid water of the midstream station of Maug River.

Dissolved Oxygen (DO)

The DO is one of the important regulators of the river systems' chemical processes and biological activity and the essential parameter for all aerobic organisms (Tumanda et al., 2003). Furthermore, this parameter can also be used as an index of water quality, primary production, and pollution.

Fluctuating measurements of Dissolved Oxygen (DO) were recorded in the three rivers. Moreover, in the case of Dumagooc River, a higher DO with 7.99 mg/L was observed in the midstream station with a lower temperature level (Figure 4F). This observation supports the study of George et al. (2003), stating that low DO concentrations reveal higher temperatures.

The water conductivity in the Maug River was increasing from upstream with 76.18 mV to downstream with 150.23 mV average measurements (Figure 4C). According to Goncharuk et al. (2010), the oxidation-reduction potential or ORP, an essential indicator of natural and wastewater values ranging from 76 mV to 344.6 mV, verifies the observed data. Furthermore, George et al. (2013) stated the inverse relationship of ORP and temperature; as the ORP value decreases, the temperature level increases.

pH

The pH means a value of the three rivers, namely Maug, Dumagooc, and Banahaw, falls within the set standard by DENR and DOH (Table 4). Almost the same pH range was also observed in the study of Quimpang et al. 2018 in Lake Duminagat, Mt. Malindang. Maug and Banahaw Rivers both have lower pH readings downstream, with an average of 7.52 and 7.54, respectively (Figure 4B). In contrast, the Dumagooc River has a lower average pH value of 8.08 in the midstream station. Heavy rainfall was observed during the reading of the water quality parameters. This event could be the reason for the lower pH reading in these rivers. This observation correlates to the study of Davie (2008) that rainfall naturally lowers the pH value. Moreover, Cuivillas et al. (2016) stated that the water pH in a river is mainly affected by its age and the chemicals discharged from communities and industries. Moreover, the pH of water is an important parameter that influences other components of water quality.

Table 4. Mean parameter values of Dumagooc, Maug, and Banahaw River, Philippines

Parameter	Dumagooc River			Maug River			Banahaw River		
	DUS	**DMS**	**DDS**	**MUS**	**MMS**	**MDS**	**BUS**	**BMS**	**BDS**
Temperature °C	24.10	23.70	25.30	21.18	23.20	26.60	23.80	24.80	27.50
pH	8.18	8.08	8.31	8.27	8.17	7.52	8.08	8.26	7.54
ORP mV	78.34	134.28	136.01	76.18	85.77	150.23	200.76	142.09	152.78
SPC-µS/cm	0.24	0.26	0.26	0.21	0.25	0.35	0.26	0.34	0.41
Turbidity (NTU)	0.17	0.42	0.45	2.06	3.26	1.82	1.05	0.78	0.97
DO mg/L	7.84	7.99	7.91	7.51	8.16	7.07	7.72	7.89	6.61
TDS mg/L	176.11	169	172	138	163.56	229.67	168	227.11	263.67

Note: DUS: Dumagooc Upstream, DMS: Dumagooc Midstream, DDS: Dumagooc Downstream, MUS: Maug Upstream, MMS: Maug Midstream, MDS: Maug Downstream, BUS: Banahaw Upstream, BMS: Banahaw Midstream, BDS: Banahaw Downstream

Figure 4. Distribution mean values of physicochemical properties of the three river systems of Mt. Hamiguitan Range Wildlife Sanctuary. A. temperature of Maug, Dumagooc and Surop River, B. pH of Maug, Dumagooc and Surop River, C. ORP mv of Maug, Dumagooc and Surop River, D. SPC - µS/cm of Maug, Dumagooc and Surop River, E. Turbidity of Maug, Dumagooc and Surop River, F. DO of Maug, Dumagooc and Surop River and G. TDS of Maug, Dumagooc and Surop River

Discussion

As to the physicochemical characteristics of the three river systems, the results showed that the DO of the sampling sites is within the minimum acceptable limit of 5mg/L to be considered as within the standards for class AA, A, and B rivers. This implies that the level of organic substances in all the sampling sites has not influenced the level of DO in the water. For the NTU, the concentration of all sites reached up to the standards, which range from 0.17mg/L to 3.26 mg/L for class AA, A, B rivers. The NTU provides the visual quality of the water with higher concentration signifying highly turbid water. The rest of the parameters, such as the pH and temperature, are within the standard ranges of DAO 2016-08 (DENR, 2016) and the TDS of DAO 34 (DENR, 1990). The scale morphology is recommended for future study as scale characters may constitute criteria for differentiating fish species within and among populations (Dapar et al., 2012).

Furthermore, it is evident that these riparian sites face threats brought by human activities like converting nearby lands to agricultural areas clearing the natural vegetation. The riparian ecosystems give direct benefits to the community like a source of potable water for the municipality of San Isidro, Governor Generoso Mati City Davao Oriental, hence riparian ecosystems should be included as a vital component in the management plan of the different LGUs with DENR by planting of indigenous tree species along the riparian zone.

Policy recommendations

Each river system should be mapped to indicate the areas that are still intact, disturbed, and denuded (i). The disturbed and denuded areas of the riparian ecosystems should be planted with indigenous/endemic tree species on each site and not exotic or introduced species (ii). Each riparian site is recommended to have a nursery of indigenous tree species as a source of seedlings to rehabilitate denuded or disturbed areas of the riparian ecosystem (iii). Cultivation of cash crops should be at least 20 meters away from the riverbanks (iv). Local communities should be involved in the riparian rehabilitation with the local government units in coordination with the DENR spearheading the activity (v). The management plan should be strategized with the stakeholders by planting indigenous tree species along the riparian zone for future environmental sustainability (vi).

The present study presents an updated assessment of the fish species richness and physicochemical characteristics of selected river systems of Mt. Hamiguitan Range Wildlife Sanctuary (MHRWS). To conclude, the MHRWS supports diverse and abundant freshwater fishes that include one endemic species, 29 native species, and two introduced species. As for the physicochemical properties of the water, there is no significant difference between the three river systems. Habitat disturbance, the presence of introduced species, and other environmental factors could have influenced the species richness of the three study sites. Anthropogenic activities were also observed, which pose threats to the MHRWS river systems. Hence, the local government unit (LGU) and stakeholders must initiate effective ecological management for fish species' future protection and sustainability.

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Chromium content in fish and rice and its effect on public health along the downstream Opak River, Bantul District, Indonesia

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Abstract. *Rahardjo D, Djumanto, Prasetyaningsih A, Laoli B, Manusiwa WS. 2021. Chromium content in fish and rice and its effect on public health along the downstream Opak River, Bantul District, Indonesia. Intl J Bonorowo Wetlands 11: 69-74.* The activities of the leather home industry are overgrowing, causing the liquid waste flowing into the river also to increase so that the threat to the river ecosystem and river water users also increases. This study aimed to determine the concentration of chromium in environmental components, agricultural commodities, fisheries, and the risk to public health. Sampling was carried out from February to August 2020 in irrigation canals and rice fields using the Opak River flow. The number of sampling locations is determined at six stations. Water, sediment, fish, and rice were collected as samples at each station. All samples were analyzed using Atomic Absorption Spectrophotometry (AAS). The results showed that chromium metal is found in solid or mineral compounds with other elements. The highest concentration was found in rice plants with an average of 1.0105-6.2870 mg/kg, followed by rice fields (1.2062 mg/kg), river sediments (0.7126), fish (0.3799-0.8489), irrigation water (0.2393 mg/L), and the lowest were found in river water (0.0188 mg/L). The Tolerable Maximum Intake of chromium in tilapia meat was 3.0271 kg/week and Spotted barb meat was 1.3546 kg/week. The daily intake of chromium in rice ranged from 18.475 to 28.733 (mg/kg BW/day). Hazard quotient (HQ) level of consumption of chromium-contaminated rice ranged from 4.618-7.183. The HQ value at all research sites exceeds the safe value for health set by World Health Organization (WHO), namely HQ<1.

Keywords: Contamination, heavy metals, home industry, Yogyakarta.

INTRODUCTION

The Governor of the Special Region of Yogyakarta, Sri Sultan Hamengku Buwono X, has inaugurated an integrated Industrial Estate in Srimulyo and Sitimulyo, Piyungan Sub-district, Bantul District, whose development is environmentally friendly and labor-intensive (Asmadi et al. 2009). Developing the Industrial Estate is expected to overcome welfare inequality between regions, equal distribution of the economy and employment opportunities, and move the local economy. The number of industries currently is 12 units, and 10 of them are leather industry. One of the ten leather industry units has carried out waste treatment relatively well. In contrast, the rest have not processed their waste and do not even have documents for Environmental Management Efforts and Environmental Monitoring Efforts (UKL-UPL) (Asmadi et al., 2009). This condition places the environment and society in a vulnerable position to contamination and receives health impacts from waste disposal that has not been appropriately managed.

The leather tanning industry is one type of industry that, in its production process, uses a lot of water and some chemical liquids, such as chromium (III) salts and sulfur compounds (McLaughlin et al., 2000). Based on the results of monitoring waste disposal by the Environmental Agency of Bantul District in 2015 (Asmadi et al. 2009), it is known that the waste disposal of six leather factories into the Opak River does not meet quality standards. Disposal of industrial leather waste containing heavy chromium metal can cause environmental pollution and threaten public health (Rajeshkumar and Li 2018).

Chromium contaminants are toxic, carcinogenic, bioaccumulative, and biomagnifying (Wardhana 2004; Kosnett 2007; Plaa 2007; Laibu et al. 2018; Pranoto et al. 2019). The continuous disposal of leather industry wastewater into the environment will cause the heavy metal chromium to spread to various environmental components in Banyakan village. The spread of heavy metal chromium can be through irrigation water, healthy water, sediment, soil, different types of food plants, aquatic animals, and can even accumulate in the hair and nails of villagers (Rahardjo 2014; Odongo et al. 2019). These results are corroborated by research conducted by Rahardjo (2015), that the heavy metal chromium has been distributed in almost all environmental components of Banyakan village such as water (1.538 mg/L), sediment (68.85 mg/kg), soil (1.582 mg/kg), shallow groundwater (0.352 mg/L), plants (14.870 mg/kg), aquatic animals (9.269 mg/kg). In addition, aquatics biotics found in these waters contain heavy metal chromium with varying concentrations ranging from 0.3-12.32 mg/kg, with an average of 3.76 mg/kg. The chromium concentration in water, sediment, and aquatic biotics from 2014 to 2016 continued to increase (Rahardjo and Prasetyaningsih 2017). Accumulation of heavy metals through the food chain can affect human health (El-Kammar et al., 2009).

The wider distribution, the increasing concentration on the environment, and the accumulation of various components of living organisms pose a dire threat to the diverse agricultural, fishery, and public health businesses around industrial areas. This condition is certainly counterproductive to the initial goal of developing the Piyungan Industrial Estate, which is for equity and encouraging economic growth in the Piyungan sub-district. Therefore, it is necessary to conduct a comprehensive study on the profile of chromium contamination along the Opak River and its effects on agricultural commodities, fisheries, and public health. The output of this research is expected to be used as a reference for determining recommendations by policymakers to make efforts to manage the environment better to avoid losses and public health problems.

MATERIALS AND METHODS

Description of the study sites and collection of samples

Sampling was carried out in February and August, representing the rainy and dry seasons. The number of areas sampled was six sub-districts: Piyungan, Banguntapan, Pleret, Jetis, Imogiri, and Pundong, Bantul District, Indonesia (Figure 1). Sampling stations in each sub-district are irrigation canals and rice fields that flow from the Opak River. Each sub-district has three sub-stations for sampling river water, irrigation water, irrigation sediment, paddy soil, and rice grains.

Eight samples were taken at each station (S1-S6), namely water samples consisting of river water, irrigation water, and healthy water. Then river sediments and paddy fields, while aquatic biota consists of fish, mollusks, and plants. Water samples were taken from the channel column using a 1 L sample bottle, while the bottom sediment was taken using a shovel as much as 100 g. The water sample was then added with concentrated HNO_3 as a preservative by 3% by volume and cooled at 4°C (APHA 2001). Fish are caught with cast nets, while mollusks are collected by handpicking. The rice plants collected consisted of 10 g of rice roots and grains, each stored separately using a plastic bag. Samples of water, sediment, biota, and rice are then brought to the laboratory using a cool box.

Chromium analysis

Water samples were extracted by adding 10 mL of concentrated HNO_3 to 100 mL of sample water. The sample water is then heated at 100°C until the remaining volume is ± 50 mL. This procedure was repeated once with the addition of concentrated HNO_3 and heating of the sample. The extracted water was then filtered using filter paper soaked with 1% HNO_3 then stored in a sample bottle.

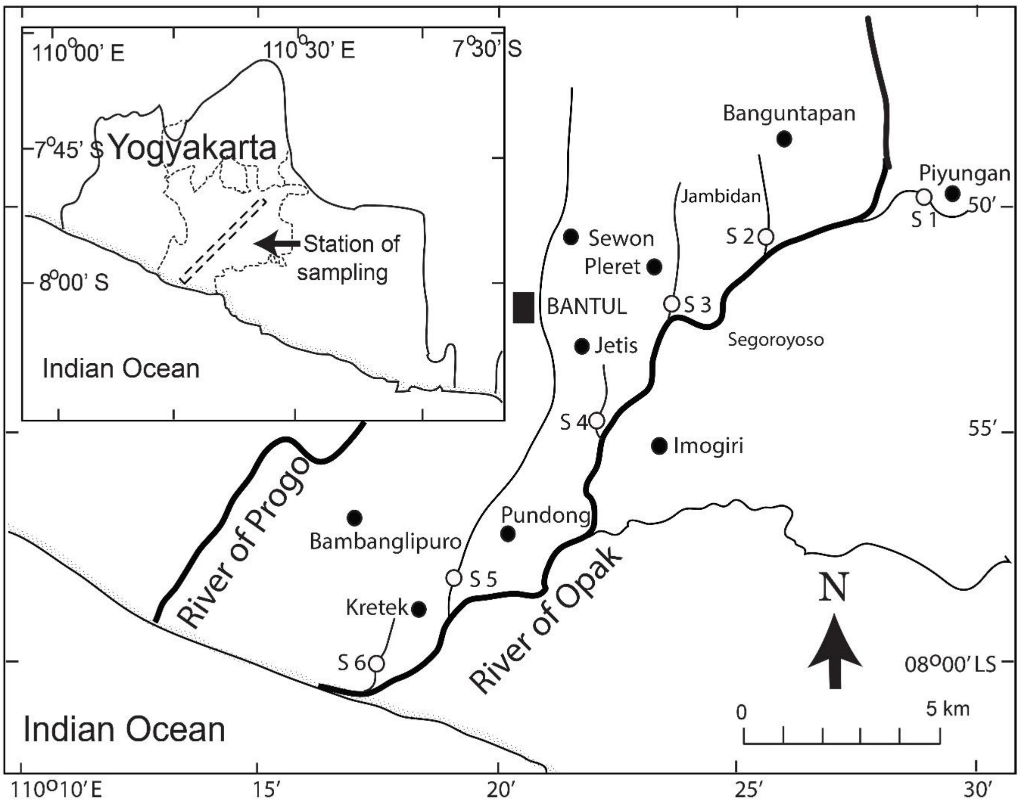

Figure 1. Determination of sampling stations in irrigation canals and rice fields in Piyungan, Banguntapan, Pleret, Jetis, Imogiri, and Pundong, Bantul District, Indonesia, received the Opak River flow. Sampling stations are indicated by open circles S1-S6.

Soil sediment samples were extracted by the acid method (USEPA 1996). The solid sample was heated using an oven at 60°C until the sample was dry. Next, as much as 3 g of dry sample was added, 18 mL of HCl and 6 mL of concentrated HNO_3. Then the sample is heated until the volume remains ±10 mL. The procedure was repeated once with concentrated HCl and HNO_3 solutions added to the sample and heating. The sample was then filtered using filter paper soaked in 1% HNO_3.

Fish and mollusk samples were extracted using the acid method. Each 2 g was taken and put into an Erlenmeyer, and then aqua regia was added in a 1-part HNO_3^{+3} parts HCl ratio so that the volume was 10 mL. The sample is heated using a stove, and this process is repeated twice. The sample extract obtained was transferred into a 10 mL volumetric flask. If the volume is less than 10 mL, distilled water is added. The extract was then filtered using filter paper.

Rice plant samples consisting of roots, stems, leaves, and grains were extracted using the acid method. The rice plant was separated, washed using distilled water three times, and rinsed using deionized water. Then the sample was dried using an oven at a temperature of 65°C. Then the sample was pulverized using a mortar and stored. Each plant sample used for extraction was 2 g.

Chromium content in the sample extract was measured using the Atomic Absorption Spectrophotometry (AAS) method based on SNI 06-6989.17-2004 (Indonesian National Standardization Agency 2004). The analysis process was carried out with the PerkinElmer PinAAcle 900T Atomic Absorption Spectrometer.

The AAS analysis was carried out in several stages: measuring the chromium concentration, comparing it with a calibration curve, and calculating the concentration. After measurement, the data obtained is calculated to obtain the concentration of chromium in the sample using the formula:

$$K= (C \times B) \times V/w$$

Description K is the concentration of Cr (mg/kg), C is the concentration of the measured sample (mg/kg), B is the concentration of the blank (mg/kg), V is the final volume of extract (10 ml) in the sample being tested, and w is the weight of the sample.

Health risk analysis

The formula can determine heavy metals that enter the body daily:

$$\text{Daily intake}=\sum(Ci \times li)/BW$$

Daily intake results from multiplying C, the heavy metal concentration (ppm), and I, namely ingestion rate (g/day). The average I in Indonesia is 223 g/day. I was then divided by BW, namely the average body weight of Indonesian adults, 60 kg (Heikens et al. 2005). The level of consumption risk or Hazard quotient (HQ) is the risk of consuming rice contaminated with heavy metals. HQ value < 1 is declared safe for health and otherwise dangerous if HQ > 1. Tolerable Daily Intake (TDI) is a safe tolerance dose for daily consumption of toxic chemicals. According to World Health Organization (WHO) (1996) in Baars et al. (2001), the value of TDI in rice, the estimated long-term value of the effect of heavy metals in the body or HQ can be calculated by the formula:

$$HQ = \text{Daily intake} / TDI$$

RESULTS AND DISCUSSION

Results

Table 1 presents chromium concentrations in river and irrigation water, river sediments, and rice fields. In all samples observed, heavy metal chromium was found with varying concentrations. The highest chromium concentration was found in the paddy soil samples with a range of 1.0370-1.6990 mg/kg and an average of 1.2062 mg/kg, then in river sediment samples with a range of 0.0736-1.4923 mg/L and an average of 0.7126 mg/L. And the concentration of chromium in irrigation water with a concentration range of 0.3000-0.1530 mg/L and an average of 0.2393 mg/L. Finally, the lowest chromium concentration was found in river samples with a 0.0004-0.0596 mg/L range and an average of 0.0188 mg/L.

The chromium concentrations in aquatic organisms and rice are presented in Table 2. The studied samples consisted of fish and all parts of the rice plant, which showed that chromium concentrations were at various levels. The chromium concentration in tilapia varied from 0.0004 to 0.6570 mg/kg, while in bony lip barb, it was 0.1780-1.4850 mg/kg. The Director-General of BPOM issued a regulation Number 0375/B/SK/89 concerning the maximum chromium concentration limit of 2.5 mg/kg. The chromium concentration in fish is still lower than the standard from BPOM. However, the Food and Agriculture Organization of the United Nations (FAO) has set a 1 mg/kg threshold. The bony lip barb fish samples at stations 2,4 and 5 have exceeded the threshold set by FAO. The average chromium content in the rice root samples was 2.416 ± 0.657 mg/kg, 1.011 ± 0.202 in the rice stem, 1.547 ± 0.292 in the leaves, and 6.287 ± 0.920 in the rice grains. The chromium concentration in rice grains is 5X more than in rice fields, resulting in a very high accumulation of chromium in rice grains. If the maximum limit of chromium concentration is 2.5 mg/kg, then the chromium concentration in rice is 2.5X more than the standard allowable limit. The chromium concentration in aquatic organisms consisting of tilapia and bony lip barb is much lower than the maximum permissible standard. The chromium concentration in bony lip barbs (herbivores) is higher than tilapia (omnivores). The chromium concentration in fish and rice between sampling locations varied and did not trend.

Table 1. The concentration of chromium (mg/L) in river water, irrigation canals, river sediments, and paddy fields between study sites

Sample type	S1	S2	S3	S4	S5	S6	Average	Std	Standards*
River	0.0596	0.0521	0.0004	0.0004	0.0004	0.0004	0.0189	0.029	0.05 (*)
Irrigation water	0.153	0.226	0.215	0.255	0.287	0.300	0.2393	0.054	0.05 (**)
River Sediment	0.813	1.492	0.706	0.607	0.584	0.074	0.7126	0.459	80.0 (***)
Rice field soil	1.699	1.168	1.037	1.198	1.071	1.064	1.2062	0.250	2.5 (***)

Note: (*) Directorate General of Drug and Food Control 1989; (**) Australian and New Zealand Environment and Conservation Council 2000; (***) Ministry of State for Population and Environment of Indonesia, and Dalhousie University, Canada 1992

Table 2. The concentration of chromium (mg/kg) heavy metal in fish and rice plants

Sample type	S1	S2	S3	S4	S5	S6	Mean	Std
Tilapia	0.638	0.492	0.0004	0.657	0.0004	0.492	0.380	0.302
Bonylip barb	0.771	0.553	1.105	0.178	1.485	1.002	0.849	0.456
root	1.249	1.092	1.169	2.553	0.802	0.768	2.416	0.657
stem	1.394	1.058	0.830	0.944	0.889	0.948	1.011	0.202
leaf	2.032	1.778	1.395	1.438	1.318	1.321	1.547	0.292
rice	6.331	7.731	6.611	5.736	6.342	4.971	6.287	0.920

The chromium concentration in rice plants consisting of roots, stems, leaves, and rice grains showed a higher concentration than chromium concentration in fish. These data indicate that fish accumulate less chromium than plants. Compared with chromium concentration in river sediments, chromium concentration in river water showed an accumulation of 37.7 times higher. Likewise, chromium concentration in the deposition of paddy soil compared to irrigation water showed a collection of 4.6X times higher. These data indicate that chromium as the heavy metal will accumulate in the sediment more. The accumulation of chromium increases as it is further away from the waste disposal center containing chromium.

Farmers were given a questionnaire to determine the amount of rice consumption. The amount of rice consumed by farmers is then used to calculate the daily intake of Cr. The results of the questionnaire data analysis on rice farmers showed that the daily intake of Cr in rice ranged from 18.5 to 28.7 (mg/kg BW/day), so that the value of chromium intake at all locations had exceeded the quality standard of 0.023 mg/kg/day (USEPA 2011). Based on the calculation of the HQ value, which describes the level of risk of rice consumption that accumulates chromium, the results of the HQ value range from 4.618 to 7.183. The HQ value at all study sites has exceeded the safe value for health set by WHO, namely HQ<1. The Provisional Tolerable Weekly Intake (PTWI) value of chromium set by WHO/FAO (2004) is 23.3 g/kg. The Maximum Weekly Intake (MWI) value within one week, assuming an adult weight of 50 kg, then the maximum value of chromium concentration in fish meat consumed is 1.15 mg Cr/week. Meanwhile, the Tolerable Maximum Intake (TMI) of chromium in tilapia meat is 3.0271 kg/week, and bony lip barb fish meat is 1.3546 kg/week.

Discussion

The leather tanning industry uses chromium for tanning. The home tanning industry in the Piyungan Industrial Estate (KIP) is suspected to be the source of the entry of chromium into the environment, especially in the downstream waters of the Opak River. KIP that disposes of liquid waste from the leather home industry into the Opak River causes the heavy metal chromium to be distributed, absorbed, and accumulated in various aquatic organisms downstream of the Opak River. The chromium concentration was found in higher amounts in paddy soil and river sediments than chromium concentration in river water and paddy field water. These results align with the research results conducted by Webera et al. (2013) and Rahardjo and Prasetyaningsih (2017) that chromium pollutants are most widely distributed in sediments than in water. It is due to the nature of chromium, which binds organic matter quickly to sediment or soil (Harahap 1991). Although chromium concentration in rice fields and river sediments is the highest, according to the Indonesian Ministry of Population and Environment and Dalhousie University, Canada (1992), the concentration is still below the critical limit of 2.5 ppm. Although chromium concentration in river and rice field sediments is still below the threshold, absorption, translocation, and bioaccumulation mechanisms can cause a high accumulation of chromium pollutants in various mollusk aquatic biota, fish, and various agricultural commodities.

Meanwhile, chromium concentration in water was found in relatively small amounts, but this amount had exceeded the specified quality standard of 0.05 mg/L, especially in irrigation water. Based on the results of this study, the existence of a tannery home industry that dumps its liquid waste into the river is a potential source of chromium pollution along the downstream Opak River and along with irrigation flows and rice fields. The location adjacent to the liquid waste disposal source has a higher concentration of chromium pollutants than other locations.

The concentration of chromium in fish is lower than in rice because fish are actively moving or transported from one location to another in search of suitable habitats, including avoiding polluted environments and finding food sources. In addition, Aquatic organisms, such as fish, have fast movements to prevent the effects of pollution (Edward 2019). However, fish that live in closed/restricted habitats, such as ponds, reservoirs, lakes, and bays, will find it difficult to avoid the effects of pollutants. In addition, tilapia and bony lip barb feed in the form of phytoplankton or zooplankton, which has a small accumulation of heavy metals. Meanwhile, rice plants that live permanently in specific locations and continuously for about 3-4 months will contact chromium to allow higher absorption, transformation, and accumulation.

The highest accumulation of chromium concentration in rice was found in the grain, followed by leaves, roots, and lowest in the stem. The very high mobility of chromium from the rice plant roots to the plant organs can cause heavy metals in rice grains and leaves. As a non-essential metal that is highly toxic, Cr metal can affect the high mobility from roots to leaves and grains of plants (Yoon et al. 2006). This effect mainly occurs during photosynthesis, synthesis of antioxidant enzymes, and chlorophyll synthesis. The accumulation process occurs in cells chemically to be toxic to plants.

Meanwhile, the concentration of chromium contaminants in the roots and stems was lower than in the leaves and grains. It is caused by the chromium absorbed by the roots being directly mobilized to other organs for metabolic processes. The roots absorb heavy metals in the soil, then transported to the stem through the endodermis, and then translocated to the plant's shoots through the xylem (Irhamni et al., 2018). Xylem sap through the membrane carries heavy metals to shoots and leaves. The presence of chromium in various environmental components poses potential environmental and health risks. Through direct contact, drinking and ingesting contaminated food can pose a severe threat to human health (Al-Saleh et al. 2004; Park et al. 2004; Komárek et al. 2008; Lu et al. 2011).

The high chromium concentration in fish and rice grains and the high rice consumption pattern resulted in a high rate of chromium intake through fish and rice consumption. Based on direct interviews with several farmers, most of the harvested rice is consumed by themselves. If there is excess, it is only sold in markets closest to the residence. The HQ calculation results show that all areas have HQ values ranging from 4.618 to 7.183, much higher than that set by WHO, namely HQ<1. It indicates that the community's consumption of fish and rice has an unsafe level of risk. It is necessary to conduct a risk management study by determining the safe limit of chromium concentration, amount of consumption, time, frequency, and duration of exposure. In addition, risk management programs can be more focused on technological approaches, for example, improving the production process and processing of leather industry waste, socio-economic systems, and institutional strategies for leather tanning industry artisans and the government.

To conclude, the chromium-contaminated wastewater from the leather tanning industry, discharged into the Opak River, is the main factor causing the distribution of chromium in various environmental components. The chromium is found in different ecological parts. The highest chromium concentration was found in rice grains, followed by rice fields soil, river sediments, fish, irrigation water, and the lowest river water. The TMI of chromium in tilapia and bony lip barb is much higher than the MWI set by WHO/FAO. The value of the daily intake of chromium in rice far exceeds the limit set by the USEPA (2011). The hazard quotient level of consumption of chromium-contaminated rice at all research sites far exceeds WHO's safe value for health.

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Crab diversity and crab potential as support ecotourism in Teleng Ria, Grindulu and Siwil Beach, Pacitan, East Java, Indonesia

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Abstract. *Irwansyah RM, Azzahra SIN, Darmastuti SA, Ramadhandi AR, Firdaus O, Daeni F, Safitri N, Fajri OPA, Nugroho GN, Naim DM, Setyawan AD. 2021. Crab diversity and crab potential as support ecotourism in Teleng Ria, Grindulu and Siwil Beach, Pacitan, East Java, Indonesia. Intl J Bonorowo Wetlands 11: 75-83.* The mangrove area in Pacitan District, Pacitan, East Java, Indonesia, is generally not polluted. Therefore, the land is suitable for growing conditions from mangrove plants and has great potential as a mangrove area with ecotourism management in Indonesia. Ecotourism activities in mangrove areas, in principle, are the use of mangrove areas while maintaining the biological/ecological functions of mangrove areas that have social and economic value for the local community. The mangrove ecosystem is a habitat of various species of Crustacea, such as the crab. Crabs are live in coastal/mangrove ecosystems and one of the key species that have a very important role in maintaining the balance of the ecosystem. The study about the diversity of crabs in the mangrove area is very important because it will improve mangrove quality and potentially support ecotourism in the mangrove ecosystem. This study aims to determine the diversity of the crab and its potential to support ecotourism if the Pacitan Beaches are ecotourism in the future. This research was conducted in Teleng Ria Beach, Grindulu Beach, and Siwil Beach, Pacitan, East Java, Indonesia, in November 2021. Plots of 10 x 10 m2 are made to record the species and the number of individual crab species. The result found five species of crab, i.e., *Austruca annulipes* (H. Milne-Edwards, 1837), *Coenobita perlatus* (H. Milne-Edwards, 1837), *Ocypode kuhlii* (De Haan, 1835), *Perisesarma guttatum* (A. Milne-Edwards, 1869), and *Scylla serrata* (Forsskål, 1775). The total crab diversity index of 1.25 is included in the medium category. The morphology, activity, number of individuals, and distribution of each crab species in an ecotourism area will increase the attractiveness of tourists to visit. For example, the morphology of *C. perlatus* that has the red color as a strawberry sometimes has a home/the shells of the Mollusca which color and unique shape so that add appeal to be seen. Then, the crab *A. annulipes* that like to dance and play the violin with the claw can also be attractions drawing tourists. Hopefully, the data can be a reference for the managers of the mangrove area in developing ecotourism and conservation of mangrove forest.

Keywords: Crab, diversity, ecotourism, mangrove, Pacitan

INTRODUCTION

Mangrove area can be defined as a forest type that grows in tidal areas, especially on protected beaches, lagoons, river mouths that are flooded and free from inundation at low tide whose plant communities tolerate salt (Kainuma et al. 2013; Junk et al. al. 2014). The benefits of mangroves in coastal areas are in the form of environmental distribution and neutralizing the presence of harmful pollutants, reducing approximately 50% of the strength of tsunami waves, and protecting coastlines. In addition, mangroves have a high productivity role compared to other ecosystems, thus making mangrove ecosystems necessary for the life of living things (Li et al., 2015). Furthermore, the mangrove ecosystem consists of organisms (plants and animals) interacting with environmental factors in a mangrove habitat (Vermeiren et al., 2015; Onyena and Sam 2020).

One of the organisms that live in the mangrove area is Crustacea. Crustacea, such as crabs, are macrobenthic animals associated with mangroves. Ecologically, mangrove areas have high productivity to support the surrounding environment because they are rich in nutrients with optimum temperature, pH, oxygen, and salinity and calm water conditions so that they are suitable for crab habitat (Sen et al. 2014; Alvareza and Leilani 2020). Crabs eat suspended matter (filter feeders), eat mangrove litter and fresh mangrove leaves, and are generally dominant on sandy and muddy substrates.

The presence of crabs is an essential indicator in the mangrove ecosystem (Freitas et al., 2021). This is because crab has an important role ecologically and economically. The ecological part of crabs in the mangrove ecosystem includes converting nutrients and enhancing mineralization, increasing the distribution of oxygen in the soil, helping the carbon life cycle, and providing natural food for various species of aquatic biota. Crab also has a high economic value because humans can sell it as a high protein food ingredient. In addition, according to Ginantra et al. (2021), the presence of crabs in the mangrove ecosystem can also be useful as an additional attraction for ecotourism activities.

Ecotourism activities in mangrove areas, in principle, are the use of mangrove areas while maintaining the biological/ecological functions of mangrove areas that have social and economic value for local communities (Duangjai et al., 2014). The conservation of mangrove areas and the ecotourism business are highly dependent on the diversity of animals and plants that live in them (Hakim et al., 2017). Ecotourism can be used as a conservation measure to protect mangrove areas and the organisms that live in them, such as crabs. A mangrove ecosystem that is used as ecotourism will increase conservation and reduce things that damage mangrove areas, such as (i) felling of mangrove trees, (ii) conversion into fish and shrimp farming pond areas, land clearing for settlements or agricultural areas, and (iii) landfills or toxic waste. The degradation of the mangrove area causes changes in the composition and structure of mangrove vegetation, destroys the balance of ecosystems and habitats (physical and chemical environmental factors), as well as the extinction of species of organisms, such as crabs (Nowak 2013).

The mangrove area in Pacitan District is quite extensive and spread over several points, such as Teleng Ria Beach, Siwil Beach, and Grindulu Beach. Research that has been conducted on the species of mangrove trees in the Pacitan mangrove area is dominated by *Rhizophora mucronata*, *Avicennia alba*, *Sonneratia alba*, *Nypa fruticans*, *Avicennia marina*, which are the result of planting (Setyawan et al. 2002). Mangrove areas in Pacitan District are generally not polluted, and the land has the potential to grow mangrove plants (Pacitan District Marine and Fisheries Service 2014). This area has a coastline of 70,709 km^2 (Central Bureau of Statistics of Pacitan District 2021), which can be a mangrove area for ecotourism management in Indonesia.

It is very important to research crab diversity in the mangrove area because it will improve the quality of mangroves and potentially support ecotourism in the Pacitan mangrove ecosystem. The diversity, abundance, morphology, activity, number of individuals, and distribution of each crab species will interest tourists. In addition, research data on crab diversity has never existed in Pacitan. Therefore, this study aims to determine the diversity of crabs and their potential to support ecotourism if Teleng Ria Beach, Grindulu Beach, and Siwil Beach, Pacitan, East Java, Indonesia, will be used as ecotourism in the future. It is hoped that this data can be a reference for managers of mangrove areas in developing ecotourism and efforts to conserve mangrove forests.

MATERIALS AND METHODS

Study area

This research was conducted on November 2021 at three coastal locations with mangrove ecosystems: Teleng Ria and Grindulu Beach in Pacitan Sub-district and Siwil Beach in Ngadirojo Sub-district, Pacitan District, East Java, Indonesia (Table 1). Apart from having a mangrove ecosystem, the three locations were chosen because of their proximity and affordable access (Figure 1).

Sampling technique

Twenty-five plots measuring 10m x 10m at each study site have been created. Plot selection was based on the different substrates in each location. After that, the species and number of crabs in each plot were counted and recorded. Then, abiotic environmental factors such as air, water and soil temperature, water and soil pH, and water salinity were made. Then, this study also recorded the dominant tree mangrove species in each research location. Finally, crab retrieval is done using a handpicking technique, a net tool, and a shovel to dig into the ground the crabs are hiding. The caught crabs were then put into bottles and given alcohol (70%) before being identified.

Crab identification and activity

Identification was carried out based on the morphological characteristics of crabs such as shell color, claw shape, body color, and body size. Identification refers to Shih and Suzuki (2016), Lapolo et al. (2018), and Ginantra et al. (2021). This identification was carried out at the Laboratory of Animal Taxonomy, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret, Surakarta, Indonesia.

Crab activity was observed directly by observing and documenting all activities at each research location. Each crab activity will be recorded, such as entering the water, entering the hole, walking on rocks, walking on the substrate, foraging for food, and other activities. Crab activity was observed for approximately 2 hours at each research location.

Data analysis

The data obtained were processed using the Shanon-Wiener diversity index, evenness, Simpson dominance, and the abundance of each location and the total research location. The analysis of the existence of crabs as a support ecotourism appeal refers to Rahmila and Halim (2018) and Ginantra et al. (2021).

Shanon-Wiener diversity indeks

$$H' = -\sum \mathbf{pi} \times \mathbf{ln\,pi}$$

Where:
H’: Diversity index of Shannon-Winner
Pi: The number of individuals of a species divided by the total number of species.
ln: The number of individuals of the type.

The criteria for the diversity index are H'<1.5; then the species diversity is low; 1.5<H'<3.5 means that the species diversity is moderate; and H'>3.5, then the species diversity is high.

The evenness index (E)

$$E = \frac{H'}{\ln(S)}$$

Where:
E : Specific evennes index
H': diversity index of Shannon-Winner
ln: Natural logarithm
S: Number of species Found

The criteria for the diversity index are 0<E<0.4, then the evenness is low, community depressed; 0.4<E<0.6 means that the evenness is moderate, community labile; 0.6<E<1.0 then the evenness is high, and community stable.

Simpson dominance index

$$D = \Sigma_1^S \frac{ni(ni-1)}{N(N-1)}$$

Where :
D: Dominance index
ni: The number of individual species to the-i
N: The number of individuals of all species

The dominance index ranges from 0 to 1, where the smaller the value of the dominance index indicates that there are no dominant species.

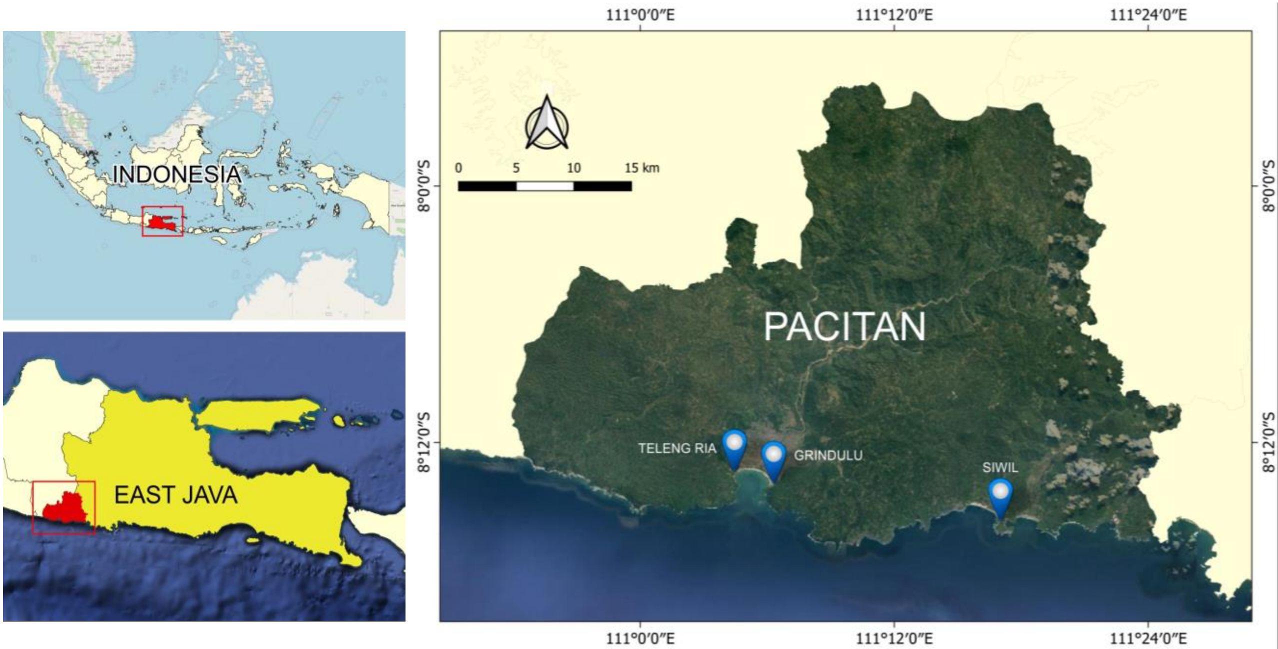

Figure 1. The location of the research crabs mangrove ecosystem in Teleng Ria, Grindulu and Siwil Beach, Pacitan, East Java, Indonesia

Table 1. Coordinates, type of subtracts, type of mangrove vegetation, and description of the location study (Teleng Ria, Grindulu and Siwil Beach, Pacitan, East Java, Indonesia)

Location	Coordinates	Type of substrate	Dominant mangrove vegetatation	Description
Teleng Ria	S 08°13'19.63" E 111°04'28.82"	Sandy, muddy	*Avicennia alba*	It is a river mouth but not too close to the beach, fishing piers, residential areas.
Grindulu	S 08°13'55.75" E 111°06'21.42"	Sandy, muddy	*Rhizophora stylosa*	Close to beach. Mangrove conservation area is still under development. It is evident from the number of mangrove plant seeds planted.
Siwil	S 08°21'49.57" E 111°07'67.15"	Sandy, rocky, muddy	*Sonneratia alba*	It is a river mouth but not too close to the beach. Tidal area with sandy, muddy and rocky substrates

RESULTS AND DISCUSSION

Crab diversity

Mangrove forests on the coast of Pacitan, such as in Teleng Ria, Grindulu, and Siwil, have a specificity: most of the substrate is white sand/quartz sand, and rocky either in the form of rocks or fragments of dead coral. Sandy beaches generally have a higher temperature than muddy sand substrates because of the larger particle size; the water will not be retained for long and dry quickly. In addition, the organic matter content of white sand is also low, so not many biotas can survive in this habitat. However, at the research site, some rivers carry food and make several points of muddy sand habitat so that organisms such as crabs can still survive (Gray and Elliot 2009). The muddy sand will make it easier for the crabs to make holes, and the abundance of organic matter carried by the river flows for crab food.

This study found 5 species of crabs (Figure 2), namely *Austruca annulipes* (H. Milne-Edwards, 1837), *Coenobita perlatus* (H. Milne-Edwards, 1837), *Ocypode kuhlii* (De Haan, 1835), *Perisesarma guttatum* (A. Milne-Edwards, 1869), and *Scylla serrata* (Forsskål, 1775). The species with the highest abundance was *O. kuhlii*, 0.33 ind./m^2, while *S. serrata* is a species with low abundance because only one individual was found in Siwil Beach. The crab diversity index was obtained for a total of three locations, including the medium category, with an index of 1.25. The family Ocypodidae is the most significant contributor to the number of species with two species (Table 2). The evenness of species is evenly distributed with a stable community structure as indicated by an evenness index of 0.78 and a low dominance index of 0.32 (Figure 3).

As for the diversity index at each location, the Siwil Beach research location has the highest diversity index, 1.3 (medium). The lowest diversity index is Grindulu Beach, 0.18 (lower). The number of species in a community and the abundance of each species will affect the diversity in an ecosystem. Diversity species in an ecosystem will decrease if there are fewer species and variations in the number of individuals of a species or several species with a more significant number of individuals. Compared to other locations, all species in this study can be found in Siwil Beach. This is related to the more diverse habitats in the Siwil Beach, whose habitat has a quartz/white sand substrate mixed with mud, sand with rocks, and sand with fragments of dead coral (Table 1).

The highest evenness index of crabs in Teleng Ria is 0.91, and Siwil, which is 0.77, is in the high category, indicating that the distribution of crabs in the area is relatively equal or even (Figure 2). The results of the dominance index in both places are the same, which is 0.32. This indicates that the dominance of crab species in the area is low. The Grindulu area has a diversity index of 0.18 and an evenness index of 0.91. Both values are low because only two species of crab were found. The crab *O. kuhlii* was dominant against *P. guttatum* in Grindulu. Compared to the other two locations, Grindulu does have a low and young mangrove tree density and size because the mangrove area is used as a mangrove nursery (Table 1). This condition will affect the canopy cover area and the organic matter produced. A wide and dense canopy cover will protect crabs from direct sunlight and predators' wave action and increase the production of organic matter produced (Ravichandran et al., 2011). The better vegetation from mangrove trees, the more diverse the crab species found.

Factor abiotic

A suitable living environment for crabs will make them survive and carry out their role as important organisms in the mangrove ecosystem. The environmental parameter values measured included temperature (°C), acidity (pH), and salinity (Table 3). The measurement of environmental parameters at the research site has average air, water, and soil temperature of 28-33 °C. Compared with research in the Mangroves of Purworejo District, Central Java (Rahayu et al. 2018) and Kuala Langsa, Aceh (Putriningtias et al. 2019), the temperature parameters there are quite different, which is around 26-30 ºC. However, the temperature of this study is not much different from research conducted in the mangrove forests of Alas Purwo National Park, East Java, 29-33 °C (Gita et al. 2015) and Segara Anakan Mangrove Forest Ecosystem, Cilacap, Central Java, 27-33 °C (Redjeki et al. 2017). According to Saparinto (2010), a suitable temperature for mangroves is not less than 20°C, and in general, crabs that live in mangrove ecosystems can survive at temperatures of 23-33°C. It is assumed that the difference in the average temperature of each location is influenced by the mangrove vegetation cover around it, the type of sediment, and the sampling time of the study.

Table 3. Abiotic factors in Teleng Ria, Grindulu and Siwil Beach, Pacitan, East Java, Indonesia

Location study	Temperature ºC			pH		Salinity
	Air	Water	Soil	Water	Soil	
Teleng Ria	33	32,6	33	7,6	6	5
Grindulu	32	32,5	33	8	7	10
Siwil	32	28,2	31	7,6	6,1	5

Table 2. Diversity and abundance of crabs crustaceans (ind./m^2) in three location studies (Teleng Ria, Grindulu and Siwil Beach, Pacitan, East Java, Indonesia)

Class/Family	Species	Location			Total
		Teleng Ria	Grindulu	Siwil	
Malacostraca/Ocypodidae	*Austruca annulipes*	0.01	0	0.19	0.2
Malacostraca/Coenobitidae	*Coenobita perlatus*	0.02	0	0.03	0.05
Malacostraca/Ocypodidae	*Ocypode kuhlii*	0.04	0.13	0.16	0.33
Malacostraca/Sesarmidae	*Perisesarma guttatum*	0.02	0.01	0.09	0.12
Malacostraca/Portunidae	*Scylla serrata*	0	0	0.001	0.001

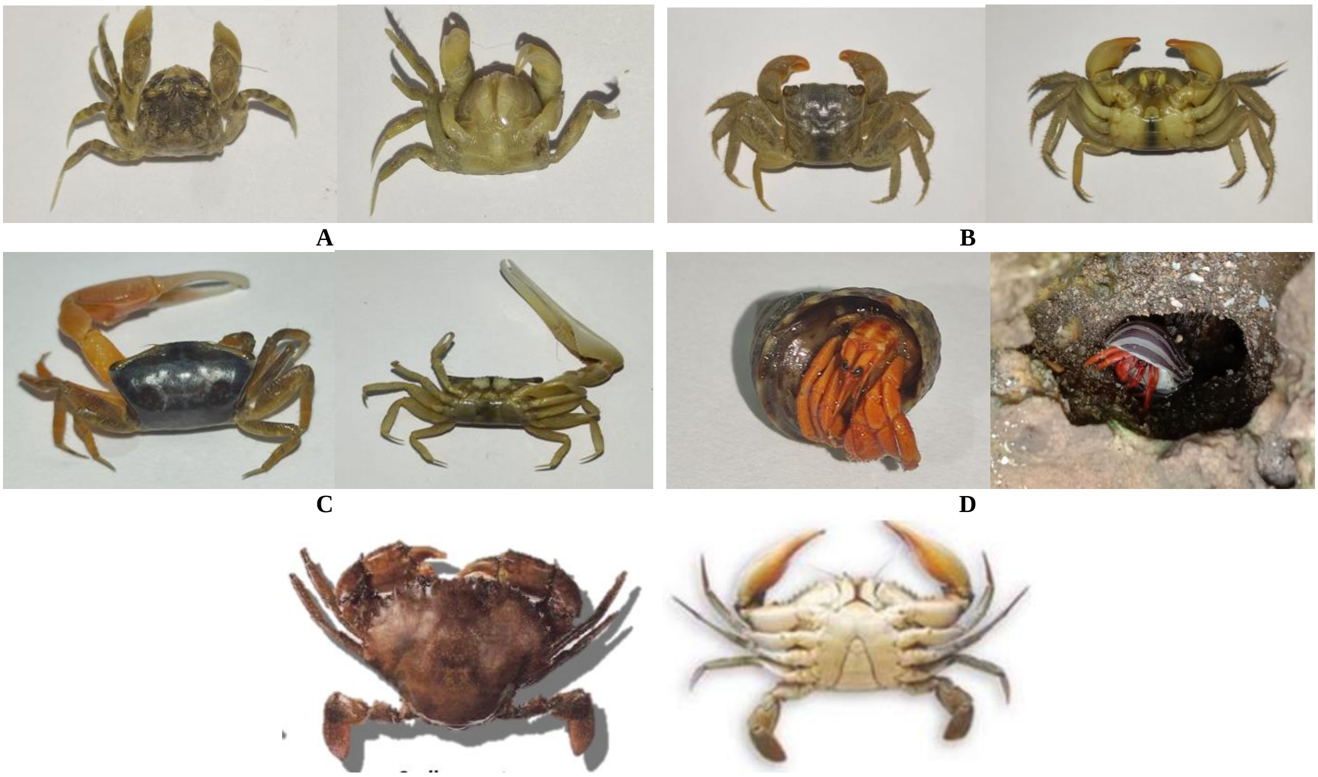

Figure 3. Species of Crustaceans in three location study (Teleng Ria, Grindulu and Siwil Beach, Pacitan, East Java, Indonesia): A. *Ocypode kuhlii*; B. *Perisesarma guttatum*; C. *Austruca annulipes*; D. *Coenobita perlatus*; E. *Scylla serrata*

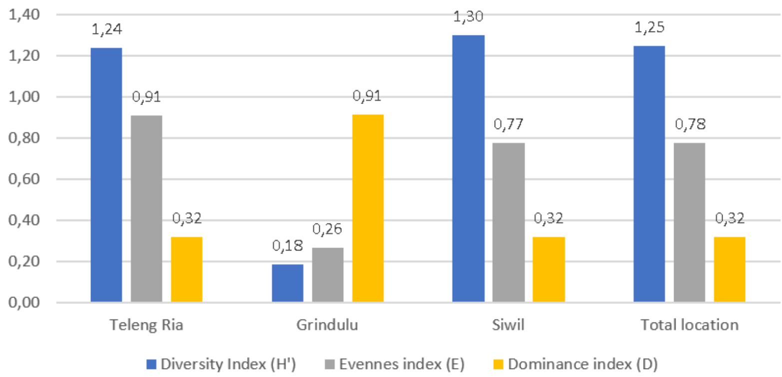

Figure 2. Diversity index, evenness index, and crab dominance index in three location studies (Teleng Ria, Grindulu and Siwil Beach, Pacitan, East Java, Indonesia)

The water and soil pH values at each location ranged from 6-8. This is still considered normal because, according to Gillikin et al. (2004), the normal pH value for brackish waters of mangrove ecosystems with animals and plants in them has a pH between 6-9. According to Pratiwi (2010), pH <5 and >9 will create unfavorable conditions for macrozoobenthos life. This means that each research location is at a good pH for crab life and development. The pH value describes the balance between acid and base, which will affect the growth of mangroves. Good mangrove growth in the composition of the mangrove ecosystem will make the litter produced to meet the needs of crab food. The pH results in the crab habitat in this study were also the same as the pH results in the crab habitat by Gita et al. (2015), Redjeki et al. (2017), Rahayu et al. (2018), and Putriningtias et al. (2019).

Based on observational data, the average salinity obtained in the observation area is in the range of 5-10 ppt. According to Rahayu et al. (2018), the range is still in the range of oligohaline (0.5-5 ppt) to mesohaline (5-18 ppt) and can still support crab life. The highest salinity of around 10 ppt is found in Grindulu. This is because Grindulu is closer to the coast, so seawater has more influence than freshwater (Table 1). Meanwhile, the lowest salinity range of 5 ppt was found in Siwil and Teleng Ria. This is because the location is far from the beach, so the seawater has less direct effect. On the other hand, freshwater has more influence because the mangrove areas in both locations receive more freshwater input from water channels, resulting in water dilution resulting in relatively lower salinity than in Grindulu. Based on the research, the water's salinity in the mangrove area's study area fluctuates and is influenced by freshwater runoff from the mainland and the entry of seawater from river mouths.

Crab potential as a support ecotourism attraction

According to Ginantra et al. (2021), information about the species of crabs found their status of existence, whether protected or not, rare or common, is important information to support the attractiveness of ecotourism. In addition, the morphology, activity, number, and distribution of each crab species in an ecotourism area has its own uniqueness and will increase the attractiveness of tourists to visit.

Unique activities of crabs as supporting ecotourism attractions

Activities in the habitat by crabs were observed, such as walking on rocks, sand/gravel, entering and exiting hiding holes, getting into mud, foraging for food, and walking on mudflats. The behavioral observations must be made carefully, because they perfectly camouflage with their environment (Figure 4). This activity is an attraction crab's that tourists can see. *Ocypode kuhlii* and *P. guttatum* will be easy to find and see by tourists because they often walk on sand or rocks. Then, the hermit crab C. perlatus runs slower than *O. kuhlii* and *P. guttatum* to be held and observed for longer by tourists. The most exciting activity of the crabs encountered was the activity of *A. annulipes*. *Austruca annulipes* have activities such as dancing and playing the violin, where the male often moves his giant claw in the air while one of the smaller claws picks up food on the substrate. In the observations made, this activity was carried out at low tide during the day while looking for food (see the youtube video of this research https://youtu.be/QNFR0hKYPZ8). The results of observations of other activities regarding the crab *A. annulipes* that this crab is very sensitive to vibration, if there is a vibration around this crab, then this crab quickly goes into its hiding hole. As long as when seeing this crab, do not make vibration around its hiding hole, then this crab will come out and dance again so the tourists can see this crab dance closely and clearly. In many plots in Siwil Beach, this dance activity is carried out by dozens of individuals of *A. annulipes* under the shade of *Rhizophora stylosa* and *Sonneratia alba* trees. Then, the activity of *S. serrata* crabs is rather difficult to observe during the day because these crabs are nocturnal (Febriyani 2018) and always hide in their hiding holes.

Unique morphology of crabs as supporting ecotourism attractions

Austruca annulipes. Morphologically, according to Rahayu et al. (2018) the crab *A. annulipes* has a body size of 25-60 mm, has a trapezoidal carapace shape with white spots that cross close to the anterior and is black, orbits are not visible, cerpus, merus, and manus are red, smooth dactyl and pollex are white. The carapace has 1 or 2 dark bands on the back. Pollex's large claws have a tubercle along the underside. The upper side of the dactyl is completely convex, especially the mid-flat. Gonopod with less torque. The posterior flange is longer and wider than the anterior. In males, this crab has a characteristic claw that is larger than other claws. The paws are red-orange or yellow and the carapace is black with blue spots. Based on their small size, a pair of claws that are very different in size and attractive colors make these crabs very attractive to tourists.

Coenobita perlatus. The *C. perlatus* is a species of land hermit crab. According to Pavia (2006), this crab is known as the strawberry hermit crab because of its reddish-orange color in the body. In addition, the entire body of this type of hermit crab is also filled with white granules (pores) which is the reason why it is also called "strawberry". The adults can grow to a typical length of 80 mm (3.1 in) and weigh 80 g. Eye color is generally clear brown, but sometimes found black, moss green, or gray eyes. The abdomen of this hermit crab is always pure white and the carapace on the back tends to widen. The *C. perlatus* utilize empty shells of Mollusca to protect its abdomen (Jeremy and Patria 2020). The third left leg, which is usually called the shield leg is useful for closing the shell with the slightly fat left pincer, while the left pin is round and flat. Because *C. perlatus* which has a reddish-orange color also filled with white granules (pores) in the body like a strawberry and has a house/shell of a Mollusca that is attractively colored and has a unique shape so that it can be an attraction for tourists to see.

Ocypode kuhlii. According to Sakai and Türkay (2013) and Amin et al. (2021), this crab is small in stature and the carapace is 33×43 mm. Carapace is wider than long; convex in the direction of its length; fine nodules. This crab has a square eye shape with a pair of eyes that rise upwards. The first limb is calf-shaped, which is unequal in size between the right and left; the surface texture is speckled. The head of the calf (palm) with a rounded top side and rough nodules; inner side with middle (8-10) nodules lined crosswise, bidirectional, stiff scraper to produce a whooshing sound. The morphology of this crab is small, has fine nodules, not large claws and unique eyes make this crab very adorable for tourists to see.

Perisesarma guttatum. This crab has a body shape (carapace) that is almost square. Carapace is about 3 cm in length. This crab has a pair of claws that are reddish in color with bright orange internal palms. The body surface also has protrusions like that of *P. darwinensis*, but does not have a striped pattern on the legs (Fauzan et al. 2020). In the present study, different types of pectinated crests (on the dorsal face of chelar palm) were recognized among the selected species of the family Sesarmidae. Males of this species have two rows of transverse crests with elevated teeth, each row (crest) being framed by a high and large tubercle on the inner side (Shahdadi and Schubart 2017). The morphological characteristics of the carapace shape and the color of the claws of this crab make this crab attractive for tourists to see.

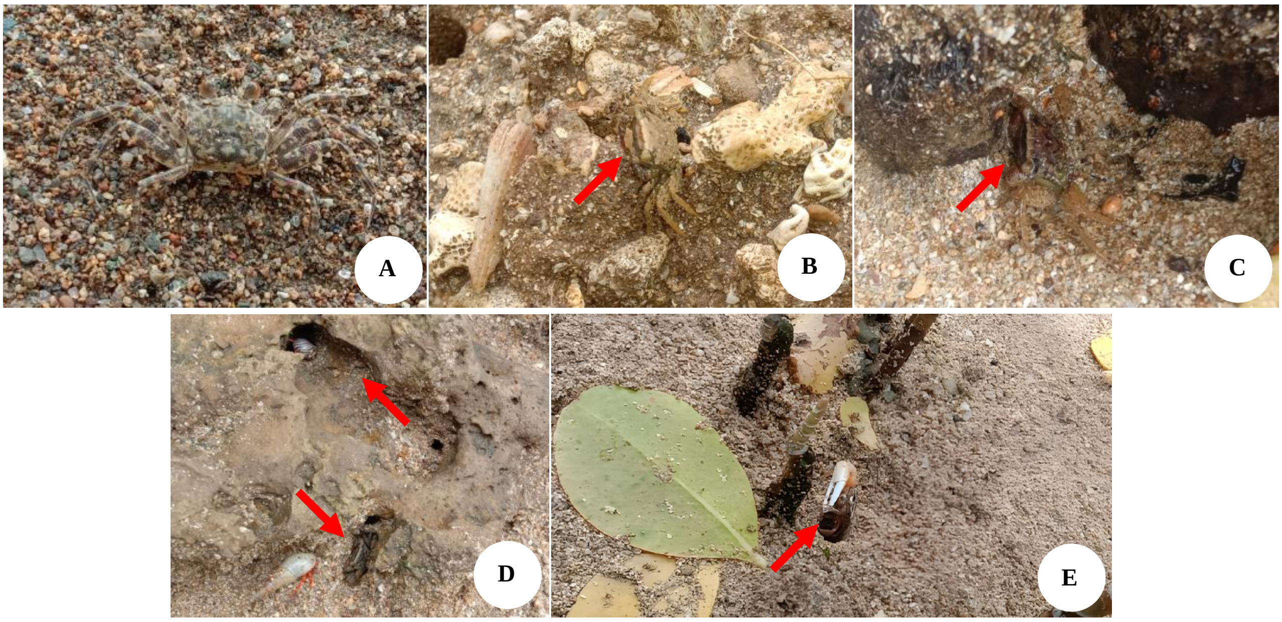

Figure 4. Some crabs activity in three location studies (Teleng Ria, Grindulu and Siwil Beach, Pacitan, East Java, Indonesia): A. *Ocypode kuhlii* walking on sand; B and C. *Perisarma guttatum* walking on the rocks; D. *Coenobita perlatus* and *Perisesarma guttatum* walking towards hiding in a rock crevice; E. *Austruca annulipes* to a hiding hole in the sand

Scylla serrata. According to Febriyani (2018), the characteristics of *S. serrata* crabs are that they have a slightly greenish, olive-green to almost black carapace, while the outer side of the claws is green, often with a spotted pattern or spots. On the frontal side, there are 4 sharp spines, the outer palm (claws) is green with a round pattern, has three pairs of walking legs and one swimmer's leg which is located at the end of the abdomen with the ends equipped with a rower. The last pair of legs (swimming legs) have spots, both in males and females. These crabs are large to very large, the maximum carapace width is between 25-28 cm and the weight reaches 2-3 kg. Compared to other crabs found in this study, this crab has a large body size, carapace and claws that make this crab have special characteristics that attract tourists to see it.

Number of individuals and distribution of crabs in research study as supporting ecotourism attractions

Twenty-five plots spread over three research sites, found 5 species of crab with a total of 613 individuals (Table 4). From the number of individuals, it is evidence that the three locations are suitable habitats for several species of crabs. Crabs are one of the Crustacea that live in coastal/mangrove ecosystems and are one of the key species that have a very important role in maintaining the balance of the ecosystem. Therefore, the presence of crabs in the mangrove ecosystem can be used to indicate whether the mangrove ecosystem is still functioning properly or not. According to Kristensen et al. (2012), Saher and Qureshi (2014), and Kalor et al. (2018) crab is a key species in mangrove forests that functions to convert nutrients and enhance mineralization, increase oxygen distribution in the soil, assist in the carbon cycle, and provide natural food for various species of biota in the waters.

Table 4. Total individual crabs in Teleng Ria, Grindulu and Siwil Beach, Pacitan, East Java, Indonesia

Species	Location			Total individul spesies
	Teleng Ria	Grindulu	Siwil	
Austruca annulipes	9	0	189	198
Coenobita perlatus	18	0	33	51
Ocypode kuhlii	38	64	156	258
Perisesarma guttatum	17	3	85	105
Scylla serrata	0	0	1	1
				613

In this study, *O. kuhlii* were found in all study sites with the highest abundance (Table 2). According to Elfandi et al. (2018) *O. kuhlii* spread in many parts of Indonesia such as Sumatra, Java, Madura, Bali, Lombok, Flores, and Papua. The existence of this crab population is strongly influenced by the condition of the beach which is its habitat. Unspoiled beaches are usually found in an abundance of these crabs because the food chain process is still maintained. Polluted beaches will rarely be found *O. kuhlii* (Schlacher et al. 2011).

Besides *O. kuhlii*, *P. guttatum* can also be found in all research sites, this species likes muddy sand habitats in each research location, eating vascular plants including mangrove litter and young sprouts. These crabs can live on the surface of the mud, or mangrove trees can tolerate a wide range of salinity, which causes this crab to dominate in mangrove forests. This is also in accordance with the research conducted by Shih et al. (2016), Lapolo et al. (2018) and Rosenberg (2019) that crabs from the Ocypodidae (*O. kuhlii* and *A. annulipes)* and Sesarmidae

(*P. guttatum*) groups are commonly found in inhabiting shorelines worldwide across the tropics and well into the temperate zones mangrove forests in Indonesia. These three species are often found in vents with stable temperatures and can adapt to their surrounding environment even in damaged or extreme conditions.

Coenobita perlatus lives in a wide swathe of the Indo-Pacific, like Indonesia (Mckenzie 1999). From the research conducted, it was found that most *C. perlatus* individuals were found in Siwil Beach. *Ceonobita perlatus* likes substrate conditions that are dominated by sandy and rocky substrates (Ingle 1993). Hermit crab can be used as an environmental bioindicator. If there are hermit crabs, the environment is still good and far from environmental pollution (McKenzie 1999). In addition, *C. perlatus* can be eaten by people, however, they are more usually found as home pets. Because they are scavengers, they also play an important part in beach cleanup. Hermit crabs are important in keeping the beach clean and creating a healthy environment for humans and other aquatic and coastal species by removing dead sea matter and other detritus that collects on the shore (McKenzie 1999).

In this study, *S. serrata* is a species that has few individuals and is only found on Siwil Beach. According to Ginanthra et al. (2021) several factors that can cause the low population of this crab include substrate, mangrove plants, seagrass, and human disturbance. In addition, according to Febriyani (2018), the *S. serrata* crab is a typical species in the mangrove area. These crabs only come out of hiding some time after sunset and move throughout the night mainly in search of food. When the sun is about to rise, these crabs immerse themselves again, so these crabs are classified as nocturnal animals. This species is edible and susceptible to hunting by humans. Crabs have a relatively stable habitat. Li et al. (2015) showed that the distribution of crabs has a significant correlation with energy flow and species because each crab responds to feed on different mangrove vegetation. This species was found in the white sand substrate with *R. stylosa* and *S. alba* vegetation. Mangrove vegetation that grows will provide nutrition and food for crabs. Kamaruddin et al. (2019) also found that the crab *S. serrata* is found on the sandy substrate in mangrove habitat in Sungai Pinang Village, Lingga and this species also were found in muddy sediments, Cibako mangrove forest, Garut, West Java by Avianto et al. (2013) and in the mangrove forests of Alas Purwo National Park, East Java by Gita et al. (2015).

The conclusion of this study was found 5 species of crabs, namely *A. annulipes*, *C. perlatus*, *O. kuhlii*, *P. guttatum*, and *S. serrata*. The crab diversity index was obtained for a total of three locations including the medium category with an index of 1.25 (medium). Morphology, activity, number of individuals, and distribution of each crabs species in an ecotourism area will increase the attractiveness of tourists to visit. It is hoped that this data can be a reference for managers of mangrove areas in developing ecotourism and efforts to conserve mangrove forests.

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Analysis of the diversity and evenness of mangrove ecosystems in the Pacitan Coast, East Java, Indonesia

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Abstract. *Sholiqin M, Pramadaningtyas PS, Solikah I, Febriyanti S, Pambudi MD, Mahartika SB, Umam AF, Liza N, Setyawan AD. 2021. Analysis of the diversity and evenness of mangrove ecosystems in the Pacitan Coast, East Java, Indonesia. Intl J Bonorowo Wetlands 11: 84-94.* Indonesia has a high mangrove diversity with 43 species of true mangrove plants. Mangrove grows along the coastline of Indonesia's islands, one of which is situated on the southern coast of Java. Pacitan, which belongs to the south coast of East Java and has 70,709 km of coastline, is an area with the potential to have diverse mangrove vegetation. The existence of mangroves plays a role in carbon sequestration and the stability of coastal ecosystems. This study aimed to determine the mangrove diversity and evenness index in the southern coast of Pacitan. This research was conducted on November 2021 in three locations, namely the Teleng Ria, Grindulu Estuary, and Siwil Beach. Data was collected using a plot of 10 x 10 m^2 for trees, 5 x 5 m^2 for saplings, and 2 x 2 m^2 for seedlings. The data obtained were analyzed using the Shannon Wiener and Evenness index to calculate the mangrove diversity and evenness value. There are 8 species of mangroves (7 species of major and 1 species of minor mangrove) and 2 species of associated mangroves, with the domination of *Rhizophora stylosa.* The Shannon Weiner diversity index shows that the mangrove diversity index in the research areas ranges from low to moderate. The Evenness Index presents that Teleng Ria Estuary possesses a high evenness value, indicating its stable mangrove condition.

Keywords: Diversity, evenness, mangrove ecosystem, Pacitan

INTRODUCTION

Mangroves have a high productivity role compared to other ecosystems, making the mangrove ecosystem essential for living things' lives. The characteristics of mangrove forests are also unique compared to other forest areas. This uniqueness can be seen in their habitat and diversity (Karimah 2017). Usually, mangroves can grow in muddy coastal wetlands found in tropical and subtropical areas (Hakim et al., 2017). In addition, mangroves can also live in lagoon areas, river estuaries that are inundated when the tide occurs or are free from inundation at low tide. Mangroves can adapt to high salt levels and have many physical, ecological, and economic (Alvareza and Leilani 2020). The benefits of mangroves in coastal areas are in the form of carbon sequestration, neutralizing the harmful pollutant materials, reducing approximately 50% of the strength of tsunami waves, protecting coastlines, and enriching coastal waters where they can be used as various flora and fauna habitats, and have the potential to ecotourism (Harahab and Setiawan 2017). The diverse functions of mangroves contribute to living things and support life (Konom et al. 2019).

The mangrove areas in the world reach 16,530,000 ha, and Indonesia is one of the countries with the world's largest mangrove ecosystem, estimated at 3,489,140.68 ha along 95,181 km of coastline (Akbaruddin et al. 2020). The area of mangroves in Indonesia reaches 23% of the total mangroves in the world, and a total of 50% of mangroves in Asia are in Indonesia (Junialdi et al. 2019). Mangrove forest areas in Indonesia grow and develop throughout the Indonesian archipelago from Sumatra to Papua. It is estimated that there are 202 species of mangrove species that grow in mangrove forest areas in Indonesia, which consist of 89 tree species, 5 palm species, 19 climber species, 44 herb species, 44 epiphytic species, 1 species of ferns; it can also be classified as 43 species of true mangroves, and the other species are associated mangroves (Khairunnisa et al. 2020). However, according to Majid et al. (2016), the mangrove ecosystem in Indonesia is in a critical condition, namely experiencing damage which is predicted to be up to 68% or around 5.9 million hectares. The damage is due to human activities that make changes in the composition of mangroves, resulting in mangrove forests being unable to function, for example, the conversion of land functions to meet human needs (Ramena et al. 2020). Most of the damage occurred in the areas of Bali and Java (Eddy et al., 2015). Thus, mangrove areas in Indonesia currently require proper management (Ritohardoyo and Ardi 2014).

One of the mangrove areas is in Pacitan District, East Java, Indonesia. It is located in the southern coastal area of Java Island, and the topography of this district is dominated by hills (Mardika et al., 2020). The coastal area in this district consists of 26 villages originating from 7 sub-districts, with coastal areas having a slope of 0 to 2% and the coastal areas of Pacitan District having an area of about 4.36% of the total area of the district (BPS Kabupaten Pacitan). Pacitan coast faces directly to the open sea of the Indian Ocean, which has strong waves. Karst areas from the Southern Mountains dominate the coastal area. This district has a coastline of 70.709 km, but generally, it is a steep beach, while on a sloping beach, it is dominated by white sand from coral. The district is fed only by small and short rivers, and the two largest rivers are the Grindulu River (70 km) and Lorog River (60 km) (BPS Pacitan 2021). The rainfall is high, the climate is C2-C3 type (Oldeman 1975), but because it is located in a karst area and the river flow is short, the sedimentation in the estuary is relatively limited and lacks nutrients. This condition causes the area for mangrove growth to be somewhat limited, and a unique mangrove ecosystem is formed according to these characteristics. For this reason, this research was conducted to find out more about mangroves in Pacitan, then to determine the mangrove diversity index and the evenness diversity index in the southern coast of Pacitan.

MATERIALS AND METHODS

Study area

This research was conducted in November 2021 and located along the Pacitan south coast, East Java, Indonesia (Figure 1). Pacitan District is located between 7 92' - 8 29' S and 110 90' - 111 43' E. In 2021, the air temperature was 26-29°C; the average humidity was 23-27.5%, the number of rainy days was 179 days with rainfall 841 mm^3 (BPS Pacitan 2021). The locations were chosen because they have unique mangrove forests. This research data was obtained from three sampling points: the Teleng Ria Estuary, Grindulu Beach, and Siwil Beach. The coordinate of each location is presented in Table 1.

Procedures

Mangrove survey was conducted using 10 square plots in each station. Each plot was divided by 10 x 10 m^2 for the tree, 5 x 5 m^2 for sapling and pole, and 2 x 2 m^2 for seedling (Figure 2). The mangrove classification based on the growth level refers to Kasmadi (2015): seedling is the initial growing stage with less than 1,5 m height (i), the sapling is the stage with a height more than 1,5 m and less than 10 cm in diameter (ii), pole has a diameter range from 10 to 20 cm (iii); and tree category with a diameter above 20 cm (iv). The observation includes species identification within the square plot, the total number of mangrove species, a height, and DBH measurement of 10 cm above the still roots. Both assessments are used to differentiate the mangrove species into different growth stages. Furthermore, the measurement of abiotic factors, including temperature, salinity, and pH, was also carried out at each observation location. For identification purposes, Rusila Noor et al. (1999) and Giesen et al. (2007) were used based analysis of morphological characters. Subsequently, key characters from unidentified species samples (e.g., flower and fruit) were taken and photographed for further identification in the Laboratory of Environment, Universitas Sebelas Maret, Surakarta, Indonesia.

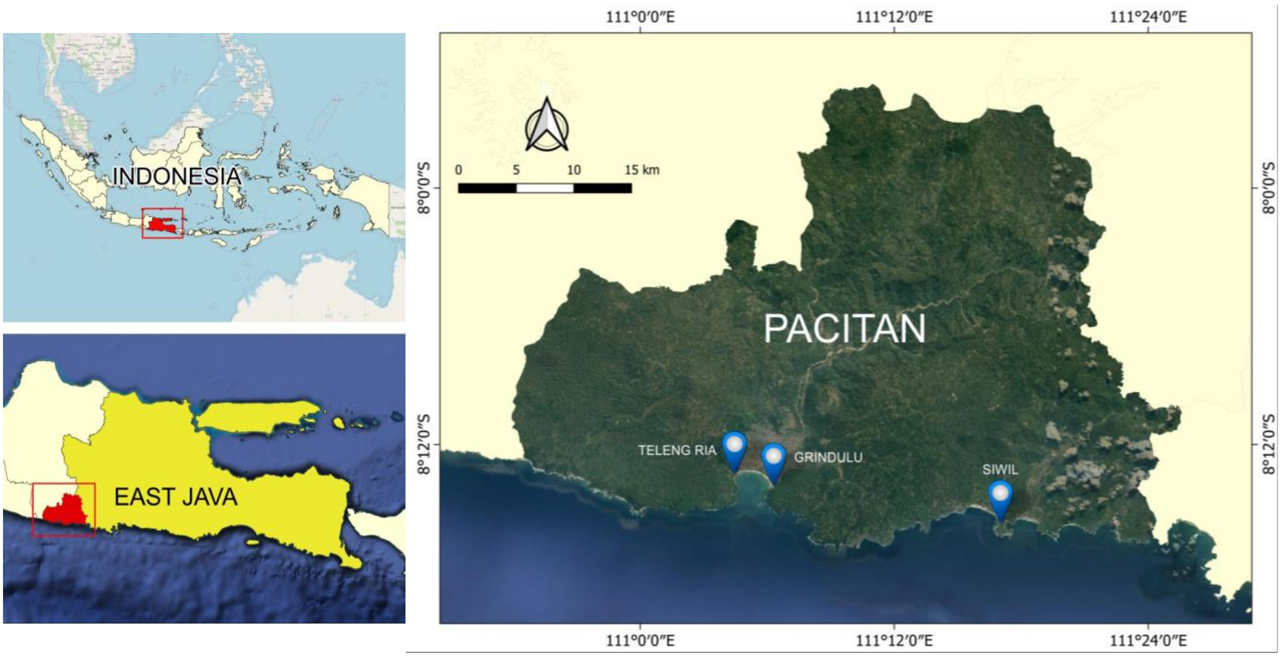

Figure 1. The sampling area is in Pacitan, East Java, Indonesia. (Location 1: Teleng Ria Estuary; location 2: Grindulu Beach; location 3: Siwil Beach)

Table 1. Coordinate research stations

Site	Location	Coordinate point	Estimation of mangrove area width	Characteristic of substrate
1.	Teleng Ria Estuary	8°13'17.0"S 111°04'25.0"E	2183 m^2	Sandy, muddy
2.	Grindulu Beach	8°13'50.4"S 111°06'13.5"E	3917 m^2	Sandy, muddy
3.	Siwil Beach	8°15'37.4"S 111°17'00.1"E	1065 m^2	Sandy, rocky, muddy

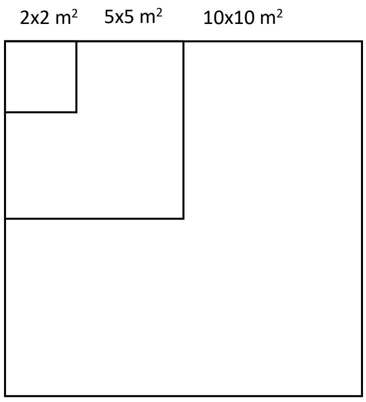

Figure 2. The square plot method for mangrove observation

Data analysis

Data analysis was carried out quantitatively using Microsoft Office Excel software. The following formulas are used to calculate the mangrove diversity and evenness index.

$$H = -\sum pi \times \ln pi$$

Where:
H' : Diversity index of Shannon-Wienner
Pi : The number of individuals of a species divided by the total number of species found

The criteria for the diversity index are:
H'<1.5 : low category
1.5<H'<3.5 : medium category
H'>3.5 : high category (Krebs 1989)

$$E = \frac{H'}{\ln(S)}$$

Where:
E : Evenness index
H : Diversity index of Shannon-Wienner
S : Number of spesies found

With the following criteria: (i) E' ≤ 0.5: low uniformity, mangrove condition is depressed; (ii) 0.5 < E' ≤ 0.75: moderate uniformity, mangrove condition is less stable; (iii) 0.75 < E' ≤ 1: high uniformity, mangrove condition is stable (Krebs 2014).

RESULTS AND DISCUSSION

Research area condition

Mangrove abundance is hugely impacted by its habitat condition, including temperature, pH, salinity, and substrate. Each mangrove develops a different range of tolerance levels to environmental factors. Based on the direct observation, the temperature in a range of 32-33°C, while pH soil level in three research locations between 6 and 7. At the same time, the salinity was documented from 5 to 10 ppt. (Table 2). Regarding temperature, it can be fluctuated according to the observation time due to the sunlight effect. It has a significant impact on mangrove growth as the connection to the photosynthesis rate. Different ranges of temperature in mangrove ecosystems were shared by some research, including at 29-32°C in Mentawai Island (Rizal and Anna 2020), between 30-31,8°C in Torsiaje Jaya Village, Gorontalo (Rahim et al. 2017), and 24-31°C in North Coast of Jakarta (Hilmi et al. 2021). Those conditions are still acceptable for mangroves to grow well because the photosynthesis process will decrease dramatically if the temperature is more than 35°C (Kusmana 2010).

In terms of pH, Teleng Ria Estuary and Siwil Beach had a similar value, when the highest level was shown in Grindulu River. These results are in the pH range for optimal mangrove species to thrive based on the Kai et al. (2012) experiment. It mentioned that *Avicennia alba* seedling would grow optimally in the pH level from 5.16-7.72. Additionally, research conducted by Nasrin et al. (2016) showed the highest percentage of germination on mangrove association occurred at pH 0-10 and then continued to decrease along with increasing pH level until no germination occurred at pH 25-35.

Table 2. Abiotic factors in mangrove area in Pacitan District, Indonesia

Research sites	Temperature (°C)	pH	Salinity
Teleng Ria Estuary	33	6	5
Grindulu River	32	7	10
Siwil Beach	32	6,1	5

Salt concentration in Grindulu River far exceeds the remaining locations, which shared the same value at 5 ppt. The site of Grindulu has a significant impact on this result as it is situated closest to the shore, causing saline water to enter the mangrove area periodically. Even though each mangrove has different sensitivity levels, as Elster (2000) proposed, Avicennia germinans was the most tolerant species in contrast to *Rhizhopora mangle* as the most sensitive mangrove. Still, a salinity level between 10-30 ppt serves the best condition for mangroves (Hilmi et al., 2021). Thus, the research locations in Pacitan have salinity value that is less supportive for mangrove development.

From the observation, the mangrove habitat in the Pacitan area is dominated by various sediments, including mud, sand, or both combinations. Like other abiotic factors, mangrove species have different preferences regarding the growth habitat. For instance, *Avicennia* is usually well-developed in the fine soil and sandy habitat, while sandy to a muddy substrate is suitable for *Rhizophora* and *Sonneratia* (Abubakar et al. 2020; Jalil et al. 2020). Furthermore, the type of sandy is correlated to the nutrient composition in a particular habitat. According to Adeney et al.'s (2016) study, it is mentioned that white sand is highly associated with nutrient scarcity and subsequently will impact the organism abundance in the area. In line with this, Siwil Beach is characterized by a white sandy habitat with soft soil in the inundation area.

Mangrove species in Pacitan coastal areas

The mangrove community of Pacitan consists of 10 species of mangrove, including seven species of the major component (*Avicennia alba*, *Avicennia marina*, *Rhizophora stylosa*, *Rhizophora mucronata*, *Sonneratia caseolaris*, *Sonneratia alba*, and *Nypa fruticans*), a species of minor component (*Aegiceras corniculatum*), and two species of mangrove associated (*Derris trifoliata* and *Acanthus ilicifolious*,). Those finding represent six families, including Acanthaceae, Arecaceae, Leguminosae, Lythraceae, Primulaceae, and Rhizophoraceae. Acanthaceae dominated the result consisting of three species, followed by Lythraceae and Rhizophoraceae that depicted by two species each (Table 3). This result shows that more major components have grown in Pacitan lately than the Setyawan et al. (2002) study that found two species (*A. alba* and *S. alba*). However, that previous research managed to identify eight species of mangrove association.

The mangrove species grows in three sites of Pacitan District is higher than the result in mangrove forest situated in Pasarbanggi, Central Java and Torosiaje Jaya, Gorontalo, that only four species were found in each location (Rahim et al. 2017; Wicaksono and Muhdin 2015), and five species in Kedawang, Pasuruan (Isroni et al. 2019). In contrast, a more significant number were presented in various studies. For example, 24 mangrove species were identified in Segara Anakan (Hilmi et al. 2021), 14 species were reported to grow in Panjang Island, Jepara (Utami et al. 2017).

Moreover, Sudarmadji and Indarto (2011) was found 14 species of true mangrove (major and minor) in Banyuwangi District (Tl. Grajagan, Tl. Pangpang, Bengkak, Alas Buluh), 12 species from Situbondo (Buyunglugur Barat, Buyunglugur Timur, Kendit, Panarukan), and 2 species from Jember (Kali Malang). Setyawan et al. (2005) was found 36 species of which 14 species of true mangrove was found in Demak District (Wulan, Sigrogol, Serang), 12 spesies of which 7 species of true mangrove was found in Jepara (Bulak, Teluk Awur), 14 species of which 5 species of true mangrove was found in Pati (Tayu, Juwana), 24 species of which 13 species of true mangrove was found in Rembang (Pecangakan, Pasar Bangi, Lasem), 24 species of which 6 species of true mangrove was found in Purworejo (Bogowonto, Ckrayasan, Lukulo), 16 species of which 7 species of true mangrove was found in Kebumen (Cingcingguling, Ijo), 36 of which 22 species of true mangrove was found in Cilacap (Bengawan, Serayu, Tritih, Motean, Muara Dua).

An impressive number of mangroves are listed in Katunggan, the Philippines, at 29 species, three listed as threatened species (Mangaoang and Flores 2019). Many aspects, including environmental factors, propagule types, and species competition, are considered a major role in the species distribution (Nakorn et al., 2018). Generally, districts on the north coast of Java have more mangrove species than the south coast (Setyawan 2005).

Teleng Ria Estuary

This station has a characteristic of sandy and soft soil as it is a riverbank area that leads directly to the Teleng Ria beach. This research identified seven kinds of mangrove grow in this location, including *A. alba, A. marina, S. caseolaris,* and *R. stylosa* in terms of major components, along with *A. ilicifolious, N. fruticans,* and *D. trifoliata* as associated species. The number of *A. alba* was much more significant than other species that accounted for 201 individuals (Table 3). According to Isroni et al. (2019), a big stem and the vast canopy provide advantages for the growth of *A. alba,* so they often reported dominating a habitat. Sedimentation also becomes a determining factor for mangrove regeneration and survival. This station belongs to the riverbank area; it contains rich organic sediment. In line with this, *A. alba* experienced a lower mortality rate in a habitat with sedimentation disturbance. However, the survival rate showed a declining trend if additional pressures were presented, such as water movement and flood (Balke et al., 2013). In this station, *A. alba* was reported to grow with a height range between 2 and 12 meters with a fruit-like-nut shape in green (Figure 3).

At this location, 110 individuals of *R. stylosa* were found, followed by *A. marina, S. caseolaris,* and *A. ilicifolious* in terms of true mangrove. *Avicennia marina* announced to have a broad salinity tolerance. In addition, a high salinity level triggers A. marina's seedling to grow significantly, but a lower salinity has no adverse impact on plant development (Cheng et al. 2020). Another fact is that *A. marina* also has a wide tolerance to metals content in soil by removing excess contamination substances in the plant body through the salt glands (Naidoo et al., 2014). However, apart from its ability, it is reported that *A. marina* should not be used as a phytoremediation agent. Its ability to remove accumulated metal is only temporary and will be released later.

Table 3. The number of mangrove species and associations were found in Pacitan District, Indonesia

Family	Species	Research sites (individuals)		
		Teleng Ria Estuary	Grindulu River	Siwil Beach
Acanthaceae	*Avicennia alba*	201	6	-
	Avicennia marina	42	3	-
	*Acanthus ilicifolious***	25	-	-
Arecaceae	*Nypa fruticans*	23	-	-
Leguminosae	*Derris trifoliata***	10	-	-
Lythraceae	*Sonneratia caseolaris*	32	30	-
	Sonneratia alba	-	-	163
Primulaceae	*Aegiceras corniculatum**	-	-	7
Rhizophoraceae	*Rhizopora stylosa*	110	195	-
	Rhizophora mucronata	-	-	3

Note: *: Minor component; **: Association mangrove; -: not present

Avicennia marina was documented to occur in this station in a height range between 1 and 5 meters with a maximum DBH of 10 cm. Similar to the first study location, muddy clay rich in organic substance becomes a characteristic of the riverbank area. However, it has been widely reported that sandy substrate is the preferred habitat for *A. marina* and leads to its dominance (Rizal and Anna 2020). The possibility of unsuitable substrate composition at this location makes *A. marina* mostly found at the seedling level.

Another species identified in Teleng Ria estuary was *S. caseolaris*, with 32 individuals. It grows at a height range between 1 and 7 meters with DBH size up to 26 cm. This species is distinguished by upward-facing flower petals and red stamens (Figure 4). *Sonneratia caseolaris* fruiting and flowering stages were documented in this research. The fruit is green, round in shape, and contains many fruits. According to (Rahim and Bakar 2018), this fruit can live afloat in the water and help this species to disperse in the tide. This species usually thrives in the upstream estuarine area with deep muddy soil as the substrate (Tatongjai et al., 2021). Thus, the characteristic of that Teleng Ria estuary has, in fact, fit with *S. caseolaris* preferences.

Mangrove associates also identified with *N. fruticans* as the most frequently encountered species during the research. Nipa is the only palm that can survive in the mangrove region and has a morphological characteristic with compound leaves that elongate like coconut leaves. This species has a height between 3 and 5 meters. Habitat with a low to moderate salinity level and high turbidity allows *N. fruticans* to adapt (Lestari and Noor'an 2019; Theerawitaya et al. 2014). *Derris trifoliata* also grew in Teleng Ria estuary with 10 individuals. It has morphological characteristics of parallel leaves with pointed ends, white flowers clustered, and small petals. The air cavities within *D. trifoliata*'s fruits help the species to float and spread in the tidal area (Raju and Kumar 2016). Both *N. fruticans* and *D. trifoliate* are only found on this site. The presence of associated mangroves supports populations in coastal areas (Rozak et al. 2020).

Physiologically, *A. ilicifolious* develop adaptation systems similar to plants that live in dry places, including salt glands and thick leaves (Hilal and Hilal 2019). The presence and dominance of this species in a particular area indicate ecosystem destruction (Irawanto et al., 2015). Furthermore, it also said that the accumulation of the wastes collected in the wetland areas is the habitat of this species as the main reason. In line with this statement, a study conducted by Wijayanti (2017) revealed that the heavy metal components that exceed the threshold were found in the Grindulu's downstream. In this research station, *A. ilicifolious* was documented in the seedling phase with a maximum height of only 1 meter. It is locally known as *jeruju* and is commonly used as a decorative plant due to its unique leaves shape. In addition, it is considered an herbal medicine that is widely used in traditional communities as it contains numerous secondary metabolites (Tan et al., 2016). Photographs of mangrove association are presented in Figure 5.

Grindulu River

The Grindulu River, as the second research location, is a muddy area where a mangrove planting program is being carried out by a non-government organization and was supported by the local authorities. This effort is insisted as a disaster management strategy for riverbank protection areas from flooding and erosion caused by overflowing rivers, especially in the rainy season (Utami and Luthfi 2019). Based on this research, four mangrove species were listed, consisting of *A. alba, A. marina, S. caseolaris,* and *R. stylosa.* As the data presented in Table 3, the number of *R. stylosa* far exceeds other species (195 individuals). Research conducted by Mayor et al. (2017) also obtained the same results where the family Rizophoraceae dominates the Mansuar Island, Raja Ampat. The reason is Rhizophoraceae can utilize solar energy, nutrients or minerals, and water to the maximum and has competitive properties compared to other species. However, Nasir and Yusmah (2007) reported that *R. stylosa* rarely exist in muddy locations and prefer to live in soil with sandy substrate. The difference result with this research is due to the planting program in the Grindulu riverbank area, causing these species to thrive even though mostly still in a seedling category. Still, *R. stylosa* is the best option for this program as it can prevent erosion in the coastal area (Nasir and Yusmah 2007).

Selecting mangrove species for reforestation, apart from considering the species function, the resistance of species with the habitat condition must also be considered. *Sonneratia caseolaris* was planted in the Grindulu river area to support the rehabilitation program. According to Githaiga et al. (2020), pneumatophores in *Sonneratia* help survive in poor conditions, such as inundation and flood. An insignificant number of *A. alba* and *A. marina* also found in this station indicates those species are not suitable for the habitat condition. This is supported by Nasir and Yusmah (2007) that *Avicennia* species can grow well in a sandy area.

Siwil Beach

Siwil Beach is a white sandy beach that faces directly to the Indian Ocean. This station was intended for mangrove restoration after being affected by heavy floods at the end of 2017 and as a prevention approach for seasonal flooding. Two major mangroves were identified in this location, namely *S. alba* and *R. mucronata.* Also found *A. corniculatum* is considered a minor mangrove. Interestingly, three species encountered in Siwil Beach were not identified in the other research locations. *Sonneratia alba* was the most abundant species, with 163 individuals were recorded. The height range that was documented in ranges from 1 to 6 meters. This species is characterized by white stamens and downward-facing flower petals (Figure 4).

Sonneratia alba belongs to pioneer species with a slow-growing type and is considered a potential coastal restoration species (Balke et al., 2013; Pillai and Harilal, 2018). The white sandy beach that dominates this location is a suitable habitat for *S. alba* to grow and dominate the ecosystem. However, this species grows dwarf, probably due to limited nutrients. In Java, the growth of dwarf mangroves is rare, and it is interesting to investigate further regarding the physiological and environmental factors that influence it. Dharmawan and Pramudji (2020) mentioned that *S. alba* dominated the area with hard sand in Biak District. Conversely, *R. mucronata* was only listed at three individuals in Siwil Beach. Improper habitat leads to this result as this species tends to live in clay habitats. The same result was also suggested by Utami et al. (2017) that *R. mucronata* grew poorly in Panjang Island, characterized by a sandy beach.

Aegiceras corniculatum, also known as pioneer species, was encountered in Siwil Beach. This species, which is considered to belong to the minor mangrove group (Tomlinson 1994), has a cylindrical, horn-like curved fruit that is light green to red when ripe. It grows as a scrub habitus with a height of approximately one meter (Figure 6). In Siwil Beach, *A. corniculatum* tends to thrive in the sandy-mud substrate in seasonal inundation areas. Like other mangrove plants, *A. corniculatum* has a unique adaptation to survive in mangrove conditions, namely salt secretion and crypto-vivipary (Feng et al., 2021). The increase in soil salinity triggers increasing salt secretion from the *A. corniculatum*'s leaves to remove salt accumulation in the plant body (Jayatissa et al., 2006). Furthermore, the crypto-vivipary reproductive system allows the embryo to penetrate the seed coat but cannot penetrate the fruit wall before being in a favorable environment (Elmqvist and Cox 1996; Shi et al. 2005; Tomlinson 2016). This reproductive system enables mangroves to reproduce, which is more stable and adaptive to unfavorable conditions.

Figure 3. *Avicennia alba* flower (A) and fruit (B) from the southern coast of Pacitan, East Java, Indonesia

Figure 4. Lythraceae family in the southern coast of Pacitan, East Java, Indonesia. A-B. Flower and fruit of *Sonneratia caseolaris*. C. Fruit of *Sonneratia alba*

Figure 5. Mangrove association in the southern coast of Pacitan, East Java, Indonesia. A. *Derris trifoliate*; B. *Acanthus ilicifolious*; C. *Nypa fruticans* (Source: Plants of the World Online)

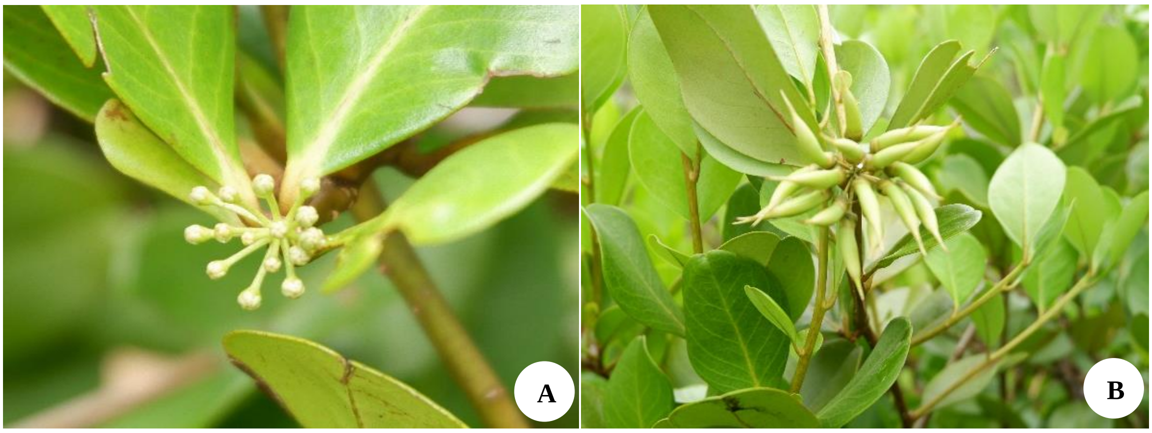

Figure 6. *Aegiceras corniculatum* flower (A) and fruit (B) in the southern coast of Pacitan, East Java, Indonesia

Diversity of mangrove species

The data obtained were analyzed using the Shannon-Wiener equation. Table 4 shows that Teleng Ria Estuary has the highest diversity index and is categorized as a medium group. In contrast, both Grindulu River and Siwil Beach belong to low categories. A low diversity status in a particular area indicates an unstable condition, mainly caused by natural and anthropogenic stress (Sreelekshmi et al., 2020). In Pacitan, natural disturbance seems to be the major factor driving the low diversity index rather than the human factor. Grindulu River usually experiences seasonal flooding and erosion, making mangrove species struggle to survive. In addition, this location has functioned as an aquaculture and ecotourism spot, making lots of people access this area. At the same time, Siwil Beach also experienced a massive flood years ago, leading to the loss of the majority of mangrove species. In addition to this, the intense domination of some species also makes the declining value of the diversity index. In this case, *R. stylosa* and *S. alba* had significant colonization numbers in Grindulu River and Siwil Beach, respectively.

On the other hand, the diversity index in Teleng Ria Estuary valued 1,52. The probable reasons are the accessibility and the wide area it has. The substrate of this location is dominated by deep mud. Thus, a proper tool (e.g., boots) is required to reach it. That condition enables mangrove species to grow well because they witness less disturbance from humans. Another thing is this area has a vast mangrove forest, and numerous species can be found here. The same result was also proposed by Poedjirahajoe et al. (2019) that the mangrove forest size heavily influences the diversity index.

Regarding growth stages in each location, it can be seen in Figure 7. Data of mangrove growth stages were obtained from height and DBH calculation, then adjusted according to the criteria proposed by Kasmadi (2015). The seedling phase dominated the Grindulu station because still in the process of planting. This also explains a small number of poles and trees there, as the mangrove is still in the regeneration stage. On the other hand, mangroves in the sapling phase are abundantly found in Teleng Estuary. The mangrove individuals grew naturally in some spots, indicated by the uneven composition. Furthermore, most mangroves are at pole level and are rarely found in tree stage in Siwil Beach. The massive flood could be the reason because it swept away the mangrove plants, and the remaining species still keep growing to reach the pole stage. Moreover, the local's effort to conduct reforestation was demonstrated in the seedling stage recorded, even not as significant as other locations, due to the impact of seasonal flooding. A similar result was proposed in Nicobar Island, that species regrowth had been conducted after tsunami causing mangrove species and habitat loss (Nehru and Balasubramanian 2018).

Understanding mangrove growth level is necessary to know the regeneration status in a particular wetland ecosystem. Regeneration condition is essential to determine the success of mangrove planting and reforestation. Such as proposed by Utami et al. (2017), a successful regeneration process is indicated by seedling > sapling > tree. Moreover, it can also be used to determine the age of mangrove ecosystems, such as Sudarmadji and Indarto's (2011) observation, which states that the age of mangrove forests in Banyuwangi is still relatively young to the absence of tree phase. From those statements, it can be seen that the Pacitan mangrove areas have a poor regeneration process because of the minimal number of seedlings in each area, with Grindulu River as an exception. The planting program in this location has a profound impact on regeneration progress with the abundance of seedling and sapling. In addition, the mangrove areas in Pacitan are considered still at an early age of development as the minimal number of trees in each location. The constant natural disturbance prevents mangroves from developing to further stages; thus, the planting program should be encouraged to preserve the sustainability of mangrove forests.

Evenness of mangrove species

The evenness index in this study ranged from 0,23-0,78 (Table 5). Teleng Ria Estuary had the most significant evenness value, while Siwil Beach and Grindulu River belonged to the low category. A high evenness index in Teleng Ria indicated that it has diverse mangroves with relatively the same proportion of individuals. On the other hand, the domination of certain species in Siwil Beach and Grindulu River makes the evenness value are classified into low. In addition, a high value also means that the mangrove ecosystem in Teleng Ria is considered stable, unlike the others that have a depressed condition. Some factors causing a low evenness are geological, anthropocentric, weather, and sustainable conservation systems (Sannigrahi et al. 2020). The dominance of several mangrove species that tend to cluster in the southern coastal area of Pacitan makes the evenness index low. In line with Farista and Virgota's (2021) research, the value of the individual evenness index of mangroves in the Cendi Manik area, Sekotong, West Lombok is low due to the dominance of certain species in the community.

The threat of mangrove species

Two major threats that lead to mangrove forest destruction in Indonesia are human and natural factors. Generally, the former is the dominant cause, whether the latter is considered an inevitable agent that can cause severe impact.

In Pacitan, the natural threat to mangroves is caused by floods and a high tide. However, its location directly connected to the Indian Ocean makes Pacitan highly prone to high and strong waves, leading to erosion and coastal destruction (Utami and Luthfi 2019). In addition, many studies mentioned the tsunami prediction in Pacitan caused by the Eurasian and Indo-Australian plate collisions (Jamilah et al., 2021). Pulau Dua, Banten also has a similar condition that moderate waves significantly impact mangrove species (Vitasari 2015). Meanwhile, during the past 40 years, extreme weather events, biological invasions, and insect outbreaks were major natural factors that contributed to mangrove forest degradation in Guangxi (Jia et al. 2014).

Table 4. Diversity Index of mangrove and associated mangrove in the southern coast of Pacitan, East Java, Indonesia

Location	Diversity index	Category
Teleng Ria Estuary	1.52	Medium
Grindulu River	0.57	Low
Siwil Beach	0.26	Low

Table 5. Evenness Index of mangrove and associated mangrove in the southern coast of Pacitan, East Java, Indonesia

Location	Evenness index	Category
Teleng Ria Estuary	0.78	High
Grindulu River	0.41	Low
Siwil Beach	0.23	Low

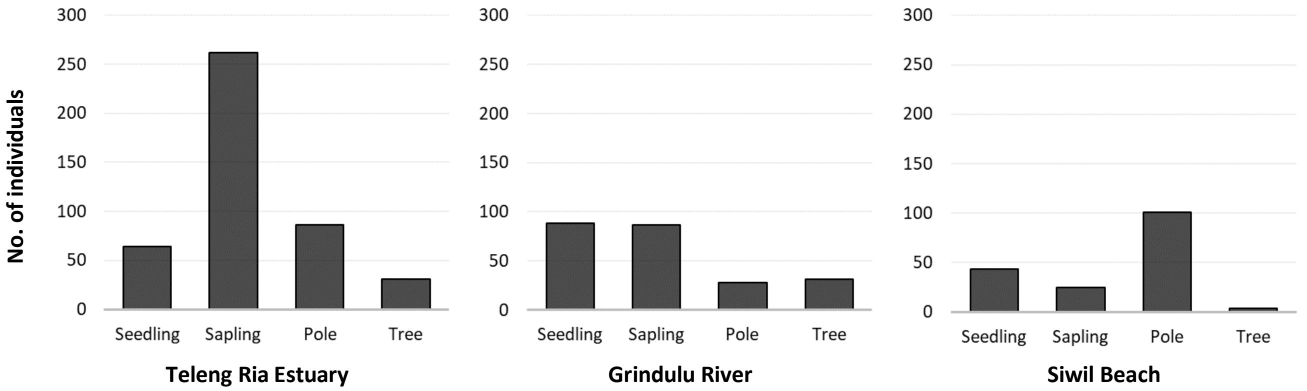

Figure 7. The number of mangrove species in four growth stages in the southern coast of Pacitan, East Java, Indonesia, i.e., Teleng Ria Estuary (*left*), Grindulu River (*middle*), and Siwil Beach (*right*)

Human activities (anthropogenic) provide the most significant contribution to the destruction of mangrove forests in Indonesia. Conversion of mangrove forests for fisheries, plantations, agriculture, salt ponds, settlements, industry, agriculture, forest logging (legal logging and illegal logging), and mining is the principal anthropogenic activity that causes degradation and loss of mangrove forests (Ilman et al. 2011). However, the local communities in Pacitan show a great effort to preserve the mangrove ecosystem. It is indicated by their participation in mangrove planting with the local government and NGOs. However, inconsistency and unsustainability in maintaining the mangrove ecosystem cause the condition of the Pacitan mangrove are not as expected. Thus, making a tourism destination based on mangrove forests in the Grindulu area is expected to trigger residents to contribute more because they benefit from the economic side.

Although Indonesia has the highest global average above-ground biomass (AGB) of mangrove forests in the world (729,075,000 tons), Indonesia is one of the countries with the highest rate of mangrove forest loss also high (Hutchison et al. 2013). The condition of mangrove forests in Indonesia continues to experience damage and a reduction in the area, with the speed of destruction reaching 530,000 ha/year. In contrast, the rate of increase in mangrove rehabilitation that can be realized is still much slower than the rate of destruction, which is only around 1,973 ha/year.

The conversion of mangrove forests into aquaculture/pond land and agriculture is the leading cause of mangrove forest degradation in Indonesia. Ilman et al. (2011) and Eong (1995) in Hamzah and Setiawan (2010) argue that anthropogenic activities in the form of fisheries, plantations, agriculture, salt ponds, settlements, industry, logging (legal logging and illegal logging), and mining are the main factors of degradation and loss of mangrove forests in Indonesia. Meanwhile, Kustanti et al. (2012) argue that more than 50% of mangrove forests are degraded or lost due to several factors, such as the conversion of mangrove forests for fisheries, urbanization, oil pollution, and industrial waste lack of public awareness (Hutchison 2013).

To conclude, mangrove species in Pacitan are considered low to moderate diversity, and Teleng Ria has a high evenness index. Therefore, further management involving local communities and stakeholders is needed to improve mangrove sustainability in Pacitan.

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